- Soil/plant/soil biology relationship
- Microbial technologies
- Mycorrhizal technologies
- Create sustainable soils for crop production
- Answer questions
Crop Production Variables

Yield inputs

Climate
- Growing Season Rainfall
- Summer Rainfall (Stored)
- Leaching & Waterlogging
- Temperature (Drought, Frost)
- Evaporation

Soil Management
- Crop Rotation
- Variety Choice
- Seed Rate & Row Spacing
- Fertilizers (Rate & Timing)
- Chemicals
- Reduced Management
  - Animals
  - Soil Amendments
  - Inoculums

Crop Yield

Soil Attributes That Influence Crop Production

Physical
- Clay Content
- Compaction Layers
- Hardsetting Surface
- Wind & Water Erosion
- Available Stored Water

Chemical
- pH (Surface & Subsoil; Al+)
- Electrical Conductivity (EC3)
- Total Soil Organic Matter
- Cation Exchange Capacity
- Water Repellency

Biological
- Disease
  - Disease Bacteria & Fungi
- Pathogenic Nematodes
- Beneficial
- Labile Soil Organic Matter
- Microbial Biomass
- Biological Nutrient Supply
“Management practices make difference to soil life, it helps to back up and examine the vast diversity of micro- and macro-organisms living in the soil and the critical roles they play in agriculture.”

**Soil Issues**

- Continuous Use of Manure
- Drought
- Low Organic Matter
- Tillage Practices
- Compaction
- Crop Rotation
- Freezing
- Flooding
## Soil Improvement Guidelines

<table>
<thead>
<tr>
<th>Soil Test Parameter</th>
<th>Compatible Microbial Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic Matter</td>
<td>0-5%+</td>
</tr>
<tr>
<td>Phosphorus P1</td>
<td>5 to 30 ppm</td>
</tr>
<tr>
<td>Phosphorus P2</td>
<td>10 to 100 ppm</td>
</tr>
<tr>
<td>Potassium light textured soils</td>
<td>50 to 200 ppm</td>
</tr>
<tr>
<td>Potassium dark textured soils</td>
<td>125 to 300 ppm</td>
</tr>
<tr>
<td>Magnesium</td>
<td>50 to 300 ppm</td>
</tr>
<tr>
<td>Sodium</td>
<td>0 to 3%</td>
</tr>
<tr>
<td>Soil pH</td>
<td>5.5 to 8.4</td>
</tr>
<tr>
<td>Cation Exchange Capacity</td>
<td>5 to 35 meq/100g</td>
</tr>
<tr>
<td>Percent Base Saturation - potassium</td>
<td>2 to 10%</td>
</tr>
<tr>
<td>Percent Base Saturation - magnesium</td>
<td>5 to 20%</td>
</tr>
<tr>
<td>Percent Base Saturation - calcium</td>
<td>50 to 80%</td>
</tr>
<tr>
<td>Zinc</td>
<td>1 to 3 ppm</td>
</tr>
<tr>
<td>Manganese</td>
<td>10 to 30 ppm</td>
</tr>
<tr>
<td>Iron</td>
<td>10 to 30 ppm</td>
</tr>
<tr>
<td>Copper</td>
<td>1 to 3 ppm</td>
</tr>
<tr>
<td>Boron</td>
<td>1 to 2.5 ppm</td>
</tr>
<tr>
<td>Soluble Salts</td>
<td>0 to 2 mmhos/cm</td>
</tr>
<tr>
<td>Sulfur</td>
<td>2 to 15 ppm</td>
</tr>
</tbody>
</table>
Factors Affecting Soil Structure

- External Loading
  - Compaction
  - Poor drainage
  - Treatment of wet soil

- Cultivation History
  - Field age
  - Crop rotation
  - Liming, use of manure
Factors Affecting Soil Structure

- **Soil Properties**
  - Soil texture
  - Soil organic matter
  - PH
  - Cation exchange capacity

- **Natural Processes**
  - Biological activity
  - Microbes
  - Roots
  - Number of drying/wetting cycles (clay soils)
Soil Components

- Mineral
  - Primary
  - Secondary
- Water
- Organic Matter
- Gases
- Microorganisms
- Fungal Hyphae
Soil Components: Soils consist of four major components: (1) mineral (or inorganic), (2) organic, (3) water, and (4) air. The relative proportions of these four soil components vary with soil type and climatic conditions. Review the approximate proportions (by volume) of the four soil components in a mineral soil under optimum conditions for plant growth.

Image Source: Leslie Dampier
Faculty of Land and Food Systems
THE UNIVERSITY OF BRITISH COLUMBIA
Well Structured Soil Will:

- Hold large amounts of water and nutrients
- Not puddle when wet or become dusty when dry
- Have adequate drainage and aeration
- Provide a medium for roots to explore for moisture and nutrients
Good Soil Features

- Drains well
- Resists erosion & nutrient loss
- Soaks up heavy rains
- Supports high populations of diverse soil organisms
- Produces healthy, high quality crops
- Stores moisture for drought periods
- Creates sustainable agriculture crops
Managing soil organic matter is the key to air and water quality.

- Reduced tillage
- Organic matter
- Water holding capacity
- Fewer pollutants
- Less dust

- Cover crops
- Prescribed grazing
- High biomass rotations
- Soil organisms
- Soil structure
- Infiltration
- Nutrients
- Air quality
- Water quality
- Productivity
- Less sediment
- Drought & disease resistance

Above provided by NRCS
**Water retention**
- 1% or less OM can hold less than 10,000 gallons of water
- 3% OM 1 acre can hold 2-3 inches of rain or 56,000 to 84,000 gal of water

**Nutrient/Organic Matter Value**
- Soil containing 4% organic matter in top 7”
- 80,000 lbs of organic matter/acre
- Will contain 5.25% N, 4,200 lbs/acre
Ways to Increase Organic Matter/H₂O

- Bioaugmentation
- Cover Crops
- Reduce Tillage
- Crop Rotation
- Forage Crops
## Value of Soil Organic Matter

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>1% organic matter = 20,000# 50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon, C:N ratio</td>
<td>=10:1</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>1000# * $0.50/#N = $500</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>100# * $0.70/#P = $70</td>
</tr>
<tr>
<td>Potassium</td>
<td>100# * $0.40/#K = $40</td>
</tr>
<tr>
<td>Sulfur</td>
<td>100# * $0.50/#S = $50</td>
</tr>
<tr>
<td>Carbon</td>
<td>10,000# or 5 ton * $4/Ton = $20</td>
</tr>
</tbody>
</table>

Value of 1% SOM Nutrients/Acre: $680.00

Relative Ration of Nutrients: 100 Carbon/10 Nitrogen/1 Phosphorus/1 Potassium/1 Sulfur
- Creates more stable and resilient soils
- Drives nutrient recycling
- Decomposition
- Disease control
- Provides structure for water retention
- Results in “Team Play” in soil
- Some nematode control
Soil biology manages nutrients

Cycling Nutrients

![Nutrient Cycling Diagram](image-url)
Soil is a Living Ecosystem

**MICROBIAL FUNCTIONS**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Advantage</th>
<th>Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose Destroyer</td>
<td>Enhanced breakdown of crop waste</td>
<td>Returns organic matter to soil</td>
</tr>
<tr>
<td>Nitrogen fixers</td>
<td>Conversion of ammonia to nitrates</td>
<td>Allows plant to utilize nitrogen</td>
</tr>
<tr>
<td>Decomposers</td>
<td>Decompose organic material</td>
<td>Builds humus for soil</td>
</tr>
<tr>
<td>Phosphate fixer</td>
<td>Solubilization of phosphorus</td>
<td>Allows plant to utilize phosphorus</td>
</tr>
<tr>
<td>Promotes root development</td>
<td>Production of phytohormones</td>
<td>Suppresses Disease</td>
</tr>
<tr>
<td>Beneficial fungi</td>
<td>Production of glomulin</td>
<td>Builds soil tilth and promotes water retention</td>
</tr>
<tr>
<td>Sulfur oxidizer</td>
<td>Convert sulfides to sulfates</td>
<td>Makes sulfur available to plants</td>
</tr>
</tbody>
</table>
# Typical Numbers of Soil Organisms in Healthy Ecosystems

<table>
<thead>
<tr>
<th></th>
<th>Ag Land</th>
<th>Prairie</th>
<th>Forest</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Organisms per gram (teaspoon) of soil</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bacteria</td>
<td>100 mil. -1 bil.</td>
<td>100 mil. -1 bil.</td>
<td>100 mil. -1 bil.</td>
</tr>
<tr>
<td>Fungi</td>
<td>Several yards</td>
<td>10s – 100’s of yds</td>
<td>1-40 miles (in conifers)</td>
</tr>
<tr>
<td>Protozoa</td>
<td>1000’s</td>
<td>1000’s</td>
<td>100,000’s</td>
</tr>
<tr>
<td>Nematodes</td>
<td>10-20</td>
<td>10’s – 100’s</td>
<td>100’s</td>
</tr>
<tr>
<td><strong>Organisms per square foot</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arthropods</td>
<td>&lt; 100</td>
<td>500-2000</td>
<td>10,000-25,000</td>
</tr>
<tr>
<td>Earthworms</td>
<td>5-30</td>
<td>10-50</td>
<td>10-50</td>
</tr>
</tbody>
</table>

Source: USDA Natural Resource Conservation Service
- Builds tilth soil
- Produces a glue compound for water retention and binds soil
- Creates more air spaces
- Helps developing root structure
- Helps establish earth worm populations
- Creates conduits for nutrient travel
- Builds organic matter

Left: High humus & rich in carbon
Right: Poor humus content
- Mother Nature's little engines that are hard at work
- Due to over-fertilization, lack of aeration and lack of organic matter in the soil, the population of microbes has been severely diminished and in some cases non-existent
- Transport nutrients to plant
- Increased oxygen & water penetration in the soil
Microbes are always present in soil.

- Microbes in soil are proportional to organic matter content.
- Microbes maintain good soil structure which promotes soil aeration, root growth & water management.
- Suppression of pathogenic microorganisms cause diseases.
- Microbes transform nutrients for plant utilization.
Seasonal Microbial Activity

Bacterial and Fungal Activity in a temperate grassland or cropland

- Early summer
- Late summer
- First frost
- Last frost

Source: USDA Natural Resource Conservation Service
Mycorrhizal Fungi

Naturally occurring in the environment

- Mycorrhizal attaches itself inside the root system
- “Soil superglue”
  - Builds soil aggregate
  - Proceeds organic matter
- Strengthens the root system
- Making the plant less susceptible to wind damage
- Less susceptible to drought
- Expedites the growth process through nutrient uptake
- Acts as a sponge in the soil to hold moisture
What Results Can be Accomplished at Bioaugmentation?

- Increased crop yield
- Lowering of input costs
- Reduce fertilizer inputs
- Increased root structure development
- Better decomposition of crop residues
What Results Can be Accomplished at Bioaugmentation?

- Increased water holding capacity
- Improved internal drainage
- Nutrient holding capacity
- Increase organic matter in soil
- Move pH toward neutral
- Better sustainable soil