Soil Health:
A Holistic Approach to Managing Soil for Resilience

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NY Soil Health Training 10-22-20
Sampling Considerations

“Ask your Best Question”

Video link: https://soilhealth.cals.cornell.edu/testing-services/collecting-samples/
Quantifying Soil Health

Biochemical:
• Organic Matter
• Protein
• Respiration
• Active Carbon

Chemical:
• pH
• Major nutrients
• Minor nutrients

Physical:
• Texture
• Aggregate Stability
• Surface/sub-surface hardness

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Biological Indicators:  
(The life of the soil)  
• Organic Matter  
  • Protein  
  • Respiration  
• Active Carbon  
• Total Carbon, Total Nitrogen
Soil Organic Matter (SOM):

Measure of carbon-containing material that is, or is derived from living organisms including plants and other soil dwelling organisms.

Basic protocol:
• Measured by Loss on Ignition at 500C
• \[ \% \text{OM} = (\% \text{LOI} \times 0.7) - 0.23 \]
• Reported as \% SOM
Soil Protein Index:

- Derived from plant residues in soil
- Indicator of protein-like substances present in SOM. Represents the large pool of organically bound N in SOM, which microbial activity can mineralize and make available for plant uptake
Soil Protein Index

Basic Protocol:

- Proteins are extracted from soil
- Aggregates are dispersed using sodium citrate buffer
- Solution autoclaved, 2 ml slurry centrifuged
- Extract analyzed in standard colorimetric protein quantification assay (Thermo Pierce BCA Protein Assay)
- Read for color with spectrophotometric plate reader
Soil Respiration

- Measure of metabolic activity of soil microbial community
Soil Respiration

Basic Protocol:
• 20g air-dried soil
• Rewetted and placed in jar with 9ml of 0.5 M Potassium Hydroxide (KOH) and 7ml water
• Jar sealed for 4 days
• Conductivity of KOH measured determining total captured CO2
• CO2 (0.25 M K2 CO2)
Active Carbon

- Indicator of SOM that can serve as readily available food and energy source for soil microbial community

https://enst.umd.edu/people/faculty/ray-weil

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Active Carbon

Basic Protocol:
• 2.5g, air-dried soil in centrifuge tube with 20ml 0.02 potassium permanganate (KMnO4)
• Shaken for 2 minutes, settled for 8 min.
• Solution lightens and color is measured with colorimeter
• Reported as ppm

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Total Carbon, Total Nitrogen

• Total Carbon is a measure of both the organic and inorganic forms of carbon in soil. Including relatively available organic carbon and more stable organic carbon that is protected in the soil.

• Total Nitrogen exists in organic forms and inorganic (or mineral) forms such as plant available ammonium (NH4+) and nitrate (NO3-). The majority of Tot N is bound in soil organic matter.
Total Carbon, Total Nitrogen

Measurement of the carbon and nitrogen in soil samples is accomplished using a temperature regulated dry combustion furnace with automatic control of gas flow and pressures.

- The Tot C in a sample is obtained with the complete oxidation of carbon to CO2 using high temperature combustion (1100 °C) and CO2 measurement using Non Dispersive Infrared Detection.

- The Tot N in a sample is obtained following the Dumas Methodology.
  - In this analysis, the sample is moved into the combustion furnace where all Nitrogen is converted to NₓOᵧ using oxygen.
  - Then the effluent gas is moved to the reduction furnace where all nitrogen is reduced to N2.
  - The N2 gas is measured by Thermal Conductivity Detection (TCD).
Physical Indicators:

• Aggregate Stability
• Texture
• Available Water Capacity
• Surface/Subsurface Hardness
Aggregate Stability

- A measure of the extent to which soil aggregates resist falling apart when hit by rain drops and wetted.
Aggregate Stability

Basic Protocol:
• Air-dried soil is shaken to remove aggregates >0.25mm
• Known weight placed on 0.25mm sieve
• Sieves “rained on” for 5 minutes
• Failed aggregates caught by filter, weighed
• Stones remaining weighed
• % stable aggregates quantified
• WSA=Wstable/Wtotal
Soil Texture

- Percentage of sand, silt and clay. Inherent soil property that affects many soil processes.
Soil Texture

Basic Protocol:

• 14g air-dried soil shaken in soap solution for 2 hours to separate sand, silt and clay
• Sand removed by 0.053mm sieve
• Silt and clay removed via water into beaker
• Silt settles to bottom of beaker in 2 hours
• Decant clay, dry at 105C weigh sand and silt
Available Water Capacity

• Indicator of the range of plant available water the soil can store.
• The upper end of the range is referred to as ‘field capacity. The lower end of the range is called the ‘permanent wilting point’

<table>
<thead>
<tr>
<th>Textural Class</th>
<th>Available Water Capacity (Inches/Foot of Depth)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse sand</td>
<td>0.25–0.75</td>
</tr>
<tr>
<td>Fine sand</td>
<td>0.75–1.00</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>1.10–1.20</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>1.25–1.40</td>
</tr>
<tr>
<td>Fine sandy loam</td>
<td>1.50–2.00</td>
</tr>
</tbody>
</table>
Available Water Capacity

Basic Protocol:
- Soil is placed on ceramic plates with known porosity
- Plates are placed in 2 high pressure chambers to extract water to field capacity (10 kPa) and permanent wilting point (1500 kPa)
- After sample equilibrates, samples dried in 105°C oven and weighed
Surface and Subsurface Hardness

- Indicators of the soil compaction status, measured as field penetration resistance in pounds per square inch (psi)
Chemical Indicators:  
(typical soil test)  
• pH  
• Major Nutrients (NPK)  
• Minor Nutrients
## Comprehensive Assessment of Soil Health

**Grower:** Bob Schindelbeck  
**Sample ID:** pp917  
**Field ID:** Caldwell Field - Intensive cultivation  
**Date Sampled:** 02/13/2017  
**Given Soil Type:** Collamer silt loam  
**Crops Grown:** WHT/WHT/WHT

### Measured Soil Textural Class: silt loam
- **Sand:** 10%  
- **Silt:** 73%  
- **Clay:** 16%

<table>
<thead>
<tr>
<th>Group</th>
<th>Indicator</th>
<th>Value</th>
<th>Rating</th>
<th>Constraints</th>
</tr>
</thead>
<tbody>
<tr>
<td>physical</td>
<td>Available Water Capacity</td>
<td>0.16</td>
<td>52</td>
<td></td>
</tr>
<tr>
<td>physical</td>
<td>Surface Hardness</td>
<td>260</td>
<td>12</td>
<td>Rooting, Water Transmission</td>
</tr>
<tr>
<td>physical</td>
<td>Subsurface Hardness</td>
<td>340</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>physical</td>
<td>Aggregate Stability</td>
<td>13.4</td>
<td>16</td>
<td>Aeration, Infiltration, Rooting, Crusting, Sealing, Erosion, Runoff</td>
</tr>
<tr>
<td>biological</td>
<td>ACE Soil Protein Index</td>
<td>4.4</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>biological</td>
<td>Soil Respiration</td>
<td>0.7</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>biological</td>
<td>Active Carbon</td>
<td>312</td>
<td>15</td>
<td>Energy Source for Soil Biota</td>
</tr>
<tr>
<td>chemical</td>
<td>Soil pH</td>
<td>6.1</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>chemical</td>
<td>Extractable Phosphorus</td>
<td>13.1</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>chemical</td>
<td>Extractable Potassium</td>
<td>78.0</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>chemical</td>
<td>Minor Elements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mg: 109.2 / Fe: 2.6 / Mn: 30.3 / Zn: 0.4</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Overall Quality Score:** 52 / Medium

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**Grower:** Bob Schindelbeck  
**Sample ID:** pp918  
**Field ID:** Caldwell Field - Sod rotation  
**Date Sampled:** 02/13/2017  
**Given Soil Type:** Collamer silt loam  
**Crops Grown:** SOD/SOD/SOD

### Measured Soil Textural Class: silt loam
- **Sand:** 7%  
- **Silt:** 77%  
- **Clay:** 14%

<table>
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<tr>
<th>Group</th>
<th>Indicator</th>
<th>Value</th>
<th>Rating</th>
<th>Constraints</th>
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</thead>
<tbody>
<tr>
<td>physical</td>
<td>Available Water Capacity</td>
<td>0.27</td>
<td>95</td>
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<tr>
<td>physical</td>
<td>Surface Hardness</td>
<td>95</td>
<td>79</td>
<td></td>
</tr>
<tr>
<td>physical</td>
<td>Subsurface Hardness</td>
<td>151</td>
<td>91</td>
<td></td>
</tr>
<tr>
<td>physical</td>
<td>Aggregate Stability</td>
<td>52.7</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>biological</td>
<td>Organic Matter</td>
<td>3.6</td>
<td>75</td>
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<tr>
<td>biological</td>
<td>ACE Soil Protein Index</td>
<td>8.8</td>
<td>75</td>
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</tr>
<tr>
<td>biological</td>
<td>Soil Respiration</td>
<td>1.9</td>
<td>99</td>
<td></td>
</tr>
<tr>
<td>biological</td>
<td>Active Carbon</td>
<td>536</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>chemical</td>
<td>Soil pH</td>
<td>5.8</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>chemical</td>
<td>Extractable Phosphorus</td>
<td>11.4</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>chemical</td>
<td>Extractable Potassium</td>
<td>118.6</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>chemical</td>
<td>Minor Elements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mg: 137.0 / Fe: 4.3 / Mn: 15.2 / Zn: 2.7</td>
<td>100</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Overall Quality Score:** 84 / Optimal
### Short and Long-Term Management

#### Management Suggestions for Physical and Biological Constraints

<table>
<thead>
<tr>
<th>Constraint</th>
<th>Short Term Management Suggestions</th>
<th>Long Term Management Suggestions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted Available Water Capacity Low</td>
<td>• Add stable organic materials, mulch</td>
<td>• Reduce tillage</td>
</tr>
<tr>
<td></td>
<td>• Add compost or biochar</td>
<td>• Rotate with sod crops</td>
</tr>
<tr>
<td></td>
<td>• Incorporate high biomass cover crop</td>
<td>• Incorporate high biomass cover crop</td>
</tr>
<tr>
<td>Surface Hardness High</td>
<td>• Perform some mechanical soil loosening (strip till, aerators, broadfork, spader)</td>
<td>• Shallow-rooted cover/rotation crops</td>
</tr>
<tr>
<td></td>
<td>• Use shallow-rooted cover crops</td>
<td>• Avoid traffic on wet soils, monitor</td>
</tr>
<tr>
<td></td>
<td>• Use a living mulch or interseeded cover crop</td>
<td>• Avoid excessive traffic/tilleage/loads</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Use controlled traffic patterns/lanes</td>
</tr>
<tr>
<td>Subsurface Hardness High</td>
<td>• Use targeted deep tillage (subsoiler, yeomans plow, chisel plow, spader.)</td>
<td>• Avoid plows/disks that create pans</td>
</tr>
<tr>
<td></td>
<td>• Plant deep rooted cover crops/radish</td>
<td>• Avoid heavy loads</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Reduce traffic when subsoil is wet</td>
</tr>
<tr>
<td>Aggregate Stability Low</td>
<td>• Incorporate fresh organic materials</td>
<td>• Reduce tillage</td>
</tr>
<tr>
<td></td>
<td>• Use shallow-rooted cover/rotation crops</td>
<td>• Use a surface mulch</td>
</tr>
<tr>
<td></td>
<td>• Add manure, green manure, mulch</td>
<td>• Rotate with sod crops and mycorrhizal hosts</td>
</tr>
<tr>
<td>Organic Matter Low</td>
<td>• Add stable organic materials, mulch</td>
<td>• Reduce tillage/mechanical cultivation</td>
</tr>
<tr>
<td></td>
<td>• Add compost and biochar</td>
<td>• Rotate with sod crop</td>
</tr>
<tr>
<td></td>
<td>• Incorporate high biomass cover crop</td>
<td>• Incorporate high biomass cover crop</td>
</tr>
<tr>
<td>ACE Soil Protein Index Low</td>
<td>• Add N-rich organic matter (low C:N source like manure, high N well-finished compost)</td>
<td>• Reduce tillage</td>
</tr>
<tr>
<td></td>
<td>• Incorporate young, green, cover crop biomas</td>
<td>• Rotate with forage legume sod crop</td>
</tr>
<tr>
<td></td>
<td>• Plant legumes and grass-legume mixtures</td>
<td>• Cover crop and add fresh manure</td>
</tr>
<tr>
<td></td>
<td>• Inoculate legume seed with Rhizobia &amp; check for nodulation</td>
<td>• Keep pH at 6.2-6.5 (helps N fixation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Monitor C:N ratio of inputs</td>
</tr>
<tr>
<td>Soil Respiration Low</td>
<td>• Maintain plant cover throughout season</td>
<td>• Reduce tillage/mechanical cultivation</td>
</tr>
<tr>
<td></td>
<td>• Add fresh organic materials</td>
<td>• Increase rotational diversity</td>
</tr>
<tr>
<td></td>
<td>• Add manure, green manure</td>
<td>• Maintain plant cover throughout season</td>
</tr>
<tr>
<td></td>
<td>• Consider reducing biocide usage</td>
<td>• Cover crop with symbiotic host plants</td>
</tr>
<tr>
<td>Active Carbon Low</td>
<td>• Add fresh organic materials</td>
<td>• Reduce tillage/mechanical cultivation</td>
</tr>
<tr>
<td></td>
<td>• Use shallow-rooted cover/rotation crops</td>
<td>• Rotate with sod crop</td>
</tr>
<tr>
<td></td>
<td>• Add manure, green manure</td>
<td>• Cover crop whenever possible</td>
</tr>
</tbody>
</table>

### ACE Soil Protein Index: Low

**Short term:**
- Add N-rich organic matter (low C:N source like manure, high N well-finished compost)
- Incorporate young, green, cover crop biomass
- Plant legumes and grass-legume mixtures
- Inoculate legume seed with Rhizobia & check for nodulation

**Long term:**
- Reduce tillage
- Rotate with forage legume sod crop
- Cover crop and add fresh manure
- Keep pH at 6.2-6.5 (helps N fixation)
- Monitor C:N ratio of inputs
Thank You!

Questions?

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