Soil Health

What is Soil Health?

Soil health is the continued capacity of the soil to function within natural or managed ecosystem boundaries that sustain plants, animals, and humans.

Healthy soils can:
1. Sustain plant and animal productivity.
2. Enhance biodiversity.
4. Maintain or enhance water and air quality.
Soil Ecosystem Services

- **Provisioning Services:** The products obtained from ecosystem.

- **Regulating Services:** The benefits obtained from the regulations ecosystem processes.

- **Supporting Services:** Ecosystem services that are necessary for the production of all other ecosystem services.

- **Cultural Services:** The non-material benefits people obtain from ecosystems.

(MEA, 2005)
Healthy Soil Characteristics

1. Biological Diversity:
   - Rich soil organic matter (SOM) and biological functions.
   - SOM sets the balance among the soil physical, chemical and biological properties for sustainable productivity.

2. Physical Strength:
   - Stable soil structure for balanced plant growth environment.
   - Balanced soil environment for root systems, microorganisms and macro-organisms needs for air, water and nutrients.

3. Chemical Capacity:
   - Nutrient cycling and supply to plant and organisms.
   - Storing capacity and release of nutrients as affected by soil water, air, and biological reactions.
Soil Organic Matter Composition

Soil organic matter
1-6% of total soil mass

Soil microbial biomass
3-9% of total SOM mass

Mineral particles

Soil

Stable (humus)
70-90%

Readily decomposable
7-21%

Fungi
50%

Bacteria & actinomycetes
30%

Yeast, algae, protozoa, nematodes
10%

Fauna
10%
Soil Health Indicators and Factors

- **Indicators**
  - Aggregate Stability
  - Soil Structure
  - Soil porosity
  - Bulk Density
  - Water Infiltration
  - Water Holding Capacity
  - Soil Available Water

- **Inputs**
  - Root system
  - Cover crops
  - Crop Residue
  - Animal manure

- **Soil Physical Properties**

- **Soil Organic Matter**
  - Tillage
  - Crop rotation
  - Cover crops
  - Grass water ways
  - Perennials

- **Soil Chemical Properties**
  - Cation Exchange Capacity
  - Organic and Inorganic N
  - Organic and Inorganic P
  - Organic and Inorganic K
  - Soil pH

- **Soil Biological Properties**
  - Earthworms
  - Soil Microorganisms
  - Particulate Organic Matter
  - Soil Respiration
  - Soil Enzymes
### Iowa Soil Health Assessment Card

**Soil Health Indicators**

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
<th>Observations</th>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>1-2</td>
<td>3-4</td>
<td>5-6</td>
<td>Poor structure, compacted, no air pockets</td>
<td>1-2</td>
<td>Poor structure, compacted, no air pockets</td>
</tr>
<tr>
<td>Water Holding Capacity</td>
<td>1-2</td>
<td>3-4</td>
<td>5-6</td>
<td>Soil has low water holding capacity</td>
<td>1-2</td>
<td>Soil has low water holding capacity</td>
</tr>
<tr>
<td>Plant Health</td>
<td>1-2</td>
<td>3-4</td>
<td>5-6</td>
<td>Plants have poor growth</td>
<td>1-2</td>
<td>Plants have poor growth</td>
</tr>
<tr>
<td>Root Growth</td>
<td>1-2</td>
<td>3-4</td>
<td>5-6</td>
<td>Roots are short and stubby</td>
<td>1-2</td>
<td>Roots are short and stubby</td>
</tr>
</tbody>
</table>

**Soil Health Field Assessment Card**

**Indicators and Recommendations**

1. **Structure**: Assess for clods, large lumps, and compacted soil.
2. **Water Holding Capacity**: Test soil for water retention. Use a soil moisture meter or feel the soil for consistency.
3. **Plant Health**: Check for plant vigor and root development.
4. **Root Growth**: Analyze root systems for density and health.

**Soil Health Score and Management Practice Recommendations**

<table>
<thead>
<tr>
<th>Soil Health Indicator</th>
<th>Score</th>
<th>Management Practice Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Soil Health</td>
<td></td>
<td>Maintain current soil management practices.</td>
</tr>
<tr>
<td>Soil &amp; Water</td>
<td></td>
<td>Avoid soil disturbance.</td>
</tr>
<tr>
<td>Plant Health</td>
<td></td>
<td>Maintain current soil management practices.</td>
</tr>
</tbody>
</table>

**Soil Health Indicators**: Use the following indicators to assess soil health:

- **Structure**: Assess soil structure by hand.
- **Water Holding Capacity**: Use a soil moisture meter to determine water holding capacity.
- **Plant Health**: Observe plant growth and vigor.
- **Root Growth**: Examine root systems for density and health.

**Soil Health Score**: Score the indicators using a 1-5 scale, where 1 is poor and 5 is excellent. The overall soil health score ranges from 0 to 100.

**Management Practice Recommendations**: Based on the soil health score, recommend appropriate management practices to improve soil health.
Major Measurements for Evaluating Soil Health

- Microbial Biomass: Intensive tillage mono-cropping system can reduce microbial biodiversity.
- Soil Bulk Density: Tillage increases both.
- Water Infiltration: Tillage reduces Inf. and increases surface runoff.
Factors Influencing Soil Health

- **Management practices:**
  - Tillage systems.
  - Fertilizer use (source and application).
  - Residue management.

- **Cropping systems:**
  - Type of Crop rotation.
  - Conservation Buffers (i.e., grass waterways, riparian buffers, etc.).
  - Cover crops.
  - Perennials.

- **Weather condition:**
  - Precipitation Events.
  - Temperature.

These factors influence soil health building blocks (Soil Health diagram).
Hyphae of arbuscular mycorrhizal fungi grow beyond nutrient depleted zones found around roots and root hairs.

- Hyphae form a frame for soil particles to collect into aggregates, which are coated with Glomalin.

Kris Nichols, USDA-ARS
Northern Great Plains Research Lab
What Management Practices Affect Soil Health/Functionality
How Land Use Affects Soil C Dynamics

$NPP = \text{Net Primary Production}$  $R_h = \text{Carbon loss via microbial decomposers}$
Soil C loss Due to Tillage system during the First hour of Tillage Operations

<table>
<thead>
<tr>
<th>Tillage Systems</th>
<th>Soil C Loss (lb/acre)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTR</td>
<td>0.56</td>
<td>0.51</td>
</tr>
<tr>
<td>NTWR</td>
<td>0.51</td>
<td>26%</td>
</tr>
<tr>
<td>ST</td>
<td>0.84</td>
<td>44%</td>
</tr>
<tr>
<td>DR</td>
<td>1.06</td>
<td>56%</td>
</tr>
<tr>
<td>CP</td>
<td>1.63</td>
<td>85%</td>
</tr>
<tr>
<td>MP</td>
<td>1.92</td>
<td>100%</td>
</tr>
</tbody>
</table>
Long Term Effects of Crop Rotations

Morrow Plots: Illinois
- Corn-Oats-Hay Rotation
- Corn-Oats (1885-1953, Corn-Soybeans (1954-Present)
- Continuous Corn

Sanborn Field: Missouri
- Wheat, 6 Tons Manure/year
- Corn, 6 Tons Manure/year
- Continuous Wheat
- Continuous Corn

Estimated to 4% in 1888
Wagner (1989)
Soil Carbon

Tillage effects on total organic carbon % in the top 6 inches soil depth after 3 years of residue removal.
Water Recharge

- NT and ST increased water recharge by 50-70% over conventional tillage systems.

Cumulative water infiltration under five tillage systems. NT=no-till; ST=strip-tillage; CP=chisel plow; DR=deep rip; MP=moldboard plow.
Example of Residue Management Effects on Bulk Density

**Lewis, IA**

<table>
<thead>
<tr>
<th>Residue Remaining (tons/acre)</th>
<th>Bulk Density (g/cm$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.7</td>
<td>1.0</td>
</tr>
<tr>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>0.1</td>
<td>1.2</td>
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<td>0.1</td>
<td>1.5</td>
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Example of Tillage and Residue Management Effects on Water Infiltration Rate

Ames, IA

<table>
<thead>
<tr>
<th>Residue Remaining (ton/acre)</th>
<th>CT</th>
<th>NT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.7</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>1</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>0.1</td>
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<td>ab</td>
<td>b</td>
</tr>
<tr>
<td>0.1</td>
<td>c</td>
<td>bc</td>
</tr>
</tbody>
</table>
Management to Increase Soil Carbon

• Increase C inputs and decrease degradation of organic matter through:
  ➢ Adoption of conservation systems and practices.
  ➢ Adequate fertilization for increasing biomass production.
  ➢ Increase crop diversity and intensity such as: crop rotation and cover crops.
  ➢ Use of animal manure.

• Manage soil compaction to reduce soil erosion.
• Reduction/elimination of tillage.
Residue Effects on Soil

- Soil organic C input.
- Soil surface structure.
- Soil temperature and org C&N mineralization.
- Nutrient Cycling.
- Sub soil water-recharge.
- Soil erosion and nutrients loss.
- Long-term yield Stability.
New Soil Health Management Manual and Soil Health Guide Available free of Charge at:

https://store.extension.iastate.edu/Product/Iowa-Soil-Health-Field-Guide
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