ASSESSING SOIL HEALTH AT SCALE AND INCORPORATING MEASURES OF THE MICROBIOME
SOIL HEALTH:

The capacity of a soil to function as a vital, living ecosystem that sustains plants, animals, and humans.
Outline

• Choosing soil health indicators

• Interpreting soil health indicators

• Incorporating measures of the microbiome in soil health
NORTH AMERICAN PROJECT TO EVALUATE SOIL HEALTH MEASUREMENTS TEAM

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GOAL: Identify most effective indicators of soil health

APPROACH: Evaluate soil health indicators on long-term agricultural research sites

124 long term experimental sites

Over 30 Measurements that indicate soil health
# Measures of Soil Health

<table>
<thead>
<tr>
<th>CARBON</th>
<th>NITROGEN</th>
<th>WATER/STRUCTURE</th>
<th>COMMUNITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Organic Carbon</td>
<td>Total N</td>
<td>Plant Available Water</td>
<td>16S Amplicon Sequencing</td>
</tr>
<tr>
<td>Active Carbon (POXc)</td>
<td>Autoclaved Citrate Extractable Protein - ACE</td>
<td>Saturated Hydraulic Conductivity</td>
<td>ITS Amplicon Sequencing</td>
</tr>
<tr>
<td>Potentially Mineralizable C (24 &amp; 96 hr CO₂-C)</td>
<td>Potentially Mineralizable N - Anaerobic</td>
<td>Porosity/Bulk Density</td>
<td>Shotgun Function Metagenomics</td>
</tr>
<tr>
<td>B-glucosidase</td>
<td>N-acetyl B-glucosamidase</td>
<td>Soil Stability Index</td>
<td>Phospholipid Fatty Acid - PLFA</td>
</tr>
<tr>
<td>Microbial Biomass C</td>
<td>H3A Extractable N</td>
<td></td>
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</tbody>
</table>
Measurement Criteria

- Primarily indicate soil health
  - Not inherent properties
  - Not fertility measurements
- Responsive to soil health management practices
  - Reduced tillage
  - Cover crops
  - Organic amendments
  - Residue retention
- Applicable for measurement at scale
  - Cost effective
  - Available commercially
- Non-redundant
  - Provide information on different ecosystem services
Measurement Selection

- **Soil organic carbon**
  - Major component of soil organic matter
  - Measure using dry combustion

- **24-hr Potential carbon mineralization**
  - “Respiration”
  - Microbial response to soil rewetting
  - Related to microbial biomass
Measurement Selection

• **Aggregate stability**
  • Linked to reduced erosion, increased infiltration
  • Fraction of aggregates remaining after exposed to wetting and/or mechanical disturbances
Measurement Selection

- Plant available water
  - Measure directly on intact cores or model using pedotransfer function
  - Model inputs include soil texture and soil organic carbon

**Carbon-sensitive pedotransfer functions for plant available water**

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Conclusion

• Numerous soil health indicator options

• Most Responsive to Management

• Not all available at commercial laboratories

• Remove redundant measures to maximize knowledge
Rationale

Soil Health Interpretation at the Farm Level
SOIL HEALTH TARGETS TEAM

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The Need for Quantifying Potential Soil Health Improvements

Rationale

Soil organic carbon stock
(metric tons OC acre$^{-1}$, 0-15 cm)

Treatment
- Conventional till + fallow
Rationale

The Need for Quantifying Potential Soil Health Improvements

0.5±0.2 metric tons OC acre$^{-1}$

Soil organic carbon stock
(metric tons OC acre$^{-1}$, 0-15 cm)

Treatment
- Conventional till + fallow
- No-till + multispecies cover
- No-till + rye cover
The Need for Quantifying Potential Soil Health Improvements: Effects of Long-Term Adoption/Innovation

Target?

Soil organic carbon stock
(metric tons OC acre$^{-1}$, 0-15 cm)

Treatment
- Conventional till + fallow
- No-till + multispecies cover
- No-till + rye cover
The Need for Quantifying Potential Soil Health Improvements: Effects of Site Characteristics

**SOIL HEALTH INSTITUTE**

**Rationale**

**Treatment**
- Conventional till + fallow
- No-till + multispecies cover
- No-till + rye cover
- Bahiagrass-peanut-cotton
- Peanut-cotton-cotton

**Soil organic carbon stock**
(metric tons OC acre$^{-1}$, 0-15 cm)
Approach

Soil Health Targets Concept

**Interpretable:** Targets represent soil health achievable under optimal management (minimal disturbance, continuous living cover, ...)

**Scalable:** Targets can be quantified even in locations where long-term soil health management systems are absent

**Locally relevant:** Targets are defined for groups of soils with similar site characteristics relevant to soil health (inherent soil properties, topography, and climate)
Soil Health Groups

• Framework for site selection and reporting results
• Preliminary version implemented summer 2021
• Derived using publicly available data:
  • USDA-NRCS Soil Survey
  • Gridded climate products
  • Topographic attributes
• Soils are grouped according to inherent factors including:
  • Mineralogy
  • Texture
  • Drainage
Soil Health Groups

Soil map units

Soil health groups
Soil Health Targets for Cotton-Producing Soils

Arkansas Delta
Blackland Prairie
Coastal Bend

39 row crop fields and 52 targets
Targets: Soil Health under Optimal Management
Proof-of-Concept

Potential Improvements in Carbon Storage across Soils and Regions
Conclusion

• Multiple indicators provide complementary insights on potential improvements in soil functioning
• Soil health groups capture trends in soil health potential across soils and regions
• Reference sites give fuller picture of soil health potential for soils lacking examples of long-term SHMS adoption
Microbiome Measurements & Soil Health

1) Enhance interpretation of common soil health measurements

2) Use as a stand alone measure
   • Specific organisms
   • Functional characteristics
Bacterial & Archaeal Community Composition by Moisture Measurements
Drivers of Microbial Diversity
Goal

• Link changes in soil microbial community structure from tillage to potential carbon mineralization across North America

• Objectives:
  • Define tillage influence on community structure
  • Identify community members enriched under no-till systems across climates and soil types
  • Identify organisms influential in Cmin measurements
• 11 of 14 sites had significantly different (p<0.01) community structures due to tillage

• 3 non-significant sites were wheat-based rotations
  • Sites represented different climates and soil properties
Community Structure: Minimum vs. Intense Tillage

- **717 ASVs** were enriched under minimum tillage
- **Representing:**
  - 16% of microbes in intense tillage
  - 33% of microbes in minimum tillage
Modeling Carbon Mineralization

- Average sequence importance averaged over 30 model runs
Modeling Carbon Mineralization

- Proteobacteria contributed the most
- 44% of sequences of model ASVs enriched under minimum tillage
Modeling Carbon Mineralization

- Proteobacteria contributed the most
- 44% of sequences of model ASVs enriched under minimum tillage
Results- *Acidobacteria Subdivision 6*

- Enriched under no-till and important in predicting Cmin
- *Acidobacteria* present in wide range of soils
- Slow growing
- Adaptive to low nutrient concentrations
- Produces uncharacterized extracellular polymeric substances

Huber et al. 2016
Linking soil microbial community structure to potential carbon mineralization: A continental scale assessment of reduced tillage

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