SOILS 101:
UNDERSTANDING SOIL FOR BETTER CROP & SOIL MANAGEMENT

Mark Dempsey, Carolina Farm Stewardship Association
Organic Growers School, Mar. 7+8, 2020
SOIL HEALTH TAKE AWAYS:

1. Build soil organic matter
2. Minimize soil disturbance
3. Ensure crops are in the ground as often as possible (24/7/365).
4. Apply nutrients sufficiently but judiciously
5. Manage for high crop diversity and biomass
WHAT DO WE WANT FROM SOIL?

- Grow plants
- Supply & cycle nutrients
- Filter water
- Store carbon
- Stay put
- BUT these require careful management!

How to manage soil well?

- Take the time to understand it
- Manage aspects you can, live with those you can’t
SOIL ISSUES

- Fertility & pH
- Soil structure
- Erosion
- Organic matter loss
SOIL ISSUES

- Fertility & pH
- Soil structure
- Erosion
- Organic matter loss
SOIL ISSUES

- Fertility & pH
- Soil structure
- Erosion
- Organic matter loss
- Compaction
- Texture

PARADIGM SHIFT:
- From “growing medium”
- To “ecosystem” view
WHERE DOES SOIL COME FROM?

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>“organic” horizon</td>
</tr>
<tr>
<td>A</td>
<td>“top soil” formed from combination of mineral + organic matter</td>
</tr>
<tr>
<td>E</td>
<td>“eluviated” horizon leached of clay, Fe- &amp; Al-oxides</td>
</tr>
<tr>
<td>B</td>
<td>“subsoil” accumulation of clay &amp; Fe- + Al-oxides</td>
</tr>
<tr>
<td>C</td>
<td>Unweathered material</td>
</tr>
</tbody>
</table>
WHERE DOES SOIL COME FROM?

- “Final” step in soil formation: Aggregation
WHERE DOES SOIL COME FROM?

- “Final” step in soil formation: Aggregation

soilquality.org
Characteristics of Soil

- Texture: sand – silt – clay
# CHARACTERISTICS OF SOIL

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Plant available</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NO$_3^-$, NH$_4^+$</td>
</tr>
<tr>
<td>P</td>
<td>H$_2$PO$_4^-$, HPO$_4^{2-}$</td>
</tr>
<tr>
<td>K</td>
<td>K$^+$</td>
</tr>
<tr>
<td>Ca</td>
<td>Ca$^{+2}$</td>
</tr>
<tr>
<td>Mg</td>
<td>Mg$^{+2}$</td>
</tr>
<tr>
<td>S</td>
<td>SO$_4^{2-}$</td>
</tr>
<tr>
<td>B</td>
<td>H$_2$BO$_3^-$</td>
</tr>
<tr>
<td>Mn</td>
<td>Mn$^{2+}$</td>
</tr>
<tr>
<td>Zn</td>
<td>Zn$^{+2}$</td>
</tr>
<tr>
<td>Cu</td>
<td>Cu$^{+2}$</td>
</tr>
</tbody>
</table>

Note: list of micro-nutrients represent example micro-nutrients, and many are not shown.
CHARACTERISTICS OF SOIL

Nutrients:

- Total vs Plant-available

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SOIL NUTRIENT DEFICIENCIES

- Yield & nutritional value reduced
- Can identify deficiency
  - Leaf color
  - Tissue sample
- Fix deficiency by
  - Applying fertility
  - Crop rotation
  - Extensive cover cropping & diversity
CHARACTERISTICS OF SOIL

- +/- charges (ions)
  - Anions (-)
  - Cations (+)

- Clay & OM are (-) charged, attract (+) ions

- Soil pH:
  - pH = H⁺ ions
  - Ca²⁺, Mg²⁺, K⁺, Na⁺ are “base cations”
    - Help increase soil pH by reducing H⁺ ions
  - Clay & OM (-) hold onto cations (+)

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<td>NO₃⁻, NH₄⁺</td>
</tr>
<tr>
<td>P</td>
<td>H₂PO₄⁻, HPO₄⁻²</td>
</tr>
<tr>
<td>K</td>
<td>K⁺</td>
</tr>
</tbody>
</table>
CHARACTERISTICS OF SOIL

- Nitrogen
- Phosphorus
- Potassium
- Sulfur
- Calcium
- Magnesium
- Iron
- Manganese
- Boron
- Copper and Zinc
- Molybdenum

pH Scale:
4 4.5 5 5.5 6 6.5 7 7.5 8 8.5 9 9.5 10
CHARACTERISTICS OF SOIL

- Cation Exchange Capacity (CEC)
  - A measure of ability of soil to hold onto (+) nutrients
  - Think of CEC like the size of a parking lot:
CHARACTERISTICS OF SOIL

- Cation Exchange Capacity (CEC)
  - A measure of ability of soil to hold onto (+) nutrients
    - Thus, it is one measure of soil fertility
  - Higher CEC = more base cations held in soil = ↑ pH
    - CEC buffers against natural process of soil acidification
    - If added lime doesn’t ↑ pH then CEC is likely too low
  - CEC is entirely from clay and organic matter
    - Because you can’t realistically add clay to your farm, CEC can only be increased by adding organic matter
SOIL BIOLOGY

- Plants: the C source that drives everything underground
- Decomposer microbes
  - Bacteria & fungi
  - Protists
SOIL BIOLOGY

- Plants: the C source that drives everything underground
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  - Springtails & mites
SOIL BIOLOGY

- Plants: the C source that drives everything underground

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- Plant-associated microbes
  - Mycorrhizal fungi
  - N-fixing bacteria
  - Pseudomonas
  - And many, many more!
SOIL BIOLOGY

- Earthworms:
  - Deep-burrowers
  - Surface-dwellers
  - Litter-dwellers
  - Manure-lovers

- Enchytraeds (like small earthworms) are decomposers

- Nematodes:
  - Plant-feeding
  - Microbivores
GETTING TO KNOW YOUR SOIL

- **Soil sampling:**
  - 8” depth - tilled soils
  - 4” depth - no-till, pasture & lawns
  - ~15 cores per sample
  - Zig-zag pattern, covering entire field/area
  - Mix 15 cores together, pull subsample to ship away for testing
## Getting to Know Your Soil

### Ca:
- 60 - 70%

### Mg:
- 10 - 20%

### K:
- 5 - 10% (not shown)

Higher CEC is better:
- Clay (piedmont): 5-10+
- Loam: (mountains): >10
- Sand (coastal): >3

### pH
5.5 - 6.8

### % of CEC occupied:
- Ca: 60-70%
- Mg: 10-20%
- K: 5-10% (not shown)
GETTING TO KNOW YOUR SOIL

Web Soil Survey: Map of Soil Types
GETTING TO KNOW YOUR SOIL

Web Soil Survey: Map of Soil Types

You are here
GETTING TO KNOW YOUR SOIL

Web Soil Survey: Soil Texture

You are here
GETTING TO KNOW YOUR SOIL

Web Soil Survey: Percent Clay

You are here
GETTING TO KNOW YOUR SOIL

Web Soil Survey: Cation Exchange Capacity

You are here
GETTING TO KNOW YOUR SOIL

Web Soil Survey:

Custom Soil Resource Report for

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Getting to Know Your Soil

BmB—Bellamy loam, 2 to 5 percent slopes

Typical profile

- **H1** - 0 to 19 inches: loam
- **H2** - 19 to 32 inches: loam
- **H3** - 32 to 54 inches: clay loam
- **H4** - 54 to 72 inches: sandy clay loam

Properties and qualities

- **Slope:** 2 to 5 percent
- **Depth to restrictive feature:** More than 80 inches
- **Natural drainage class:** Moderately well drained
- **Capacity of the most limiting layer to transmit water (Ksat):** Moderately high (0.20 to 0.60 in/hr)
- **Depth to water table:** About 18 to 36 inches
- **Frequency of flooding:** None
- **Frequency of ponding:** None
- **Available water storage in profile:** High (about 10.1 inches)

Interpretive groups

- **Land capability classification (irrigated):** None specified
- **Land capability classification (nonirrigated):** 2e

- **Hydrologic Soil Group:** C
- **Hydric soil rating:** No
GETTING TO KNOW YOUR SOIL

Observation is just as or more important than quantifying soil characteristics.
PRIORITIES: Build Organic Matter

- OM is the nutrient bank of soil
  - Nutrient release via decomposition
  - “Parking lot” for nutrients (improves CEC)
- Building OM best recourse for infertile soil
- Increase water-holding capacity
- Associated with good structure
  - Resists erosion
  - Water infiltration
PRIORITIES: Limit Tillage

- Increase soil OM
- Improve soil structure
- Reduce erosion
- Improve water infiltration, maybe retention
- Habitat for beneficial insects
- Cover crops on surface can suppress weeds
- Alter soil microbes
**NO-TILL COVER CROP MGMT**

<table>
<thead>
<tr>
<th>ROLLER-CRIMPERS</th>
<th>ROLLER-CRIMPERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lay down &amp; crimp; flowering or later</td>
<td>Lay down &amp; crimp; flowering or later</td>
</tr>
<tr>
<td>Harder to kill, persistent mulch</td>
<td>Harder to kill, persistent mulch</td>
</tr>
<tr>
<td>Low-tech but highly specialized</td>
<td>Low-tech but highly specialized</td>
</tr>
<tr>
<td>Fast and fuel-efficient</td>
<td>Fast and fuel-efficient</td>
</tr>
</tbody>
</table>

Bill Curran extension.org

Mark Dempsey
## NO-TILL COVER CROP MGMT

### MOWER

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cut or chop; flowering ± 2 weeks</td>
<td>Easier to kill, shorter-lived mulch</td>
</tr>
<tr>
<td>Easier to kill, shorter-lived mulch</td>
<td>Higher-tech but more versatile</td>
</tr>
<tr>
<td>Higher-tech but more versatile</td>
<td>Slow and fuel-guzzling</td>
</tr>
</tbody>
</table>

LocalRootsFarm.wordpress.com

FieldsofAgape.com
NO-TILL COVER CROP MGMT

TARP or FABRIC

Lay down & smother; whenever

Consistent kill & suppression

Low-tech but labor-intensive

Slow going

NO-TILL COVER CROP MGMT

springforthfarmnc.com

arktarps.com.au
PRIORITIES: Live Plants 24/7/365

- Cash & cover crops
- Protects against erosion
- Increases soil OM
  - Nutrients for crops
  - Build soil structure
  - Soil biodiversity
  - CEC
- Nutrient scavenging & N-fixation
- Solar-derived fertility
PRIORITIES: Nutrient Management

- Test soil annually – apply fertilizer judiciously
PRIORITIES: Nutrient Management

- Test soil annually – apply fertilizer judiciously
- Watch for signs of deficiency
PRIORITIES: Nutrient Management

- Test soil annually – apply fertilizer judiciously
- Watch for signs of deficiency
- “Fixed” N:P:K ratios
- Careful about P
- Use N-fixation & nutrient scavenging by cover crops
- High-K fertilizer if needed

<table>
<thead>
<tr>
<th></th>
<th>N%</th>
<th>P₂O₅%</th>
<th>K₂O%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cattle</td>
<td>0.25</td>
<td>0.15</td>
<td>0.25</td>
</tr>
<tr>
<td>Chicken</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Hog</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Bone meal</td>
<td>2-6</td>
<td>15-27</td>
<td>0</td>
</tr>
<tr>
<td>Blood meal</td>
<td>12</td>
<td>1.5</td>
<td>0.50</td>
</tr>
<tr>
<td>Fish emulsion</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Kelp</td>
<td>1</td>
<td>0.5</td>
<td>4-13</td>
</tr>
<tr>
<td>Soy meal</td>
<td>7</td>
<td>1.5</td>
<td>2.25</td>
</tr>
<tr>
<td>Granite meal</td>
<td>0</td>
<td>0</td>
<td>3-5</td>
</tr>
<tr>
<td>Greensand</td>
<td>0</td>
<td>15</td>
<td>4-10</td>
</tr>
<tr>
<td>Kainite</td>
<td>0</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Rock phosph.</td>
<td>0</td>
<td>20-30</td>
<td>0</td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>16</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Compost as nutrient source?

Should be thought of as soil conditioner and long-term P and K source

P and K content is variable - depends on feedstock

Not as N source
PRIORITIES: Nutrient Management

- Compost as a nutrient source?

Data courtesy of Dr. Kate Cassidy (UGA) via Dr. Julia Gaskin (UGA)
PRIORITIES: Nutrient Management

- **Cover crops for nitrogen (legumes)**

<table>
<thead>
<tr>
<th>Winter Legumes (Fall-planted)</th>
<th>Summer Legumes (Spring-planted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crimson &amp; red clover</td>
<td>Sunnhemp</td>
</tr>
<tr>
<td>Hairy vetch</td>
<td>Cowpea</td>
</tr>
<tr>
<td>Winter pea</td>
<td>Forage soybean</td>
</tr>
<tr>
<td>Favabean</td>
<td>Mungbean &amp; other Vigna spp.</td>
</tr>
</tbody>
</table>
PRIORITIES: Nutrient Management

- Nitrogen fixation by legumes

![Graph showing cover crop total nitrogen (lbs/ac) for different species with sample sizes.](image)
PRIORITIES: Diversity & Biomass

- Crop diversity
  - Disease suppression
  - Microbial diversity
- Diversity = “redundant species”
  - Decomposers & symbionts
- Go for high plant biomass
  - High OM & nutrient supply
  - Cover cropping & limiting tillage
ANY QUESTIONS?