Introduction to Soil Health and Restoration

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Why should we care about soil?

Farming is a craft. Craftsmen understand the medium they work with. A farmer’s medium is the soil.
Soil Health

• Key to farm profitability
• The farm’s “bank account”
• Our legacy
• The inheritance we leave the next generation
Soil Profile
Soil

**Physical**
- Aggregation and Structure
- Surface Sealing
- Compaction
- Porosity
- Water Movement and Availability

**Chemical**
- pH
- Soluble Salts
- Sodium
- Nutrient Holding Capacity
- Nutrient Availability

**Biological**
- Macrofauna
- Microfauna
- Microorganisms
- Roots
- Biological Activity
- Organic Matter

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Soil Particles

Relative soil particle sizes

- **Gravel**
- **Sand**
- **Silt**
- **Clay**

Measurements:
- **mm**
- **inches**

Scale:
- 0
- 1
- 2
- 3
- 4
- 5

Not visible at this scale:
- **Clay**
Cation Exchange Capacity

• CEC = Cation Exchange Capacity
  – The soils capacity to absorb important nutrients (e.g. calcium, magnesium, potassium).
  – A measure of soil fertility.
  – In general, the higher the better.
  – CEC lower in acid (low pH) soils.
  – Lowest in sandy soils
  – Highest CEC in soils with high levels of humus followed by clay soils.
Humus

- Humus = dark, spongy looking soils
- Decomposed organic matter (OM) in a stable form.
- Byproduct of microbial decomposition of OM
- OM = dead plant and animal material (carbon)
- Higher levels of humus = greater CEC, greater water infiltration and holding capacity
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Soils – the basis of life.
What is Soil Health?

- Soil health = soil function
- Soil function = ability to capture, store and cycle water.
- And the ability to cycle nutrients.
Soil microbial activity mediates 90% of soil function
For soil to function properly:

- Active soil biology
- Critical mass in microbial population
  - Measured in ng/g
  - Most agricultural soils 1000 – 2000 ng/g
  - Some “conservation lands” 500 ng/g
  - Critical mass around 6000 ng/g
  - Some commodity ag. field utilizing principles of soil health 12,000 – 13,000 ng/g
For soil to function property:

• Balanced fungi:bacteria ratios
  – Most agricultural soils higher in bacteria due to lack of SOM or crop residues
  – Fungal centric soils preferred (higher C:N Ratio)

• Balanced predator:prey ratios
  – Or, protozoa:bacteria
  – Higher = better = active community releasing N via predation of protozoa on bacteria

• Creates good soil aggregate structure.
• Takes time to rebuild these
The Soil Food Web

- Plants
  - Shoots and roots
- Organic Matter
  - Waste, residue and metabolites from plants, animals and microbes.
- Fungi
  - Mycorrhizal fungi
  - Saprophytic fungi
- Nematodes
  - Root-feeders
- Arthropods
  - Shredders
  - Predators
- Protozoa
  - Amoebae, flagellates, and ciliates
- Bacteria
- Birds
- Animals

First trophic level: Photosynthesizers
Second trophic level: Decomposers, Mutualists, Pathogens, Parasites, Root-feeders
Third trophic level: Shredders, Predators, Grazers
Fourth trophic level: Higher level predators
Fifth and higher trophic levels: Higher level predators
Soil Aggregate Structure
Glomulin attached to fungal hyphae

Photo credit: Sara Wright
Glomulin

- Microbes secrete glomulin ("biotic glue")
- Glomulin is carbon
- This "glue" holds soil particles together forming soil aggregates
- Aggregates have pore spaces between them
- Most important microbes = arbuscular mycorrhizal fungi
Fungal Hyphae
Water Cycle

condensation

interception

precipitation

infiltration

runoff

transpiration

evaporation

groundwater
Nutrient Cycle – Carbon (C)
Nutrient Cycles – Phosphorus (P)
Energy Flow

[Diagram showing the process of photosynthesis with the following steps:
- Carbon Dioxide + Water → Carbohydrates + Oxygen]

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Soil Health
How can we promote soil health?

• By providing a home or habitat for soil microbes.
SOIL HEALTH PRINCIPLES

1. Keep the soil covered
2. Minimize soil disturbance
3. Increase crop diversity
4. Keep living roots in the soil
5. Integrate livestock

Learn more at www.sfa-mn.org
1. Keep the soil covered

Cover crops can provide "armor" to protect the soil from wind and water erosion.
No cover = erosion
The value of cover.
2. Minimize soil disturbance

Cover crops can provide a mulch for direct planting.
• https://www.youtube.com/watch?v=CEOyC_tGH64
3. Increase crop diversity
Major Crop Types

• Warm season grass
  – Corn, millets, sorghum, sudangrass, teff

• Warm season broadleaves
  – Sunflower, soybean, cowpea, buckwheat

• Cool season grass
  – Oats, wheat, annual ryegrass, cereal rye

• Cool season broadleaves
  – Clovers, turnips, field pea, radish, vetches
Crop Diversity

• Crop diversity promotes diverse soil microbe populations
• Some microbes associated with only certain plant species.
• Diverse soil microbe populations promote crop productivity and reduced input costs.
Seeded Annuals

Brown's Ranch, Bismarck, ND, 8/20/13

~30 cover crop species, planted 6/26, 0.5" rain, picture taken 8/20, 1PM, 100 degrees F
Complex cover crop blend
4. Keep living roots in the soil
Inter-seed Cover Crop Into Cash Crop

Image: Ian Cunningham
Double Crop System
5. Integrate livestock
• Dr. Dwayne Beck, Dakota Lakes Experiment Station, SDSU says the worst thing we have done in agriculture for soil health is to remove livestock from the landscape.

• Fara Brummer, NDSU Extension Specialist states that livestock are the missing link in soil health.
Livestock Integration
Managed Livestock Grazing Promotes Soil Microbes
Custom Grazing Leases
### Value of Livestock Integration

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<th>Management</th>
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CT = Conventional Tillage, NT – No-Till, LD = Low Diversity, MD = Moderate Diversity, HS = High Synthetics, NS = No Synthetics, Lvst = Livestock.
“Cover Crops”

• Not the “silver bullet”
• A crop planted to address one or more resource concerns (a “tool”)
• Work best when managed as a crop.
• Work best in conjunction with other techniques – no-till, diverse rotation, etc..
• Cover crop selection based on:
  1) goals for a particular field,
  2) biological, chemical (herbicide history), physical, social and economic factors influencing management of that field.
Midwest Cover Crops Council

http://mccc.msu.edu/
Tips to Remember...

• If we provide a comfortable home for soil microbes and feed them well they will do most of the work for us.
• Crop diversity and managed livestock grazing promotes soil microbial activity.
• Most microbial activity happens near the soil surface and in the root zone of living plants.
• Tillage is harmful to soil microbes.
Questions?