Managing Carbon in Wisconsin Soils

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Extension Soil Scientist
UW-Madison
Carbon: The key element for life

Outline:
- The “ultimate” essential plant nutrient needed for life as we know it
- Soil C and organic matter basics
- Tillage impacts on soil organic matter
- Potential impacts of biofuel production on soil C
Carbon: The key element for life

- **Carbon**: Forms both the hardest and one of the softest minerals on earth
  - Diamond used as an abrasive
  - Graphite used as a lubricant
- Fourth most abundant element in the universe (H, He, O)
- Bonds to itself in a myriad of configurations to form over 10,000,000 different molecules
- Cycled through variety of phases
  - Solid (cellulose)
  - Liquid (gasoline)
  - Gas (carbon dioxide)
Why worry about soil carbon: C is a major component of the soil organic matter

- Energy source for microorganisms
  - Nutrient cycling
  - Residue decomposition
- Improves aggregation
  - Aeration, drainage, erosion, tilth, etc.
- Storehouse for nutrients
  - Included in organic structure
  - Held on exchange sites
- C is sequestered in organic matter
- Interacts with environmental contaminants
What is soil organic matter

“The fraction of soil composed of anything that once lived”

- Consists of ….
  - Plant and animal remains in various stages of decomposition
  - Living soil organisms
  - Root and microbial exudates/waste products

- Not all the same
  - Labile (active)
  - Stabile (recalcitrant)

- Need continuous additions from crop residue, roots, and amendments
Labile or biologically active

- Living or microbial biomass
  - One gram of soil contains:
    - >100,000,000 bacterial cells
    - >16,000 species of bacteria
- Macro-organic matter
- Polysaccharide molecules
- Mostly involved in decomposition; energy and nutrient cycling
Macrofauna: Soil ‘Engineers’

Mesofauna: Soil predators, pathogens, herbivores

Microorganisms: Soil process controllers

FIGURE 4.3 Size classification of organisms in decomposer food webs by body width (Swift et al., 1979).
Stabile or recalcitrant organic matter

- **Humus**
  - Very well decomposed
  - Dark, porous and spongy
  - No definite chemical structure
  - Resistant to decay
- **Age measured in decades/centuries**
- **Contributes to structural development, CEC, and affects compounds added to the soil**
- **Relatively constant content for a soil**
Long-term studies assess N effect on soil organic matter management (Vanotti et al., 1997)

- **Arlington**
  - Established 1958
  - Continuous corn
  - History of residue burning
  - Three N rates
    - None
    - 50-75 %
    - 150 %

- **Lancaster**
  - Established 1967
  - Several rotations
  - Previous alfalfa history
  - Four N rates
    - 0 – 300 through ’77
    - 0 – 200 since
Arlington Long-Term N Study
Effect of N fertilization on soil C accumulation, Arlington, 1958 - 1983

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Biomass</th>
<th>Total C (above ground)</th>
<th>Soil C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grain</td>
<td>Stover</td>
<td>t/a</td>
</tr>
<tr>
<td>No N</td>
<td>1.7</td>
<td>2.6</td>
<td>30</td>
</tr>
<tr>
<td>50 – 75 %</td>
<td>3.0</td>
<td>3.4</td>
<td>41</td>
</tr>
<tr>
<td>150 %</td>
<td>3.1</td>
<td>3.6</td>
<td>42</td>
</tr>
</tbody>
</table>

Initial soil C = 1.9 %
Effect of N fertilization on soil C accumulation, Lancaster, 1967 - 1989

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<th>Treatment</th>
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<th>Total C (above ground)</th>
<th>Soil C</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Grain</td>
<td>Stover</td>
<td></td>
</tr>
<tr>
<td>lb N/a</td>
<td>t/a/yr</td>
<td>t/a</td>
<td>%</td>
</tr>
<tr>
<td>No N</td>
<td>1.5</td>
<td>2.4</td>
<td>25</td>
</tr>
<tr>
<td>50 or 75</td>
<td>2.7</td>
<td>3.3</td>
<td>34</td>
</tr>
<tr>
<td>100 or 150</td>
<td>3.1</td>
<td>3.5</td>
<td>37</td>
</tr>
<tr>
<td>200 or 300</td>
<td>3.3</td>
<td>3.7</td>
<td>38</td>
</tr>
</tbody>
</table>

Initial soil C = 1.6 %
Tillage effect on soil organic matter
(adapted from Al-Kaisi and Licht, 2005)
Effect of 10 years of tillage and rotation on soil organic matter, Arlington, 2007
(Incremental sampling @ 2”)

<table>
<thead>
<tr>
<th>Depth (in)</th>
<th>Chisel</th>
<th>No-till</th>
</tr>
</thead>
<tbody>
<tr>
<td>0_2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4_6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6_8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8_10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1997: 3.5, 3.5, 3.3, 3.3

Soil Organic Matter (%)
Effect of 10 years of tillage and rotation on soil organic matter, Arlington, 2007

(Averaged over 0 – 8”)

- CC
- CSb
- SbC

Chisel vs. No-till
Effect of tillage and corn management on soil C cycling (Hooker et. al. U-Conn.)

- Moldboard or No-till
- Harvested for silage or grain
- Field created from forested land in 1957 and in continuous corn with the tillage/harvest systems since 1972
- Until 1972 C inputs were as C3-C; whereas corn is a C4-C plant
- Utilize $^{13}$C analysis to evaluate cycling
Effect of tillage and corn management on soil C amount over 28 years (Hooker et. al. U-Conn.)

- **Silage**
  - Depth (in):
    - 0.6
    - 2.6
    - 0.2
  - Soil Organic Matter (%):
    - 1.5
    - 2.0
    - 2.5
    - 3.0
    - 3.5

- **Grain**
  - Depth (in):
    - 0.6
  - Soil Organic Matter (%):
    - 2.0
    - 2.5
    - 3.0
    - 3.5
    - 4.0
    - 4.5
Effect of tillage and corn management on soil C partitioning (Hooker et. al. U-Conn.)

<table>
<thead>
<tr>
<th>Tillage</th>
<th>Corn Mgt.</th>
<th>C4-C</th>
<th>C3-C Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT</td>
<td>Grain</td>
<td>42</td>
<td>19</td>
</tr>
<tr>
<td>NT</td>
<td>Silage</td>
<td>35</td>
<td>18</td>
</tr>
<tr>
<td>MB</td>
<td>Grain</td>
<td>32</td>
<td>15</td>
</tr>
<tr>
<td>MB</td>
<td>Silage</td>
<td>27</td>
<td>14</td>
</tr>
</tbody>
</table>

0 – 2 in.
Effect of tillage and corn management on soil C partitioning  
(Hooker et. al. U-Conn.)

<table>
<thead>
<tr>
<th>Tillage</th>
<th>Corn Mgt.</th>
<th>C4-C</th>
<th>C3-C Half-life</th>
</tr>
</thead>
<tbody>
<tr>
<td>NT</td>
<td>Grain</td>
<td>17</td>
<td>57 years</td>
</tr>
<tr>
<td>NT</td>
<td>Silage</td>
<td>13</td>
<td>61 years</td>
</tr>
<tr>
<td>MB</td>
<td>Grain</td>
<td>24</td>
<td>32 years</td>
</tr>
<tr>
<td>MB</td>
<td>Silage</td>
<td>21</td>
<td>24 years</td>
</tr>
</tbody>
</table>

2 - 6 in.
Current challenges of bio-energy production on soil organic matter

- Corn ethanol is currently driving corn production
- Question of alternative methods
  - Cellulosic ethanol
  - Wind
  - Solar
- UW-CALS bio-energy initiative
### Estimated ethanol from biomass
(Jeffries, USDA-FPL)

<table>
<thead>
<tr>
<th>Biomass Source</th>
<th>Ethanol Produced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural Residues</td>
<td>20 - 25 B gal (conserv.)</td>
</tr>
<tr>
<td></td>
<td>36 - 45 B gal (optim.)</td>
</tr>
<tr>
<td>Energy Crops</td>
<td>33 - 61 B gal</td>
</tr>
<tr>
<td>MSW</td>
<td>5 - 10 B gal</td>
</tr>
<tr>
<td>Forestry/Mill Waste</td>
<td>0.5 - 1.0 B gal</td>
</tr>
<tr>
<td><strong>Total (average)</strong></td>
<td><strong>66.5 – 107 B gal</strong></td>
</tr>
</tbody>
</table>

Grain ethanol: ~ 13 B gal by 2009; 100 % grain use = 15% current fuel use
Concerns with using corn residues for bio-energy

(Blanco-Canqui and Lal, OSU)

- Long-term no-till: Removed 0, 25, 50, 75, and 100 % of stover after grain
- Three Ohio locations
- Removing > 50 % reduced soil C and grain yield by ~ 30 bu/a on one site
- Removing > 25 % reduced infiltration on two sites
- Removing > 50 % reduced PAW and earthworms on all sites.
- Recommend limiting stover removal to < 25 %
Many produces already chop stalks for bedding

Current practice leaves a considerable amount of stover (> 50 %?)
Removing stover also removes nutrients
(Sawyer and Mallarino, ISU, 2007)

Elemental composition of corn stover and cobs

<table>
<thead>
<tr>
<th>Crop component</th>
<th>N</th>
<th>P$_2$O$_5$</th>
<th>K$_2$O</th>
<th>Ca</th>
<th>Mg</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stover</td>
<td>20</td>
<td>4</td>
<td>35</td>
<td>11</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Cobs</td>
<td>8</td>
<td>2</td>
<td>20</td>
<td>2</td>
<td>1</td>
<td>9</td>
</tr>
</tbody>
</table>
What is Switchgrass?
Warm season perennial grass (Panicum virgatum)

Source: http://www.iowaswitchgrass.com/benefits~onfarmbenefits.html
Karl Green, LaCrosse County CNRED Agent, 2007
Benefits of Switchgrass?

Karl Green, LaCrosse County CNRED Agent, 2007

- Dominant native species found on native North American plains/prairies of Canada & United States
- Attains reasonable yields w/o high rates of nitrogen fertilizer (low inputs)
  - Cost component
  - Groundwater component
- Longevity of Crop
  - Approximately 10 years
- Adapts to numerous soil/climatic conditions, therefore can be introduced onto marginal cropland
  - Converting row crops to perennial grasses may increase soil stability
  - Carbon sequestration in root mass and stubble
- Excellent burn qualities
  - Can be co-fired w/ certain coal plants
  - *This creates an immediate end use (market) for crops, allowing establishment of crops as cellulosic technology develops*
Soil under switchgrass stores more C

Readily oxidizable C
H$_2$O$_2$ added

Arlington Research
K. Shinners, BSE
Potential soil (pheasant) loss from converting CRP to corn

- A3830 and A3831
  - Addresses soil and P losses
  - Many contracts are expiring by 2010
  - Wis. has relatively low re-enrollment 56%
  - National average re-enrollment is 83%
Estimated soil and P loss from CRP conversion to corn (Panuska et al., 2007)

Soil Loss - D Slope Fields

With Manure
No Manure

Rotation and tillage

Wisconsin P Index - D Slope Fields

With Manure
No Manure

Rotation and tillage
Estimated Soil Conditioning Index for CRP conversion to corn
(Panuska et al., 2007)
Summary

- Soil organic matter is important
- Practices that maintain or build SOM should be encouraged
- Follow conservation plans and strive to reduce tillage intensity
- Return crop residues when possible
- Carefully consider impact of converting CRP
- Crop production for bio-energy may hurt or help soil quality