Instilling Health into Unhealthy Soils

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Consumables
“The rich, soft soil has all run away, leaving the land nothing but skin and bone” --Plato, 400 B.C.
“…. did not so much collapse as consume itself.”

How do we get away from treating soil as a consumable?
Recent Times

- U.S. Piedmont used to be a major agricultural region.
- Cultivation brought immediate and devastating soil erosion.
More Recently

• In the U.S. Midwest, extensive flat grasslands were plowed and put into grain production about 100 years ago.

• Multiple and damaging large flood events caused severe soil erosion and property damage between 1926-1936. Grain crop yields for many fields actually declined when compared to the previous century (Bennett, 1939).
120 Years of Erosion

Average 7 inches of soil loss over the whole field (that’s ~7.5 tons/A/yr)

Areas of extreme have lost 16 inches (that’s ~23 tons/A/yr)
What is the impact of past erosion on productivity?

- Average 7” topsoil lost since farming started ~120 yrs ago
- Impact on production today?
  - Soybean: 7” x 0.9 bu/in/a/yr x $13/bu = $82/a/yr
  - Corn: 7” x 3.1 bu/in/a/yr x $5/bu = $109/a/yr
  - C-S rotation: average loss $96/a/yr
Few Years Ago

- A 4-inch rainfall event created gullies that followed the planter rows (channeled by the planter furrow)
- About 2-inches deep x12-inches wide, of a 30-inch-row spacing corn crop
- Erosion “consumed” 1.5 inches of topsoil
- Could be replaced by growing grass for 300-400 years
“... the slower the emergency, the less motivated we are to do anything about it.”

Dirt, David R. Montgomery
Soil Functions

- Physical Stability and Support
- Hydrologic Buffer
- Filtering and Buffering
- Food, Biodiversity and Habitat
- Nutrient Cycling
Dysfunctional Soils

- Physical Stability and Support
- Hydrologic Buffer
- Filtering and Buffering
- Food, Biodiversity, and Habitat
- Nutrient Cycling
Chemical
- pH
- CEC
- Phosphorus
- Potassium
- Micronutrients
- Mineralizable Nitrogen
- Organic Matter
- Proteins
- Respiration
- DNA/PLFA

Biological
- Enzymology
- Infiltration
- Proteins
- Texture
- Bulk Density
- Porosity
- Aggregation
- Structure

Physical
- Electrical Conductivity
- Bulk Density
- Porosity
- Aggregation
- Infiltration
- Proteins
What do we know about soil health and cover crops today that we didn’t already know 30 years ago?
2016 Cover Crop Survey Respondents

Legend
- states
- 2016 Total Responses
- 0 - 7
- 8 - 21
- 22 - 67
- 58 - 104
- 105 - 357

* This map represents only those who indicated their state location in the survey, about two-thirds of all respondents.
Acres of Cover Crops per Respondent

Data from 2015-16 SARE/CTIC/ASTA national cover crop survey

< 2012 Census of Ag reported 10.3 million acres of cover crops
What is the single, biggest benefit you receive from using cover crops on your farm?

- Erosion Control: 26%
- Improves Soil Health: 30%
- Increased Organic Matter: 15%
- Better Farm Management: 7%
- Grazing: 5%
- Weed Control: 5%
- Less Compaction: 3%
- Water Quality & Moisture Retention: 2%
- Economic Benefit: 2%
- Other: 2%
- Increase Yields: 1%
- Benefit to Habitat/Insects: 1%
Yield increase following cover crops?

<table>
<thead>
<tr>
<th>Crop Year</th>
<th>Corn</th>
<th>Soybeans</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>9.6%</td>
<td>11.6%</td>
</tr>
<tr>
<td>2013</td>
<td>3.1%</td>
<td>4.3%</td>
</tr>
<tr>
<td>2014</td>
<td>2.1%</td>
<td>4.2%</td>
</tr>
<tr>
<td>2015</td>
<td>1.9%</td>
<td>2.8%</td>
</tr>
</tbody>
</table>

Data provided from farmers in the SARE/CTIC national cover crop survey. Differences are statistically significant based on analysis by Purdue University.
Summary of Typical Positive Impacts Attributed to Cover Crops

1. Greatly reduced erosion
2. Increased soil organic matter
3. Recycle nutrients
4. Fix N with legumes
5. Enhanced infiltration
6. Enhanced aeration with improved soil structure/aggregation
7. Preventive of soil compaction
8. Reduced evaporation potential
Sediment Loss

Goodwater Creek Watershed

Comparison of sediment loss between Conventional and PAS with No-till and CC treatments.
Average Annual Sediment Loss

- Average Annual Sediment Loss: 32% of Watershed
- Rate of Soil Formation: 350% more @ Field than Watershed

**Bar Chart:**
- **Field 1** and **GWC Watershed**
- **Sediment (tons/Ac/yr)**
- **Rate of Soil Formation**
- **1993-2003**
Percent Reduction in Phosphorus in Runoff
(summary of studies; Sharpley and Smith; 1991)
Summary of Typical Positive Impacts Attributed to Cover Crops

1. Greatly reduced erosion
2. Increased soil organic matter
Role of Organic Matter on Nutrients

- Organic matter is a reservoir of nutrients that can be released to the soil.

- Each percent of organic matter in the soil releases ~20 to 30 pounds of N, ~4 to 6 pounds of \( \text{P}_2\text{O}_5 \), and ~2 to 3 pounds of sulfur per year.

- The nutrient release occurs predominantly in the spring and summer, so summer crops benefit more from organic-matter mineralization than winter crops.
Summary of Typical Positive Impacts Attributed to Cover Crops

1. Greatly reduced erosion
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Radish and Rye Capture Nitrate-N in the Soil Profile

Forage radish and other cover crops clean up nitrate from a sandy soil profile by mid-November. Control soil had no cover crop, only winter weeds. (Data from Dean and Weil, 2009)
Percent Reduction in Nitrate Leaching
(summary of studies; Meisinger et al., 1991)
## Cost to Remediate Nitrate Losses
*(Gulf Hypoxia and Local Water Quality Concerns Workshop, 2005)*

<table>
<thead>
<tr>
<th>Practice</th>
<th>Range of N removed (lb N /acre)</th>
<th>Cost ($ per lb of N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constructed Wetlands</td>
<td>?</td>
<td>&gt; $2.00</td>
</tr>
<tr>
<td>Controlled Drainage</td>
<td>Up to 30%</td>
<td>$1.40 - $2.00</td>
</tr>
<tr>
<td>Buffers and Filter Strips</td>
<td>10-20</td>
<td>$0.60 – $0.40</td>
</tr>
<tr>
<td>Conservation Tillage</td>
<td>10-20</td>
<td>$0.38 - $1.11</td>
</tr>
<tr>
<td>Cover Crops</td>
<td>20 - 45</td>
<td>$0.57-$1.42</td>
</tr>
</tbody>
</table>
“Cover Crops: Grow your own fertilizer”

“Cut fertilizer costs” with cover crops

“Cover crops help farmers produce own fertilizer”
Summary of Typical Positive Impacts Attributed to Cover Crops

1. Greatly reduced erosion
2. Increased soil organic matter
3. Recycle nutrients
4. Fix N with legumes
### Chart 2 PERFORMANCE AND ROLES

<table>
<thead>
<tr>
<th>Species</th>
<th>Legume N Source</th>
<th>Total N (lb/A)</th>
<th>Dry Matter (lb/A/yr.)</th>
<th>N Scavenger²</th>
<th>Soil Builder³</th>
<th>Erosion Fighter⁴</th>
<th>Weed Fighter</th>
<th>Good Grazing⁵</th>
<th>Quick Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Berseem clover p. 118</td>
<td>★</td>
<td>75–220</td>
<td>6,000–10,000</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>★</td>
<td>●</td>
</tr>
<tr>
<td>Cowpeas p. 125</td>
<td>★</td>
<td>100–150</td>
<td>2,500–4,500</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Crimson clover p. 130</td>
<td>★</td>
<td>70–130</td>
<td>3,500–5,500</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Field peas p. 135</td>
<td>★</td>
<td>90–150</td>
<td>4,000–5,000</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Hairy vetch p. 142</td>
<td>★</td>
<td>90–200</td>
<td>2,300–5,000</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Medics p. 152</td>
<td>✅</td>
<td>50–120</td>
<td>1,500–4,000</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Red clover p. 159</td>
<td>✅</td>
<td>70–150</td>
<td>2,000–5,000</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Subterranean clovers p. 164</td>
<td>★</td>
<td>75–200</td>
<td>3,000–8,500</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>Sweetclovers p. 171</td>
<td>★</td>
<td>90–170</td>
<td>3,000–5,000</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>White clover p. 179</td>
<td>★</td>
<td>80–200</td>
<td>2,000–6,000</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
</tr>
<tr>
<td>Woollypod vetch p. 185</td>
<td>★</td>
<td>100–250</td>
<td>4,000–8,000</td>
<td>●</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>●</td>
<td>○</td>
</tr>
</tbody>
</table>

¹Total N—Total N from all plant. Grasses not considered N source. ²N Scavenger—Ability to take up/store excess nitrogen. ³Soil Builder—Organic matter yield and soil structure improvement. ⁴Erosion Fighter—Soil-holding ability of roots and total plant. ⁵Good Grazing—Production, nutritional quality and palatability. Feeding pure legumes can cause bloat.

○ = Poor;  ○ = Fair;  ● = Good;  ○ = Very Good;  ● = Excellent

Managing Cover Crops Profitably, SARE
Cover Crop and Kill Date on Plant Available Nitrogen

Source: D. Sullivan.
<table>
<thead>
<tr>
<th>Physical Score</th>
<th>Biological Score</th>
<th>Chemical Score</th>
<th>Nutrient Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>bulk density</td>
<td>organic C</td>
<td>pH</td>
<td>extractable P</td>
</tr>
<tr>
<td>water-filled pore space</td>
<td>B-glucosidase</td>
<td>electrical conductivity</td>
<td>extractable K</td>
</tr>
<tr>
<td>water-stable aggregates</td>
<td>microbial C</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>mineralizable N</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Agricultural Continuum of Soil Health

Veum KS, Goyne KW, Kremer RJ, Miles RJ, Sudduth KA (2014) Biological indicators of soil quality and soil organic matter characteristics in an agricultural management continuum. Biogeochemistry

Physical Score
- bulk density
- water-filled pore space
- water-stable aggregates

Biological Score
- organic C
- B-glucosidase
- microbial C
- mineralizable N

Chemical Score
- pH
- electrical conductivity

Nutrient Score
- extractable P
- extractable K

SMAAF Total Score (0-5 cm)
“While the chemistry (and physics) of the soil system provides the context. . . it is the soil biota which is adaptive to changes in environmental circumstances”

-Kibblewhite et al. 2008
What risks are associated with cover crops?

<table>
<thead>
<tr>
<th>Downside Risks</th>
<th>Opportunity Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planted when time and labor is limited</td>
<td>Reduce soil erosion, nutrient loss, and increase residue cover</td>
</tr>
<tr>
<td>Addition costs (planting and killing)</td>
<td>Increased water infiltration</td>
</tr>
<tr>
<td>Reduced or increased soil moisture effects depending on weather or management</td>
<td>Increased soil organic carbon</td>
</tr>
<tr>
<td>Difficult to incorporate cover crops with tillage</td>
<td>Improved soil physical properties/reduced soil compaction and improved field trafficability</td>
</tr>
<tr>
<td>May increase disease risks</td>
<td>Recycle nutrients, fix nitrogen with legumes</td>
</tr>
<tr>
<td>May increase insect pests</td>
<td>Improve weed control, beneficial insects, disease suppression</td>
</tr>
<tr>
<td>Allelopathic effects</td>
<td>Wildlife habitat and landscape aesthetics</td>
</tr>
</tbody>
</table>
CAN I NOT AFFORD TO DO COVER CROPS?
(short- and long-term cost and benefits)
“How might we rethink the conventional wisdom of conventional agriculture to find a way to work with nature?”

Stop “trying to make soil adapt to our technology.”

Use innovation and technology to adapt to how we manage soils.