

Soil health testing: Can you manage what you measure?

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AGVISE Soil Fertility Seminars

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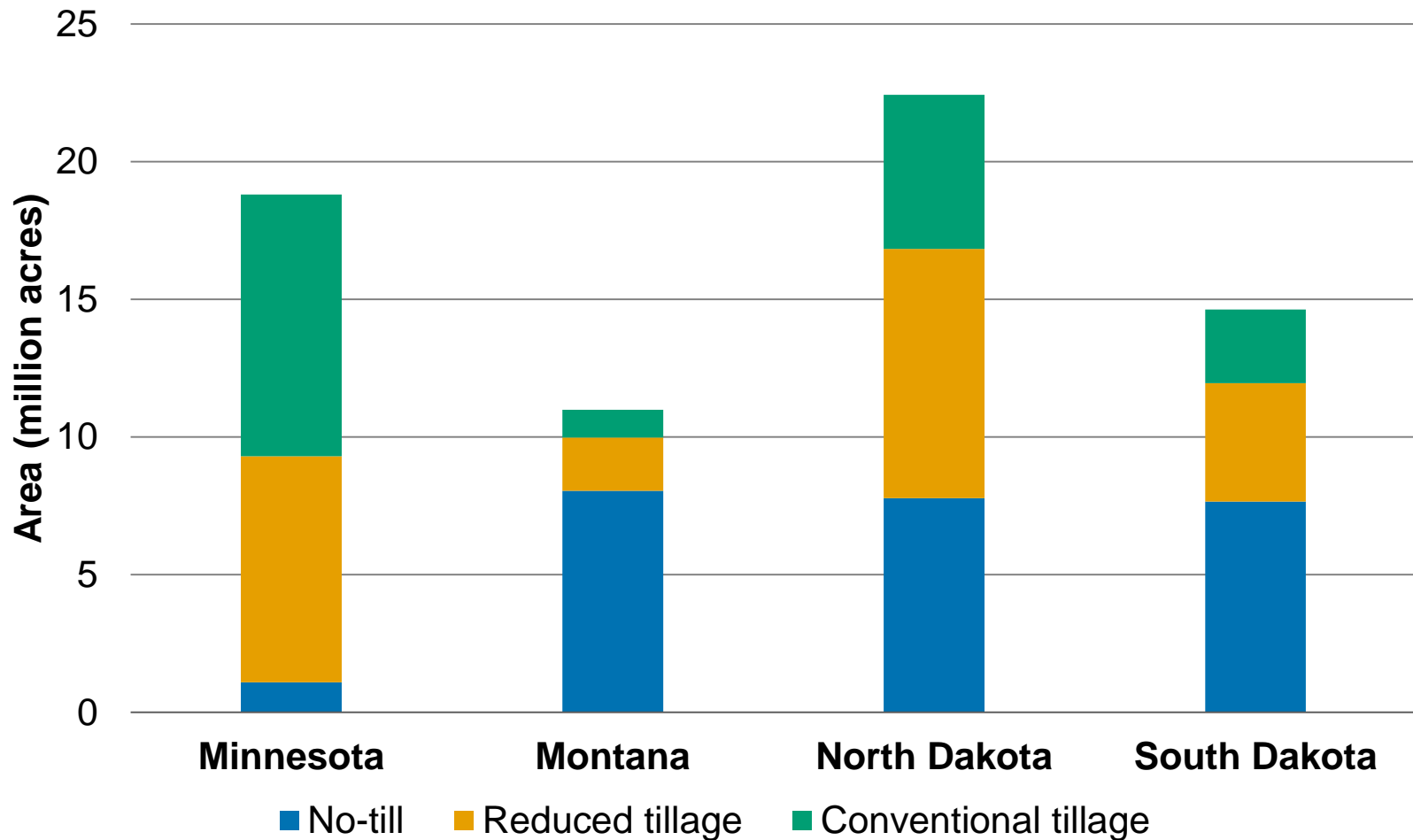


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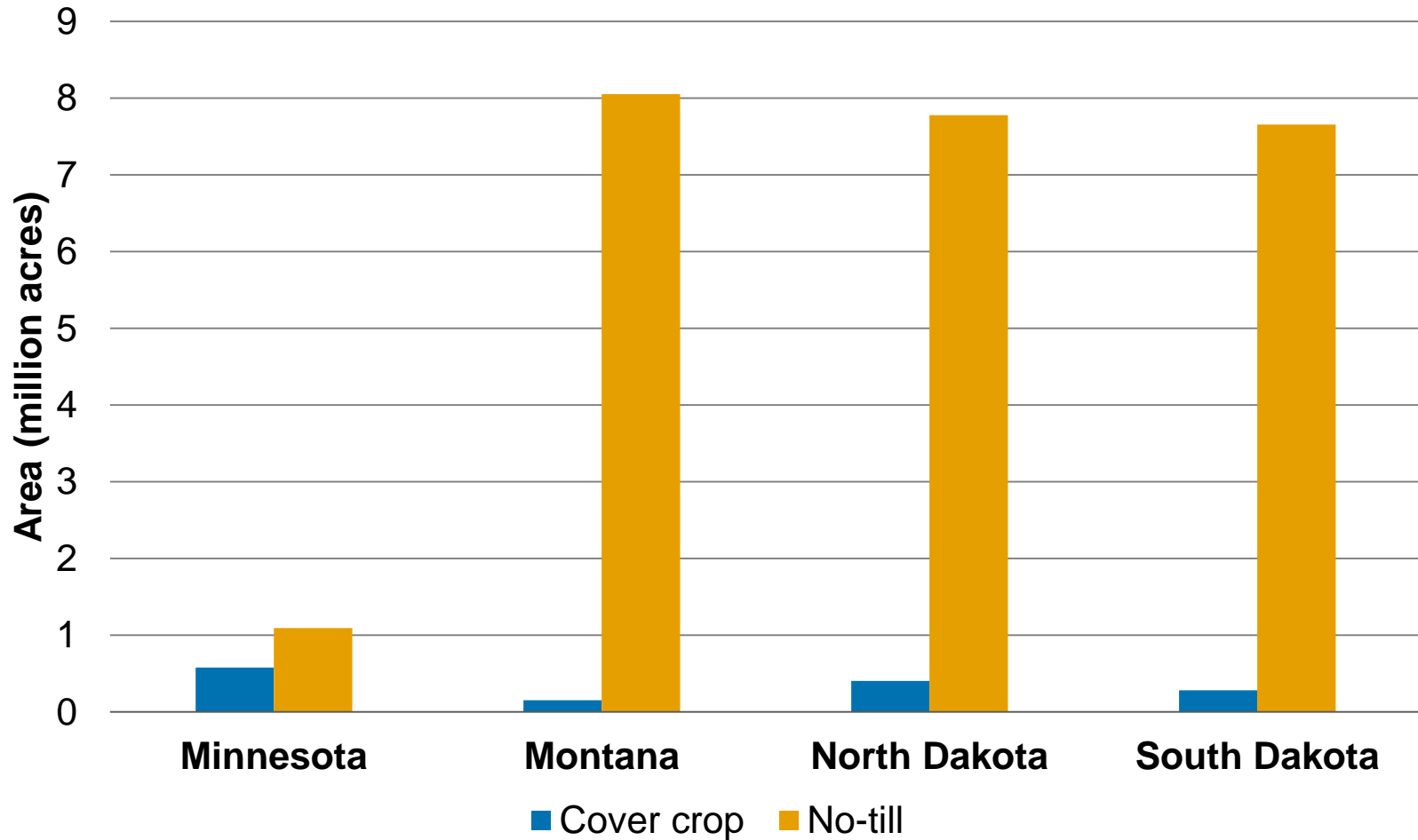
@jsbreker

Conservation tillage adoption 2017 U.S. Census of Agriculture



Cover crop adoption

2017 U.S. Census of Agriculture



Today's outline

1. How do we talk about soil health
2. What a soil health test must do
3. Soil health tests
 - 24-h CO₂ respiration (Solvita)
 - Haney Soil Health Assessment
 - Active carbon (POXC)
 - Bioavailable nitrogen (ACE protein)
 - Soil aggregate stability
4. Interpretation of soil health data

Define: soil health versus soil quality

- Soil health: the continued capacity of the soil to **function** as a vital living ecosystem that sustains plants, animals, and humans (USDA-NRCS, 2012)
- Soil health: the **maintenance** of soil ecology and properties aimed at sustaining plants, animals, and humans (USDA-NRCS, 2018)
- Soil quality: the soil's fitness for **use**
 - Agricultural? Environmental? Engineering?

Soil health in context (oh, you mean the whole system?)

- Physical properties
 - Soil texture, soil structure, soil aggregate stability, bulk density, water infiltration rate, water holding capacity
- Chemical properties
 - pH, salinity, organic matter, plant-available nutrients (N, P, K, Ca, Mg, S, B, Cl, Cu, Fe, Mn, Mo, Ni, Zn)
- Biological properties
 - Microorganism communities (bacteria, fungi, arthropods, earthworms), mineralization rates, enzyme activity, CO₂ respiration

How about a working definition

Basic goals of soil health

- Reduce soil erosion
- Improve soil structure
- Enhance nutrient use efficiency
- Increase crop yield

Where does soil health start?



Soil health assessment with laboratory testing

Early 2010s, 24-h CO₂ respiration (Solvita) introduced to measure biological activity

2014 Farm Bill included Conservation Stewardship Program (CSP)

- NRCS programming allowed enhancement SQL15 Soil Health Nutrient Tool (Haney Test), so farmers started requesting the Haney Test
- AGVISE has provided the Haney Test since 2015

Soil health is so confuddled, even economists are taking a stab at it

Soil Science Issues—Pedology

New Soil Index Development and Integration with Econometric Theory

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Soil scientists have worked on the conceptualization and contextualization of soil-related notions, such as soil quality, soil health, and soil security, over the past few decades. We reviewed the massive amount of literature regarding those major concepts, and summarized definitions, visions, and constraints. Indicators (In) and indices (Ix) are well suited to aggregate soil and environmental data to assess soil quality, health, and security quantitatively. Our literature review showed that (i) more sophisticated quantification methods are necessary; (ii) often only a single soil property and/or class is modeled rather than more complex soil functions, risks, or services; (iii) there is a lack of harmonization, standardization, and reference frameworks that allow soil comparisons across regions and time; and (iv) methods frequently used to calculate soil In/Ix, such as ordination and factor analysis, do not consider rigorous axiomatic criteria of scientific sound indication systems. In summary, the complex soil concepts stand in sharp contrast to the applied indication methods in the soil science discipline. We investigated the potential to apply econometrical methods to assess soil quality, health, and security that serve as alternatives to more traditional In/Ix in soil science. A case study demonstrated the profound transformative potential of linking econometrics–soil–environmental sciences.

To improve soil health...

“You cannot manage what you do not measure.”

1. Do we measure what is measurable, rather than what is important?
2. Does this measurement actually measure something we can manage?
3. Are we ignoring other items that should be measured?

What questions are we trying to answer with soil health testing?

- Is reduced tillage actually doing anything?
- Has that root-restricting tillage pan disappeared?
- How are cover crops improving my soil?
- Is soil salinity decreasing?
- Can my soil store more water?
- Will there be greater nitrogen mineralization?
- Can I reduce fertilizer rates?

Who is interested in the data?

- Farmers and ranchers
- Agronomists
- Researchers
- Government (e.g. NRCS, Farm Bill)
- Supply chain sustainability (e.g. General Mills, Anheuser-Busch, Walmart)
- Landowners, esp. absentee

Useful or simply measurable?

| Parameter | Can you measure it? | Can <u>you</u> change it? | Can you <u>reliably</u> track it? | Can you <u>use</u> it? |
|-------------------------|---------------------|---------------------------|-----------------------------------|------------------------|
| Soil texture | ✓ | ✗ | n/a | ✓ |
| Soil organic matter | ✓ | ✓ | ✓ | ✓ |
| Nitrogen mineralization | ✗ | ? | ✗ | ? |
| | | | | |
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Requirements of any soil health test

- Sensitive to soil management changes
- Rapid, repeatable procedure
- Inexpensive (at least affordable if done every few years)
- University validation to define interpretation

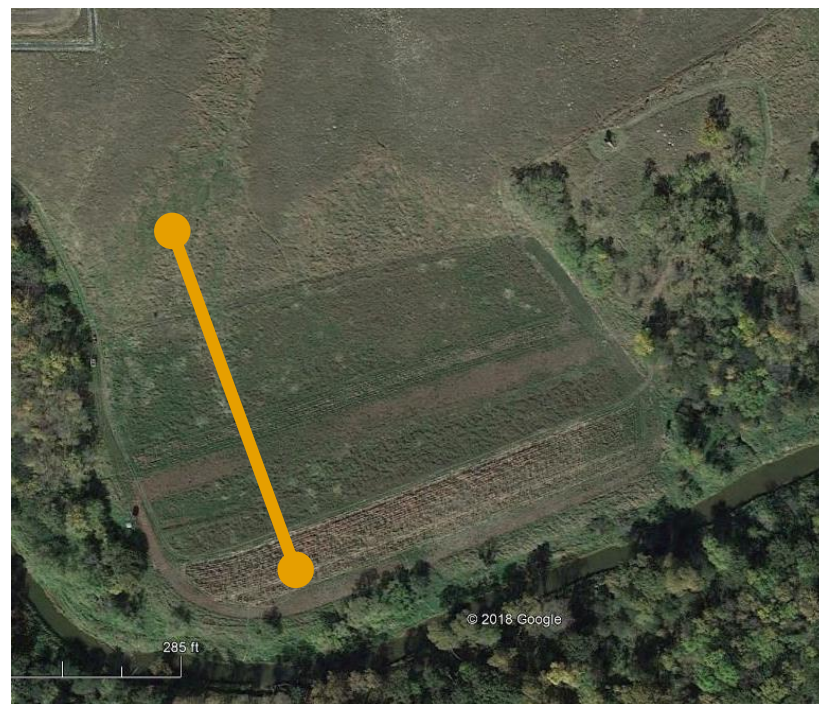
AGVISE Soil Health Tracking Project

**Long-term cropping sequence
~10 years, near Hatton, ND**

| Crop | Soil organic matter (LOI, %) |
|--------------------|---------------------------------|
| Alfalfa | 5.5 |
| Corn (C-S rot.) | 5.4 |
| Soybean (C-S rot.) | 4.7 |
| CRP | 7.6 |

Conventional tillage after each crop,
only CRP without tillage

**LaDelle silt loam
(Cumulic Hapludolls)**



24-h CO₂ respiration (Solvita)

- Amount of CO₂ respiration from microorganisms, measured 24 hours after soil is rewetted
- General biological activity
- More biological activity, more organic matter decomposition and N mineralization?

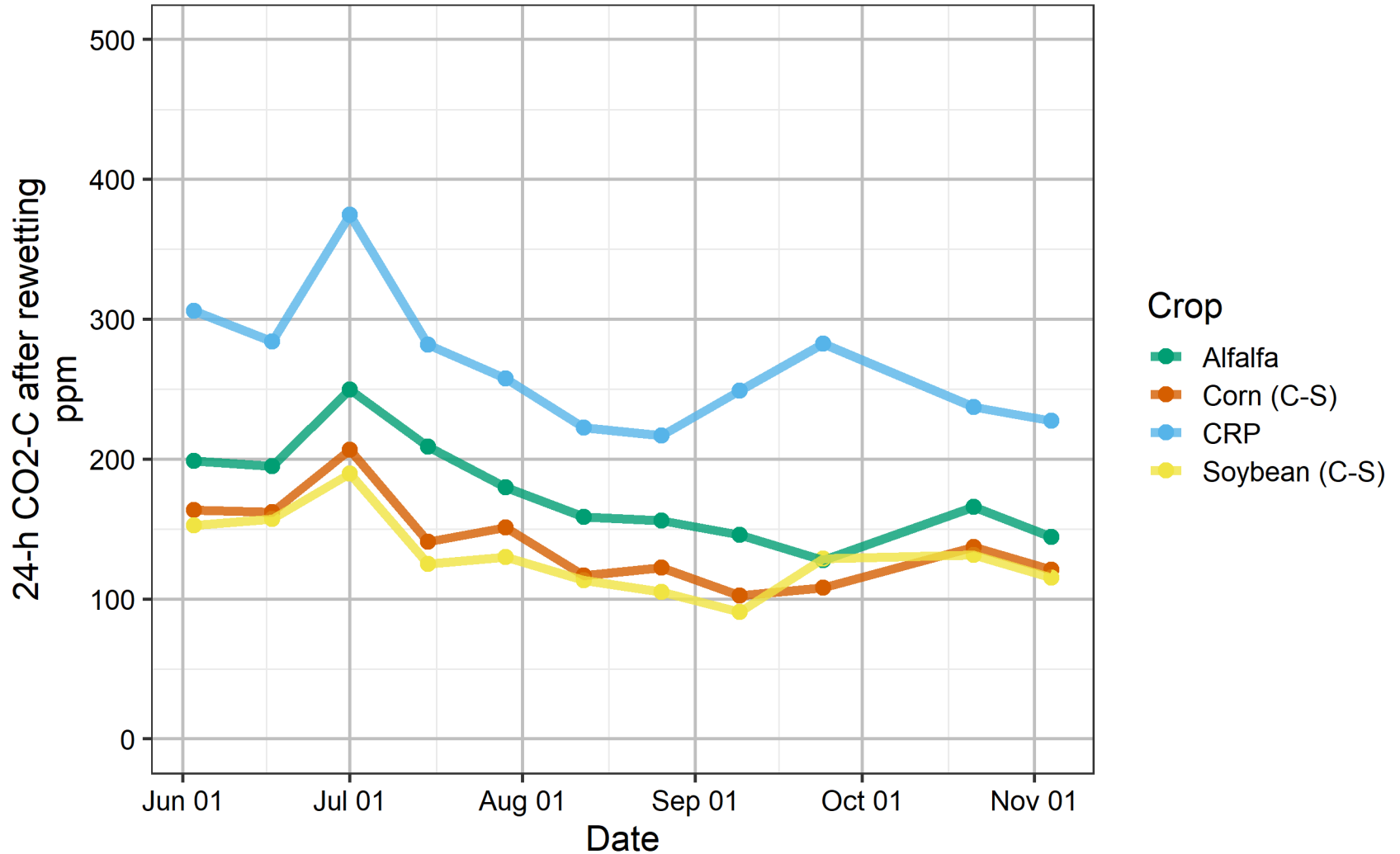


24-h CO₂ respiration (Solvita)

- Equipment and method have changed: jars may leak, CO₂ paddles may saturate (highly active soils)
- AGVISE uses pressure-checked jars and infrared CO₂ determination

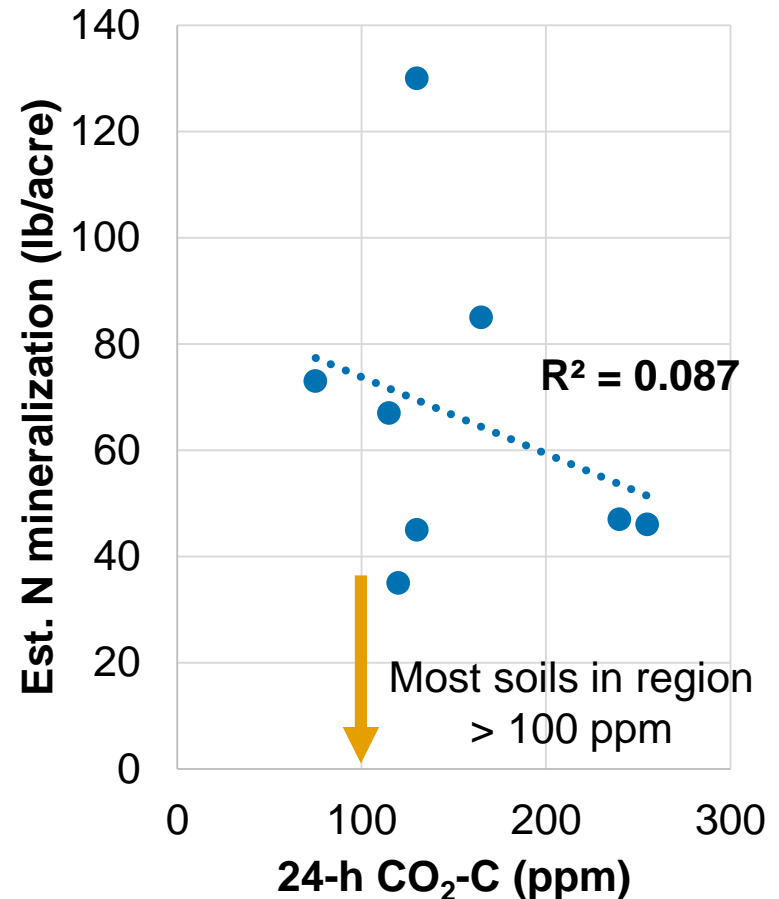
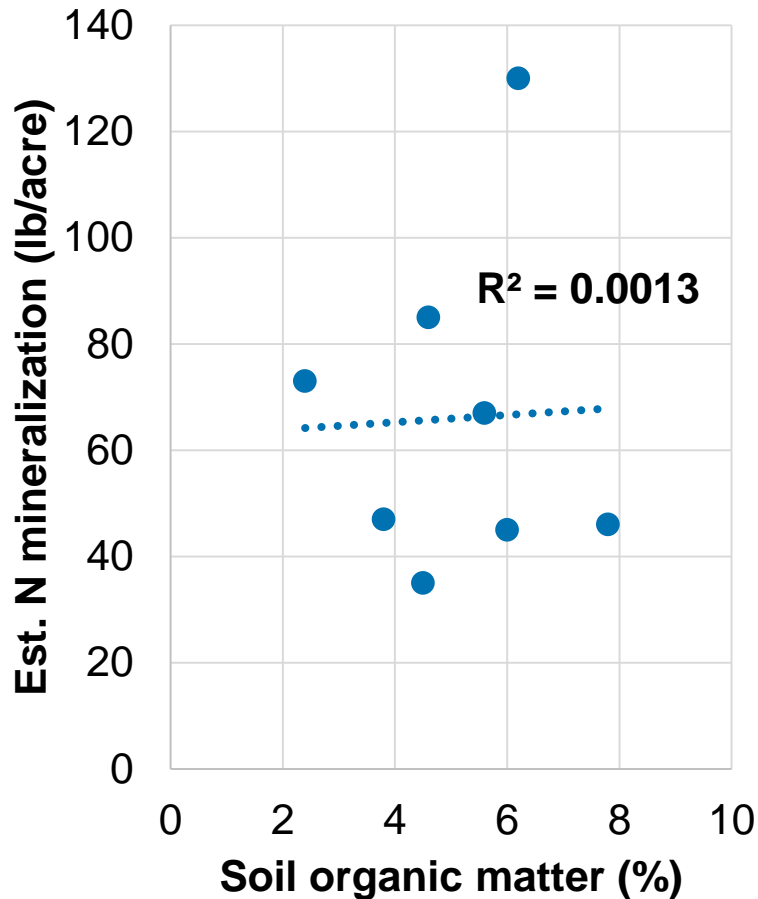


Tracking 24-h CO₂ respiration



AGVISE Laboratories, Northwood, ND

Does 24-h CO₂ respiration predict N mineralization?



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| Nitrogen mineralization | ✗ | ? | ✗ | ? |
| 24-h CO₂ respiration | ✓ | ✓ | ✗ | ✗ |
| | | | | |
| | | | | |
| | | | | |

Haney Soil Health Assessment (HSHA)

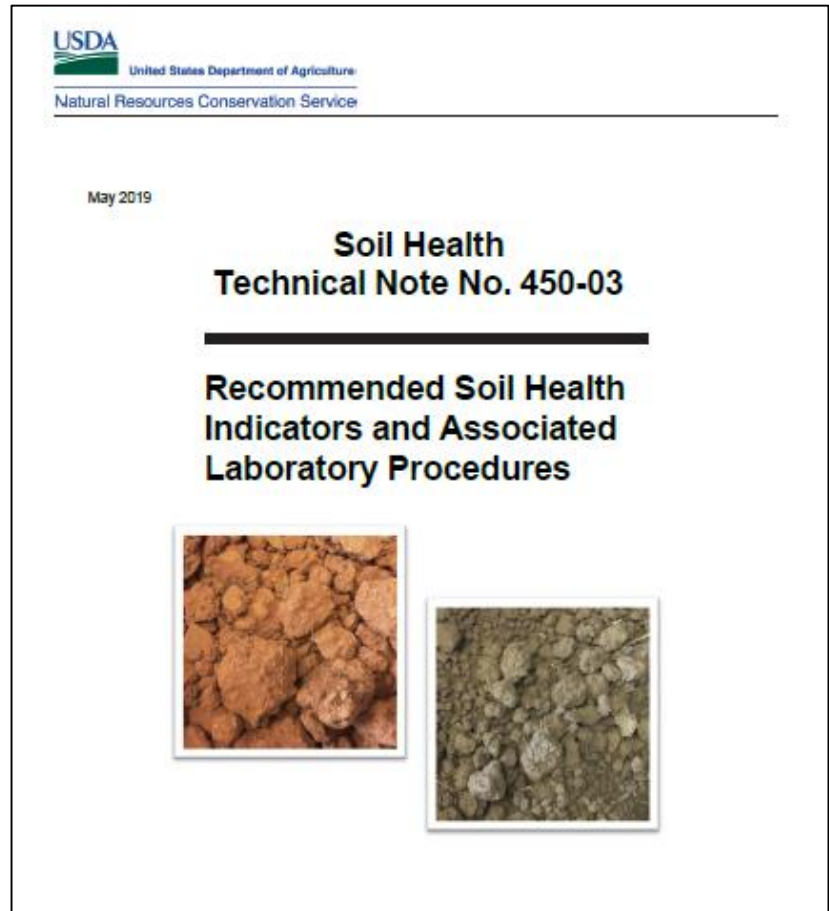
- Soil health calculation based on
 - 24-h CO₂ respiration
 - Water-extractable organic C and N
- H3A chemical extraction
 - Alternative method for P, K, and micronutrients
 - Weak acid extractant (lithium citrate, citric acid, malic acid, oxalic acid, EDTA, DTPA)
 - Formulation has changed, now on version 4
 - Estimation of mineralizable P from organic matter

NRCS Technical Note No. 450-03

Released May 2019

Basic soil health package

- Organic matter and carbon sequestration (total organic C)
- General microbial activity (CO₂ respiration)
- Carbon food source (active C, POXC)
- Bioavailable nitrogen (ACE protein)
- Soil structural stability (water-stable macroaggregates)



The new methods

- Active carbon (permanganate-oxidizable carbon, POXC)
- Soil protein (autoclave citrate-extractable protein, ACE protein)
- Soil aggregate stability (water-stable aggregation)

These “new” methods have long been used in soil quality research with no reason to commercialize, until now with recent farmer demand in the soil health era

Active carbon (POXC)

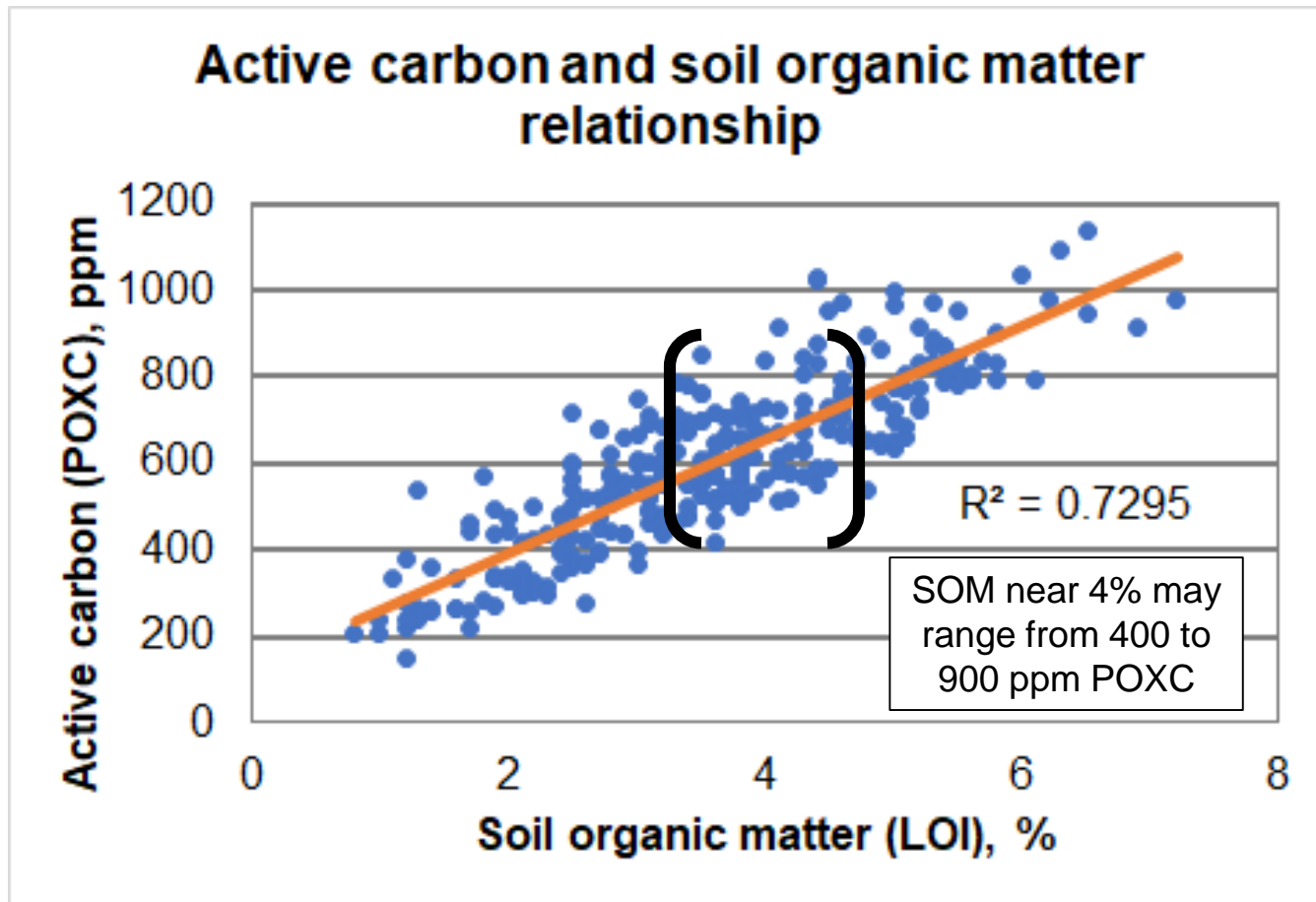
- The biologically active carbon fraction, that is living and particulate organic matter, involved in nutrient cycling (i.e., microorganism food)
- Responds to changes in crop and soil management more quickly than total organic matter, leading indicator of soil organic matter stabilization
- Laboratory analysis is fast, repeatable, low cost

Active carbon (POXC)

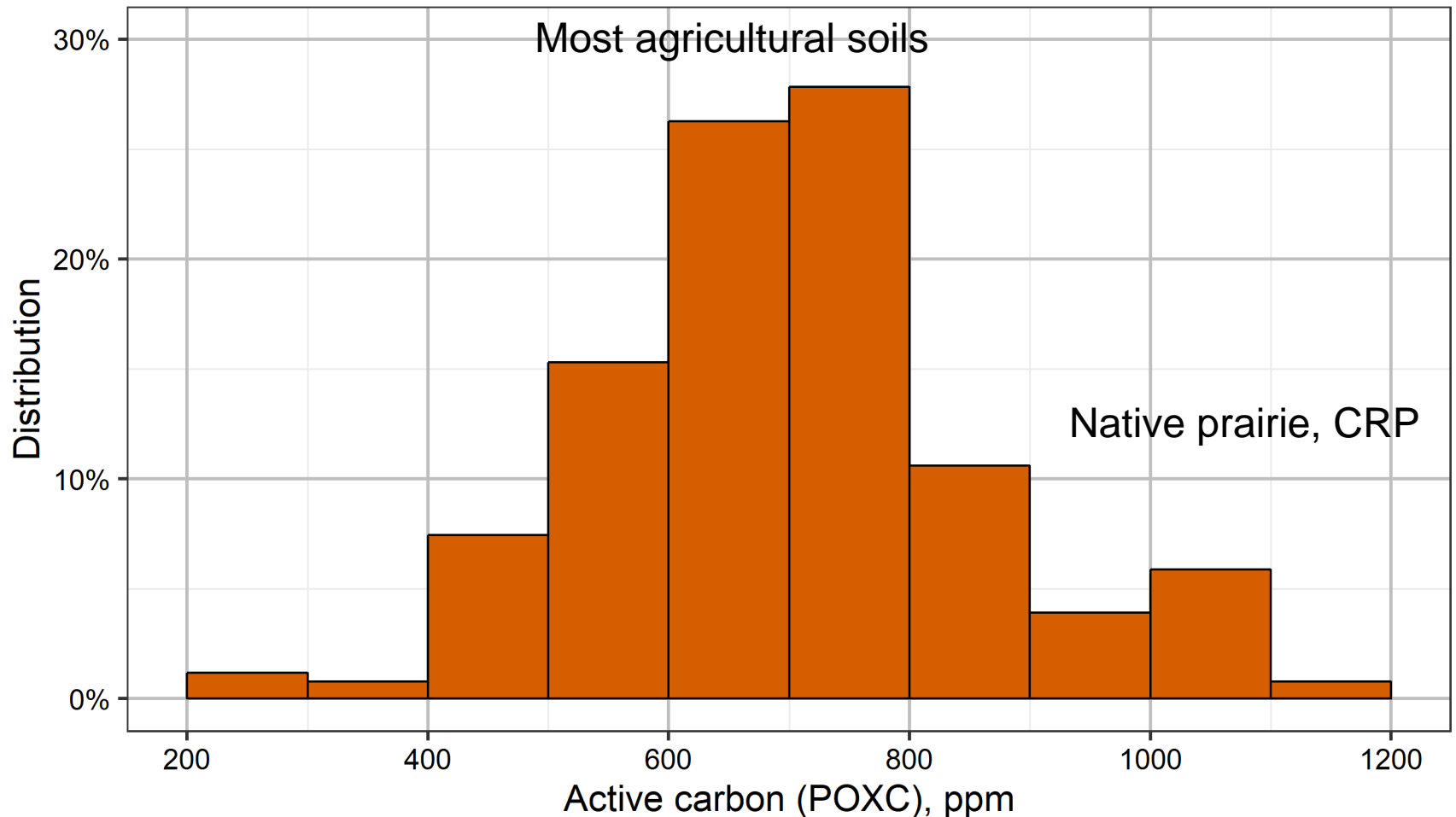


Potassium permanganate oxidizes readily available C, colorimetric determination

Active carbon (POXC) is one fraction of soil organic matter



Active carbon (POXC) distribution among agricultural soils of the Northern Plains

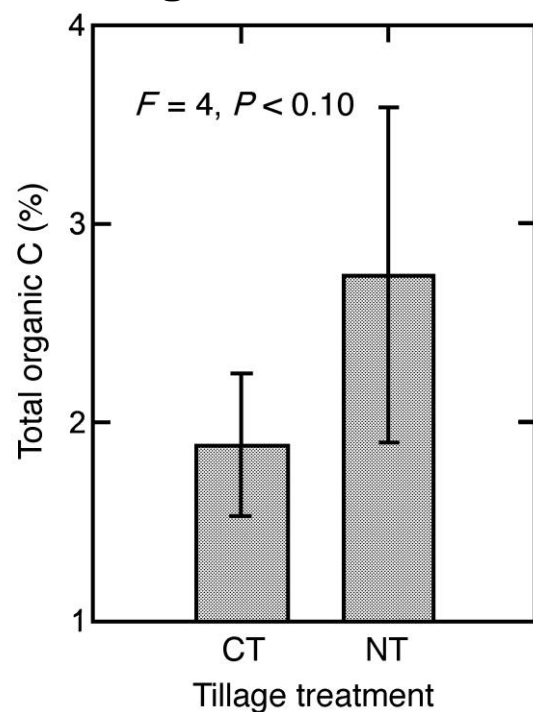


AGVISE Laboratories, Northwood, ND

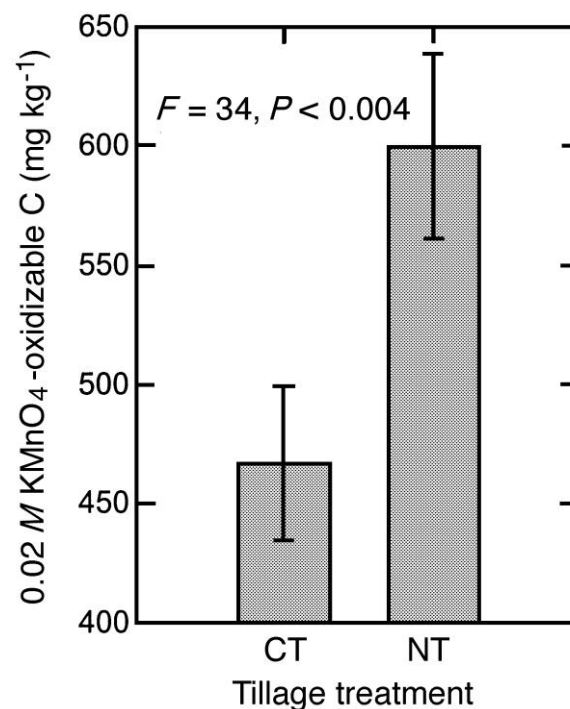
Active carbon (POXC) is a more sensitive indicator than total organic carbon

North Dakota, 17 year experiment

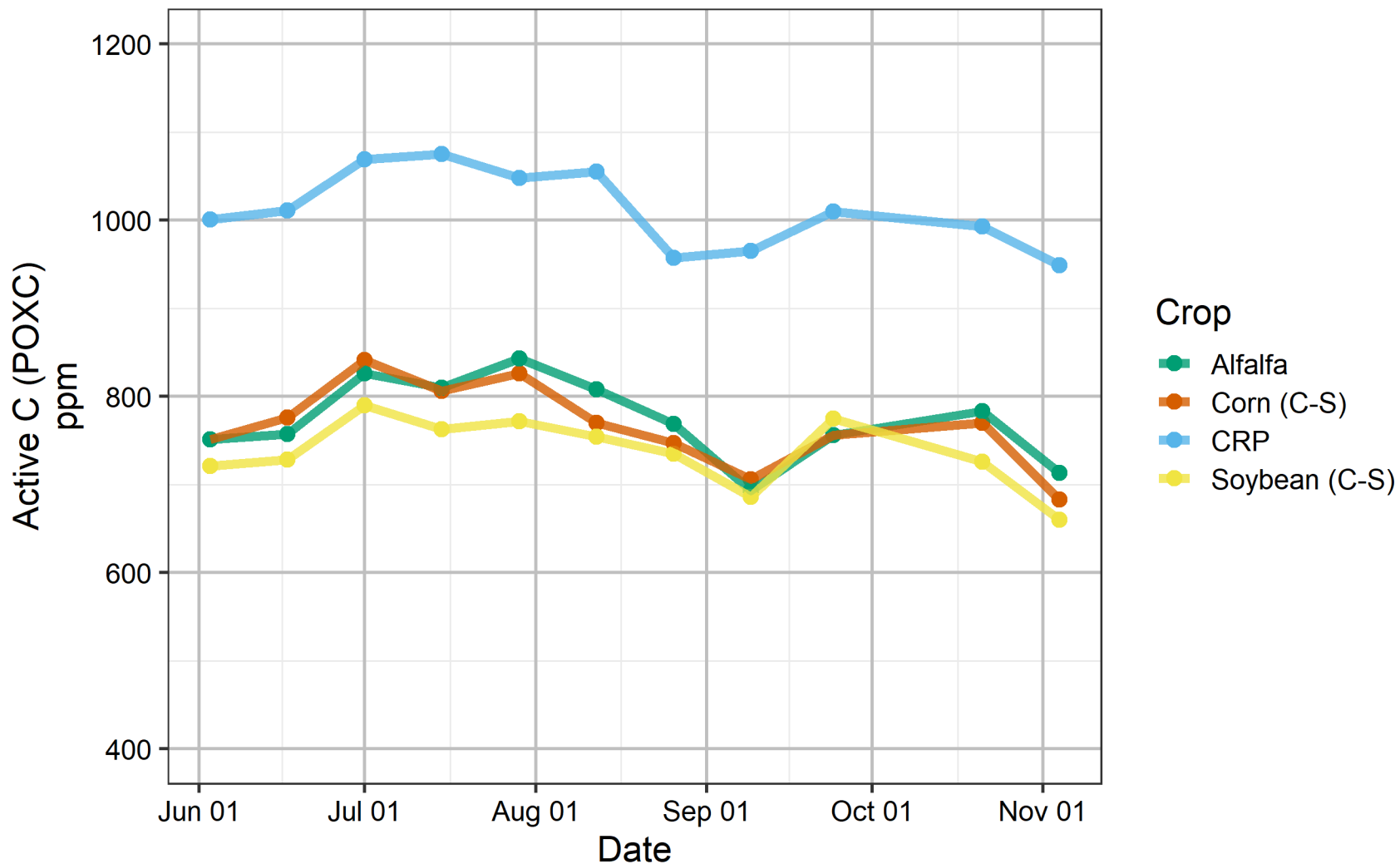
Total organic carbon



Active carbon (POXC)



Tracking active carbon (POXC)



AGVISE Laboratories, Northwood, ND

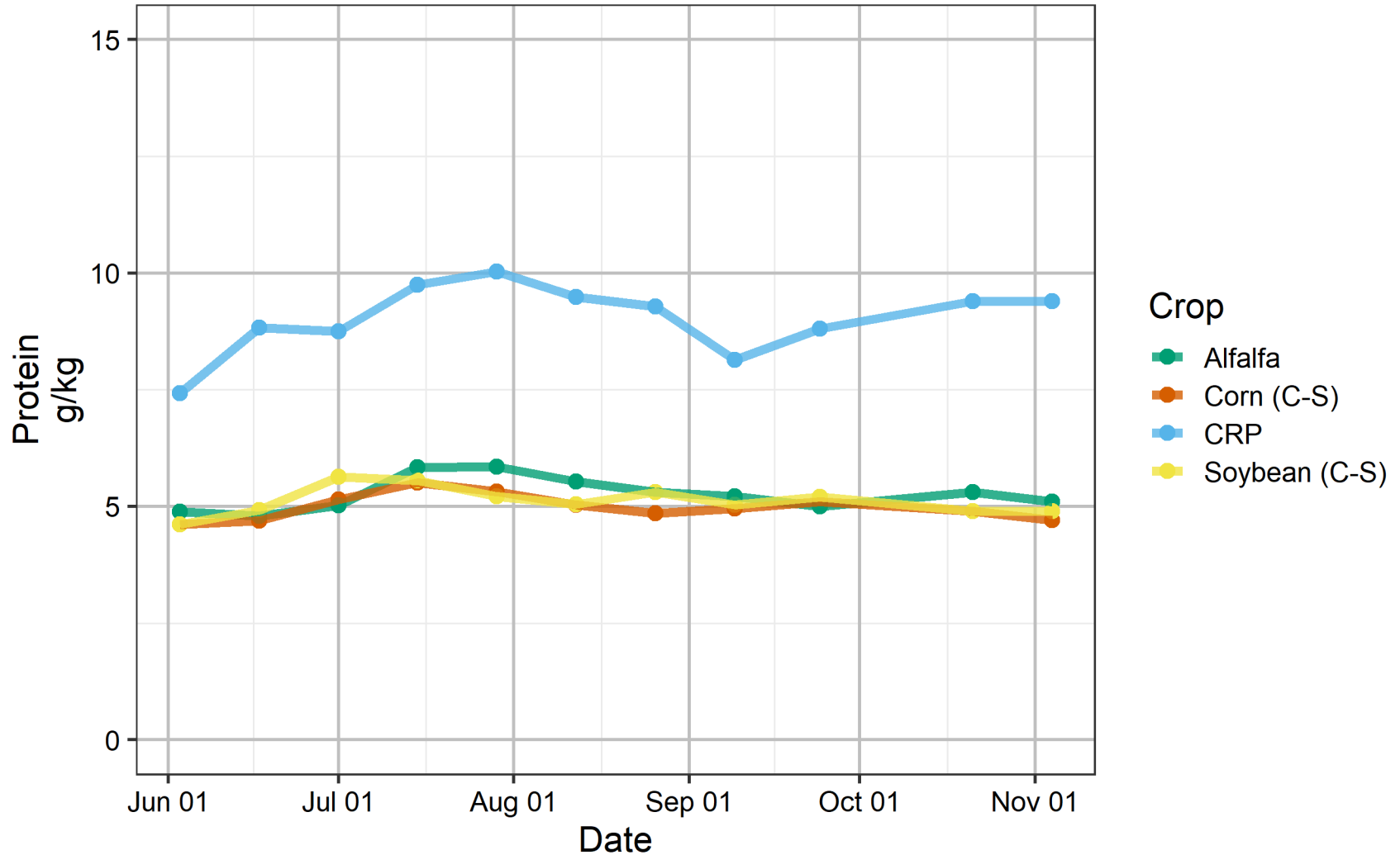
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|----------------------------------|---------------------|---------------------------|-----------------------------------|------------------------|
| Soil texture | ✓ | ✗ | n/a | ✓ |
| Soil organic matter | ✓ | ✓ | ✓ | ✓ |
| Nitrogen mineralization | ✗ | ? | ✗ | ? |
| 24-h CO ₂ respiration | ✓ | ✓ | ✗ | ✗ |
| Active carbon (POXC) | ✓ | ✓ | ✓ | ✗ |
| | | | | |
| | | | | |

Bioavailable nitrogen (ACE protein)

- The protein-like organic nitrogen fraction in soil organic matter accessible for microbial mineralization
- Organic matter quality for N mineralization (greater mineralizable N pool)
 - Amount actually mineralized will depend on environment (i.e., soil water, soil temperature)
 - Requires further university research for its ability to predict N mineralization
- Laboratory analysis is fast, repeatable, affordable (not as expensive)

Tracking bioavailable nitrogen (ACE protein)



AGVISE Laboratories, Northwood, ND

Useful or simply measurable?

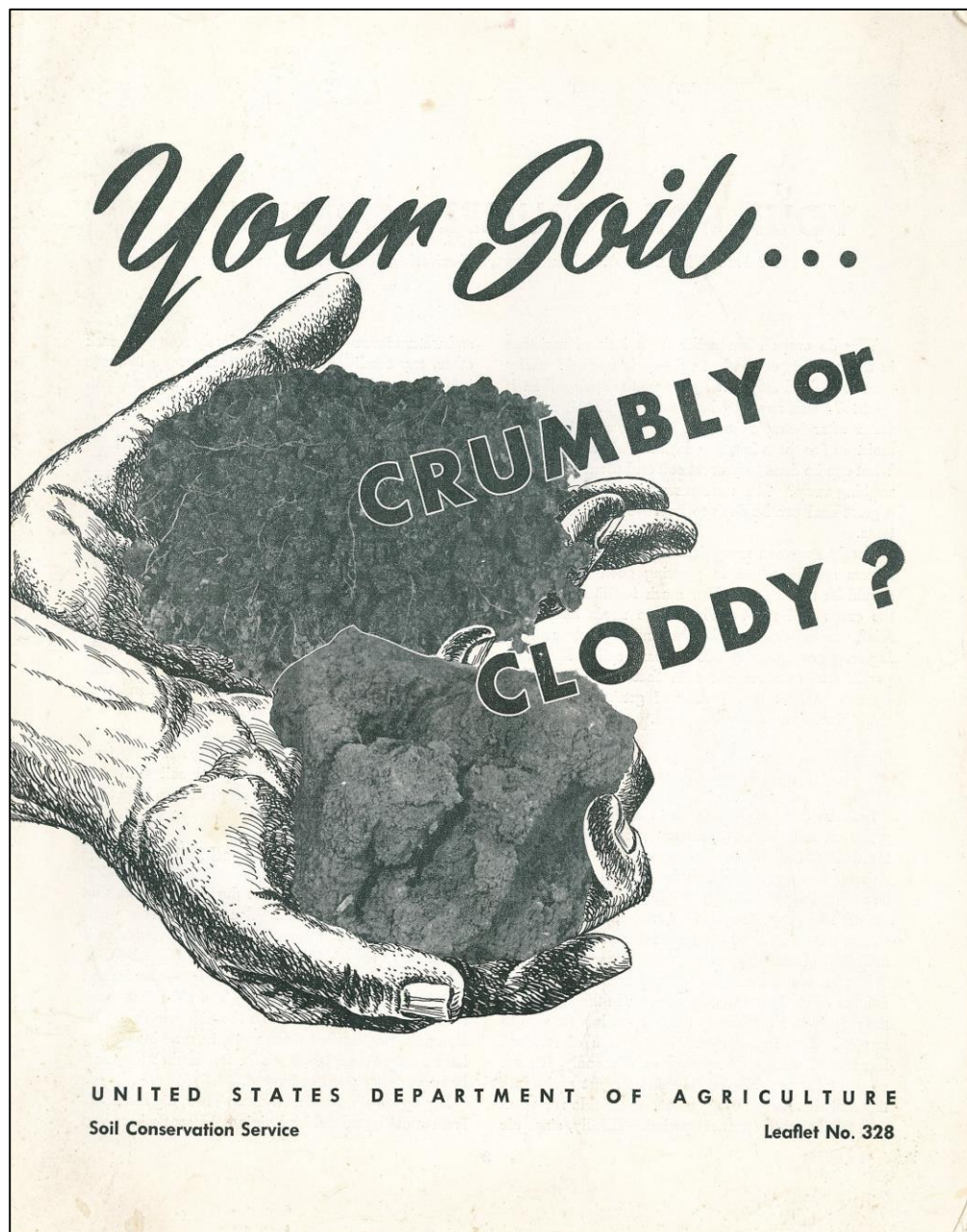
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| 24-h CO ₂ respiration | ✓ | ✓ | ✗ | ✗ |
| Active carbon (POXC) | ✓ | ✓ | ✓ | ✗ |
| Bioavailable nitrogen (ACE protein) | ✓ | ✓ | ✓ | ✗ |
| | | | | |

Soil aggregate stability

- The strength of soil aggregates to resist physical degradation and maintain soil structure
- Strong soil aggregates are the building blocks of good soil structure
- Soils with high aggregate stability have:
 - Less soil erosion
 - Better equipment trafficability
 - Faster water infiltration
 - Less surface crusting
 - More diverse habitat for soil microorganisms

The question has
been asked before

USDA-SCS 1952



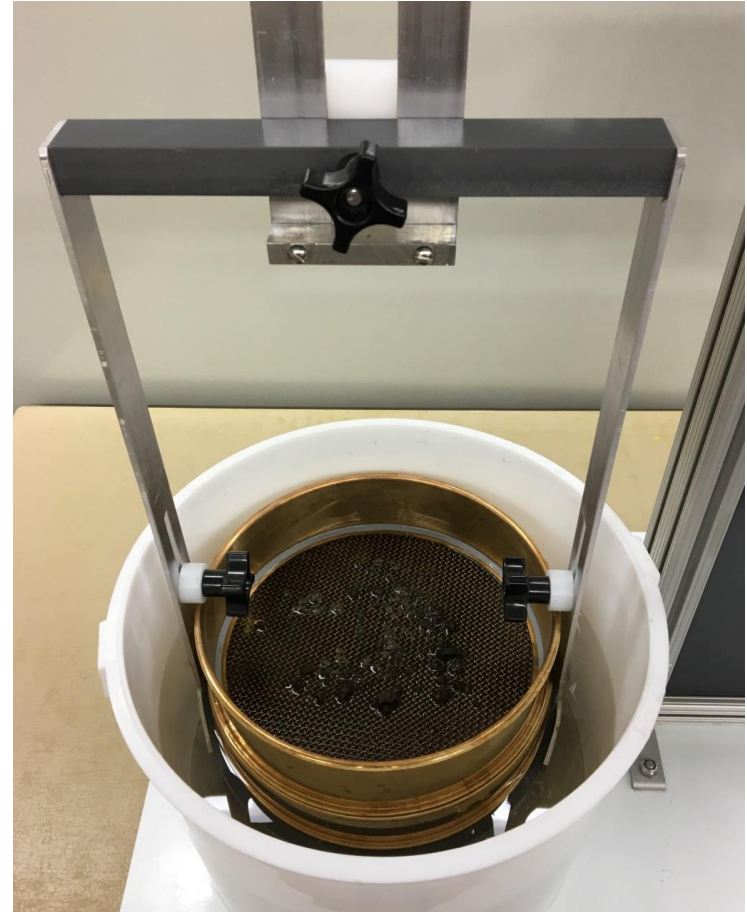
Soil aggregate stability

- Common parameter in soil quality research for decades
- Wet-sieving separates aggregate size and strength
- Manual method is expensive and time-consuming



Soil aggregate stability

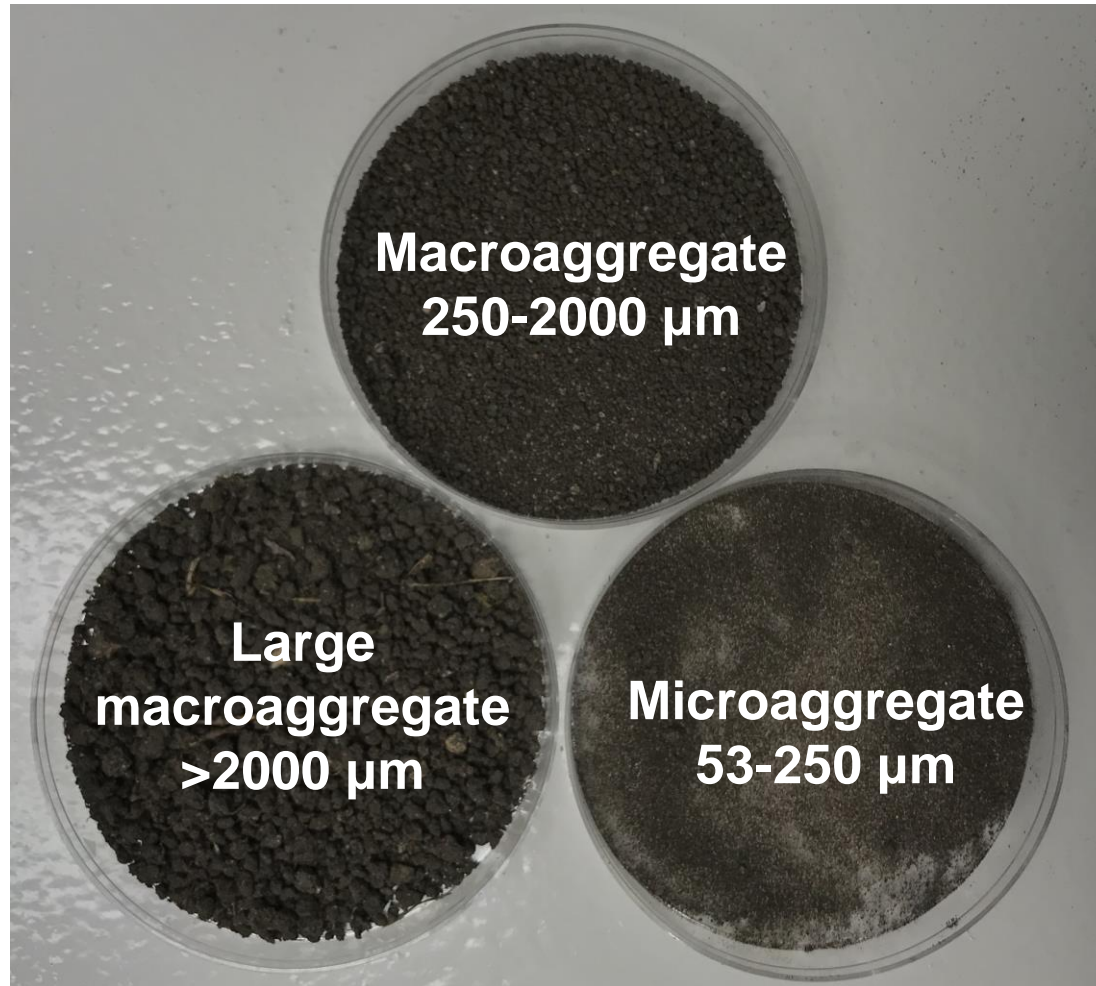
- AGVISE built an automated sieve-dunking system
- Quicker, repeatable results
- Reduced person-to-person method error



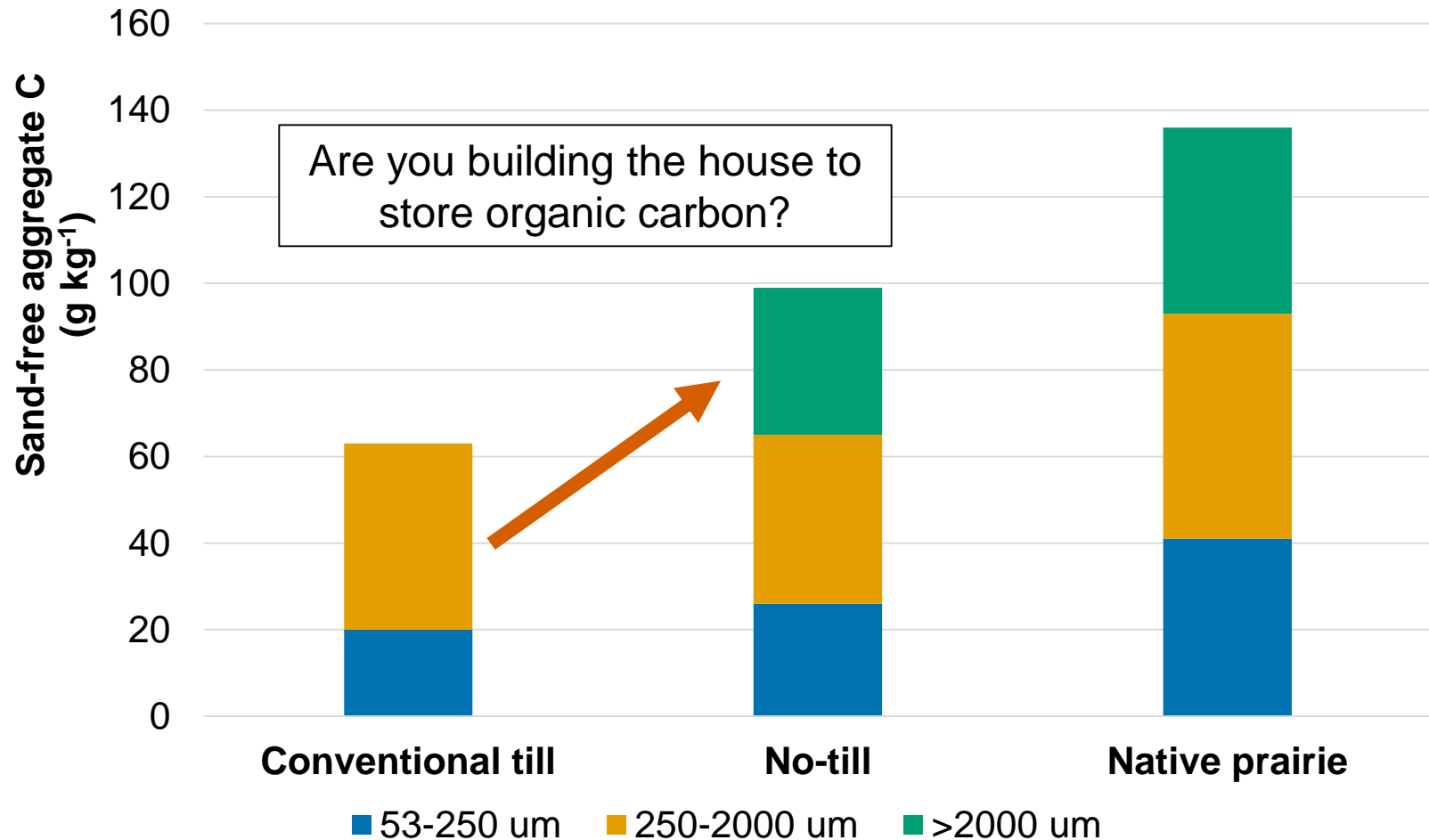
Soil aggregate stability



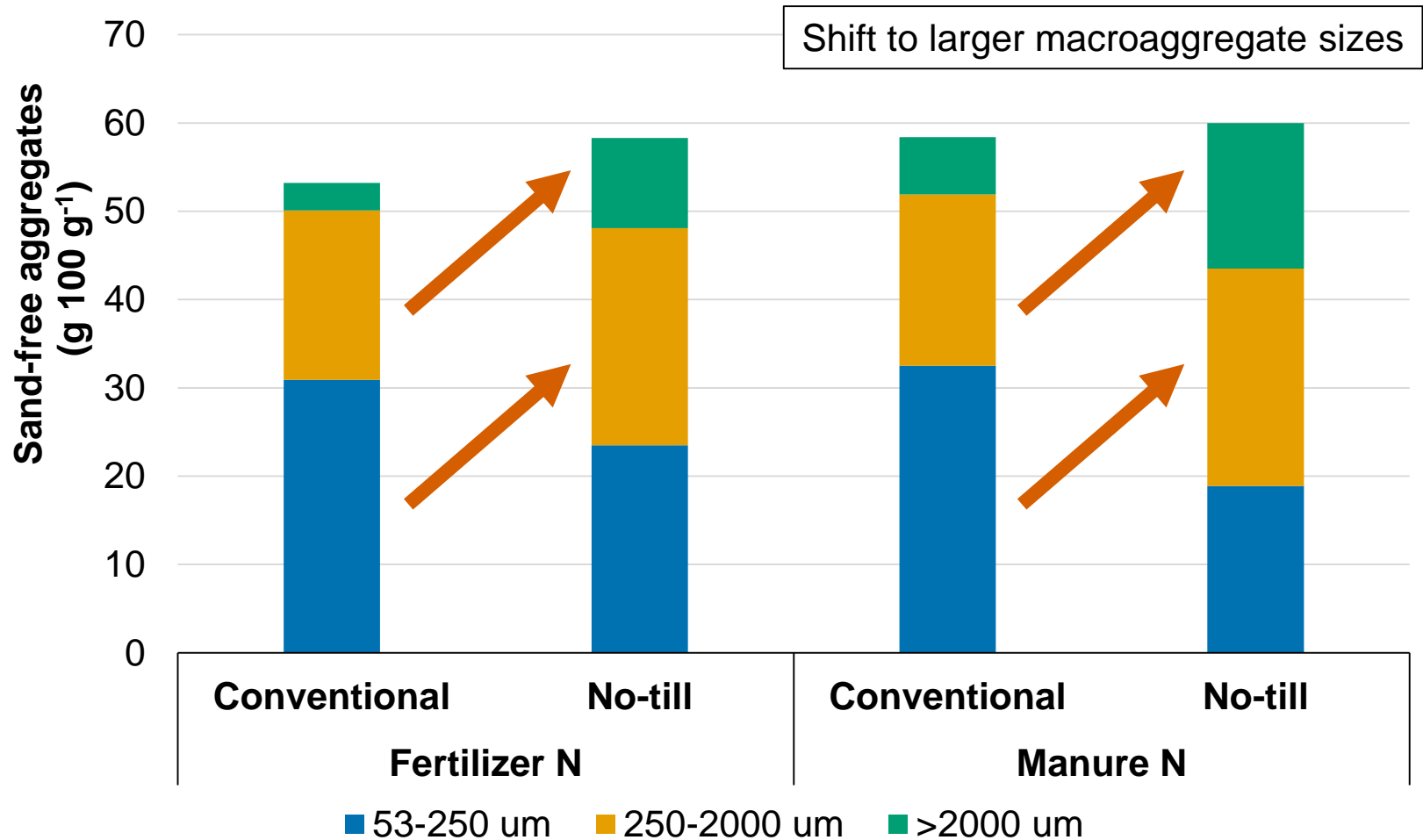
Soil aggregate classes



Stable macroaggregates hold more organic carbon



Soil aggregate stability increased with reduced tillage



Successful
Farming

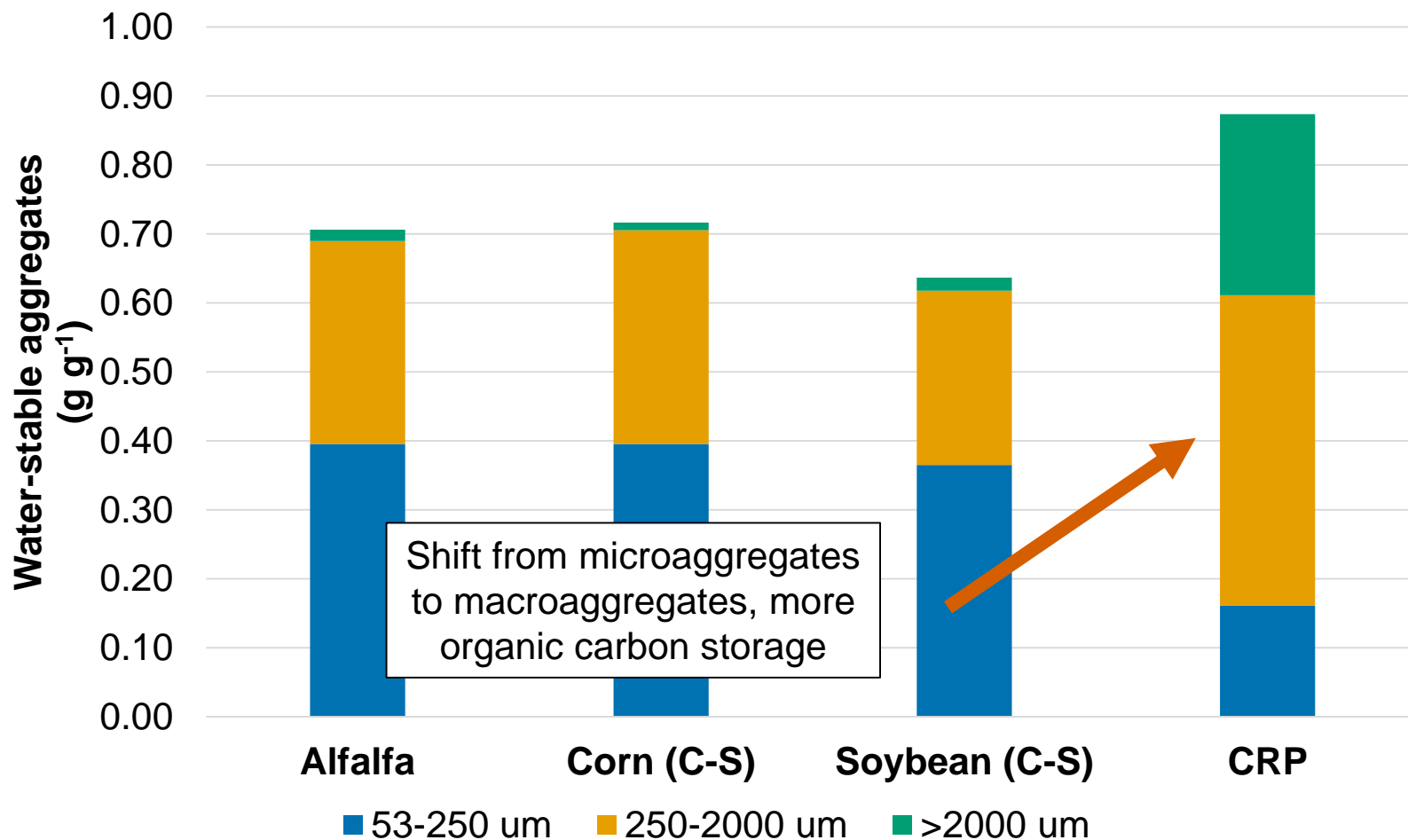
A better living from your soil

Bigger yields of grain, healthier livestock,
better living for you and your family—
these are the benefits of taking proper care
of your soil. With this book you can give
your soil the care that will insure success in
your business of farming.

Tillage and crop rotation drive soil aggregate formation



Tracking soil aggregate stability



Useful or simply measurable?

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| Soil organic matter | ✓ | ✓ | ✓ | ✓ |
| Nitrogen mineralization | ✗ | ? | ✗ | ? |
| 24-h CO ₂ respiration | ✓ | ✓ | ✗ | ✗ |
| Active carbon (POXC) | ✓ | ✓ | ✓ | ✗ |
| Bioavailable nitrogen (ACE protein) | ✓ | ✓ | ✓ | ✗ |
| Soil aggregate stability | ✓ | ✓ | ✓ | ✗ |

Soil health testing as a tracking tool

- Be consistent: Microbial communities are dynamic, collect soil samples at the same time each year
- Be patient: Soil ecosystems take time to change, do not expect big results from small changes
- Set benchmarks: Each soil is different, obtain baseline data for each soil
- **Take measurements every 3-5 years**



Soil sampling protocol

- Active carbon (POXC) and ACE protein can be added onto any routine soil test
- Soil aggregate stability requires its own soil sample
 - Collect with spade, about 2-inch thick
 - Take soil slice from 3-4 locations in field or zone
 - Soil bag must be specially flagged (we do not want it to be accidentally dried and ground with routine samples)
- All locations should be GPS marked, these are tracking tools

Picking a stable soil health indicator

Coefficient of variation (CV) across growing season

| Parameter | Alfalfa | Corn (C-S) | Soybean (C-S) | CRP |
|--|-----------|------------|---------------|-----------|
| 24-h CO ₂ respiration | 19% | 21% | 20% | 17% |
| Water-extractable organic carbon (WEOC) | 18% | 14% | 19% | 13% |
| Haney Soil Health Score | 38% | 44% | 35% | 24% |
| Active carbon (POXC) | 6% | 6% | 5% | 4% |
| Bioavailable nitrogen (ACE protein) | 6% | 5% | 6% | 8% |

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| Active carbon (POXC) | ✓ | ✓ | ✓ | ✗ |
| Bioavailable nitrogen (ACE protein) | ✓ | ✓ | ✓ | ✗ |
| Soil aggregate stability | ✓ | ✓ | ✓ | ✗ |

How high can you go?

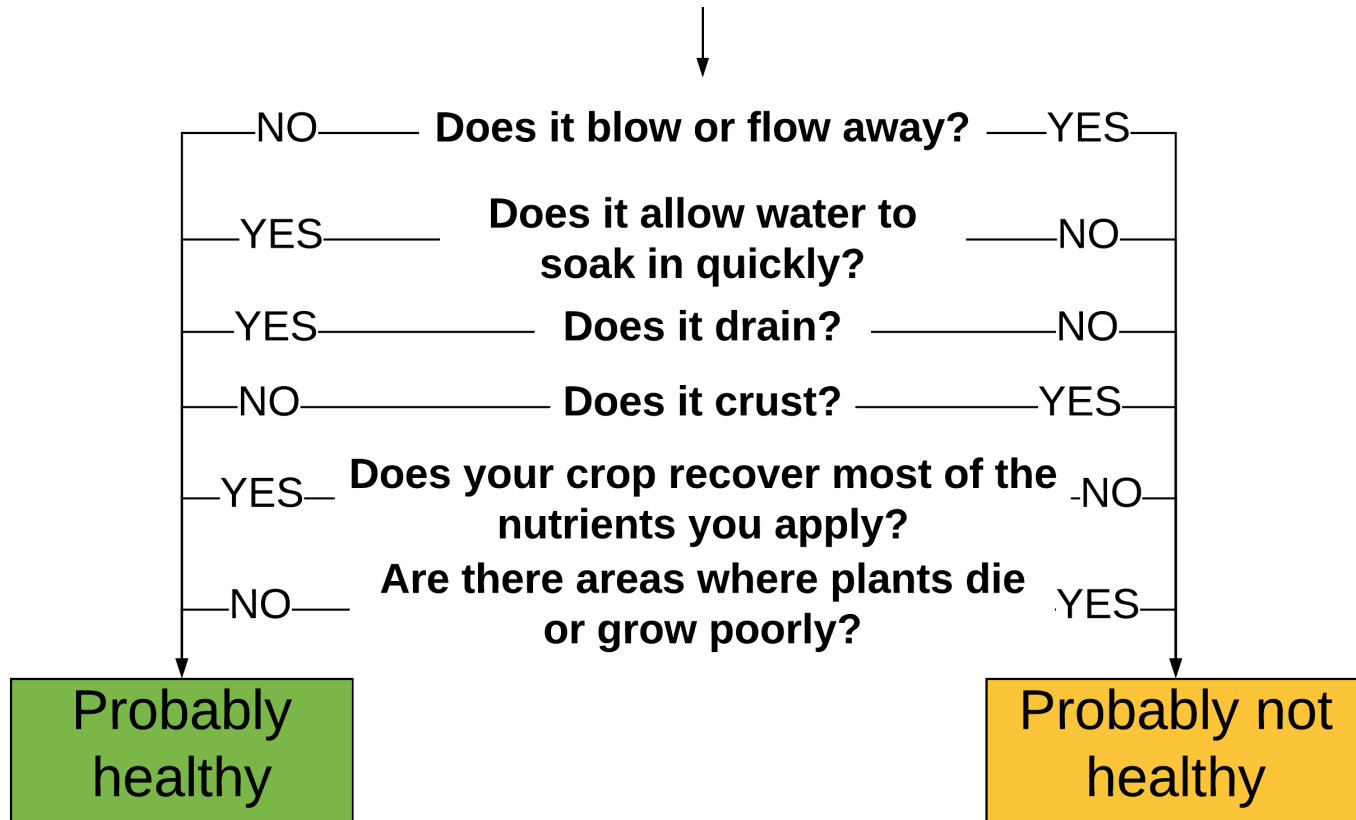
- Recognize long-term, undisturbed perennial system is the best your soil type and climate can likely provide
- Collect soil sample from adjacent grass or woodland (CRP, fence line, shelterbelt)
 - Deposition of eroded soil?
- Cropland may have better soil nutrient levels considering fertilizer history

Don't forget the backbench: physical and chemical soil properties

- Soil pH
- Salinity (electrical conductivity, EC)
- Sodium adsorption ratio (SAR, %Na)
- Total organic carbon
- Bulk density
- Soil texture
- Available water holding capacity

Problem-based soil evaluation

Is your soil healthy?



Soil salinity, Public Enemy No. 1

**Estimated 20% cropland in North
Dakota affected by soil salinity**



“Stop draggin’ my [soil] around.”

with apologies to Stevie Nicks and Tom Petty



For perspective

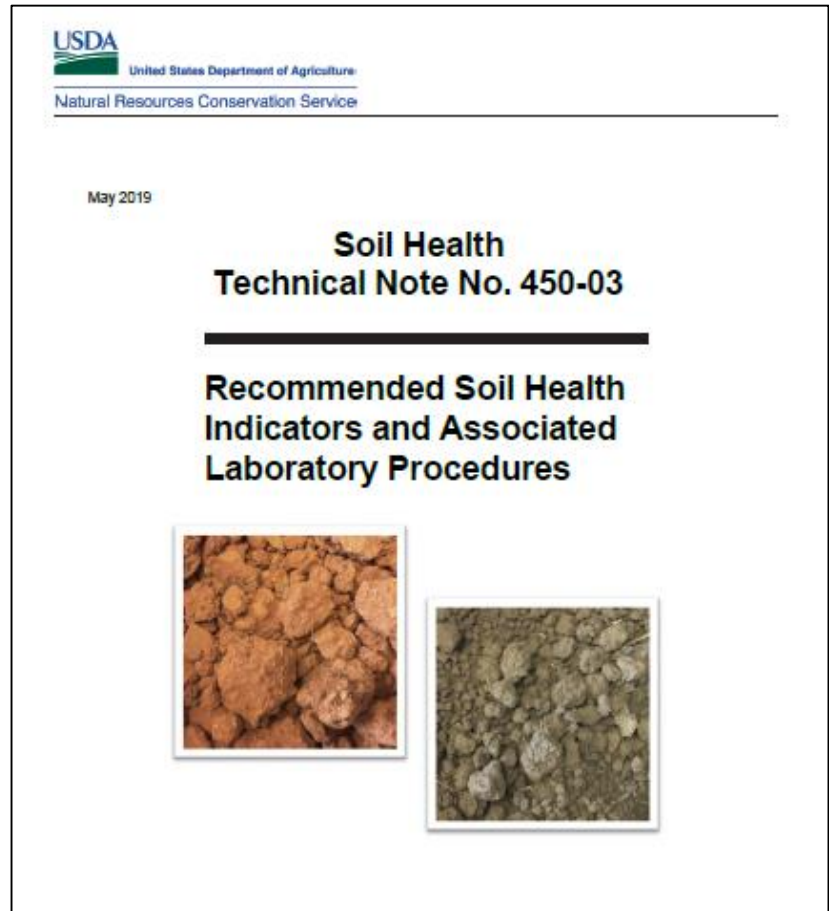
- Soil health testing is still in its infancy
- Soil fertility testing took decades to reach acceptance and adoption (1930s → 1970s)
 - 1845: first soil test method using carbonated water
 - 1894: first fertilizer recommendation for phosphorus
 - 1930/40s: extensive method and fertilizer studies
 - 1953: NDSU Soil Testing Laboratory started (public)
 - 1976: AGVISE Laboratories started (private)
- Various and sundry soil health methods will be introduced and evaluated by universities

NRCS Technical Note No. 450-03

Released May 2019

Basic soil health package

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- General microbial activity (CO₂ respiration)
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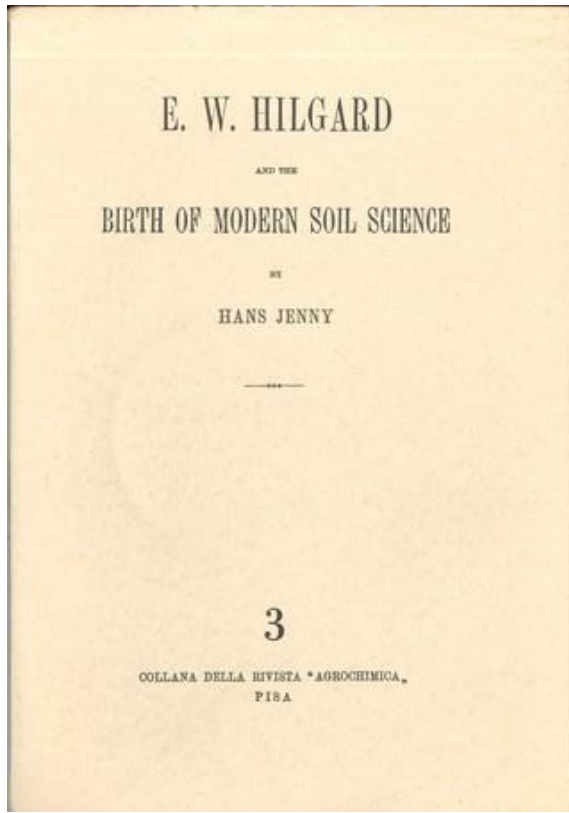


Who is interested in the data?

- Farmers and ranchers
- Agronomists
- Researchers
- Government (e.g. NRCS, Farm Bill)
- Supply chain sustainability (e.g. General Mills, Anheuser-Busch, Walmart)
- Landowners, esp. absentee

Questions for you

- What should you expect soil health tests to provide you? Information on soil properties (facts) or nutrient management (functions)?
- What does soil aggregate stability say?
 - Important information for erosion, compaction, and field trafficability
 - Doubtful utility in nutrient management
- Are we expecting too much (or the right things) from new soil health tests?



“It is our right to use, but not abuse, the inheritance which is ours, and to hand it down to our children as a blessing, not as a barren, inert incubus, wherewith to drudge through life as a penalty for their fathers’ wastefulness.

“That no land can be permanently fertile, unless we restore to it, regularly, the mineral ingredients which our crops have withdrawn.

– E.W. Hilgard (1860), *Report on the Geology and Agriculture of the State of Mississippi*

Thank you for your kind attention!

Are there any questions?