Soil Quality / Understanding Soil Health
what are we missing?

Soils are not machines:
It’s an ecosystem that needs to be Fed and Covered
with Plants and residue at all times.

Clarence Chavez
Soil Scientist

The USDA is an Equal Opportunity Provider and Employer.
Farming or Rangeland practices will determine the direction of soil quality.

We as an agency have started to teach our field employees about soil quality and how to determine soil health as they relate to Water Quality, Plant Health, Air Quality, Energy Efficiency, etc…!

Testing for your Soil Baseline

Soil, Water & Tissue Lab Tests - $130 to about $150 (items ordered).

Active Carbon Tests

Soil Quality Test Kits in each office
What do we assess and where?

The Soil Survey is a good start.

What are the assessments

Soil Quality Test Kits
### Soil Respiration

<table>
<thead>
<tr>
<th>Soil Respiration (lbs CO$_2$-C/a/d)</th>
<th>Class</th>
<th>Soil Condition (Table 1, pg. 53)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No soil activity</td>
<td>Soil has no biological activity and is virtually sterile</td>
</tr>
<tr>
<td>&lt; 9.5</td>
<td>Very low soil activity</td>
<td>Soil is very depleted of available OM and has little biological activity.</td>
</tr>
<tr>
<td>9.5 - 16</td>
<td>Mod. low soil activity</td>
<td>Soil is somewhat depleted of available OM, and biological activity is low.</td>
</tr>
<tr>
<td>16 - 32</td>
<td>Medium soil activity</td>
<td>Soil is approaching or declining from an ideal state of biological activity.</td>
</tr>
<tr>
<td>32 - 64</td>
<td>Ideal soil activity</td>
<td>Soil is in an ideal state of biological activity, has adequate OM and active populations of microorganisms.</td>
</tr>
<tr>
<td>&gt; 64</td>
<td>Unusually high soil activity</td>
<td>Soil has a very high level of microbial activity and has high levels of available OM, possibly from the additions of large quantities of fresh OM or manure.</td>
</tr>
</tbody>
</table>

### Infiltration Rate

<table>
<thead>
<tr>
<th>Infiltration Rate (inches/hr)</th>
<th>Infiltration Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 20</td>
<td>Very rapid</td>
</tr>
<tr>
<td>6 – 20</td>
<td>Rapid</td>
</tr>
<tr>
<td>2 – 6</td>
<td>Mod. rapid</td>
</tr>
<tr>
<td>0.6 – 2</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.2 – 0.6</td>
<td>Mod. slow</td>
</tr>
<tr>
<td>0.06 – 0.2</td>
<td>Slow</td>
</tr>
<tr>
<td>0.0015 – .06</td>
<td>Very slow</td>
</tr>
<tr>
<td>&lt; 0.0015</td>
<td>Impermeable</td>
</tr>
</tbody>
</table>

### Table 3, pg. 56

- Very rapid
- Rapid
- Mod. rapid
- Moderate
- Mod. slow
- Slow
- Very slow
- Impermeable
Soil Respiration

Use of cover crops helps control erosion as well as improve:

- Soil tilth
- Increase organic matter levels
- Enhances water infiltration
- Lessens pests
- Enhances Soil Biota diversity

Soil Infiltration

is sensitive to near surface conditions.

Indicator of compaction or soil pore clogging (degradation)

Which leads to decreased yields and increased erosion rates.

Soil Biota help create good infiltration
Bulk Density

<table>
<thead>
<tr>
<th>Bulk Density (Soil Type Table 4, pg. 57)</th>
<th>Ideal Bulk Densities (g/cm³)</th>
<th>Bulk Densities that restrict root growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>sands, loamy sands</td>
<td>&lt; 1.6</td>
<td>&gt; 1.80</td>
</tr>
<tr>
<td>sandy loams, loams</td>
<td>&lt; 1.4</td>
<td>&gt; 1.80</td>
</tr>
<tr>
<td>S. C. loams, loams, clay loams, silts, silt loams</td>
<td>&lt; 1.3</td>
<td>&gt; 1.75</td>
</tr>
<tr>
<td>silt loams, silty clay loams</td>
<td>&lt; 1.4</td>
<td>&gt; 1.65</td>
</tr>
<tr>
<td>S. clays, silty clays, some clay loams (35-45% clay)</td>
<td>&lt; 1.10</td>
<td>&gt; 1.58</td>
</tr>
<tr>
<td>clays (&gt; 45% clay)</td>
<td>&lt; 1.10</td>
<td>&gt; 1.47</td>
</tr>
</tbody>
</table>

Bulk Density / Compaction

Ground Truth
Bulk Density

Minimize the number and weight of field operations.

- We all know that working soil too wet is detrimental. It should be avoided at all costs.

- However, soil with good structure and an extensive network of roots will be resilient to compaction.

Indicates the amount of salts present in the soil.

Cations = K⁺, Ca²⁺, Mg²⁺, Na⁺ and Anions = Cl⁻, SO₄²⁻, NO₃⁻, CO₃⁻, HCO₃⁻

Excess salts will hinder plant growth (i.e., salts affected irrigation water.

### Irrigation Salinity (pg. 80)

<table>
<thead>
<tr>
<th>Classification - Table 11</th>
<th>EC</th>
<th>TDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>No effects usually noticed</td>
<td>0.75</td>
<td>500</td>
</tr>
<tr>
<td>Can have detrimental</td>
<td>0.75 – 1.50</td>
<td>500 – 1,000</td>
</tr>
<tr>
<td>effects on sensitive crops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can have adverse</td>
<td>1.50 – 3.00</td>
<td>1,000 – 2,000</td>
</tr>
<tr>
<td>effects on many crops</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Can be used for tolerant</td>
<td>3.00 – 7.50</td>
<td>2,000 – 5,000</td>
</tr>
<tr>
<td>plants (on permeable soils)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Salts in the soil

<table>
<thead>
<tr>
<th>Rating</th>
<th>EC range for 1:1 soil:water suspension for which yield reductions occur</th>
</tr>
</thead>
<tbody>
<tr>
<td>S = Sensitive</td>
<td>&gt; 0.90 dS/m</td>
</tr>
<tr>
<td>MS = Mod. Sensitive</td>
<td>&gt; 1.40 dS/m</td>
</tr>
<tr>
<td>MT = Mod. Tolerant</td>
<td>&gt; 2.50 dS/m</td>
</tr>
<tr>
<td>T = Tolerant</td>
<td>&gt; 4.0 dS/m</td>
</tr>
</tbody>
</table>

Electrical Conductivity

Indicates the amount of salts present in the soil.

Cations = K⁺, Ca²⁺, Mg²⁺, Na⁺ and Anions = Cl⁻, SO₄²⁻, NO₃⁻, CO₃⁻, HCO₃⁻
Soil and Water EC

The bottom line

- Timing and amount of watering will help in the management of salts in any soil.

- Soil Quality and determination of Soil Health are very important when referring to: Infiltration, Leaching, Structure, Nutrient Uptake, Water Requirements for crop.

pH -- is the measure of the acidity or alkalinity of a soil or Water, which affects the availability of plant nutrients, activity of microorganisms, and the solubility of soil minerals.
Soil and Water pH

The bottom line

• Soil pH also affects the activity of beneficial microorganisms, which affects nutrient availability, uptake and stability.

• A healthy soil, high in Organic Matter will regulate its own pH, appropriate to the plant root.

• pH values between 6 and 7.5 are optimum for general crop growth (NM soils range from 7.5 to 8.2)

Nitrogen requirements from fertilizers, irrigation water and the decompositions of crop residue by microbes must be checked for excess

Lab Tests have the best results:
Soil *, Water and Tissue * samples
WHAT TO USE?

Soil Nitrate Test Kit: NECi test kit for agriculture.

www.nitrate.com

Simple to use and extremely accurate.

Or

Send it to your local Lab and request nitrate analysis.
Nitrate ($\text{NO}_3^-$) / Nitrite ($\text{NO}_2^-$)

Proper fertilizer use.

- Fertilizers (in crop residue, manure, etc…) that enhance the soil. The best approach is to feed the soil biota, which will in turn feed the plant.

- A healthy soil will grow healthy crops. Don’t over do it with fertility amendments (follow a nutrient management plan) as that is a waste and can be a pollutant.

Aggregate Stability / Soil Slaking
Aggregate Stability / Soil Slaking - Classes

✓ Class 0 to 3 are relatively unstable.

✓ Class 4 indicates some stability, but very little strength.

✓ Classes 5 and 6 represent relatively stable soil fragments or aggregates.

strength relates to the ability of the soil to resist loss of its structure

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Aggregate Stability

- Table 8:

<table>
<thead>
<tr>
<th>Organic Matter (%)</th>
<th>Water Stable Aggregates (%)</th>
<th>Clay (%)</th>
<th>Water Stable Aggregates (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>53</td>
<td>5</td>
<td>60</td>
</tr>
<tr>
<td>0.8</td>
<td>66</td>
<td>10</td>
<td>65</td>
</tr>
<tr>
<td>1.2</td>
<td>70</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>2</td>
<td>75</td>
<td>30</td>
<td>74</td>
</tr>
<tr>
<td>4</td>
<td>77</td>
<td>40</td>
<td>78</td>
</tr>
<tr>
<td>8</td>
<td>81</td>
<td>60</td>
<td>82</td>
</tr>
<tr>
<td>12</td>
<td>85</td>
<td>80</td>
<td>86</td>
</tr>
</tbody>
</table>

- For example: for a soil with 2% organic matter and 10% clay, the suitable aggregate stability range (taken from Table 8) would be 65 to 75% water stable aggregates.
Aggregate Stability

- Assist in Water Holding Capacity / increase Soil Organic Matter.
- Protects organic matter from rapid breakdown from soil biota.
- Minimize tillage. Plow – Disk – Floating etc...

Note: Tillage systems that maximize surface residues are preferred. Use tillage sparingly to solve specific soil problems.

Major practices – cover crops, no till, crop rotation, mulching, composting, etc.

Fungal Hyphae – produce humic compounds and organic “glues” (extra-cellular polysaccharides, proteins, lipids, etc…)

Glues bind soil particlas into aggregates and improves soil porosity.

Mycorrhizal fungi and other members of the fungi family are — soil structure builders
Increasing the availability of nutrients. “Available plant nutrients (N, P, & K) tend to be higher in fresh earthworm casts than in the bulk soil.” [Edwards et al., 1995]

10 Earthworms per cubic food is a good indicator of soil quality/soil health.
Soil Temperatures

- 140 degrees, soil bacteria die.
- 101-130 degrees, 100% moisture lost through evaporation and transpiration. Some species of bacteria, arthropods, start dying
- 95 -100 degrees, 15% moisture used for growth, 85% moisture lost through evaporation and transpiration.
- 65 - 95 degrees, 100% moisture used for growth. Soil Biota is active and doing their job.

Soil physical observations and estimations of: depth, roots, structure, texture, and aggregate stability

- Measuring the depth of topsoil
- Observe plant roots
- Examine soil structure, texture, color, fragments, pore space, resistance depth etc...
Soil Management Strategies

Mulching,
No-Till, or Minimum Till
Cover Crops
Crop Rotations, Root Diversity,
Green Manure,
Fewer Fertilizers and Pesticides,
Etc…

Sustainability is our future!!!!!