What you’ll learn:

• What is soil made of?
• What does each part do?
• How does each part help plants?
What is soil?

A resource!

What have you done to help soil?
What's in soil?

- Solid matter: 45-50%
- Mineral: 25%
- Air: 25%
- Water: 45-50%
Soil is only 1/2 solid

Mineral particles are divided into 3 size classes:

- Sand
- Silt
- Clay

The amount of each particle size determines soil “texture”
Soil Texture: Sand

- 0.05 - 2.0 mm in size
- Sometimes visible to the eye
- Gritty when wet and dry
- Drains quickly
- Irrigation is especially important due to drainage
SOIL TEXTURE: Silt

- 0.002 – 0.05 mm
- About as thick as a strand of hair!
- Feels like flour
- Don’t till more than necessary, or this good soil will get washed away!
SOIL TEXTURE: CLAY

- **The smallest particle size**
- **Less than 0.002 mm**
- **Invisible to the eye**
- **Feels sticky when wet**
- **Dries slowly in the spring; plan accordingly!**
SOIL TEXTURE

- Air: 25%
- Water: 25%
- Mineral: 45-50%
SOIL IS ONLY 1/2 SOLID

Organic Matter can make up anywhere from 1 to 5% of soil.

It’s VERY important!

We can change how much is in soil with how we manage soil.
Soil is half pore space

Soil pore space is made up of air and water:

- When it rains, it’s more water than air
- When it’s been dry, it’s mostly air
SOIL IS HALF PORE SPACE

Why do plants need both air and water?
Soil Organic Matter (SOM)

ORGANIC = MATERIALS THAT WERE ONCE ALIVE, EITHER RECENTLY OR THOUSANDS OF YEARS AGO

Mostly a source of carbon (C) and nitrogen (N), but can also provide other nutrients - very nutritious!

More on this in the next unit...
Soil Health

Peyton Ginakes
University of Minnesota

NORTH CENTRAL SARE
Sustainable Agriculture Research & Education
What you’ll learn:

- What soil health means
- How organic matter makes soil healthy
- Why we should care about soil health
- What we do that affects health of soil
Soil quality is the capacity of a soil to function, within land use and ecosystem boundaries, to sustain biological productivity, maintain environmental quality, and promote plant, animal, and human health.

- Doran and Parkin, 1994
Why Should I Care about Soil Health?

» What conditions let crops do well? What is soil like when crops are healthy?

» How did you manage soil where you farmed previously? How do you manage it here? Are the practices you use different?

» What did you do when you farmed before to re-energize the soil? Have you discovered alternative methods that are more or less suitable for re-energizing soil here?
Why Should I Care about Soil Health?

Having a more diverse soil food web can mean that inputs are broken down more efficiently for plants to use.
Why Should I Care about Soil Health?

Having better aggregation decreases erosion and runoff.
Why Should I Care about Soil Health?

Having good soil quality means good water filtration!
Why Should I Care about Soil Health?

Having healthier soil can improve crop resistance against pests and environmental stresses.
MORE PRODUCTIVE CROPS
THINK LIKE A ROOT!
How Can I Help Soil Health?
Cover Crops

Peyton Ginakes
University of Minnesota
What you’ll learn:

• What a cover crop is
• Benefits and challenges of using cover crops
• How to select a cover crop
• Estimating how much N a cover crop is providing
What is a cover crop?

- **Cover Crop**: grown to prevent soil erosion and manage SOM
- **Green Manure**: maintain SOM and increase plant available nitrogen
- **Catch Crop**: retrieves left over nutrients to prevent pollution

COVER CROPS
How do cover crops help soil?

How are cover crops different from other amendments?
How do cover crops help soil?

Brings in beneficial insects.
How do cover crops help soil?

InCREASES M YCORRHIZAE
How do cover crops help soil?

Reduces nematodes
How do cover crops help soil?

DECREASES RUNOFF AND EROSION
How do cover crops help soil?

Increase water infiltration
How do cover crops help soil?

Scavenge excess nutrients
How do cover crops help soil?

Adds nitrogen.
How do cover crops help soil?

Controls weeds
How do cover crops help soil?

Adds organic matter.
Have you used cover crops?
Challenges of cover cropping

- What do I do with all this residue?
- Will they compete with my main crops?
- Equipment & machinery
- Timing of planting and termination
Selecting a Cover Crop

1. Make a goal
2. Establish seasonal windows
3. Make plans for termination
Estimating N Credits
Estimating N Credits

1. How much plant material is in a given area?
2. How much nitrogen is in that material?
3. How quickly will the material decompose and become available?
4. Do you need extra nitrogen?
Estimating N Credits

1. How much plant material is in a given area?

- Use a ruler or yardstick to measure out a known area in your cover cropped area.
- Clip the plants within the square at several places in your field.
- Dry the samples in the oven until they are crunchy dry.
Estimating N Credits

1. How much plant material is in a given area?

How much biomass per acre do I have?

\[
\text{LB biomass/acre} = \frac{\text{dry sample weight (lb)}}{\text{area sampled (ft}^2\text{)}} \times \frac{43,560 \text{ ft}^2}{\text{acre}}
\]

\[
= \frac{2.5 \text{ lb}}{18 \text{ ft}^2} \times \frac{43,560 \text{ ft}^2}{\text{acre}} = 6,050 \text{ lb biomass/acre}
\]
Estimating N Credits

<table>
<thead>
<tr>
<th>Cover Crop</th>
<th>Examples</th>
<th>% N</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Legumes</strong></td>
<td>Hairy vetch</td>
<td>4% at flowering</td>
</tr>
<tr>
<td></td>
<td>Clovers</td>
<td>3% is seeds are maturing</td>
</tr>
<tr>
<td></td>
<td>Pea</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sunn hemp</td>
<td></td>
</tr>
<tr>
<td><strong>Non-legume grasses</strong></td>
<td>Rye</td>
<td>3% at flowering</td>
</tr>
<tr>
<td></td>
<td>Oat</td>
<td>2% is seeds are maturing</td>
</tr>
<tr>
<td></td>
<td>Sorghum sudangrass</td>
<td></td>
</tr>
<tr>
<td><strong>Non-legume broadleaves</strong></td>
<td>Buckwheat</td>
<td>Similar or a little less than</td>
</tr>
<tr>
<td></td>
<td>Tillage radish</td>
<td>grasses</td>
</tr>
<tr>
<td></td>
<td>Canola</td>
<td></td>
</tr>
</tbody>
</table>

2. How much nitrogen is in that material?
Estimating N Credits

The cover crop was flowering red clover

⇒ 4% N

6,050 lb/acre

6,050 lb/acre × 0.04 = 242 lb N/acre
Estimating N Credits

Microbes have to eat the material for it to be available for plants.

Will you leave the cover crop on the surface, or incorporate it belowground?

40% will be available in year 1

50% will be available in year 1

242 lb N x 0.4 = 97 lb N/ac

242 lb N x 0.5 = 121 lb N/ac

How quickly will the material decompose and become available?
Estimating N Credits

What are you planting now?

Cabbage removes approx. 220 lb N/ac

⇒ will need 220 - 121 = 99 more lb N if we tilled in the clover

What now?

Use manure, compost, or fertilizer; or, rely on accumulated soil organic N from all the organic matter you have been adding!

4. Do you need extra nitrogen?
Nutrient Management

Peyton Ginakes
University of Minnesota
What you’ll learn:

- How cover crops become plant nutrients
- Do’s and don’ts of soil sampling
- Reading and using a soil test report
Where does it come from?

Plants grow through *photosynthesis*, which uses:

- **Sunlight**
- **CO₂ from the air**
- **Water**

to make carbon-based *plant matter*.
Where does it come from?

All living things (plant or animal) contain carbon, because they either photosynthesize or eat things that photosynthesize.

This process starts with plants when they fix (change) CO$_2$ into carbohydrates, using it to grow.
Where does it come from?

Organic (carbon-based) OR Inorganic (not carbon-based)

Organic sources called “R-NH₂”

Nitrate (NO₃⁻) or ammonium (NH₄⁺) based
Where does it come from?

Organic (carbon-based)

Organic N needs to be turned into nitrate ($\text{NO}_3^-$) or ammonium ($\text{NH}_4^+$), which is called "mineralized", by soil microorganisms before plants can use it.

These are "made available" over time as microbes mineralize them, not all at once like fertilizers.

Organic sources called "R-$\text{NH}_2"
Where does it come from?

Organic:
- SOM, Plant matter
- Compost

Mineral:
- Weathering from rock → HPO$_4^{-2}$ and H$_2$PO$_4^{-1}$

Inorganic:
- P$_2$O$_5$

Phosphorus
Where does it come from?

Organic

SOM, plant matter, compost

Mineral

Weathering from rock →
HPO$_4^{2-}$ and H$_2$PO$_4^{-1}$

Plants can only take up inorganic and soluble P.

Like N, microbes mineralize P over time from organic sources.
Where does it come from?

Organic:
- SOM, plant matter, compost

Mineral:
- Weathering from rock (feldspar and mica) → K⁺

Inorganic:
- K₂O
Where does it come from?

Organic:
- SOM, plant matter, compost

Mineral:
- Weathering from rock (feldspar and mica) → K^+ 

Plants can only take up K ions (K^+).

K^+ adheres to SOM, which keeps it from leaching and helps some of it stay available to plants.
If plants get carbon from the air, why do we need to build SOM?
If plants get carbon from the air, why do we need to build SOM?

**SOM** holds other nutrients like nitrogen and phosphorus! When microbes eat SOM, they mineralize N and P, which makes them available for plants.
C AND N IN SOM
C AND N IN SOM

Mineralization...

25 (OR LESS) PARTS C TO 1 PART N
C and N in SOM

Mineralization...

When microbe food is high in N, they excrete excess N back into soil as mineral forms that plants can use.

25 (or less) parts C to 1 part N
C AND N IN SOM

... or immobilization

25 (or more) parts C to 1 part N
C AND N IN SOM

...or immobilization

WHEN MICROBE FOOD IS LOW IN N, THEY HAVE TO USE N FROM THE SOIL TO METABOLIZE THE AVAILABLE CARBON, EFFECTIVELY TAKING AWAY N THAT PLANTS COULD HAVE USED

25 (OR MORE) PARTS C TO 1 PART N
C AND N IN SOM

Low C:N (10:1) is better than High C:N (40:1)
browns

- brown bags
- dried landscape waste
- fall leaves
- sawdust
- straw
- wood chips

greens

- alfalfa meal
- coffee grinds
- crushed eggshell
- hair
- fresh landscape waste
- fruits & vegetables
- tea bags

no nos

- fish
- meat
- bones
- dairy
- diseased plants
- poop from people & meat eating animals

http://farmanywhere.growmycitygreen.com/blog/how-to-make-your-own-compost
Soil Testing

• You can submit multiple *samples*
• Many “composites” make up one *sample* – for instance, take 10 soil cores and combine them in a bucket, and submit the total
• Take representative *samples* (only composite soil from uniform areas)
• Don’t include surface plant material
• Sample as deeply as you till (usually 6-8” deep)
• The more variable your landscape (hilly, different crop rotations, different soil types, etc.), the more composites you should take!
Soil Testing

The University of Minnesota has a Soil Testing Laboratory!

- **Drop off samples at the Crops Research Building, rm 135 (1902 Dudley Ave, St. Paul MN 55108)**
- They have a great website: soiltest.cfans.umn.edu
- A normal soil report costs $15 per sample
  - **NOTE:** this does not include nitrogen!
- However, plant available nitrogen can be estimated from other values on the soil test report
- When you drop off the samples, you will be asked to fill out the following form....
### Sample Identification

<table>
<thead>
<tr>
<th>Field or Sample No.</th>
<th>Crop History</th>
<th>Proposed Crops</th>
<th>Check Test Requested</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Number (Lab Use Only)</td>
<td>Crop Grown Before Last</td>
<td>Crop Grown Last</td>
<td>Option 1</td>
</tr>
<tr>
<td>04</td>
<td>4e</td>
<td>4e</td>
<td></td>
</tr>
<tr>
<td>06</td>
<td>2-3</td>
<td>2-3</td>
<td></td>
</tr>
<tr>
<td>07</td>
<td>0-1</td>
<td>0-1</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>4e</td>
<td>4e</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>2-3</td>
<td>2-3</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>0-1</td>
<td>0-1</td>
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<tr>
<td>14</td>
<td>4e</td>
<td>4e</td>
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<tr>
<td>15</td>
<td>2-3</td>
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<td>16</td>
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<tr>
<td>17</td>
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<td></td>
</tr>
<tr>
<td>23</td>
<td>4e</td>
<td>4e</td>
<td></td>
</tr>
</tbody>
</table>

**Recommendations available for these crops:**

- **LEGS**
  - Alfalfa, New Seed
  - Red Clover
- **CORN**
  - Corn, Grain
  - Corn, Silage
  - Sweet Corn
- **LEGUMES**
  - Legume/Grass Hay
  - Legume/Grass Pasteure
- **SMALL GRAINS**
  - Barley
  - Oats
  - Rye/Triticale
  - Wheat
- **MISCELLANEOUS**
  - Buckwheat
  - Edible Beans
  - Fallow
  - Flax
  - Grass Hay
  - Grass Seed Prod.
  - Grass Pasture
  - Millet
  - Native Grasses
  - Potatoes
- **VEGETABLES**
  - Asparagus, New Planting
  - Asparagus, Establ. Planting
  - Beans, Snap
  - Beets, Table
  - Broccoli
  - Brussels Sprouts
  - Cabbage
  - Cauliflower
  - Carrots
- **FRUITS**
  - Apples
  - Blueberries
  - Grapes
  - Raspberries/Brambles
  - Strawberries
- **TURF**
  - Cultured Sod
- **NURSERY - FIELD STOCK**
  - Trees/Scrubs

**Before selecting this test please read the section on nitrate on the back side. Sampling to 24" is required for this test.**

- $8 0-6'-24' sample 0-24' sample
- $8 0-6'-24' sample 0-24' sample
- $8 0-6'-24' sample 0-24' sample
- $8 0-6'-24' sample 0-24' sample
- $8 0-6'-24' sample 0-24' sample
- $8 0-6'-24' sample 0-24' sample
- $8 0-6'-24' sample 0-24' sample
- $8 0-6'-24' sample 0-24' sample

**THE REGULAR SERIES INCLUDES PERCENT ORGANIC MATTER**
Soil Testing

- pH – alkaline or acidic?
- % Organic Matter
- Soil Texture
- Potassium (K) and Phosphorus (P)
- Can measure micronutrients (Ca, Mg, Zn, B, Cu, Mn)
- Can also measure nitrate
  - Both add to cost
- Soluble salt concentrations

How do I read the report?
## Soil Test Results

### Sample/Field Number: 1

<table>
<thead>
<tr>
<th>Organic Matter %</th>
<th>pH</th>
<th>Soluble Salts mmhos/cm</th>
<th>Buffer Index</th>
<th>Nitrate NO₃-N ppm</th>
<th>Olsen Phosphorus ppm</th>
<th>Bray 1 Phosphorus ppm</th>
<th>Potassium ppm K</th>
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</thead>
<tbody>
<tr>
<td>3.0</td>
<td>7.6</td>
<td>6</td>
<td>4</td>
<td>75</td>
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</tbody>
</table>

### RECOMMENDATIONS

#### Crop Before Last: Sweet Corn; Last Crop: Cabbage

<table>
<thead>
<tr>
<th>Crop and Yield Goal</th>
<th>Method</th>
<th>Lime #ENP/A</th>
<th>N lb/A</th>
<th>P2O5 lb/A</th>
<th>K2O lb/A</th>
<th>S lb/A</th>
<th>Zn lb/A</th>
<th>Fe lb/A</th>
<th>Mn lb/A</th>
<th>Cu lb/A</th>
<th>B lb/A</th>
<th>Ca lb/A</th>
<th>Mg lb/A</th>
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</thead>
<tbody>
<tr>
<td>Sweet Corn 8 tons/acre</td>
<td>Broadcast</td>
<td>0</td>
<td>150</td>
<td>60</td>
<td>100</td>
<td></td>
<td></td>
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<td></td>
<td>Row/Drill</td>
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#### Comments: 18,50,57

<table>
<thead>
<tr>
<th>Crop</th>
<th>Method</th>
<th>Lime #ENP/A</th>
<th>N lb/A</th>
<th>P2O5 lb/A</th>
<th>K2O lb/A</th>
<th>S lb/A</th>
<th>Zn lb/A</th>
<th>Fe lb/A</th>
<th>Mn lb/A</th>
<th>Cu lb/A</th>
<th>B lb/A</th>
<th>Ca lb/A</th>
<th>Mg lb/A</th>
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<tbody>
<tr>
<td>Cabbage</td>
<td>Broadcast</td>
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<td>150</td>
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<td>Row/Drill</td>
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#### Comments: 18,50,57

<table>
<thead>
<tr>
<th>Crop</th>
<th>Method</th>
<th>Lime #ENP/A</th>
<th>N lb/A</th>
<th>P2O5 lb/A</th>
<th>K2O lb/A</th>
<th>S lb/A</th>
<th>Zn lb/A</th>
<th>Fe lb/A</th>
<th>Mn lb/A</th>
<th>Cu lb/A</th>
<th>B lb/A</th>
<th>Ca lb/A</th>
<th>Mg lb/A</th>
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<tbody>
<tr>
<td>Tomatoes</td>
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</table>

#### Comments: 18,50,57
Soil Testing

So what if you want to know how much nitrogen you have, but you don’t want to pay (and wait) for nitrate measurements?

We can do the math!

• All the soil in the top 6 inches of an acre weighs about 2,000,000 pounds.
• If we have 3% SOM, like in the report, that means we have $0.03 \times 2,000,000 = 60,000$ lb/ac of SOM
• But SOM is only about 7% nitrogen...
• So in the soil, about $60,000 \times 0.07 = 4,200$ lbs of nitrogen exist as SOM (org N)
• BUT, finally, only about 2% of this is mineralized annually...
  • $4,200 \times 0.02 = 84$ lb mineral N per acre (quite a lot!)