Soil Management: How Cover Crops Can Impact Soil Health and Water Quality

Iowa Water Conference
Tuesday March 4, 2014
Ames, IA
Big Problems for Soil Health

1. Erosion
   a. Iowa has lost 50% topsoil

2. Organic Matter Loss
   a. 50% loss of soil organic matter

3. Nutrient Losses – runoff & leaching

4. Lack of Action on Big Problems
   a. Short-term outlook
   b. Yield increases with tillage and drainage
   c. Easier management – way we have done it
### Erosion from 3 simulated rainfall events (9.5 cm) over 2 months

<table>
<thead>
<tr>
<th></th>
<th>Ames</th>
<th>Castana</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Erosion kg/ha</td>
<td>Erosion kg/ha</td>
</tr>
<tr>
<td>Moldboard Plow</td>
<td>17070</td>
<td>87250</td>
</tr>
<tr>
<td>Chisel Plow</td>
<td>7720</td>
<td>53290</td>
</tr>
<tr>
<td>No Till</td>
<td>4780</td>
<td>31410</td>
</tr>
</tbody>
</table>

Laflen and Colvin Trans ASAE 1981
Does soil erosion affect corn yield?

DRY Corn Yield vs Erosion/Deposition

\[ y = 3.1189x + 153.55 \]
\[ R^2 = 0.5065 \]

Corn Yield (bu/acre) vs Erosion/Deposition (tons/acre/year)

DRY Corn Yield vs A horizon depth

\[ y = 26.676\ln(x) + 69.797 \]
\[ R^2 = 0.5705 \]

A Horizon Depth (in) vs Corn Yield (bu/acre)
Rye after Corn Silage
Corn and Soybeans have a 7 Month “BROWN” Gap

Winter Cover Crops “Catch” Losses

Cover Crops Fill the “BROWN” Gap with “GREEN” Plants
Benefits of Using Cover Crops

- Reduced erosion
- Reduced nitrate leaching
- Reduced phosphorus losses
- Increased soil organic matter
- Improved weed control
- Support and maintain soil organisms
- Improve soil structure – especially no-till
- Grazing and forage potential
- Recycling manure nutrients
Erosion Measurements with Simulated Rainfall

NO COVER CROP       OAT COVER       RYE COVER
Relative Rill and Interrill Erosion Rate in No-till Soybean as Affected by Cover Crops

RUSLE2 Erosion Estimates Using Beta Version of Cover Crop Vegetation Files

- Corn–Soybean rotation, NT, spring anhydrous, 5% slope, 150 ft slope length, Ames, IA
  - without rye cover crop = 2.1 t/ac/yr
  - with rye cover crop = 1.2 t/ac/yr

- Continuous Corn Silage, NT, spring anhydrous, 5% slope, 150 ft slope length, Ames, IA
  - without rye cover crop = 4.8 t/ac/yr
  - with rye cover crop = 1.9 t/ac/yr
Nitrate Loss in Tile Drainage
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Nitrate-N lost</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12-yr</td>
<td>12-yr total</td>
<td>lbs/acre</td>
</tr>
<tr>
<td>Corn-soybean</td>
<td>428</td>
<td>428</td>
<td>36</td>
</tr>
<tr>
<td>Corn-Soyb w. Rye</td>
<td>191</td>
<td>191</td>
<td>16</td>
</tr>
<tr>
<td>Reduction</td>
<td>237</td>
<td>237</td>
<td>20</td>
</tr>
<tr>
<td>% Reduction</td>
<td>55</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cover Crop Shoot Biomass</td>
<td>Cover Crop Shoot N Concentration</td>
<td>Cover Crop Shoot N Content</td>
</tr>
<tr>
<td>------------------</td>
<td>--------------------------</td>
<td>----------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td></td>
<td>lbs/acre</td>
<td>%</td>
<td>lbs N/acre</td>
</tr>
<tr>
<td>Avg 02-13</td>
<td>1526</td>
<td>2.86</td>
<td>38</td>
</tr>
<tr>
<td>Sum 02-13</td>
<td>18307</td>
<td>457</td>
<td>237</td>
</tr>
</tbody>
</table>
Cover Crops and No-Till
Soil Structure and Health
Rye Cover Crop Effect on Soil Quality in a Corn Silage System after 10 years

- A rye cover crop increased total soil organic matter (SOM) in the top 4 inches from 4.8% to 5.3% or ½% change in SOM

- Very rough estimates would say a ½% change in SOM would result in an additional ½ inch of water and 11 kg/ha of mineralized soil N.

- 48% greater Potential N mineralization

- Rough estimates would say this would be 9-11 kg/ha of mineralized soil N.

- These are really hard measurements to make
Soil biology

- Plant growth during normally “fallow” period (Sept-Nov, March-April) provides continuous and stable food source for soil organisms.

- Plant cover moderates temperature and water content.

- Diversity of plant materials may also increase diversity of soil biological community.

- Soil organic matter maintained and cycled from coarse residue to humic acids.
Cover Crops and Worms

- Reeleeder et al. (2006) found higher worm densities (3X) following 8 years of rye cover crops.
- Ketterings et al. (1997) found that earthworms increased aggregate stability following cereal rye and hairy vetch cover crops and preferred the high N residues of the cover crops as a food source.
Reddy et al. (2003) found that after three years of crimson clover or rye cover crops soil had greater populations and activity of bacteria and fungi.

Lundquist et al. (1999) found that incorporation of rye cover crop increased bacteria and bacterial-feeding nematodes within 14 days.
Sticky substance, glomalin, surrounding soil aggregates, water insoluble. Photo by Sara Wright.
Roots are important

- When building soil quality, esp. with NT, the cover crop ROOTS are probably more significant than the shoot growth
- Still need good shoot growth for erosion control, mulch effects for moisture conservation, weed suppression, etc.
Soil physical properties improved

- Aggregation (esp. fibrous-rooted cover crops)—
  - cover crop roots enmesh particles or connect soil particles
  - exudates feed microbes which then produce polysaccharides that “glue” particles together and hyphae that physically bind particles
  - Aggregates have a shelf life and need to be refurbished or reformed
Microaggregates-macroaggregates model

Microaggregates 20-90 and 90-250 µm

Plant and fungal debris
Silt-size microaggregate
Clay microstructures
Particulate organic matter

Mycorrhizal hyphae

Pore space; polysaccharides and other amorphous interaggregate binding agents

Microaggregate <250 µm
Macroaggregate >250 µm

Adapted from Jastrow and Miller, 1997

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Soil physical properties improved (cont.)

• Porosity, permeability (esp. tap-rooted)
  – Macropores or root channels formed by cover crops roots growing through the soil can aid water infiltration, aeration, and rooting.
  – These root-derived macropores rapidly deteriorate or fill-in over time especially with freeze-thaw cycles and need to constantly strengthened and reformed with new roots.
  – Williams and Weil (2004) showed that macropores formed by the roots of forage radish cover crops improved rooting depth of soybean in soil with a compacted soil layer. They observed soybean roots growing in old root channels.
Cereal Rye Cover Crop Root Weight and Rooting Depth in the Spring

<table>
<thead>
<tr>
<th>Year</th>
<th>Root Dry Weight (lbs/acre)</th>
<th>Rooting Depth (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>294.4</td>
<td>38.0</td>
</tr>
<tr>
<td>2005</td>
<td>642.3</td>
<td>32.7</td>
</tr>
<tr>
<td>2006</td>
<td>606.7</td>
<td>45.8</td>
</tr>
<tr>
<td>2007</td>
<td>458.3</td>
<td>36.4</td>
</tr>
<tr>
<td>2008</td>
<td>388.1</td>
<td>38.8</td>
</tr>
<tr>
<td>Avg.</td>
<td>478.0</td>
<td>38.2</td>
</tr>
</tbody>
</table>
Future of Cover Crops

• Great untapped potential
• Cover crop cultivars that are better adapted, grow faster, winter hardy, and easy to terminate. Univ. breeding programs needed
• Cover crop mixtures – could be even better
• More experiment station research on long-term benefits of cover crops and on-farm studies for improving management
• More seed, products, machinery, services, and consulting from agribusiness.
Nitrogen Summary

• Winter cover crops reduce N losses in tile drainage by taking up N and reducing nitrate concentrations in soil and drainage water. There is some lag between cover crop N uptake and reduced water concentrations.

• Winter cover crops don’t seem to have a large impact on the total annual amount of drainage, but could have seasonal effects.

• Unlike other practices used to reduce N contamination of water, winter cover crops provide other benefits.
Cumulative Nitrate-N Load

Annual N Loss in Tile Drainage for a Corn-Soybean Rotation With and Without a Rye Cover Crop

- **No Cover Crop**
- **Rye Cover Crop**

<table>
<thead>
<tr>
<th>Year</th>
<th>No Cover Crop</th>
<th>Rye Cover Crop</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>40.4</td>
<td>11.2</td>
</tr>
<tr>
<td>2003</td>
<td>81.1</td>
<td>33.9</td>
</tr>
<tr>
<td>2004</td>
<td>47.2</td>
<td>23.0</td>
</tr>
<tr>
<td>2005</td>
<td>34.4</td>
<td>11.1</td>
</tr>
<tr>
<td>2006</td>
<td>36.0</td>
<td>9.0</td>
</tr>
<tr>
<td>2007</td>
<td>66.9</td>
<td>37.1</td>
</tr>
<tr>
<td>2008</td>
<td>62.7</td>
<td>36.6</td>
</tr>
<tr>
<td>2009</td>
<td>28.9</td>
<td>19.0</td>
</tr>
<tr>
<td>2010</td>
<td>34.8</td>
<td>21.9</td>
</tr>
<tr>
<td>2011</td>
<td>25.9</td>
<td>14.9</td>
</tr>
<tr>
<td>2012</td>
<td>7.8</td>
<td>6.4</td>
</tr>
<tr>
<td>2013</td>
<td>7.8</td>
<td>6.4</td>
</tr>
<tr>
<td>Avg.</td>
<td>40.0</td>
<td>17.8</td>
</tr>
</tbody>
</table>
Soil physical properties improved

- Aggregation (esp. fibrous-rooted)—
  - cover crop roots enmesh particles;
  - exudates feed microbes which then produce polysaccharides that “glue” particles together
- Porosity, permeability (esp. tap-rooted)
  - Deep roots, macropores, can aid water infiltration, aeration, rooting
- Soil surface protected, plus better aggregation, can mean less crusting or erosion
- Roots give strength to soil for trafficability

Eileen Kladivko Purdue Univ.
Sticky substance, glomalin, surrounding root heavily infected with mycorrhizal fungi. Fungi help roots explore up to 20% of the soil volume. A root by itself can only explore 1% of the soil volume. Photo by Sara Wright.
Subsurface Drainage

Advantages:
• Remove excess water
• Decrease runoff
• Can increase field days
• Can increase crop yield

Disadvantages:
• Increase N loss
Corn and soybean yields at Crawfordsville, IA with and without drainage from ISRF10-34 Brenneman & Helmers.

<table>
<thead>
<tr>
<th></th>
<th>Corn Yield</th>
<th>Soybean Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Drainage</td>
<td>46.7</td>
<td>47.7</td>
</tr>
<tr>
<td>Drained (4 ft;</td>
<td>57.8</td>
<td>46.9</td>
</tr>
<tr>
<td>60 ft)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Tillage

Advantages:
• Bury residue
• Kill weeds
• Prepare seed bed
• Release N
• Remove compaction
• Remove furrows
• Homogenize field
• Increase corn yield

Disadvantages:
• Bury residue
• Bury weed seeds
• Dry out seed bed, crust
• Burn up organic matter
• Increase compaction
• Destroy macropores
• Reduce aggregates
• Decrease soybean yields
Impacts of Cover Crops – Nashua

- 29% reduction in corn
- 22% reduction in soybean
### Corn Yields Averaged over 4 Years in Central Iowa

<table>
<thead>
<tr>
<th>Method</th>
<th>Yield (bu/acre)</th>
<th>Difference from No Till (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moldboard Plow</td>
<td>156</td>
<td>8</td>
</tr>
<tr>
<td>Chisel Plow</td>
<td>148</td>
<td>3</td>
</tr>
<tr>
<td>No Till</td>
<td>144</td>
<td>--</td>
</tr>
</tbody>
</table>

M. Al-Kaisi PM 1901d Reviewed July 2009
Rye Cover Crop Effect on Soil Quality in a Corn Silage System after 10 years

- 10% more soil organic matter (SOM) in the top 4 inches or ½% change in total SOM
- Very rough estimates would say a ½% change in SOM would result in an additional ½ inch of available water.
- 48% greater Potential N mineralization
- Rough estimates would say 8-10 lbs/acre of mineralized soil N.
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Estimated Change in Soil Total N Balance over 4 years (2002-2005)

Fertilizer N added
Estimated N Fixation by Soybean - estimate relative to yield
N in Rainwater
N Removed in Grain
N Lost in Drainage Water
Change in Inorganic Soil N
Gaseous losses of N - ??????? – assume not different

Corn-Soybean with rye cover crop increased  73 lbs N/acre
Corn-Soybean without cover crop decreased -16 lbs N/acre

Change in total soil N - ???????
## Total Nitrate-N Lost 2002-2013

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Nitrate-N Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12-yr sum</td>
</tr>
<tr>
<td>Corn-soybean</td>
<td>480</td>
</tr>
<tr>
<td>Corn-soybean with rye</td>
<td>214</td>
</tr>
<tr>
<td>Total Reduction</td>
<td>266</td>
</tr>
<tr>
<td>% Reduction</td>
<td>55%</td>
</tr>
</tbody>
</table>
Oats after Soybean
Tap root extended another 18+ inches beyond the end of tuber. These roots are probably of more benefit for soil structure and permeability than the tuber itself.

Eileen Kladivko, Purdue Univ.
Which side has 30% cover?