Payback Potential for Enhancing Soil Health - The Journey

Dan Towery
Ag Conservation Solutions
January 9, 2013
Signs of a Great Soil
Microbes, etc
MICROBES in the Body

• They’re Invisible
• They’re Everywhere
• And they RULE!
• Microbes in your body can weigh as much or more than your brain
• Outnumber your own cells 10:1
Human Gut Bacteria
- Help digest food
- Absorb nutrients
- Protect intestinal walls
- Help regulate weight
- Wards off autoimmune diseases
- Most are either beneficial or unobtrusive freeloaders
Microbes/Antibiotics

- Diarrhea from antibiotics – due to gut microbiota being disturbed
- Scientists are seeing the microbiota not as a collections of species but as a dynamic environment
Types of microbes in the soil

- Bacteria
- Algae
- Fungi
- Mycorrhizae
- Nematodes
- Macroarthropods
- Microarthropods
- Earthworms
- Protoza
Plant Roots

- Roots leak sugars to Mycorrhizae Fungi-
- Fungi bring additional water and nutrients for the plant
Soil Critters
Carbon to Nitrogen ratio of Microbes

- Bacteria: 5:1 (20% Nitrogen)
- Fungus: 10:1 (10% Nitrogen)
- More nitrogen less carbon in Bacteria than in Fungus
- Reproduction Phase
  - Bacteria: 30 minutes  Fungus: ??
  - Protozoa: 6 hours  Nematodes: 2 years
- Where are the microbes located?  1,000 to 2,000 times more located next to the roots.
Soil Biology
Soil Biology

✓ Mycorrhizal fungi increase
✓ Act as an extension of plant roots – improving nutrient and moisture uptake
Soil Biology

✓ Mycorrhizal fungi increase
  ✓ Act as an extension of plant roots – improving nutrient and moisture uptake
✓ May take several years for a population shift
Soil Biology

✓ Mychorrhize fungi increase
  ✓ Act as an extension of plant roots – improving nutrient and moisture uptake
✓ May take several years for a population shift
✓ Fungi produce glomulin
Soil Biology

✓ Mycorrhizal fungi increase
  ✓ Act as an extension of plant roots – improving nutrient and moisture uptake
✓ May take several years for a population shift
✓ Fungi produce glomulin (like super glue)
  ✓ Improves soil aggregation
Soil Properties

- Physical
- Chemical
- Biological

Soil is meant to have something growing as much as possible.
Improved Soil Health Systems

• **Dynamic system** – it changes over time
  – Primarily due to changes in **soil biology**.
So How Do We Get More Active Soil Biology?

• We manage it.
• We increase the numbers and diversity of the microbes.
• Let’s use a scale of 1-100 regarding biological activity.
Poor Soil Structure
Biological rating - 10
Improved Soil Health Basics
Sustainable and Profitable Agriculture

1. Minimal soil disturbance
Improved Soil Health Basics
Sustainable and Profitable Agriculture

1. Minimal soil disturbance
2. Permanent soil cover
Improved Soil Health Basics

Sustainable and Profitable Agriculture

1. Minimal soil disturbance
2. Permanent soil cover
3. Diverse crop rotation cover crops
Four Phases of Soil Health Improvement

• Phase 1 – Initialization

- Soil structure starts to improve and microbial activity increases
- Additional N may be required

Biological rating - 30
Four Phases of Soil Improvement

Phase 1 – Initialization

• Phase 2 – Transition
  - OM accumulates
  - Soil aggregation and soil microbial activity elevates
  - P accumulation, N immobilization and
Four Phases of Soil Improvement

Phase 1 – Initialization

Phase 2 – Transition

Phase 3 – Consolidation

- Carbon accumulates and additional water is available in the soil
  - N mineralization and immobilization
  - >CEC and nutrient cycling
Four Phases of Soil Improvement

Phase 1 – Initialization
Phase 2 – Transition
Phase 3 – Consolidation

• Phase 4 – Maintenance
  - Continuous flow of N and C
  – Greater availability of water
  – High nutrient cycling with increases in N
Clean Water and Air depend on Healthy Soil

- Environmental Quality (Water and Air)
- Productivity
- Water & Nutrient Holding

Soil Quality

- Aggregation & Infiltration
- Carbon

Time

Best

Worst

0

Thursday, January 17, 13
Roots are chiefly responsible for increasing soil carbon.

<table>
<thead>
<tr>
<th>Crop</th>
<th>Estimated Root Residue (lbs/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Native Prairie</td>
<td>15,000 - 30,000</td>
</tr>
<tr>
<td>Annual ryegrass</td>
<td>2,600 - 4,500</td>
</tr>
<tr>
<td>Cereal rye</td>
<td>1,500 - 2,600</td>
</tr>
<tr>
<td>Red Clover</td>
<td>2,200 - 2,600</td>
</tr>
<tr>
<td>Oats</td>
<td>1,300 - 1,800</td>
</tr>
<tr>
<td>Corn</td>
<td>3,000 - 4,000</td>
</tr>
</tbody>
</table>
Nutrient Management

S
C
P
N
Nutrient Management
Nutrient Management

✓ C:N ratio is critical
✓ C:N ratio is critical
✓ One tillage pass may release 40 lb/ac of N
C:N ratio is critical

One tillage pass may release 40 lb/ac of N

Early years of no-till may need slightly more N to compensate for no tillage
Nutrient Management

✓ C:N ratio is critical
✓ One tillage pass may release 40 lb/ac of N
✓ Early years of no-till may need slightly more N to compensate for no tillage
✓ Sulfur addition
Nutrient Management

✓ C:N ratio is critical
✓ One tillage pass may release 40 lb/ac of N
✓ Early years of no-till may need slightly more N to compensate for no tillage
✓ Sulfur addition
✓ Microbes may cause
Nutrient Management

✓ C:N ratio is critical
✓ One tillage pass may release 40 lb/ac of N
✓ Early years of no-till may need slightly more N to compensate for no tillage
✓ Sulfur addition
✓ Microbes may cause corn N shortage early in growing season
1% Organic Matter Contains

- 1,100 pounds of Nitrogen
- 116 ponds of Phosphate
- 105 pounds of Potash
- 145 pounds of Sulfur
- 6 tons of Carbon
4% Organic Matter

- 4,400 pounds of Nitrogen
- 464 ponds of Phosphate
- 420 pounds of Potash
- 580 pounds of Sulfur
- 24 tons of Carbon or 48,000 pounds
But How Much N is Available from Organic Matter?

• Typically about 2%
  – 1% OM – 1,110 lbs/ac or 22 lbs/ac
  – 4% OM – 4,400 lbs/ac or 88 lbs/ac

  – * The 2% is traditional text book under conventional tillage. The more active organic portion may be closer to 3% or 132 lbs/ac.
C:N Management

Early kill date most effective
• High nutrient content/ quickly decomposes
• Releases nutrients captured/ stored

Later kill date
• More cellulose produced
• Nutrient tie up/uses available Nitrogen
Common C:N Ratios of Cover Crops

- Organic Material: C:N Ratio
- Young rye plants: 14:1
- Rye at flowering: 36:1
- Rye stems (mature): 72:1
- Annual Ryegrass: 20:1
- Hairy vetch: 11:1
- Crimson clover: 15:1
- Corn stalks: 60:1
<table>
<thead>
<tr>
<th>Crop</th>
<th>Tops % N</th>
<th>Roots %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybeans</td>
<td>93</td>
<td>7</td>
</tr>
<tr>
<td>Vetch</td>
<td>89</td>
<td>11</td>
</tr>
<tr>
<td>Cowpeas</td>
<td>84</td>
<td>16</td>
</tr>
<tr>
<td>Red Clover</td>
<td>68</td>
<td>32</td>
</tr>
</tbody>
</table>
Average biomass yields and nitrogen yields of several legumes.

<table>
<thead>
<tr>
<th>Cover Crop</th>
<th>Biomass</th>
<th>Nitrogen*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet Clover</td>
<td>1.75</td>
<td>120</td>
</tr>
<tr>
<td>Berseem Clover</td>
<td>1.10</td>
<td>70</td>
</tr>
<tr>
<td>Crimson Clover</td>
<td>1.40</td>
<td>100</td>
</tr>
<tr>
<td>Hairy Vetch</td>
<td>1.75</td>
<td>110</td>
</tr>
</tbody>
</table>
Biomass yield and nutrient accrual by selected cover crops:

- **Crop**  | **Biomass** | **N**  | **K**  | **P**  
- Hairy Vetch | 3,260       | 141    | 133    | 18    
- Crimson Clover | 4,243      | 115    | 143    | 16    
- Rye | 5,608      | 89     | 108    | 17    
- Austrian | 4,114      | 144    | 159    | 19    

Winter Peas
Average biomass yields and N lbs/ac

Biomass tons/ac

- Annual ryegrass 1-3 40-100
- Cereal rye 2-4 30-100
- Crimson Clover 1.40 80-130
- Forage radish 1.50 70-120
- Hairy Vetch 1.75 80-160

- Ranges from 12 to 200 lbs/ac with 40-70%
<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Concentration%</th>
<th>Content lbs/ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>1.89</td>
<td>250</td>
</tr>
<tr>
<td>Potassium</td>
<td>3.27</td>
<td>230</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.81</td>
<td>60</td>
</tr>
</tbody>
</table>

Recycling of nutrients by

Thursday, January 17, 13
C:N Ratio Management

- **Immobilization** - Early spring N is tied up by microbes breaking down residue;
- **Mineralization** – Early summer microbes die and nitrogen is released
C:N Management

• Early Spring

C:N ratio < 30:1 – Nitrogen may be available to corn plant by July

C:N ratio > 30:1 – Nitrogen will not be available until sometime after August
Timing of N Application
As near to crop use as practical

Corn N Uptake

Nitrogen

Jan     Mar     May     July       Sept

Time
Timing of N Application
As near to crop use as practical

Timing of N Application

Corn N Uptake

Nitrogen

Jan     Mar     May     July       Sept

No Cover
Poorest

Time

Thursday, January 17, 13
Timing of N Application
As near to crop use as practical

- Poor
- No Cover
- Poorest

---

Thursday, January 17, 13
Timing of N Application

As near to crop use as practical

Corn N Uptake

Nitrogen

Poor

Better

Poorest

Jan
Mar
May
July
Sept
Nov

No Cover

Time
Timing of N Application

As near to crop use as practical

Corn N Uptake

Nitrogen

Poor Better Best Poorest

Jan Mar May July Sept Nov

No Cover

Time
Timing of N Application

As near to crop use as practical

- Cover N Uptake
- Corn N Uptake
- Cover N Uptake

Nitrogen

Jan Mar May July Sept Nov

Poor Better Best Poorest

No Cover

Nitrogen Application Time

Document: Thursday, January 17, 13
Timing of N Application

As near to crop use as practical

<table>
<thead>
<tr>
<th>Nitrogen</th>
<th>Jan</th>
<th>Mar</th>
<th>May</th>
<th>July</th>
<th>Sept</th>
<th>Nov</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Cover N Uptake**
  - **OK**
  - **Better**
  - **Best**

- **Corn N Uptake**
  - **Poor**
  - **Better**
  - **Best**

- **Cover N Uptake**
  - **Poor/OK**
  - **Better**
  - **Best**

- **Cover**
- **No Cover**
Cameron Mills example

• North Central Indiana – Logansport area
• Continuous no-till for 12 years and cover crops for 5 years
Cameron Mills – 2012
165 bu/ac with 170 lbs/ac of 28% sidedressed

- No cover crop N test
  0-12” – 60 lbs/ac
  12-24”- 56 lbs/ac
- Total 116 lbs/ac

- Annual ryegrass flown on
  0-12” - 8 lbs/ac
  12-24”- 4 lbs/ac
- Total 12 lbs/ac
- Annual ryegrass biomass
  1350 lbs top & 1350 in roots (est)
  78 lbs/ac N & 100 lbs/ac K
Beck’s Central Illinois CC plots

2012 Corn After Cover Crop: Yield/Acre

<table>
<thead>
<tr>
<th></th>
<th>100% Nitrogen</th>
<th>75% Nitrogen</th>
<th>50% Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>RyeGrass</td>
<td>154.1</td>
<td>152.3</td>
<td>148.6</td>
</tr>
<tr>
<td>Corn Mix</td>
<td>150.6</td>
<td>141.9</td>
<td>108.6</td>
</tr>
<tr>
<td>SB Mix</td>
<td>148.8</td>
<td>145.5</td>
<td>127.7</td>
</tr>
<tr>
<td>Radish</td>
<td>147.7</td>
<td>133.0</td>
<td>118.5</td>
</tr>
<tr>
<td>Clover</td>
<td>142.4</td>
<td>135.5</td>
<td>119.1</td>
</tr>
<tr>
<td>No Cover Crop</td>
<td>135.3</td>
<td>126.9</td>
<td>104.7</td>
</tr>
</tbody>
</table>

2012 Corn After Cover Crop: Return/Acre

<table>
<thead>
<tr>
<th></th>
<th>100% Nitrogen</th>
<th>75% Nitrogen</th>
<th>50% Nitrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>RyeGrass</td>
<td>$772.59</td>
<td>$792.12</td>
<td>$800.44</td>
</tr>
<tr>
<td>SB Mix</td>
<td>$733.32</td>
<td>$744.00</td>
<td>$669.13</td>
</tr>
<tr>
<td>Corn Mix</td>
<td>$739.14</td>
<td>$717.96</td>
<td>$551.64</td>
</tr>
<tr>
<td>Clover</td>
<td>$698.56</td>
<td>$688.00</td>
<td>$621.39</td>
</tr>
<tr>
<td>Radish</td>
<td>$730.03</td>
<td>$673.45</td>
<td>$618.05</td>
</tr>
<tr>
<td>No Cover Crop</td>
<td>$677.67</td>
<td>$658.26</td>
<td>$557.43</td>
</tr>
</tbody>
</table>
Economics

• Cover crop
  – Seed - $15 to $27/ac
  – Seeding -$12 to $18/ac  - Total $27 to $45
VS
-Tillage cost of  $12-$30/ac
Does It PAY??

- CNT and cover crops – 0.2%/yr increase in organic matter;
- 5 years – 1% increase;
- 10 years – 2% increase
- Following changes may occur:
  - N mineralization rate
  - Moisture holding capacity
Does It Pay??

• Better yields, especially in years with extreme weather events and on soils with low organic matter
• Less fertilizer inputs
• Less ponding,
• Less loss of nutrients & improved cycling
Summary

• Understand dynamics of C:N ratio
• Field history will greatly influence N scavenging
• Growth of cover crop may vary widely and will affect results
• Dynamic system – understand it takes time to get your soil biology cranking!
Ultimate Sustainable System

- Continuous no-till - row crops
- Cover crops – keep something growing
- Grazing cattle – cheapest way to harvest forage and to add fertilizer
  - Manure application – alternative to grazing cattle
• Dan Towery
Ag Conservation Solutions
dan@ag.conservationssolutions.com