



United States Department of Agriculture



Soil Health Tests Why, What and How?

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What is soil health?

Soil Health

- The continued capacity of the soil to **function** as a vital living ecosystem that sustains plants, animals, and humans.



Soil Health Functions



- Produce food, feed, fiber, biofuels & medicine
- **Capture, filter, and store water**
- **Cycle and recycle nutrients**
- Resilience to drought, flood & temp extremes
- Protect plants from pathogens and stress
- Detoxify pollutants
- **Store C and moderate release of gases**
- **Resist erosive forces**



Soil Health Functions

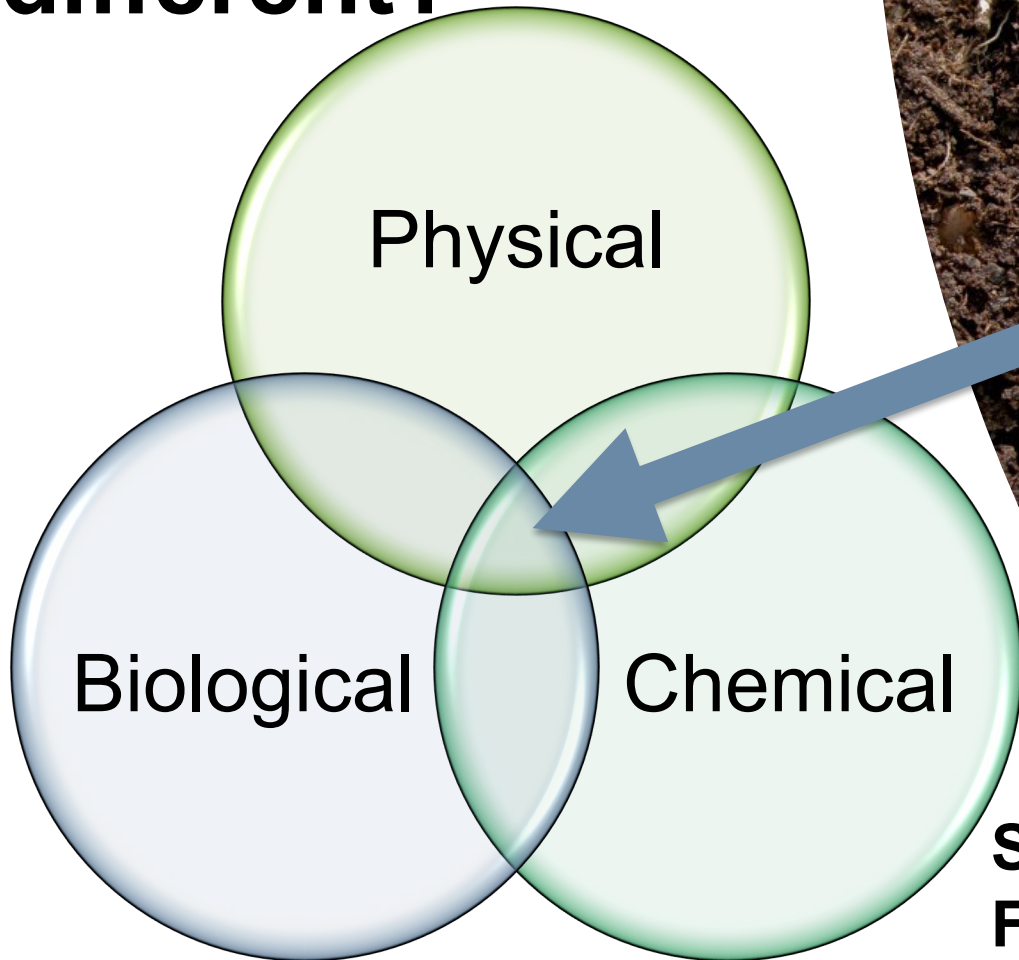


Difficult to measure directly

Soil health tests are a proxy for measuring soil functions.



What makes soil health tests different?



Soil Fertility



Soil Health

Soil Health Indicator Requirements

NRCS Tech Note 450-03

Indicator Effectiveness

- **Management sensitive**
- **Short-term sensitivity**
 - Within 1 to 3 years for significant management changes.
- **Interpretable—related to soil function or process**
 - Standalone or in combination with other tests.
- **Useful**
 - Provides useful information towards assessing soil health status and addressing specific resource concerns

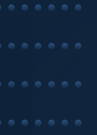


Soil Health Indicator Requirements

NRCS Tech Note 450-03

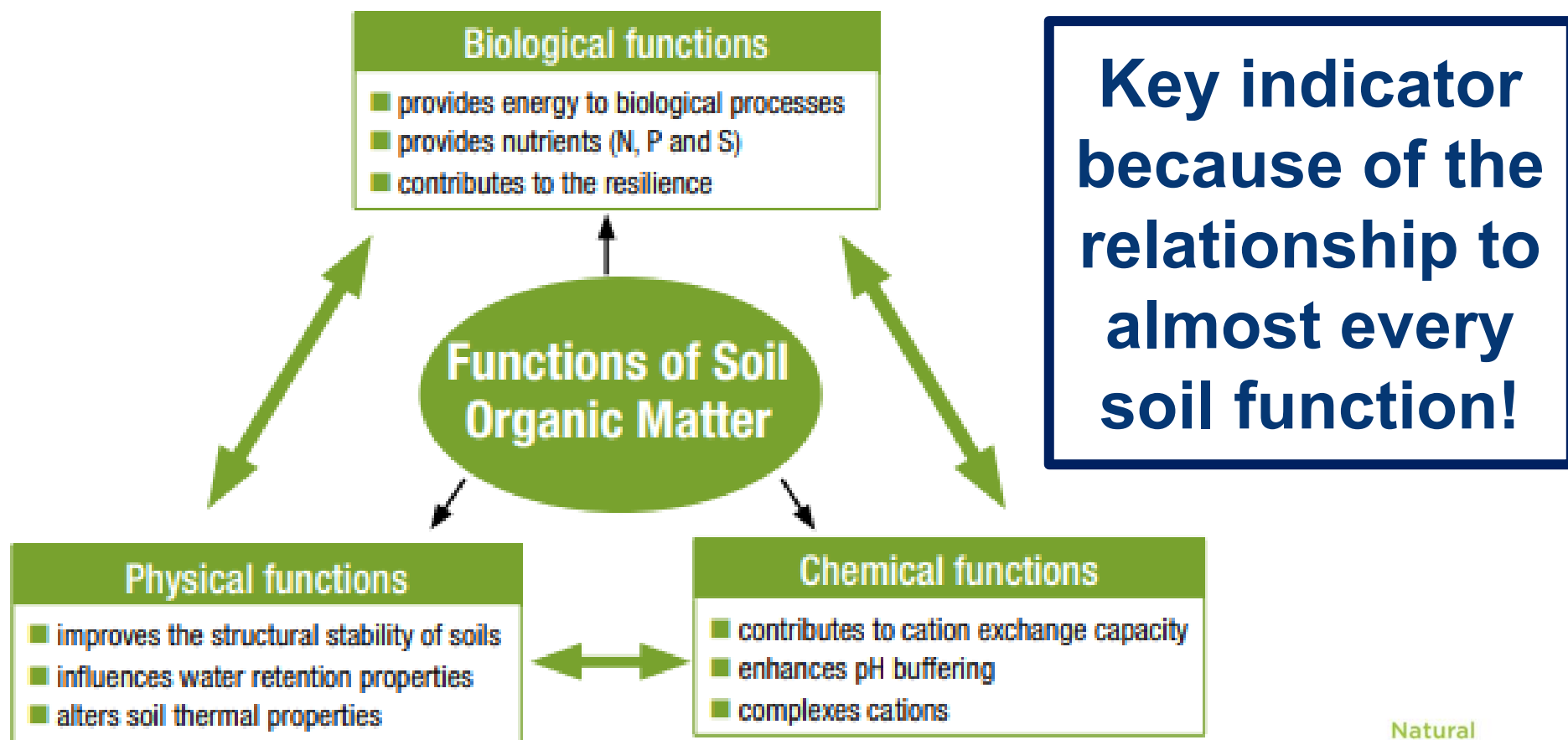
- **Production Readiness**
 - Ease of Use
 - Cost Effectiveness
- **Repeatability**
- **Interpretable for agricultural management decisions**





Organic Matter Cycling

Soil Organic Matter/Carbon



GRDC, Australia

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Soil Organic Matter/Carbon

- **Soil organic matter (SOM)**
 - 58% carbon
- **Soil organic carbon (SOC)**
- **May take 3 to 5 years to show appreciable change.**
- **Could take longer in soils with higher inherent SOM.**

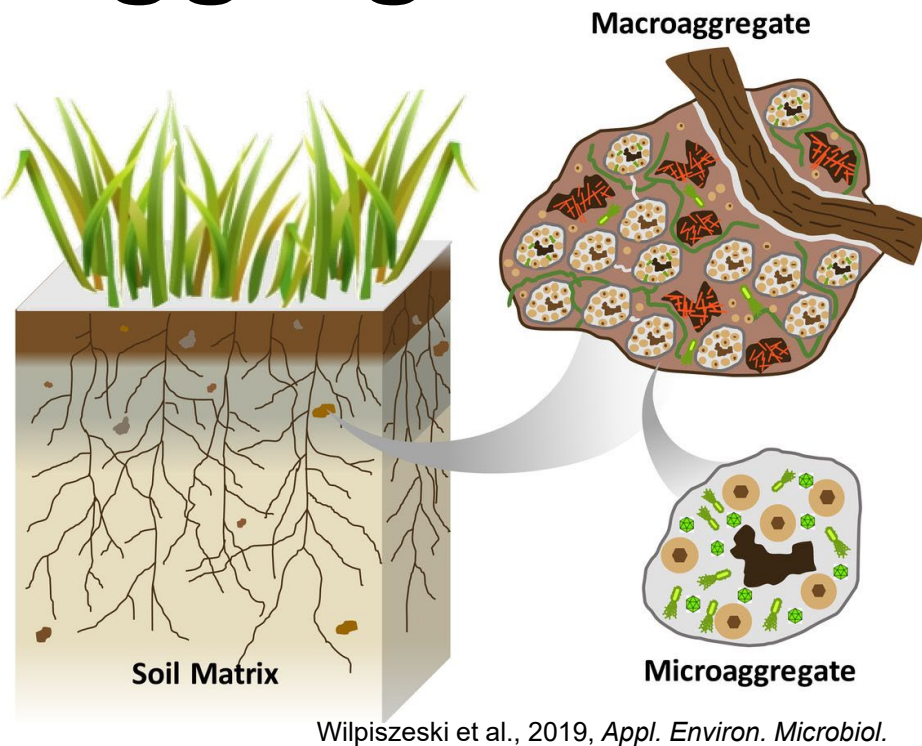


Soil Structure

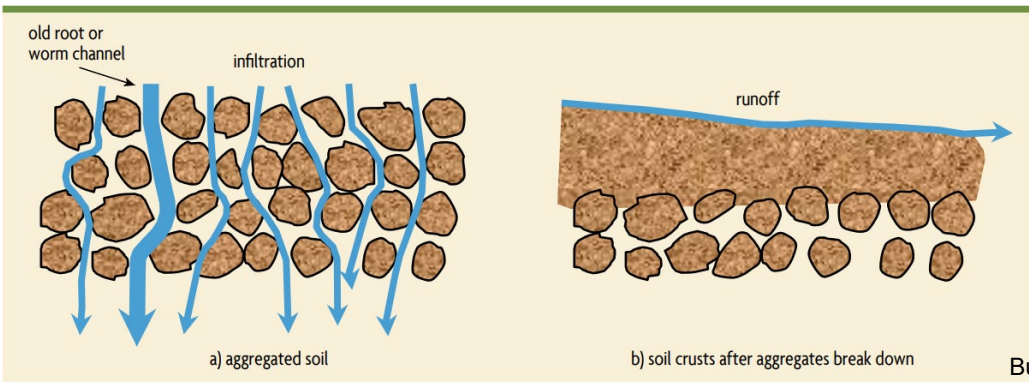
Infiltration

Resistance to Erosion

Aggregate Stability

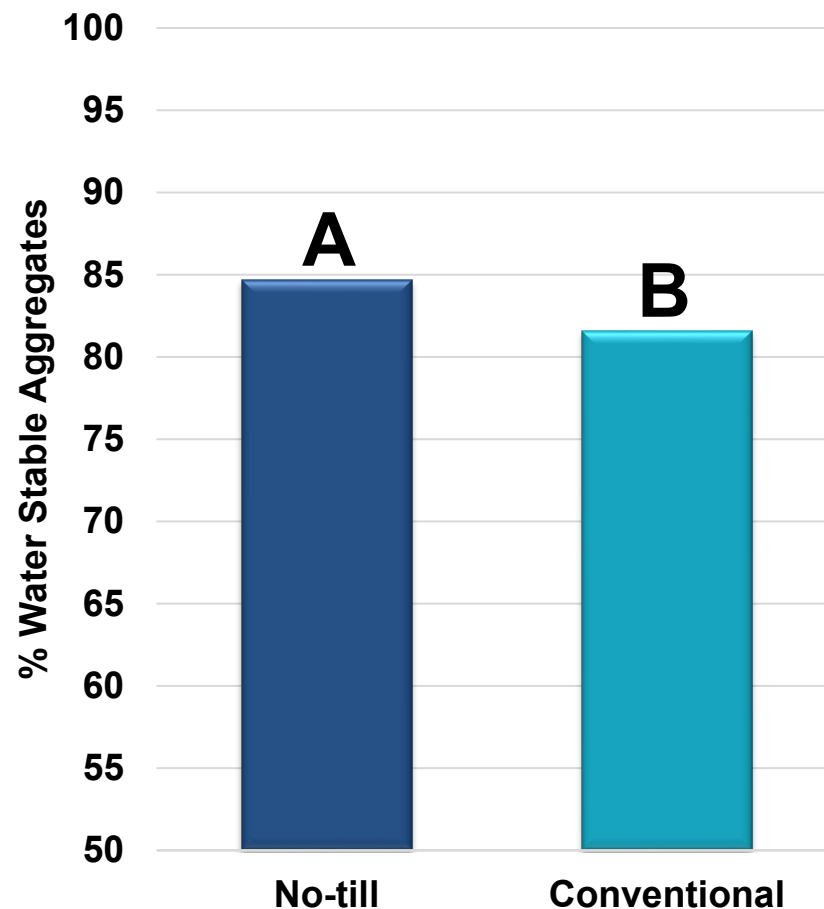
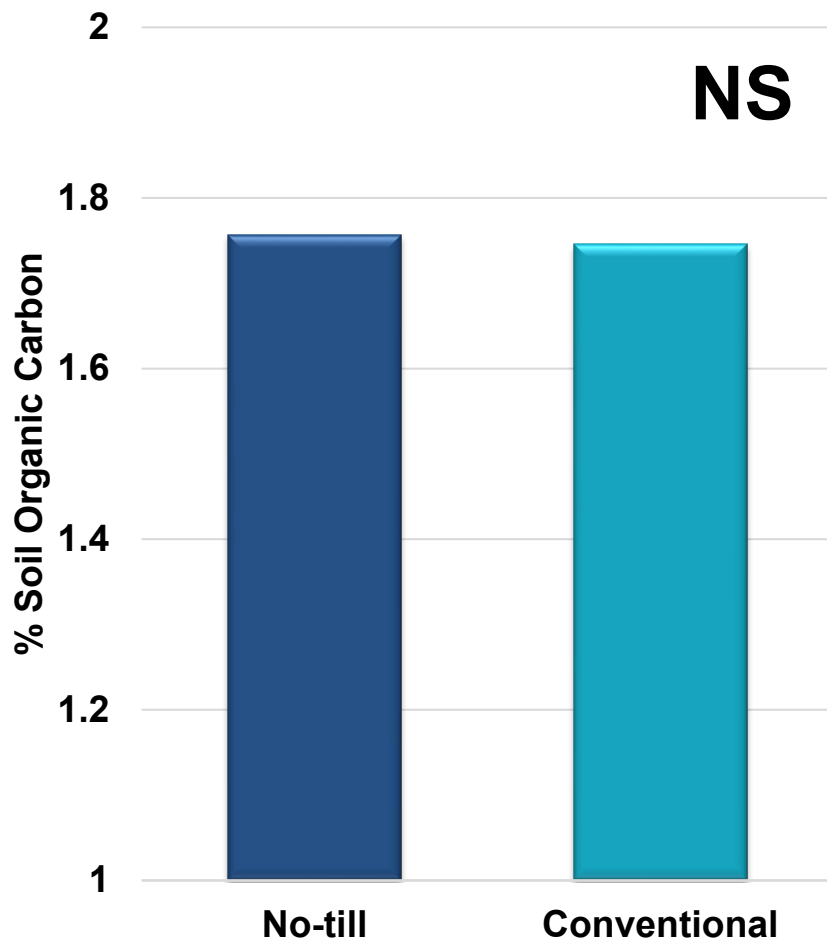


- Strongly related to water infiltration & ability to resist erosion.
- Different methods available, but usually reported as %.
 - What % of aggregate hold together?





Aggregate Stability



Average of two Western IL sites and several
crop rotations (CC, CS, CSW, SS)



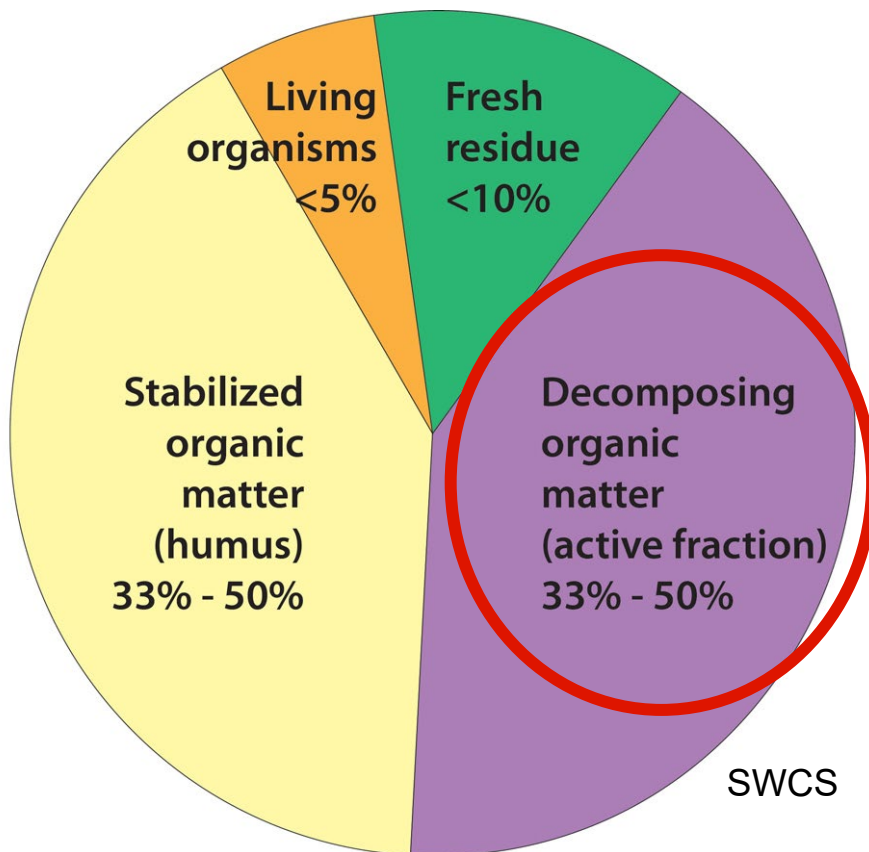


Readily Available Carbon Food Source



Carbon Food Source

Soil Organic Matter Composition

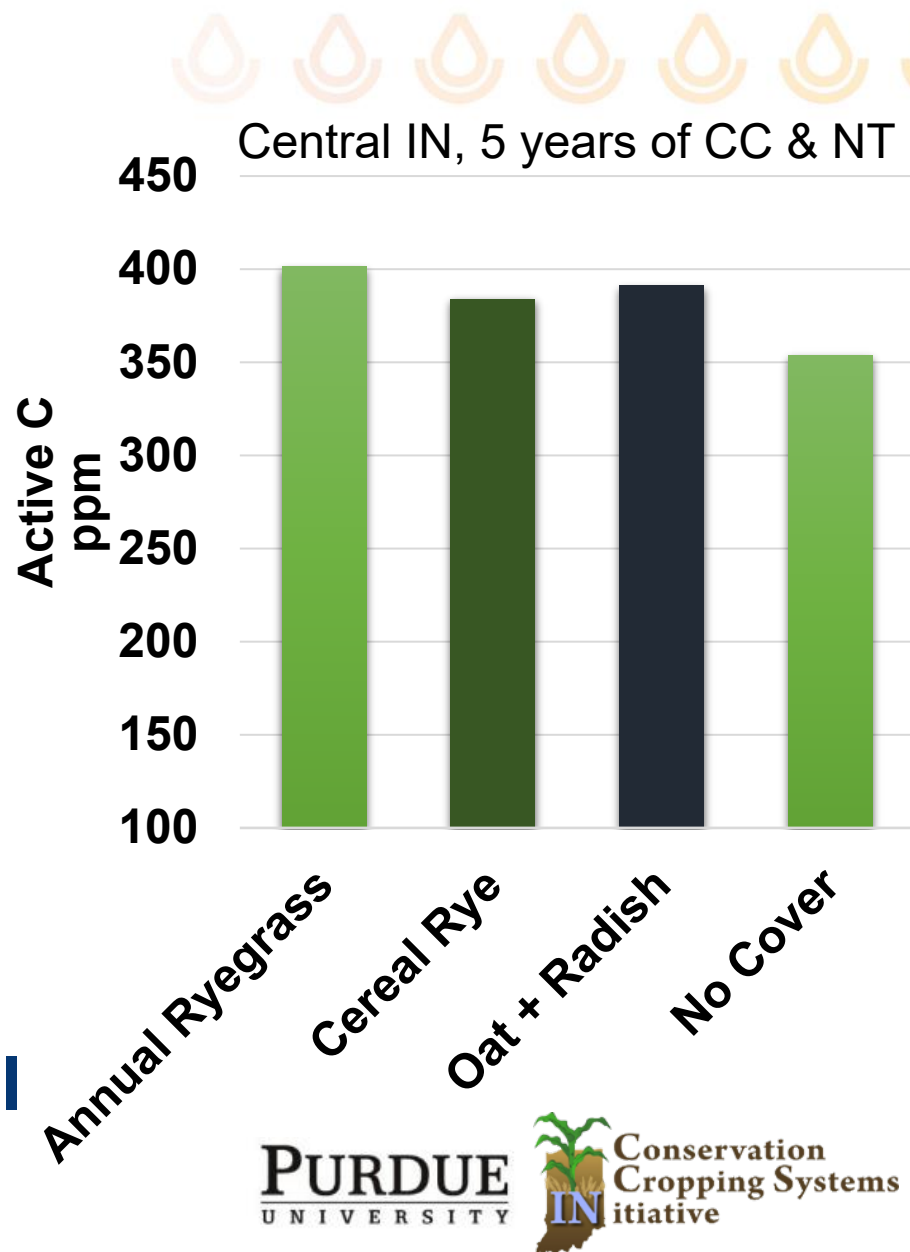


Microbial food source



Active Carbon

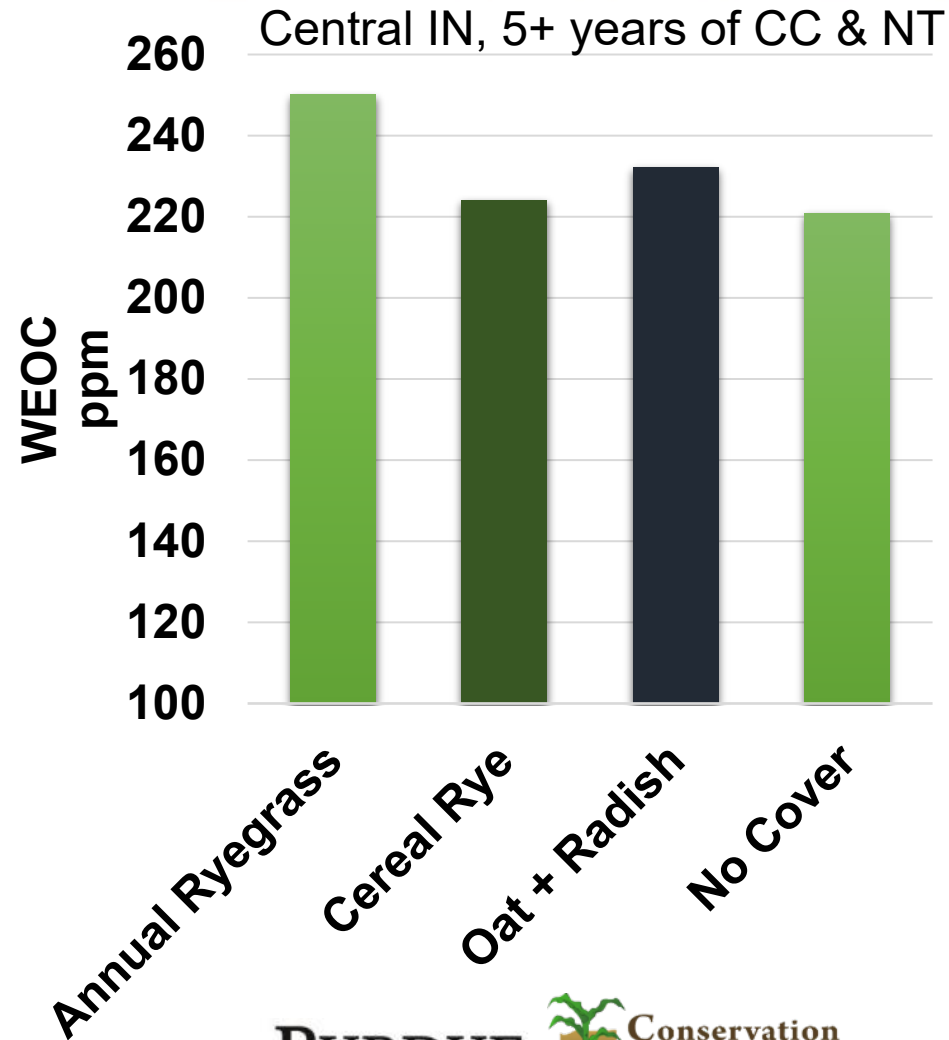
- Permanganate oxidizable carbon (POXC)
- Useful indicator of long-term C sequestration.
- More sensitive to changes in crop and soil management than SOC.



Water Extractable Organic C



- Cold-water extractant
- Used in Haney Test
- Rationale is that C that can dissolve in water is most available to microbes.





Microbial Activity

Soil Respiration



- **Rewetting dried soil then incubated**
- **Measures CO₂ release over certain # of hours**
 - Commonly either 96 hrs or 24 hrs
- **Provided indication of how much the microbes are eating and how active they are.**
- **Also called “Short-term C mineralization”**



Bioavailable Nitrogen

ACE Soil Protein



- **ACE=Acid Citrate Extractable**
- **Majority of N in soil organic matter is in proteins.**
- **Indicates amount of organic N that is cycling through microbial biomass and may be released in plant-available forms.**

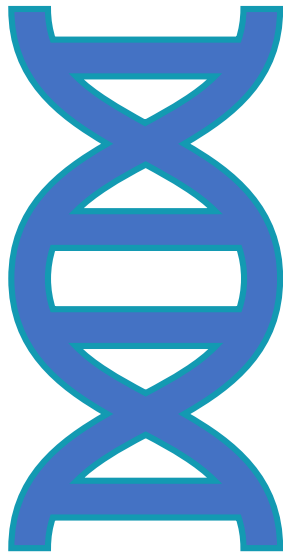


Water Extractable Organic N



- **Part of Haney Test**
- **Same as WEOC.**





Microbial & Functional Diversity

Enzyme Activities

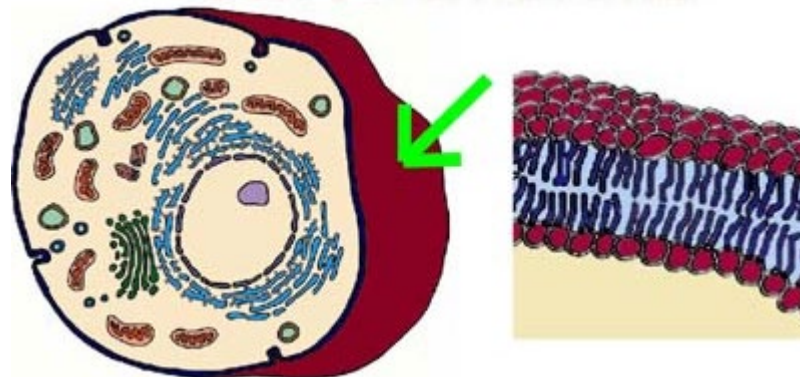


- **Reflect potential for microbes to convert and cycle nutrients.**
- **Enzymes are the metabolic protein keys for breaking up larger molecules.**
 - Cellulose, DNA, lipids, chitin, lignin, proteins
- **Recommended:**
 - β -glucosidase (BG) for C
 - N-acetyl- β -D-glucosaminidase (NAG) for N & C
 - Arylsulfatase for S
 - Acid/alkaline phosphatase for P



Phospholipid Fatty Acids (PLFA)

- Biochemical marker in cell membranes.
- Unique to broad classifications in soil biology.
- Provides an indication of relative abundance of microbial groups and total microbial biomass.



http://www.staff.brookings.k12.sd.us/Reidell/2011%20Facebook%20cells/cellmembrane%20janeg/cell_membrane.png



Phospholipid Fatty Acids (PLFA)

- **Typical PLFA groups include:**
 - Total Microbial Biomass
 - Total Bacteria—Gram (+) & Gram (-)
 - Total Fungi—Arbuscular Mycorrhizae & Saprophytic
 - Protozoa
- **Other reported info:**
 - Fungi: Bacteria
 - Predator: Prey (i.e. Protozoa: Bacteria)
 - Gram(+): Gram(-)
 - Other stress ratios (Sat:Unsat, Mono:Poly, etc.)



Soil Health Test Packages



- **Becoming more widely available from commercial soil testing labs.**
- **Sometimes include overall rating of soil health, integrating several metrics together.**



Comprehensive Assessment of Soil Health

Measured Soil Textural Class: **silt loam**
Sand: 7% - Silt: 66% - Clay: 26%

Percentile ratings based on soils in the CASH database.

Group	Indicator	Value	Rating	Constraints
physical	Available Water Capacity	0.27	94	
physical	Surface Hardness	148	57	
physical	Subsurface Hardness	241	70	
physical	Aggregate Stability	15.2	19	Aeration, Infiltration, Rooting, Crusting, Sealing, Erosion, Runoff
biological	Organic Matter	3.2	58	
biological	ACE Soil Protein Index	4.2	23	
biological	Soil Respiration	0.3	18	Soil Microbial Abundance and Activity
biological	Active Carbon	499	49	
chemical	Soil pH	6.6	100	
chemical	Extractable Phosphorus	4.3	100	
chemical	Extractable Potassium	164.4	100	
chemical	Minor Elements Mg: 538.9 / Fe: 4.0 / Mn: 8.3 / Zn: 0.4		100	

- Scores between:**
- 0 - 20 → very low (red)
 - 20 - 40 → low (orange)
 - 40 - 60 → medium (yellow)
 - 60 - 80 → high (light green)
 - 80 - 100 → very high (dark green)

Overall Quality Score: **66 / Excellent**

Haney Test



- **Package available from many commercial labs**
- **Nitrogen and nutrients component**
- **Soil Health Measurements**
 - Water Extractable Organic C & N
 - 24 hour Soil Respiration/ CO₂ Burst



Haney Soil Health Calculation

$$\text{Soil Health Calculation} = \frac{\text{CO}_2(24\text{hr})}{10} \times \frac{\text{WEOC}}{100} \times \frac{\text{WEON}}{10}$$

CO₂(24hr) → Soil Respiration/ CO₂ Burst

WEOC → Water Extractable Organic Carbon

WEON → Water Extractable Organic Nitrogen

- No specific goal threshold, but look for increase over time.



How do you interpret soil health test results?

- **Few or no thresholds on soil health tests.**
 - **Must have a relative comparison.**
- **Almost all tests are more is better, but limited by soil's potential for improvement.**
 - Depends on inherent soil characteristics and forming factors.



How to Start Soil Health Testing



Decide on Sampling Strategy

- **What is the goal?**
- **What questions are you trying to answer?**
 - Do you want to compare the current soil health indicators of different management practices or of different zones within your field?
 - Do you want to monitor the soil health changes after implementing new practices?



Comparisons or Monitoring

Comparisons—Management

- **Make sure soil types and landscape position are similar**
 - Don't compare **apples** to **oranges**.

Monitoring over time

- **Sample every 3-5 years**
 - Consider crop rotation-sample in the same phase.
- **Consider evaluating different zones or taking a reference sample when you take your baseline**
 - Undisturbed area, fence row, long-term pasture, etc.



How many samples per field?



- **Soil health tests (~\$50-120) are more expensive than fertility tests (<\$10) per sample.**
 - Can focus on sampling zones of field based on soil type, yield map, etc.
- **May only want to sample 1-3 locations per field to monitor.**

Sampling Procedures—How?

- **Slice method is recommended—especially for aggregate stability**
 - Use tile spade, sharpshooter or straight shovel.
 - Dig hole 8 inches deep.
 - Remove 2-inch thick slice of soil 6-8 inches in depth. Repeat 3-4 times in 20-50 ft area.



Sampling Procedures—How?



- **If slice method is not possible:**

- Use soil probe that is 1 inch or more in diameter to 6-8”.
- Collect 15-20 soil cores from appropriate area and composite into single sample.

- **For both methods:**

- Record GPS coordinates of all sample locations (at least center spot).
- Make sure you collected enough soil
 - Often 3-4 cups, but depends on analyses & lab



Spatial Variability

- **Most soil health indicators closely related to soil biology.**
- **High amount of spatial variability.**
- **Soil microbes tend to be concentrated in hotspots and are very sensitive to soil environmental conditions.**



Sampling Procedures



Be CONSISTENT!

- **If monitoring over time, take detailed notes to match up conditions for the next time:**
 - GPS coordinates
 - Sample depth
 - Residue on the soil surface
 - Proximity to plant roots (row vs inter-row)
 - Soil moisture & temperature
 - Date of sampling
 - Tillage
 - Amendments—manure, lime, NPK, etc.



Consistency with Lab and Tests Too!

Be CONSISTENT!

- **Methods may vary between labs.**
 - Aggregate Stability
 - PLFA
- **How samples are handled may differ**
 - Air-drying, sieving, etc.



Shipping Samples



Check into what your lab recommends

- **Most commercial lab tests and packages use air-dried samples –no special requirements.**
- **BUT, soil biological measurements may require next-day shipping or shipping on ice.**
 - PLFA
 - Enzymes





Soil Health Tests

- **Follow these recommendations to minimize variability and maximize usefulness of the tests.**
- **These tests are more sensitive, but small changes may still not be detectable.**
- **Tests are expensive, make sure you take the time to do them right!**





Thank You!

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