Practical Soil Health Specialist Training Curriculum
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Principles and Benefits of Building Healthy Soils

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American Farmland Trust
New York Soil Health: Merging Discovery Science with Farmer Needs and Protection of Natural Resources

• An era of discovery:
  – Amazing biodiversity and abundance beneath our feet
  – Prescription crops and innovative management to build healthy soils

• Farmer motivation and innovation:
  – Healthy soils = resilience and increased profits

• Soil health and the environment:
  – Erosion and water quality;
  – Food security and climate change challenges
Healthy soils maintain a diverse community of soil organisms that:

- Suppress plant disease, insect and weed pests;
- Form beneficial symbiotic associations with plant roots;
- Retain and recycle essential plant nutrients;
- Improve soil aggregation for better water infiltration, retention, and drainage;
- Increase grower profits and protect the environment
Salman Waksman, a pioneer soil biologist, coined the term “antibiotic”, and discovered Streptomycin in 1943.
Organic Matter (OM): Key to Soil Health

- OM is “food” for the many beneficial organisms in the soil food web.
- Fungal hyphae and sticky substances released by soil biota are essential for aggregate stability.
- Well aggregated soils buffer plants from short-term drought, flooding, compaction.
- OM is a source of plant nutrients and also sequesters carbon in the soil.
- Highly stable OM fraction increases cation exchange capacity and nutrient retention.
Soil Health Principles To Support High Functioning Soils

- **Feed**
  - diverse, continuous inputs (C sources, energy)

- **Protect**
  - habitat (aggregates and organic matter)

- **Maximize**
  - living roots

- **Minimize**
  - disturbance

- **Maximize**
  - diversity

- **Maximize**
  - cover

Source: USDA-NRCS
Benefits of Maximizing Vegetation and Residue Cover Year Round

- Prevents erosion
- Moderates soil temperatures
- Reduces evaporation/evapotranspiration
- Increases infiltration
- Builds organic matter, food for microbes
- Weed control

Source: USDA-NRCS
Breakthroughs in Root Biology: Much More Than Water and Nutrient Uptake

- Roots exude substances that:
  - inhibit weeds, insects, disease
  - attract beneficial microbes
  - dissolve plant nutrients in soil

- Create pathways for water, oxygen, roots to follow

- Sequester organic matter (carbon) deep in soil profile
Sudangrass: roots suppress weeds and pathogenic nematodes; break through compacted soils; pump organic matter (carbon) into the soil

Cover Crops Research and “plant legacy” effects
Rhizosphere:
The most dynamic interface on Earth

- a narrow zone of soil, within millimeters, that surrounds plant roots
- hotspot of plant-soil interactions involving microbiota

Source: J. Kao-Kniffin, Cornell
Biodiversity Benefits From Cover Crop Mixes and Rotation

• Species mixes can support each other:
  – Nutrients (e.g., legume-grass)
  – Wind protection
  – Shade

• Complementary use of resources (e.g., different rooting depths, canopy architecture and sunlight capture)

• Each species can provide unique benefits to subsequent crops

• Increases and diversifies the soil food web

• Mixes provide cover crop insurance
Biomass Production
Annual Cropping Systems

Cover crops for resource assimilation and dry matter production

Dry matter production or resource loss (mass/time)

Annual grain crop

Winter cover crop

Or winter grain for forage or grain

A. H. Heggenstaller, University of Alberta
The Challenge:
Establishing and terminating fall/winter cover crops into cash crop systems

Field experimentation by farmers and researchers
Why Tillage?

The physical manipulation of the soil for the purpose of:

- Management of previous crop residue
- Control of competing vegetation (weeds)
- Incorporation of amendments (fertilizer/manure)
- Preparation of a soil for planting equipment
- Breakup compaction layers
- Recreation for folks who don’t fish or golf.

Source: USDA-NRCS
Tillage: the Dark Side

- Destroys aggregates
- Exposes organic matter to decomposition
- Compacts the soil
- Damages soil fungi
- Reduces habitat for the Soil Food Web
- Disrupts soil pore continuity
- Increases salinity at the soil surface

Source: USDA-NRCS
Tillage, Soil Health, and Carbon

Tillage oxygenates soil, stimulating microbial decomposition of OM, releasing stored carbon as CO2.

Increased tillage → Compaction → Declining OM (less “food” for soil) → Unhealthy microbial communities → Poor drainage → Reduced soil aggregation → The downward spiral of poor soil health → CO2
Cover crops for compaction remediation

Source: Ray Weil, Univ of MD
“The plow is one of the most ancient and most valuable of man’s inventions; but long before he existed the land was in fact regularly plowed, and still continues to be plowed by earthworms.”

- Charles Darwin, 1881
Directly Adding Organic Matter and Carbon to Soils: Composts and other soil amendments for improving soil health
The Energy-Waste Management Challenge: Re-coupling animal and plant production systems to re-cycle nitrogen, carbon, energy
**Biochar:**

Capturing energy from biomass or waste through pyrolysis, and creating stable charcoal that is stable in soils and benefits soil structure and function.

Soil Health and “win-win” solutions: Low-cost resilience to weather extremes while reducing the carbon footprint of agriculture

Building soil organic matter (reducing tillage; winter cover crops; using manure, composts, biochar; more perennial crops):

- Adaptation: increases resilience to drought, flooding, erosion
- Mitigation: stores carbon in the soil that otherwise would be in the air as $\text{CO}_2$
Farmer Survey (n=183) Regarding 2016 NY Drought

Farmer Strategies to Build Resilience

Did what you experienced in 2016 changed your perspective on future drought?

- Yes: 61%
- No: 39%

Are you planning to do anything different after experiencing the 2016 drought?

- Increase soil organic matter: 32%
- Develop water sources: 26%
- Alter irrigation scheduling: 11%
- Invest in irrigation equipment: 6%
- Adjust crop management: 10%
- Mulch crops: 3%
- Adjust planting regime: 5%
- Increase crop diversity: 3%

NY Farmer Soil Health Survey (n=182)

Economic and Environmental Costs and Benefits
C Mason and D Wolfe

Weather Resilience

<table>
<thead>
<tr>
<th>Practice</th>
<th>Improved drainage</th>
<th>Drought resilience</th>
<th>Less erosion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover crops</td>
<td>60%</td>
<td>60%</td>
<td>80%</td>
</tr>
<tr>
<td>Reduced tillage</td>
<td>60%</td>
<td>60%</td>
<td>80%</td>
</tr>
<tr>
<td>Amendments</td>
<td>20%</td>
<td>40%</td>
<td>20%</td>
</tr>
</tbody>
</table>

% of practitioners
Building Healthy Soils Takes Time!
And some benefits are realized sooner than others

Benefits not just about yield:
- Reduced input costs (e.g., fuel, labor, fertilizer)
- Reduced capital investments (e.g., irrigation or drainage system)
- Resilience to drought or flooding in extreme weather years

Source: USDA-NRCS
How long does it take to see specific benefits?

C Mason and D Wolfe

Reduced Tillage
Less erosion or sedimentation repairs

Chi-square p-value = 0.002

Experience
- 1-5 yrs
- 5-10 yrs
- 10-20 yrs
- 20+ yrs
How long does it take to see specific benefits?

C Mason and D Wolfe

Cover Crops
Greater yields of cash crops

Chi-square p-value = 0.032

Experience
1-5 yrs
5-10 yrs
10-20 yrs
20+ yrs

% of group
0 20 40 60
New York Has Been at the Forefront of the Soil Health Movement For More Than 20 Years

Where Do We Go From Here?

What Are the Priorities for Research, Outreach, Policy?
Current “New York Soil Health” Collaborators

• Farmers
• Agriculture service providers, agribusiness leaders
• Researchers
• Government agencies
• Non-profits
• Cornell Cooperative Extension and other educators
• Policy-makers
• Others
New York Soil Health: Priorities and Research

- Promote statewide communication, coordination, collaboration (www.newyorksoilhealth.org)
- Identify and address barriers to wider adoption
- Quantify economic and environmental benefits
- Innovative cropping systems and soil ecology research
- Research on biochar and composts
- Held first “NY Soil Health Summit” July 2018
- Complete the NY “Soil Health Roadmap”
Selected References


