# AGVISE Demonstration Project Update

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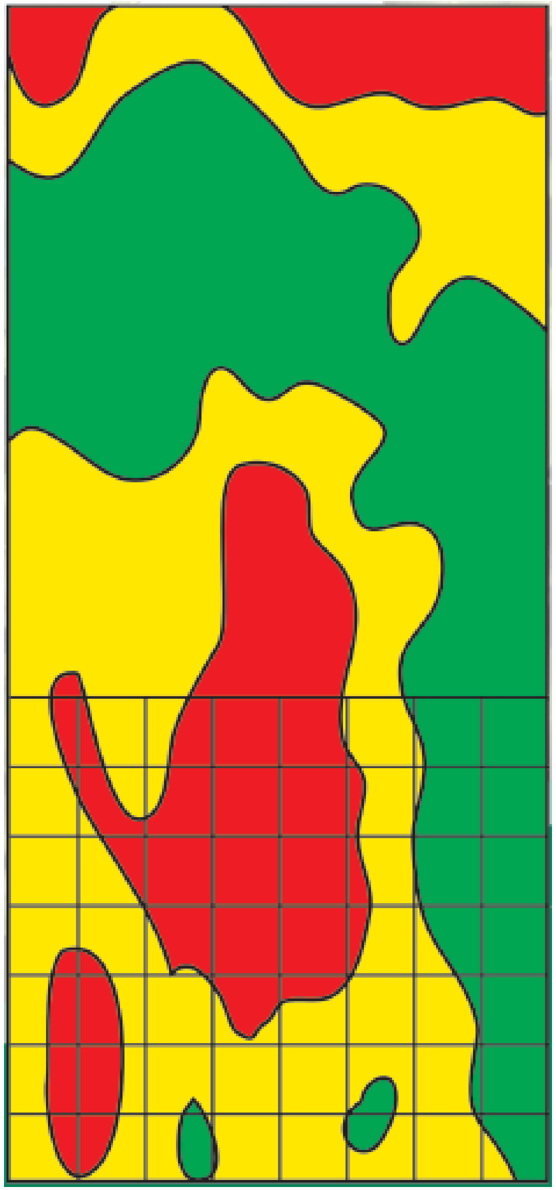
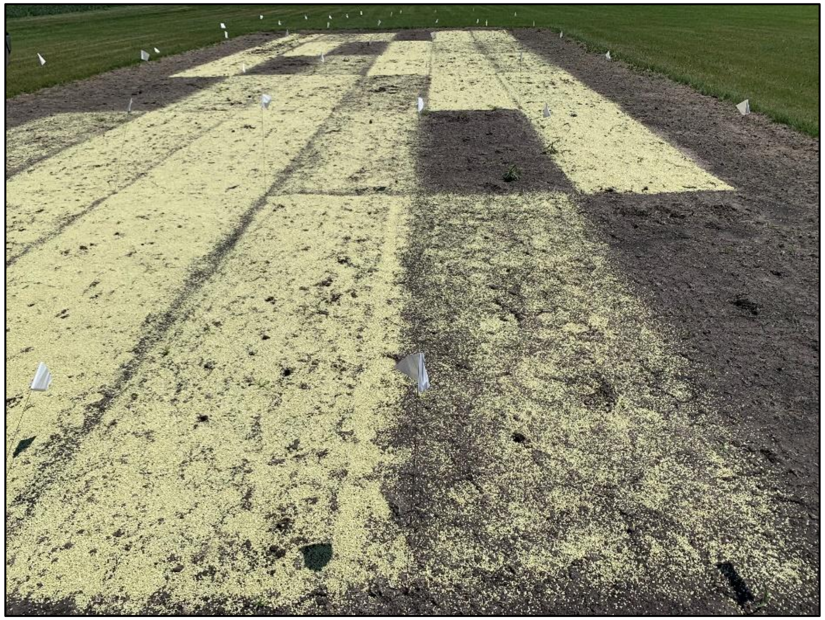


# AGVISE Long-term Trial Site at the Northwood Laboratory

**Elemental sulfur: up to 40,000 lb/acre**

**MAP: up to 1,250 lb/acre**

**Potash: up to 8,500 lb/acre**



Why the silly high rates? Requires 6,400 lb/acre elemental sulfur to neutralize 1% CCE.

# Update on the AGVISE long-term trials

## Trial 1: Elemental sulfur to lower soil pH

- Installed 2020; initial soil pH 8.0 and 4.5% carbonate (CCE)
- Elemental sulfur rates from 0 to 40,000 lb/acre

## Trial 2: High phosphorus and potassium rates for building high pH/high clay soils

- Installed 2021; initial 4 ppm Olsen P, 226 ppm K, 1.1% K saturation
- MAP rates from 0 to 1,250 lb/acre
- Potash rates from 0 to 8,500 lb/acre

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# Soil pH, 0-6 inch topsoil

| Relative level | pH (1:1 method) | Interpretation |
|---|---|---|
| Very Acidic | <5.5 | Aluminum toxicity, liming important |
| Acidic | 5.5-6.5 | Liming may be necessary, crop choice |
| Neutral | 6.5-7.5 | |
| **Alkaline** | **7.5-8.5** | **Band P fertilizer, maybe Zn?** |
| Very Alkaline | >8.5 | Sodium problem, gypsum may be required |

- Herbicide breakdown affected in low or high pH soils
- pH > 7.3 indicates calcium carbonate (CCE) present

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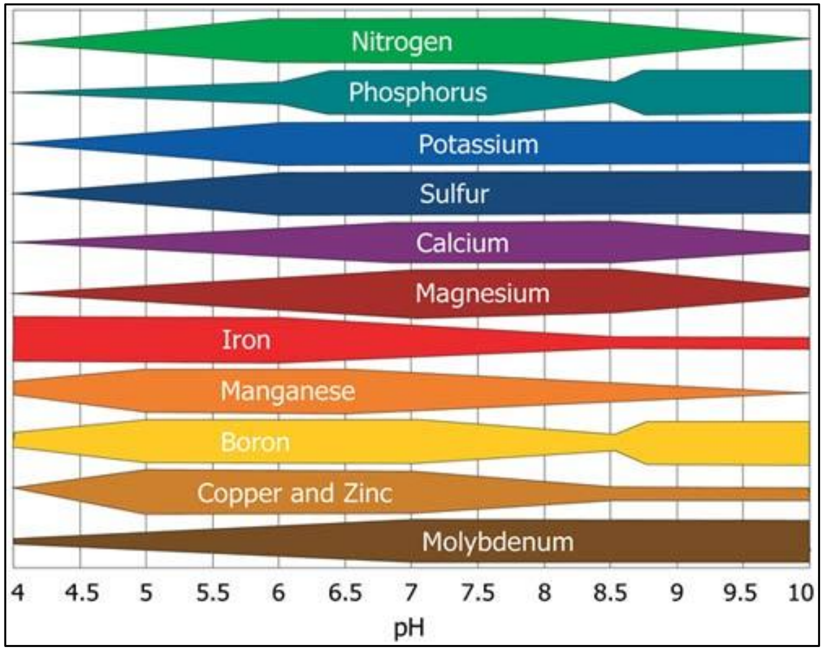
# Why are basic (alkaline) soils problematic?

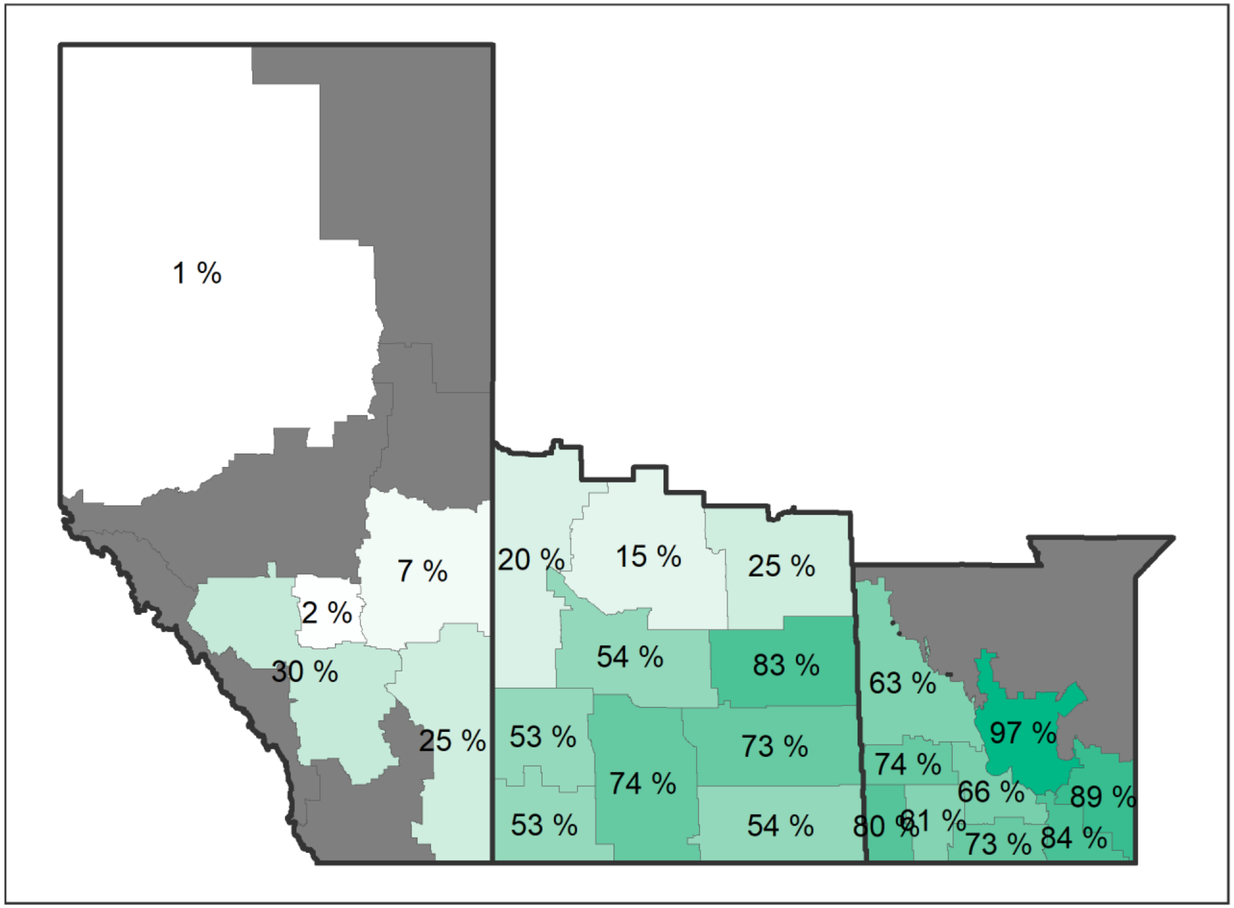
**Reduced nutrient availability**




**Saline and sodic soils**

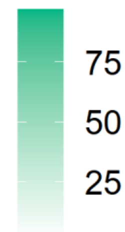
Salinity and sodicity are often correlated with high soil pH, but not necessarily causal

# Soil samples with soil pH above 7.3 in 2024




**Any soil with pH > 7.3 will contain some calcium carbonate**

Percent of samples (0-6 inch)

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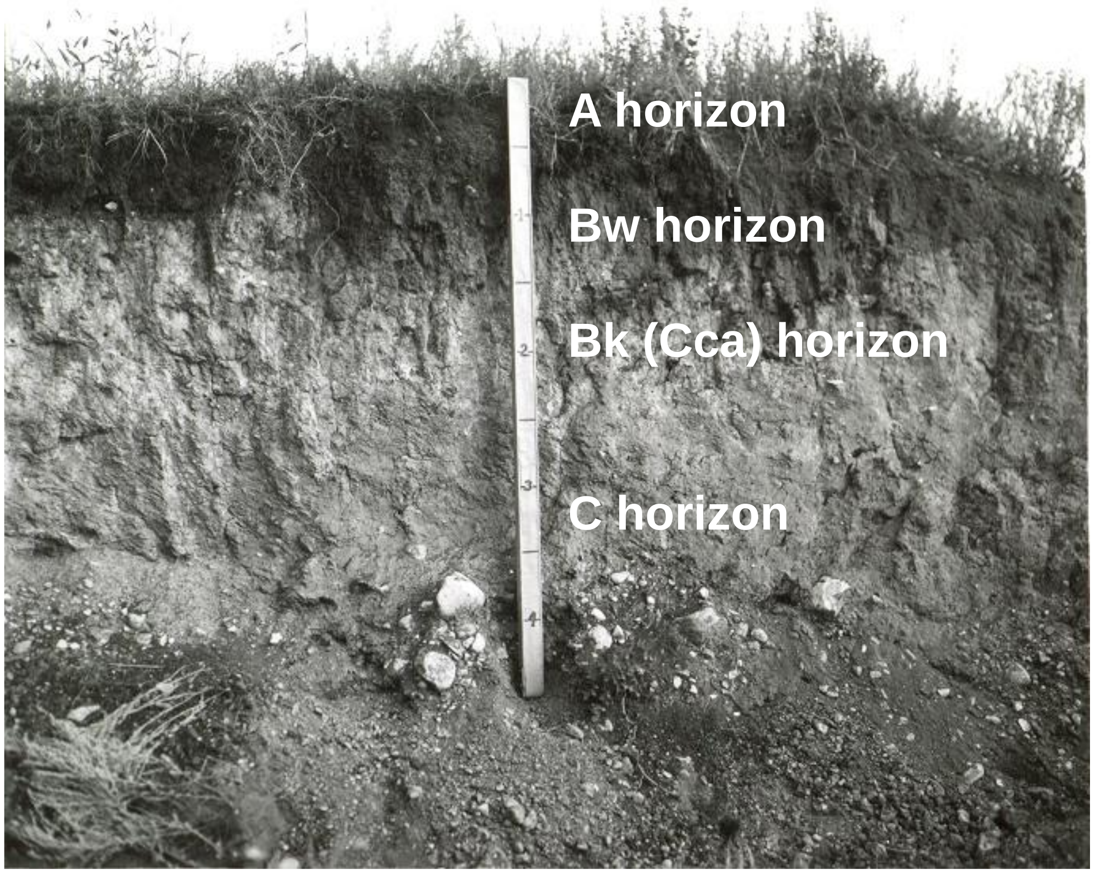
# What is calcium carbonate ($CaCO_3$, free lime)?

$CaCO_3$ is a very insoluble naturally occurring mineral

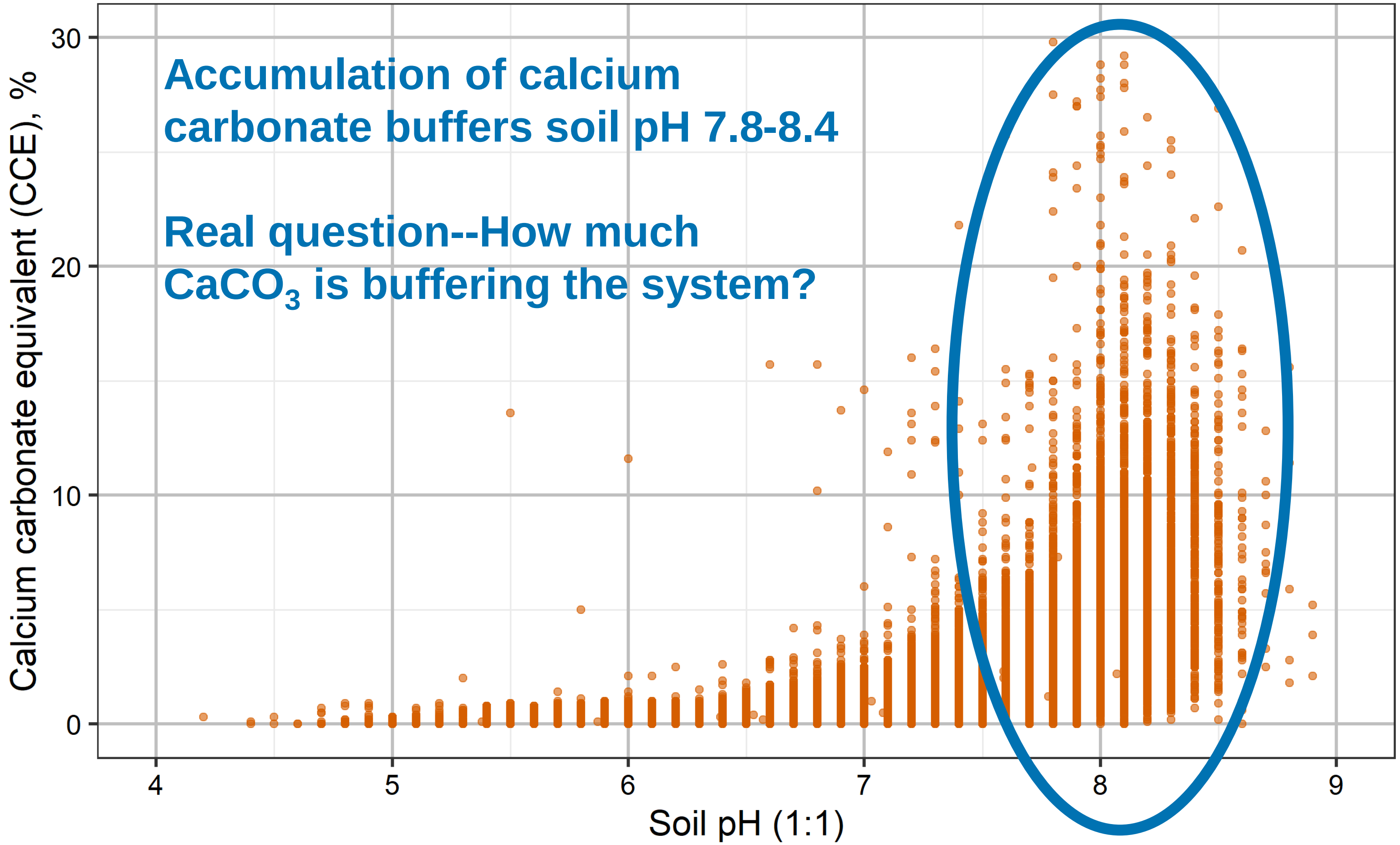
Offers a "whitish" color to soil, often seen in subsoil; accumulates in the calcic (Bk or Cca) horizon

Present since glaciation, often present in groundwater




From historical photograph collection of D.G. Hopkins, North Dakota State Univ., Fargo, ND.

# Calcium carbonate (free lime) controls and buffers high soil pH

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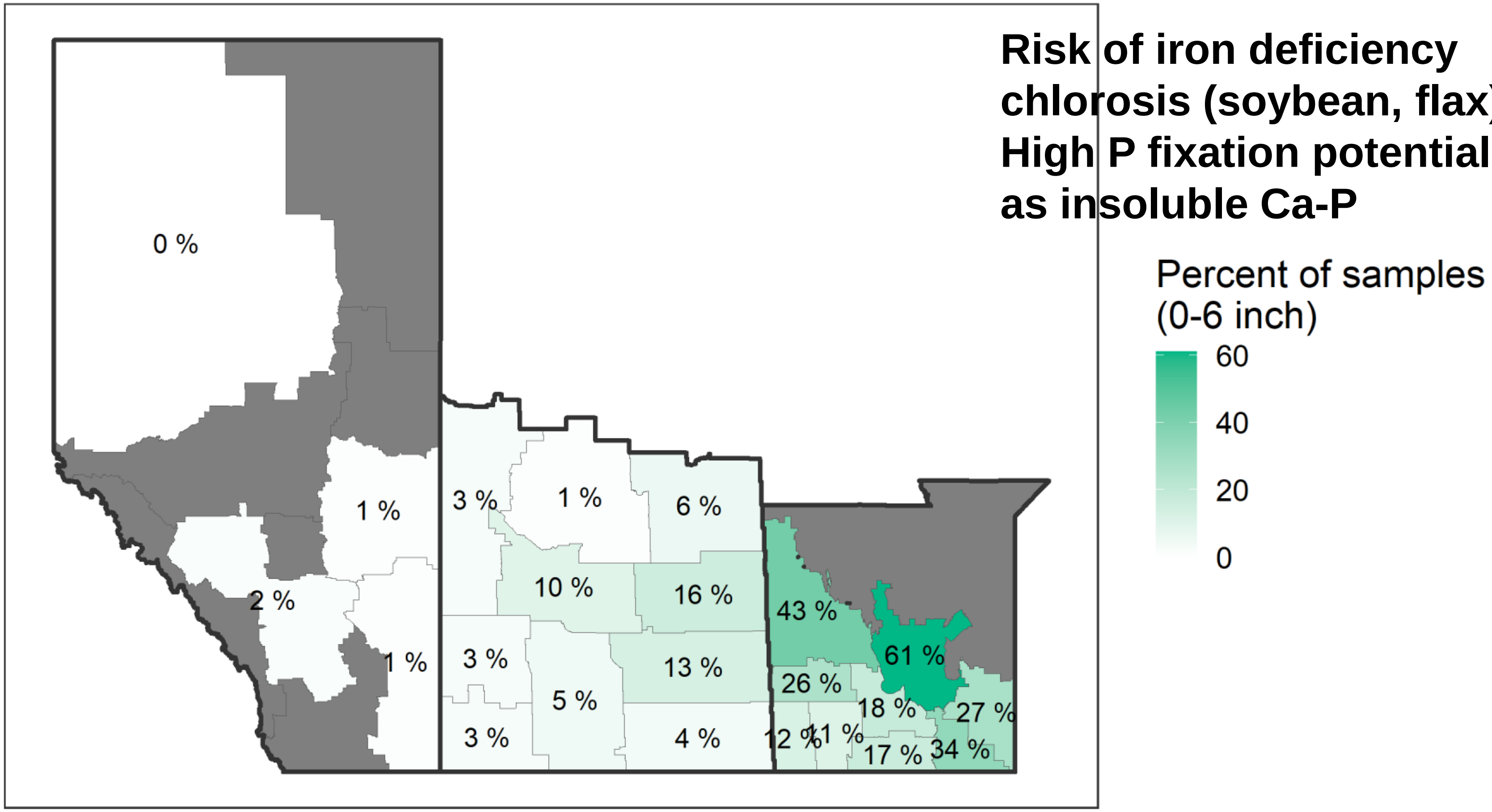
# Soil samples with calcium carbonate above 5.0 % CCE in 2024

**Risk of iron deficiency chlorosis (soybean, flax)**
**High P fixation potential as insoluble Ca-P**

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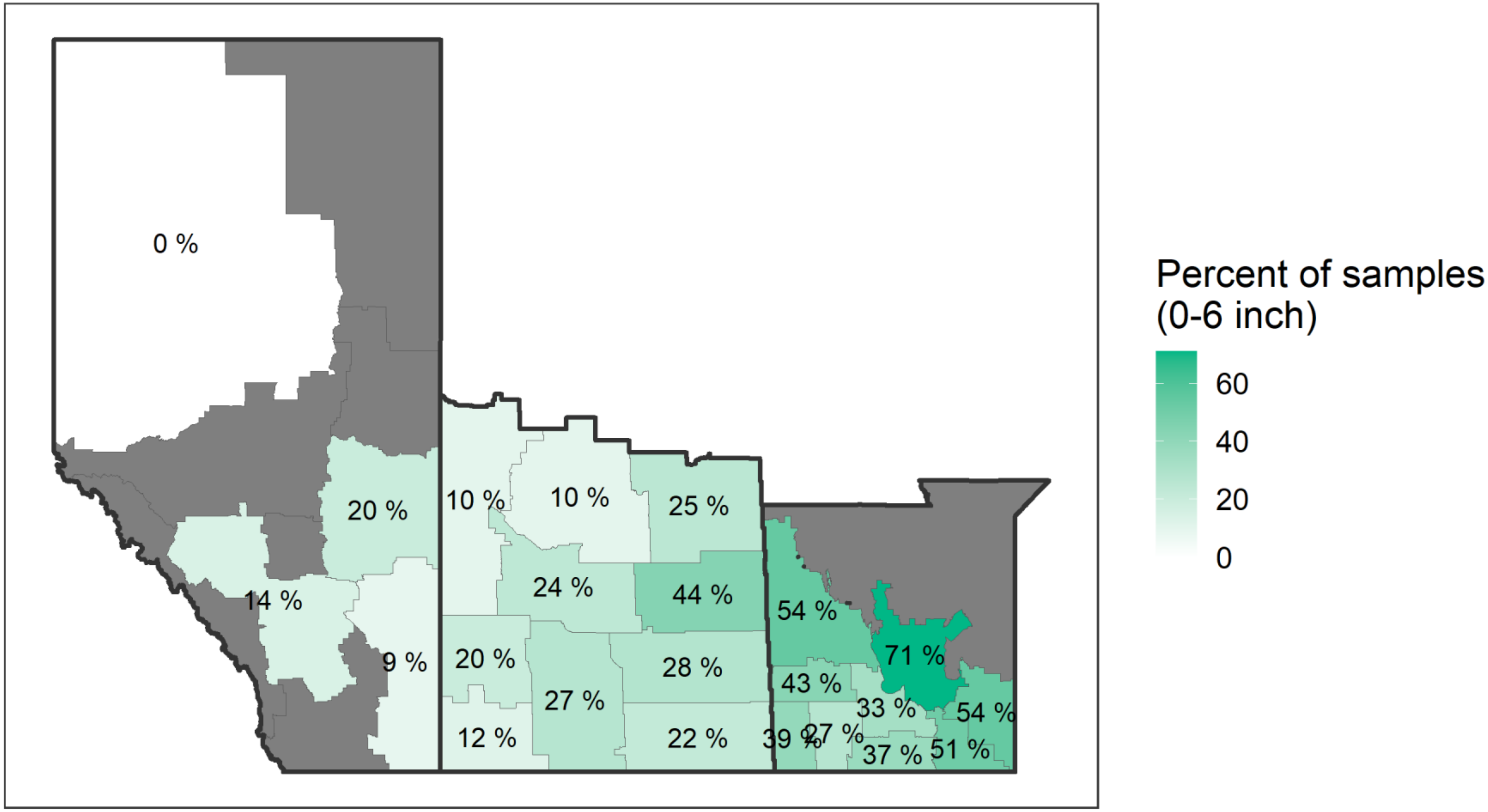
# AGVISE Soybean IDC Risk Index

| | Soybean IDC risk potential | | |
|---|---|---|---|
| **EC(1:1)** | **Calcium carbonate equivalent (CCE)** | | |
| **dS/m** | **< 2.5 %** | **2.6 – 5.0 %** | **> 5.0 %** |
| **< 0.25** | Low | Low | Moderate |
| **0.26 – 0.50** | Low | Moderate | High |
| **0.51 – 1.00** | Moderate | High | Very high |
| **> 1.00** | Very high | Very high | Extreme |

**Based on observations and soil samples from 103 fields (2001)**

Foundational research from Franzen, D.W., and J.L. Richardson. 2000. Soil factors affecting iron chlorosis of soybean in the Red River Valley of North Dakota and Minnesota. J. Plant Nutr. 23(1):67–78.

# Soil samples with high soybean iron deficiency chlorosis risk in 2024

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# How easily can you lower soil pH?

Calcium carbonate naturally present, buffers soil pH around 7.8-8.2

Acidity required to neutralize carbonate, then lower soil pH

- Rainfall (naturally acidic)
- Ammonium-containing fertilizers (nitrification)
- Elemental sulfur (oxidation)

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# How much elemental sulfur is needed?

**Elemental sulfur: converts to sulfuric acid**

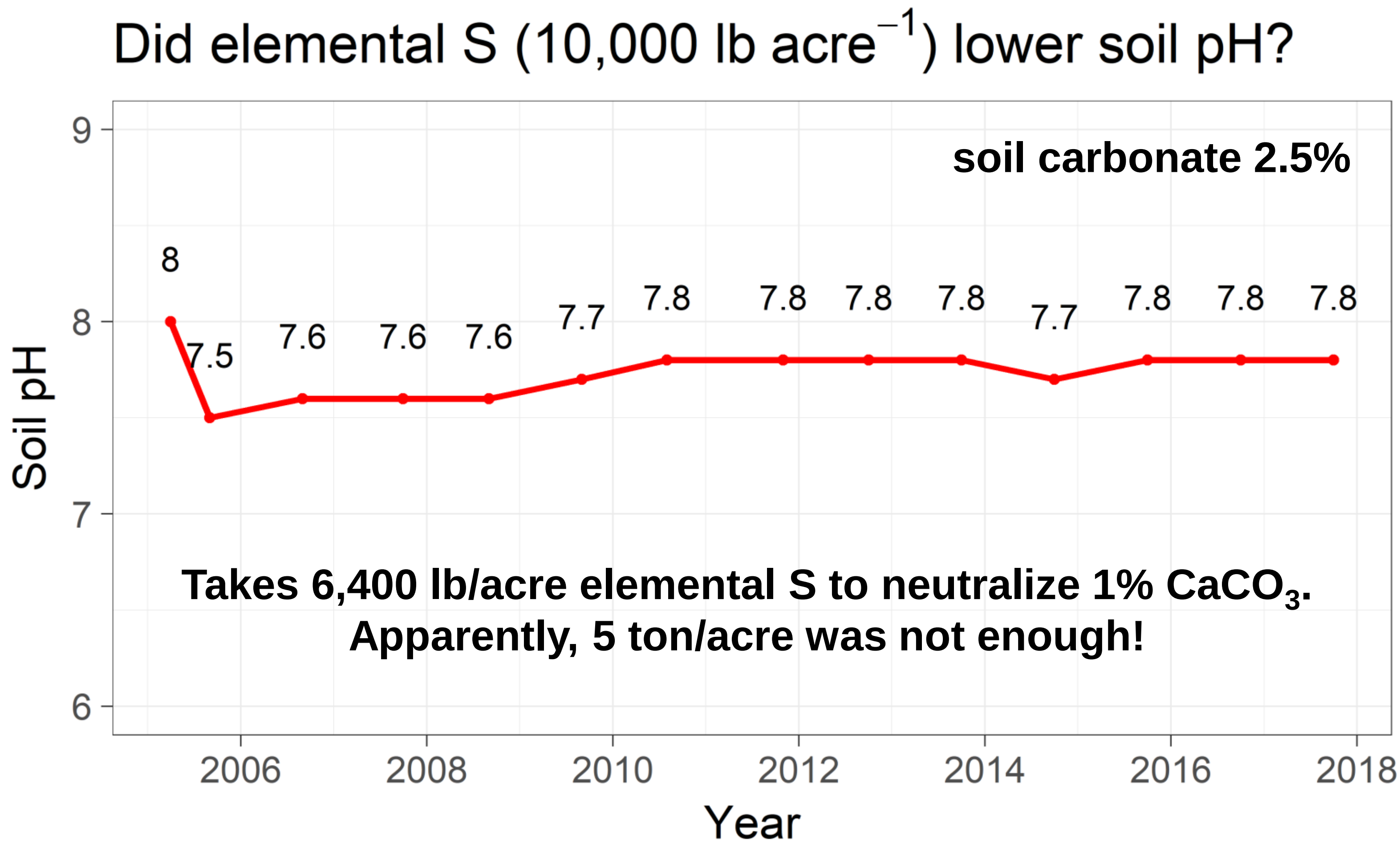
$$2S + 3O_2 + 2H_2O \rightarrow 2H_2SO_4$$

*sulfur* *oxygen* *water* *sulfuric acid*

- Elemental sulfur creates acidity slowly through bacterial oxidation

- For each **1% calcium carbonate (CCE)** in soil, you need **6,400 lb/acre elemental S** to neutralize carbonate alone
- More elemental sulfur required to lower soil pH

# AGVISE elemental sulfur project started 2005; Northwood, ND

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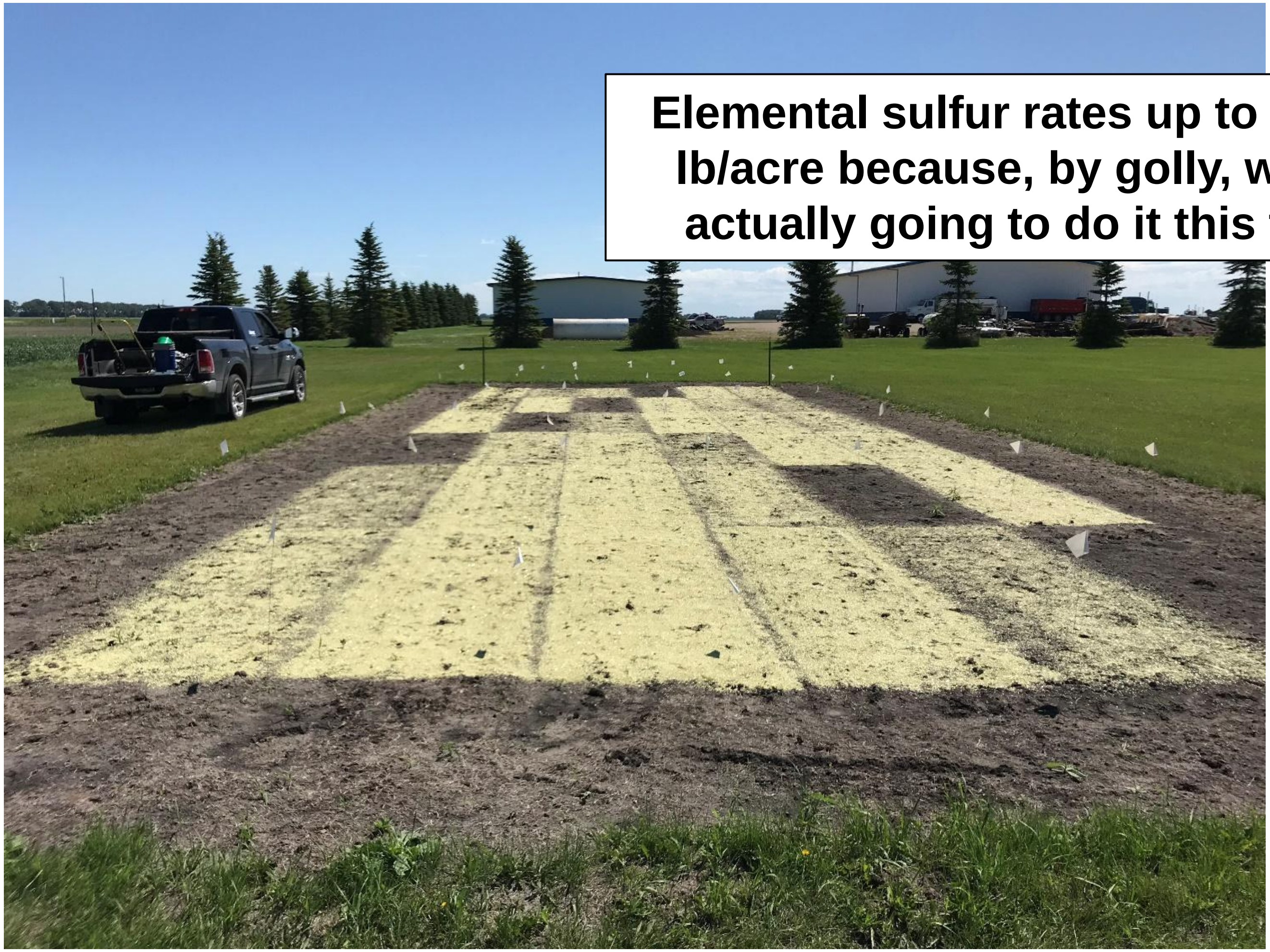
# AGVISE elemental sulfur project started 2020; Northwood, ND



**Elemental sulfur rates up to 40,000 lb/acre because, by golly, we are actually going to do it this time!**

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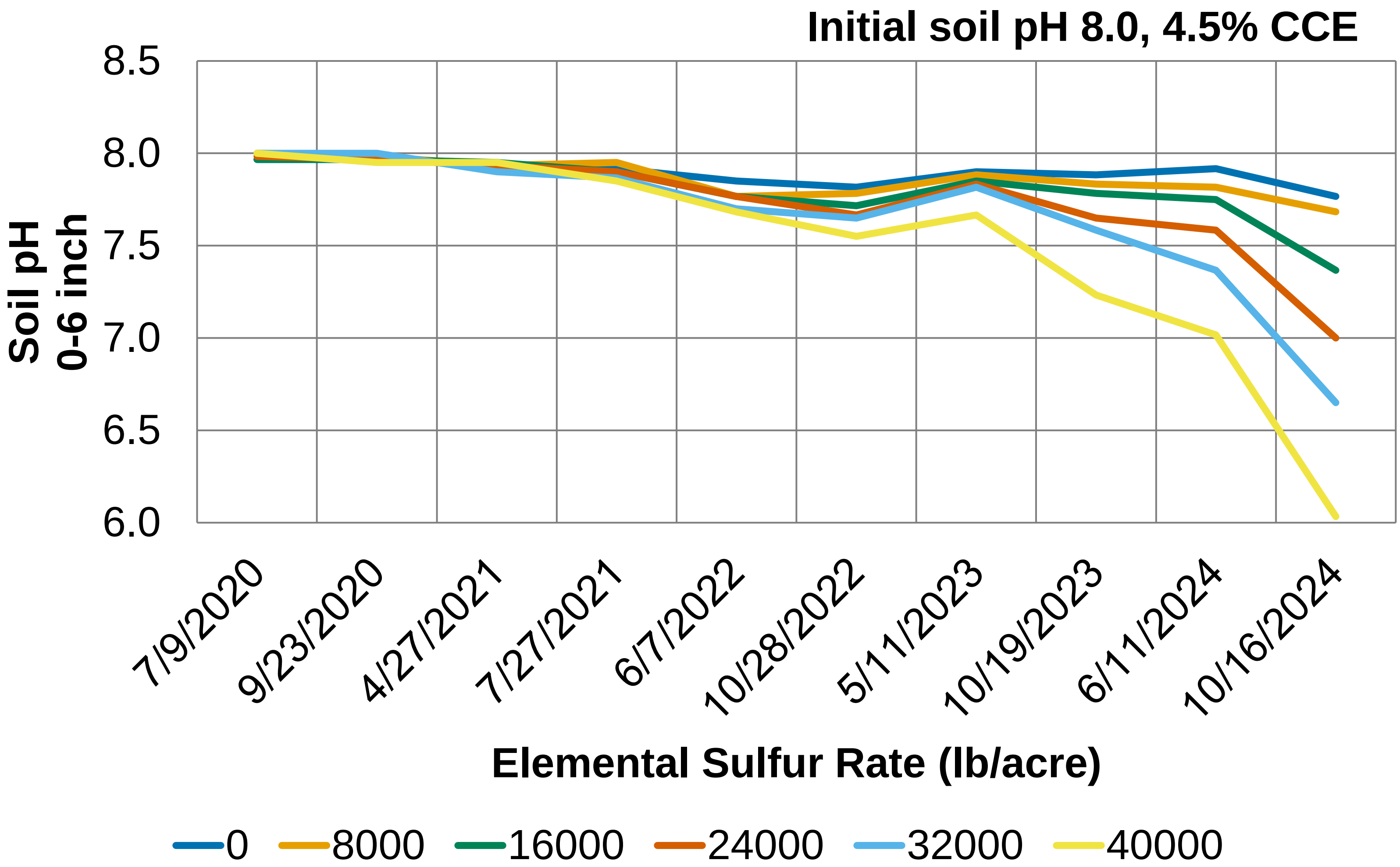
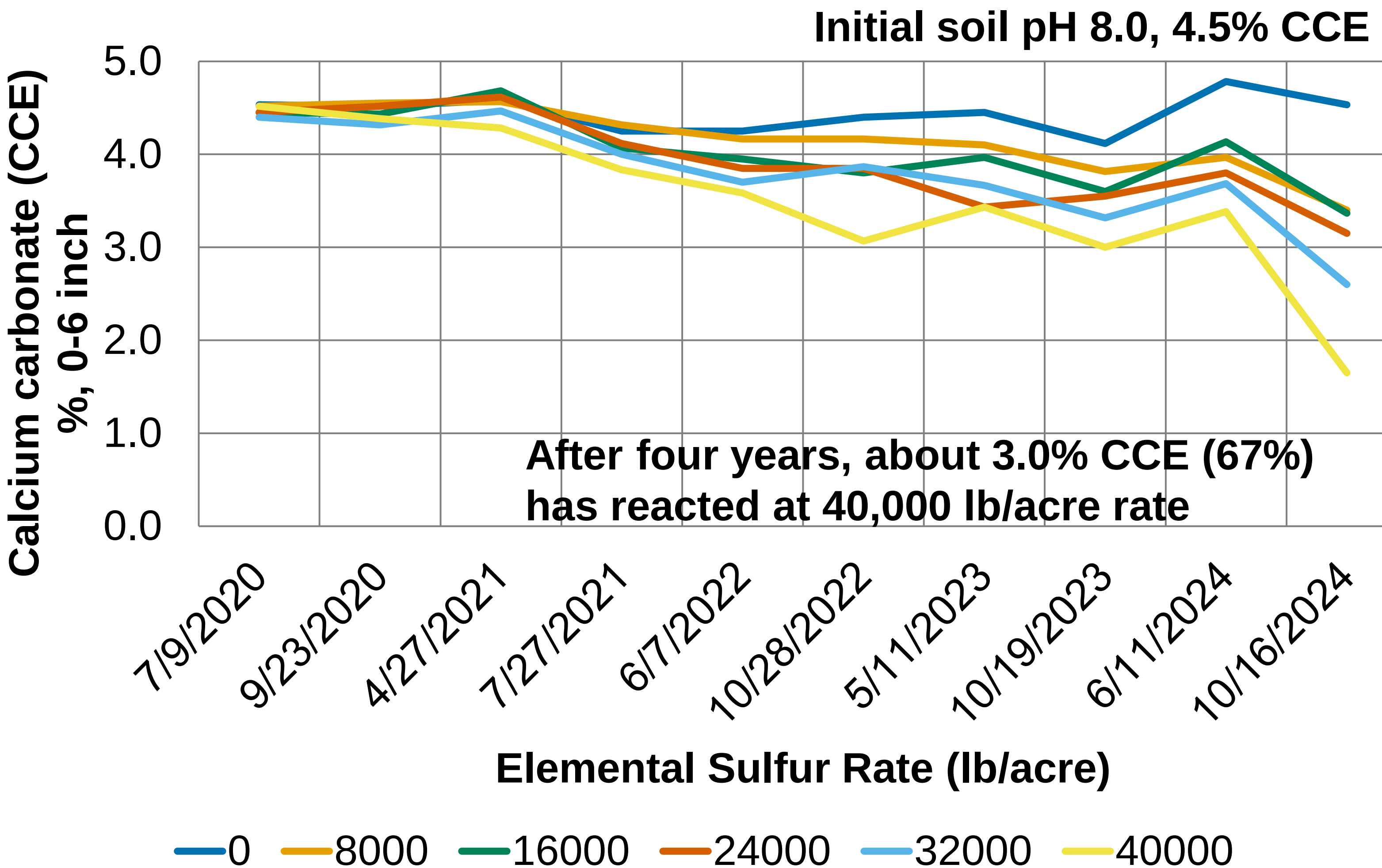
# Elemental sulfur and soil pH



# Elemental sulfur and calcium carbonate



# Learning to live with high soil pH and carbonate

- Calcium carbonate buffers soil pH at 7.8 – 8.2
- Lowering soil pH is very difficult because calcium carbonate must first be neutralized
  - Elemental sulfur is not a profitable or practical strategy
  - Ongoing soil erosion exposes new Bk and C horizons, bringing new calcium carbonate to the soil surface
- Soil nutrient availability concerns are phosphorus, iron, and zinc
  - Other management options to improve availability, more practical than lowering soil pH

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# Long-term phosphorus and potassium fertilizer rate trial

- **Site:** Northwood, ND
  - Bearden silty clay loam
  - soil pH: 7.9
  - carbonate: 4.5% CCE
- **Treatments:**
  - 0 to 1,250 lb/acre MAP (11-52-0)
  - 0 to 8,500 lb/acre potash (0-0-60)
  - Tilled to 6 inches after application

**Trial initiated:** September 1, 2021

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# Questions from growers

- Can you actually increase soil test phosphorus on high pH and calcareous soils?
  - We know high pH and calcium carbonate do increase phosphorus fixation.
- Are you able to increase potassium saturation (%K) or change base cation saturation ratios?
  - We know soils with high clay content and CEC have higher K buffering capacity.
  - We know soils with high pH, calcium carbonate, or salinity have inflated CECs and screwy BS calculations.
  - We know %K saturation is not important for soil potassium availability or crop uptake, so why do we still keep getting these questions?
- How much P or K does it actually take to move these soil test numbers in our soils?

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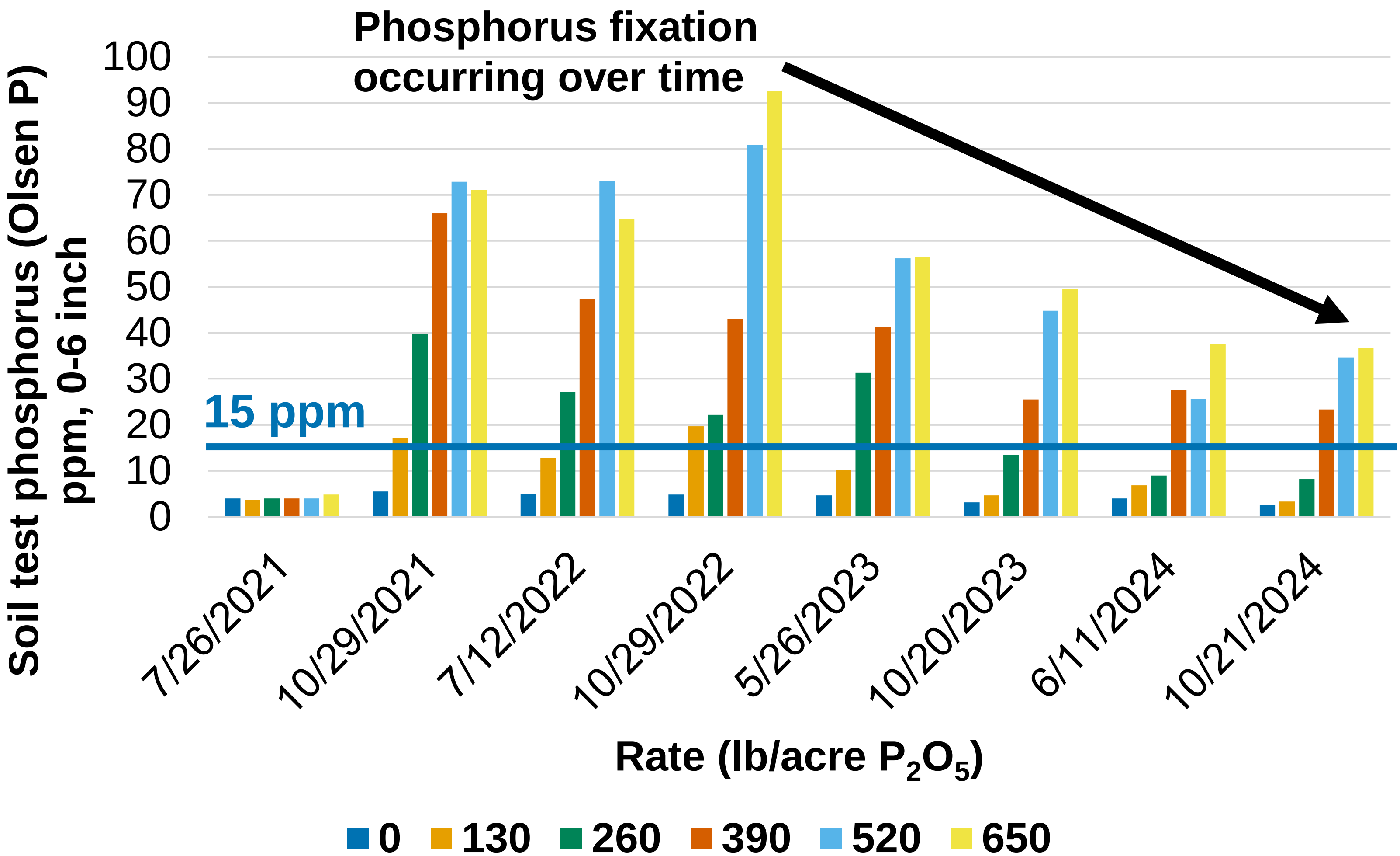
# Building soil test phosphorus



# More grower meetings promoting "base saturation" and "cation ratios"

- Base saturation is a calculation showing percentage of each cation, relative to total cations
  - Calcium ($Ca^{2+}$) 5,000 ppm (65-78%)
  - Magnesium ($Mg^{2+}$) 1,000 ppm (15-35%)
  - Potassium ($K^{+}$) 150 ppm (1-7%)
  - Sodium ($Na^{+}$) 50 ppm (0-5%)
- Poor research from 1930s and 1940s suggested an "optimum" percentage range of each cation for an "ideal soil" to achieve high crop yields
- Research from 1930s through today has shown percentage of each cation is not important and does not limit crop yield – wide range of BCSRs can produce high crop yields
- What is important? Part per million (ppm) of each cation

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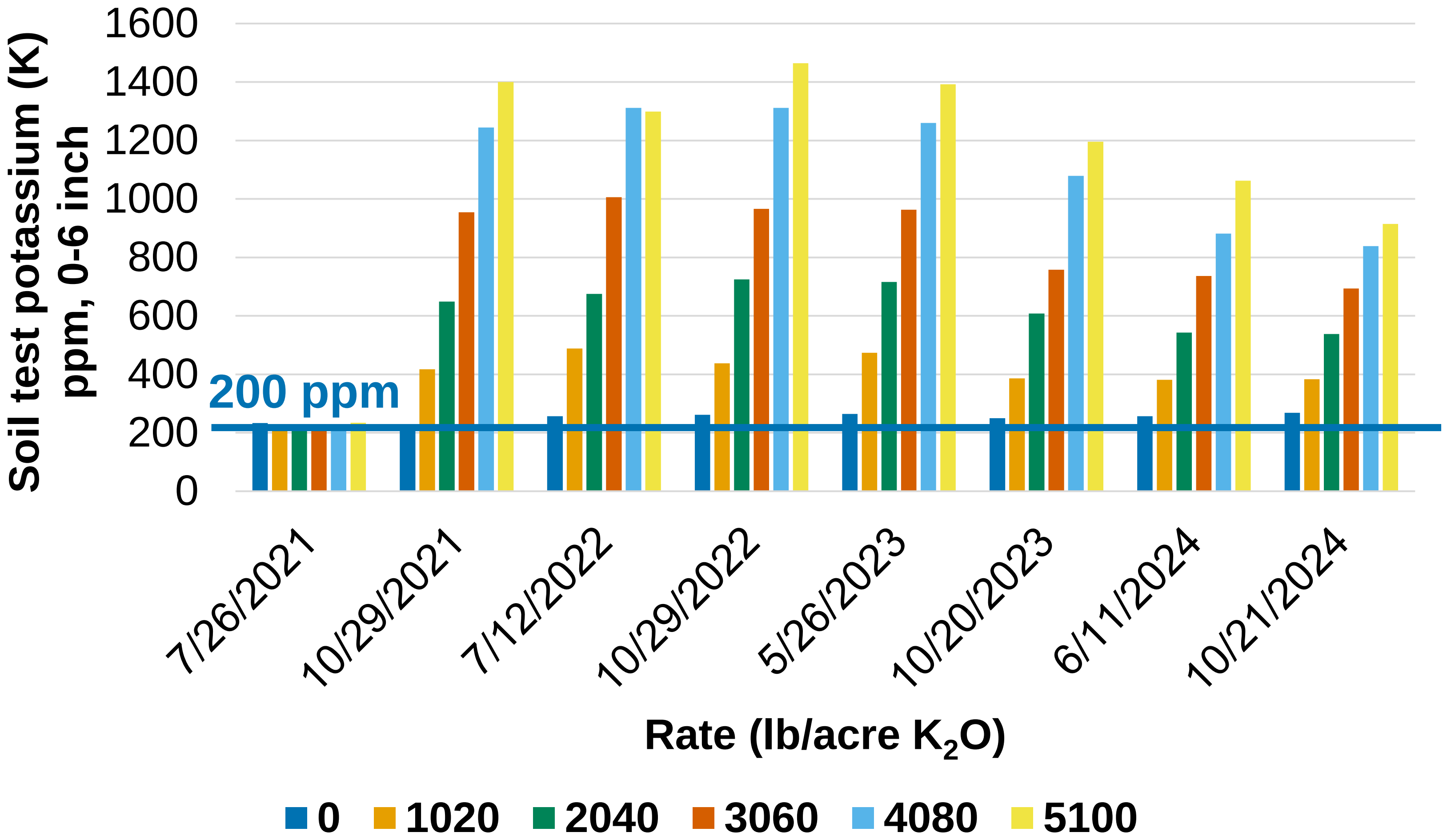
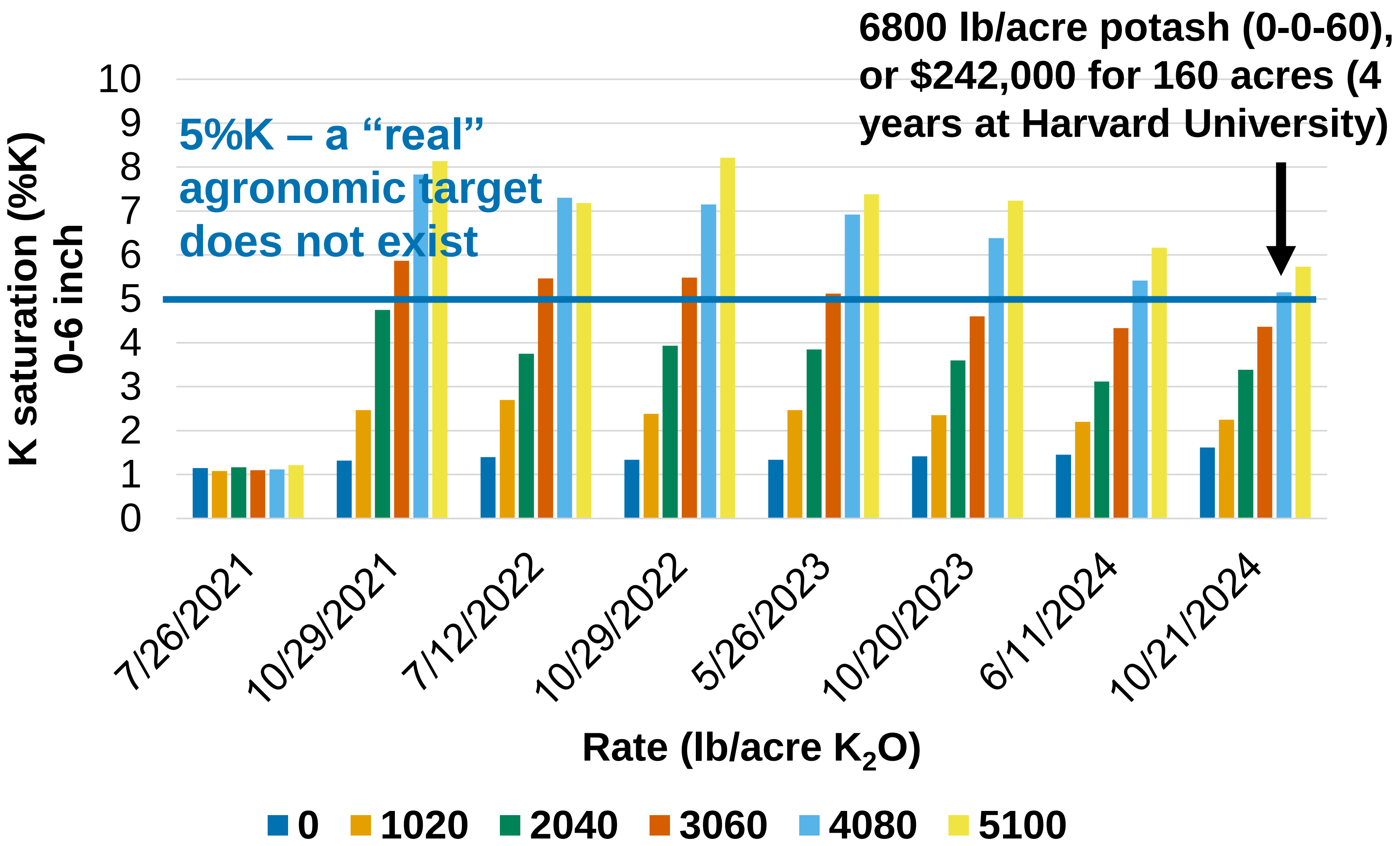
# Building soil test potassium



# Building potassium base saturation

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# Good reasons to apply potassium fertilizer

- Soil test K below 150 or 200 ppm, depending on crop and clay mineralogy/soil texture
- Plant tissue K consistently below sufficiency range
- Compaction restricting root growth
- Replicated strip trials showing significant crop yield increases
- Low soil chloride (small grains may require Cl)
- **Base cation saturation ratios are NOT reasons to apply more K fertilizer (leave bad research back in the 1940s)**

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# Soil buffering capacity, so far

Soil buffering capacity (building factor) describes how much added nutrient (fertilizer) is required to increase the soil test level. Factors include soil pH, soil texture, mineralogy, carbonate, and others.

**Bearden silty clay loam, pH 7.9, 4.5% CCE.**

| Parameter | General range | Unit | Oct 2021 (2 months) | Oct 2024 (3 years) |
|---|---|---|---|---|
| Soil test P (Olsen) | 15-20 lb per 1 ppm | $P_2O_5$ | 7.2 lb/ppm | 19.0 lb/ppm |
| Soil test K | 5-10 lb per 1 ppm | $K_2O$ | 4.5 lb/ppm | 6.7 lb/ppm |
| K saturation | soil dependent | $K_2O$ | 660 lb/% | 980 lb/% |

Phosphorus fixation is occurring. Soil test P will decline, resulting in the buffering capacity to increase over time and approach the expected range of 15-20 lb/ppm. Potassium sits close to the expected range of 5-10 lb/ppm.

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# Quick observations

- Elemental sulfur can decrease soil pH and neutralize carbonate. However, the required rates are impractical and not profitable on calcareous soils.
- Soil test phosphorus increased quickly, showing that we can build soil test P on high pH, calcareous, clay soils. Phosphorus fixation is occurring, and soil test P is starting to decrease over time.
- Soil test potassium (ppm) increased as expected when you apply high potash rates.
  - Soil test K is well above critical level. Good soil testing would indicate no additional potash is required.
- Potassium saturation (%K) increased to 4-8% K range suggested by BCSR proponents, only when 5,100 to 8,500 lb/acre potash was applied.
  - No agronomic reason to apply this much potassium; might cause crop yield loss (UMN, NDSU, SDSU research). No economic reason, unless you want to apply 100 years of crop K removal in one application (soils are not FDIC insured deposits).

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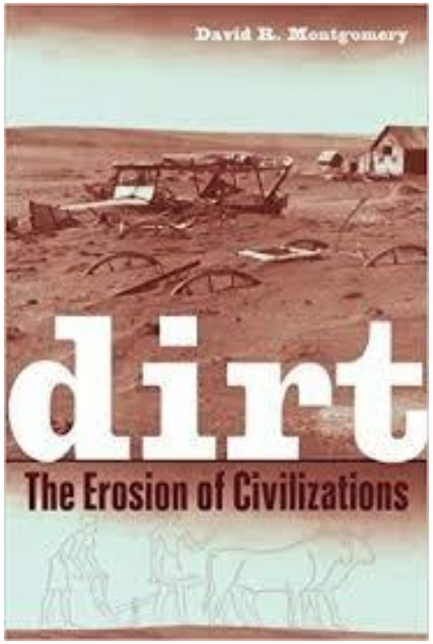


If you want to learn more about humankind's long struggle with soil erosion…

# Thank you for your kind attention!

Are there any questions?

Remember: Your soil test is only as good as the soil sample.

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