Principles of Soil Health Management

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Presentation Contents

• What do we mean by “Soil Health”

• Why is soil health important

• Soil health issues on farms

• Some strategies for overcoming soil health constraints
What is Soil Health (Quality)?

• Ability of the soil to support crop growth ... (Power & Myers, 1989)

• Capacity of the soil to function in a productive and sustained manner ... (NCR-59 Madison WI, 1991)

• The capability of the soil to produce safe and nutritious crop .... (Parr et al., 1992)

• Fitness for use (Pierce & Larson 1993)
Approach to Soil Health

Soil Health

Chemical

Biological

Physical
Soil Health Indicators

**Physical**
- Bulk density
- Penetration resistance
- Aggregate stability
- Water infiltration rate
- Water holding capacity
- Pore size distribution

**Chemical**
- Cation exchange capacity
- N, P, K
- Salinity
- Micronutrients
- [Toxins, pollutants]

**Biological**
- Soil disease suppressive capacity
- Beneficial and pathogenic nematodes, [other pathogens]
- N mineralization rate (PMN)
- Decomposition rate
- Respiration rate
- Earthworm counts
- % OM
- “Active” C, N in OM
Physical issues

• Poor aggregation – how well the soil binds together

• Low water Retention – how much water the soil can retain

• Field compaction – how tightly the soil is packed together
Aggregation

Affects

- Soil erosion by water and wind
- Pore size distribution (water movement/retention)
- Drought tolerance of soils
- Root growth and proliferation
- Soil aeration
Aggregation as a function of soil management
Low water retention

Affects

- Plant water availability
- Susceptibility to drought
- Reduced yield of crops
Soil water relationships

- **Adhesion water**: All pores drained
- **Wilting point**: Micropores full; macropores have air
- **Field Capacity**: Macropores drained
- **Saturated Soil**: All pores full
Soil water availability – Available Water Capacity

- **Available Water Capacity (AWC)** – the difference between the water held at field capacity and the permanent wilting point
  
  - AWC = FC – PWP

- AWC is mostly soil dependent
Soil water availability – Plant Available Water Capacity

- **Plant Available Water Capacity (PAWC)** – the amount of water available for the growth of a crop
  - Often less than the AWC
  - It is soil dependent *(Organic Matter Important)*
  - Some crops can survive in drier soil than others
  - PAWC may vary for different crops in the same soil
Compaction

Affects

- Water movement
- Water holding capacity
- Root growth and proliferation
- Soil aeration
Roots in loose or compacted soil
Soil Compaction

- Surface crusting
- Plow layer compaction
- Subsoil compaction
How compaction occurs

Damage is greatest
• when soils are wet
• when loads are high
Compaction Prevention

- Avoid tillage of wet soils
- Use wider tires, dual tires
- Maintain minimum tire inflation
- Avoid over-sized equipment
- Combine field operations
- Add organic matter to the soil
- Practice controlled traffic
Chemical aspects of soil health

– Nutrient sufficiency
– Soil salinity levels/Sodium issues
– Water salinity levels
Resolving Chemical Issues

Soil Testing is Important !!!

– Helps to know what is in your soil
– Helps to plan how much of nutrients to apply
– Nutrient needs vary with soil and crop
– Helps to know if your soil is building up salts
– Will let you know if your management is improving, degrading or maintaining your soil
Biological aspects of soil health

- Amount Soil Organic Matter
- Soil Microbial Activity
- Diversity of Flora and Fauna
- Soil Nitrogen Mineralization
- Organic Matter Decomposition
- Soil Borne Pathogens
Types of organic matter

- Living organisms <5%
- Fresh residue <10%
- Stabilized organic matter (humus) 33% - 50%
- Decomposing organic matter (active fraction) 33% - 50%

Very Dead

Dead

Living

Organic Matter

—Living —

organisms of various sizes such as bacteria, fungi, nematodes, earthworms, mites, springtails, moles, etc.

plant roots
<table>
<thead>
<tr>
<th>Soil Organisms</th>
<th>Count/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>100 million to 1 billion</td>
</tr>
<tr>
<td>Fungi</td>
<td>6-9 ft fungal strands put end to end</td>
</tr>
<tr>
<td>Protozoa</td>
<td>Several thousand flagellates &amp; amoeba, One to several hundred ciliates</td>
</tr>
<tr>
<td>Nematodes</td>
<td>10 to 20 bacterial feeders and a few fungal feeders</td>
</tr>
<tr>
<td>Arthropods</td>
<td>Up to 100</td>
</tr>
<tr>
<td>Earthworms</td>
<td>5 or more</td>
</tr>
</tbody>
</table>
Healthy soils maintain a diverse community of soil organisms that:

- Suppress plant disease, and insect and weed pests;
- Form beneficial symbiotic associations with plant roots
  - Mycorrhizae, Rhizobium
- Recycle essential plant nutrients
- Improve soil structure for water and nutrient retention
- Ultimately, increase grower profits and protect the environment
Nitrogen Fixation Through Legumes (making nitrate-N available to crops)

- Examples of legumes are alfalfa, clovers, beans
- Bacteria that make nitrate in plant roots with plants are called Rhizobium
- Nitrogen come from the soil air (79% N₂ in soil)
- It is a relationship of give and take
- Plants supply bacteria with food and bacteria gives back nitrate to plants

Symbiotic = up to 270 lb N/ac/year
Non-symbiotic = up to 20 lbs N/ac/year
Sesbania Nodules

- Sesbania used as green manure in an organic rotation experiment

Active Nodules
## Potential of legumes to add N to Soil

<table>
<thead>
<tr>
<th>Cover Crop</th>
<th>C:N</th>
<th>Nitrogen (lb N/ac)</th>
<th>Biomass (t/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sesbania</td>
<td>25</td>
<td>248</td>
<td>7.3</td>
</tr>
<tr>
<td>Cowpea I&amp;C</td>
<td>15</td>
<td>221</td>
<td>3.7</td>
</tr>
<tr>
<td>Lablab</td>
<td>14</td>
<td>192</td>
<td>3.3</td>
</tr>
<tr>
<td>Cowpea CA</td>
<td>12</td>
<td>182</td>
<td>2.7</td>
</tr>
<tr>
<td>Cowpea CC36</td>
<td>18</td>
<td>150</td>
<td>2.9</td>
</tr>
<tr>
<td>Bush bean</td>
<td>10</td>
<td>146</td>
<td>1.9</td>
</tr>
<tr>
<td>Pigeon Pea</td>
<td>10</td>
<td>131</td>
<td>1.6</td>
</tr>
<tr>
<td>Guar Durga</td>
<td>15</td>
<td>124</td>
<td>2.3</td>
</tr>
<tr>
<td>Tepary Bean</td>
<td>14</td>
<td>120</td>
<td>2.0</td>
</tr>
<tr>
<td>Lima Bean</td>
<td>12</td>
<td>119</td>
<td>1.8</td>
</tr>
<tr>
<td>Green Bean</td>
<td>15</td>
<td>82</td>
<td>1.5</td>
</tr>
<tr>
<td>Guar Evergreen</td>
<td>18</td>
<td>79</td>
<td>1.6</td>
</tr>
<tr>
<td>Mung Bean</td>
<td>21</td>
<td>70</td>
<td>1.8</td>
</tr>
<tr>
<td>Adzuki Bean</td>
<td>11</td>
<td>70</td>
<td>1.0</td>
</tr>
<tr>
<td>Moth Bean</td>
<td>15</td>
<td>69</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Summer green legume experiment conducted in Las Cruces, NM under irrigated system
Barley after sesbania summer legume
Oats after sesbania summer legume
Wheat after sesbania summer legume
Rye after sesbania summer legume
Recently dead soil organisms and crop residues provide the food (energy and nutrients) for soil organisms to live and function. Also called “active” or “particulate” organic matter.
Active Fraction

- 10 to 30% of the soil organic matter (active fraction) is responsible for maintaining soil microorganisms.
- The active fraction of organic matter is most susceptible to soil management practices.
Organic Matter
—Very Dead—

Well decomposed organic ➔ **Humus**
Humus contains very high amounts of negative charge
Stable Organic Matter - Humus

- Cation nutrients are held on negatively charged organic matter and clay

- a) cations held on humus
- b) cations held on clay particle
- c) cations held by organic chelate
Stable Organic Matter - Humus

- Over time, soil organic compounds become stabilized and resistant to further changes by microorganisms.
- Stabilized organic matter acts like a sponge and can absorb 2-6 times its weight in water.
Improving Soil Health

• Long-term Thinking and Strategy

Basic Methods (Toolbox)

▪ Tillage Management (Reducing tillage)

▪ Cover Cropping

▪ Crop Rotation

▪ Organic Matter Addition & Management
Merits/demerits of using proprietary products from different vendors

• Beware of “magical products”
• Query the science of the product
• Ask for University research on the product
• If you are convinced of the science, test out the product in a way that you can see the difference
• Evaluate the cost to benefit ratio of the product, especially those that need to be applied yearly
Reduced Tillage Goals

- Enhance soil quality
  - Conserve soil organic matter
  - Conserve soil moisture
- Reduce erosion
- Reduce fuel use
- Optimize weed control
- Maintain yields
Reduced Tillage Facts

- Depends on equipment (capital intensive)
- Depends on crop (works better for large seeds)
- Little difference between full width tillage and reduced tillage in terms of yield (short-term)
- Labor savings during early season field prep.
- Investment in long term soil health
Soil organic carbon by depth after 9 years of no-till, ridge-till or plow-till treatment

Oxidizable carbon by depth after 9 years of no-till, ridge-till or plow-till treatment

No-till wheat after corn silage
Vado, NM
Strip-till after corn silage
Vado, NM
Cover Crops

- Cover crops can help prevent erosion
- reduce leaching of nutrients by serving as catch crops
- can help alleviate soil compaction
- can help suppress perennial and winter annual weeds
- can add organic matter to the soil

Important:
- what is your goal?
- selection of proper cover crop
- seeding time
- good management techniques
Crop Rotation

• Good crop rotation can break disease cycle

• decrease pest pressure from insects, weeds and diseases

• enhances soil biological diversity

• enhances sustainable cropping systems
Organic Matter

- Adding organic matter improves nutrient supply of the soil
- Tends to reduce pesticide toxicity
- Increases microbial degradation of pesticides
- Increases soil biological activities
- Improves soil structure
- Improves water holding capacity
- Prevents soil erosion
Adding organic matter results in many changes.

Modified from Drinkwater and Oshins, 1998.
Animal Manures

- **Cow manure**
  - Good general nutrient source (especially K)
  - OM benefit depends on amount of bedding
  - Can carry weed seed

- **Poultry manure**
  - Potent source N, P, Zn, and lime
  - Organic matter addition is relatively low
  - Best if composted

- **Horse manure**
  - Heavily bedded with wood shavings
  - *Nitrogen availability can be a problem in the first year*
Peat Moss

- Improves soil moisture retention
- Minor improvement to nutrient holding capacity
- Provides **negligible** nutrient benefit
- High proportions may make soil **hydrophobic**
Materials to Avoid

- Sawdust, wood shavings, wood chips
  - very high carbon/nitrogen ratio
  - will tie up all available N during breakdown (immobilization)

- Worst when tilled in
  - minor detrimental effect if used as mulch
# Nutrient content of organic materials

<table>
<thead>
<tr>
<th>Organic Material</th>
<th>Percent N</th>
<th>Percent P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt;</th>
<th>Fertilizer Pounds Needed for 1 Pound of Nutrient*&lt;sup&gt;**&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>N</td>
</tr>
<tr>
<td>Alfalfa hay</td>
<td>2.3</td>
<td>0.3</td>
<td>43</td>
</tr>
<tr>
<td>Blood meal</td>
<td>12.0</td>
<td>3.0</td>
<td>8</td>
</tr>
<tr>
<td>Bone meal</td>
<td>3.0</td>
<td>28.0</td>
<td>33</td>
</tr>
<tr>
<td>Compost, garden</td>
<td>1.0</td>
<td>0.2</td>
<td>100</td>
</tr>
<tr>
<td>Cottonseed meal</td>
<td>7.0</td>
<td>1.0</td>
<td>14</td>
</tr>
<tr>
<td>Fish meal</td>
<td>12.0</td>
<td>3.0</td>
<td>8</td>
</tr>
<tr>
<td>Manure - hen</td>
<td>1.1</td>
<td>0.8</td>
<td>98</td>
</tr>
<tr>
<td>Manure - horse</td>
<td>0.7</td>
<td>0.3</td>
<td>143</td>
</tr>
<tr>
<td>Manure - pig</td>
<td>0.5</td>
<td>0.3</td>
<td>200</td>
</tr>
<tr>
<td>Manure - rabbit</td>
<td>2.4</td>
<td>1.4</td>
<td>42</td>
</tr>
<tr>
<td>Manure - sheep</td>
<td>0.7</td>
<td>0.3</td>
<td>143</td>
</tr>
<tr>
<td>Manure - steer</td>
<td>0.7</td>
<td>0.3</td>
<td>143</td>
</tr>
<tr>
<td>Peanut shells</td>
<td>3.6</td>
<td>0.7</td>
<td>28</td>
</tr>
<tr>
<td>Rock phosphate</td>
<td>0.0</td>
<td>0.5</td>
<td>0</td>
</tr>
<tr>
<td>Sewage sludge</td>
<td>5.0</td>
<td>3.0</td>
<td>20</td>
</tr>
<tr>
<td>Sunflower seed oil</td>
<td>5.5</td>
<td>1.0</td>
<td>18</td>
</tr>
<tr>
<td>Wood ashes</td>
<td>/</td>
<td>/</td>
<td>/</td>
</tr>
</tbody>
</table>

*Percent N and Percent P<sub>2</sub>O<sub>5</sub>*

**Fertilizer Pounds Needed for 1 Pound of Nutrient**

*Do Not Use*
Thanks!