Soil Quality, Nutrient Cycling and Soil Fertility

Ray Ward
Ward Laboratories, Inc
Kearney, NE
www.wardlab.com
Purposes of Soil Quality

- Employ new & modified crop management systems
- Increase efficiency of nutrients and water
- Increase quantity & quality of organic matter
- Decrease soil erosion
- Increase biological diversity
Effect of cultivation on soil nitrogen content over the length of cultivation, years.
Total N vs Total Carbon

\[ y = 0.0998x - 0.0077 \]

\[ R^2 = 0.9163 \]
Soil Organic Matter

- Enhance crop productivity
- Build soil fertility
- Improve structure
- Build aggregate stability
- Increase nutrient retention
- Increase water holding capacity
Soil Structure

- Retention & transport of water & nutrients
- Habitat for Microbes
- Reduced Soil Erosion
Granular Soil Structure
Raindrop Splash
Crusted Soil
Soil Compaction
Soil Structure and Root Growth
Over 14 years of No-Till
Native Soil Structure
Success of No-Till

• Sanitation
  – Prevent weeds from going to seed
  – Avoid introducing weeds or disease
  – Break insect and disease cycles

• Competition
  – Fast uniform canopy formation
  – Less than optimum conditions for weeds

• Rotations
  – Diversity, Intensity, and Profitability
Save Water
Wheat Yield Starting Soil Water

bu/a = 5.56 + 5.34*in

$r^2 = 0.76$
SOIL MOISTURE LOSS

½ TO ¾ INCH LOSS PER TILLAGE OPERATION

TILLING FOR A GROWING SEASON … WATER LOSS IS 2 – 2 ½ INCHES OF WATER

SOIL MOISTURE SAVINGS

1 – 4 INCHES OF WATER SAVED FROM STANDING RESIDUE
Poor Soil Structure Prevents Water Movement

Water
Saturated Soil
Air Space
Moisture Soil
Dry Soil
Water Penetration
No. 1 Environmental Enemy in Production Agriculture

Intensive Tillage
Soil carbon is the “Keystone” for all soil physical, chemical and biological processes and properties.

Management platform

fertility, variety, irrigation, species, cover crop, manure, rotations, tillage, soil type, erosion, timing,
Water Management

• Greater Soil Cover To:
  – Reduce evaporation
  – Increase water penetration
  – Decrease water runoff

• GOAL: Efficient Water Use
Oats and Turnips
Turnip Cover Crop for Grazing
Maintenance of Soil Cover

• GOAL: Keep soil surface covered with crop or residue at all times
  – Reduce runoff & erosion
  – Conserves moisture by reducing evaporation
  – Aggregate stability is enhanced
  – Improves infiltration of rain & irrigation
  – Increases organic matter & biodiversity
<table>
<thead>
<tr>
<th>Microbes/Livestock</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacteria</td>
<td>1000 lbs/A</td>
</tr>
<tr>
<td>Actinomycetes</td>
<td>1000 lbs/A</td>
</tr>
<tr>
<td>Molds</td>
<td>200 lbs/A</td>
</tr>
<tr>
<td>Algae</td>
<td>100 lbs/A</td>
</tr>
<tr>
<td>Protozoa</td>
<td>200 lbs/A</td>
</tr>
<tr>
<td>Nematodes</td>
<td>50 lbs/A</td>
</tr>
<tr>
<td>Worms</td>
<td>1000 lbs/A</td>
</tr>
</tbody>
</table>
Nutrient Uptake and Root Structure

Fig. 10.2. Longitudinal section of herbaceous dicot root. I. Root tip with regions of cell division (A), elongation (B), and matura-
tion (differentiation) (C). II. Section of mature root with lateral roots in varying stages of development. III. Meristem of a lateral root arising from the pericycle. IV. Cross section of a young root. Differentiated tissues: root hair (a), epi-
dermis (b), cortex (c), endo-
dermis (d'), pericycle (e), central cylinder or stele (f), meristem with quiescent center (g), root cap (h), xylem (i), phloem (j).
General view of the research plots (Ponta Grossa - PR)

No residue

5 ton/ha

10 ton/ha
Effect of the amount of residue in the corn root system distribution with depth (Mean 13 hybrids / residue treatment)
C:N Ratio and Rate of Residue Decomposition

1. Average microbe C:N ratio is 8:1
2. 1/3 of the carbon used by microbes is incorporated into their cells
3. 2/3 of the carbon is respired as CO2
4. Therefore, microbes need 1 lb N for every 24 lbs of carbon in their food
5. If the C:N ratio is greater than 24:1 the microbes must scavenge soil solution for Nitrogen
C:N Ratio: An Example

- Wheat Straw
- 100 lbs per bushel of wheat grain
- 50 bushels of wheat/A = 5000 lbs Straw
- 42 % C in straw = 2100 lbs of Carbon/A
- 4 % Protein in straw = 32 lbs of N/A
- C:N Ratio = 66:1
N Release From Wheat Straw

C:N ratio 66:1
5000 lbs of straw/acre

Carbon: 2100 lbs of Carbon per acre
88 lbs of N is needed to bring the C:N ratio to 24:1
88 – 32 = 56 lbs of N will be taken from the soil by the decomposers before N can be released.
Nitrogen Tie-up or Nitrogen Release

- Wheat Straw  C:N = 66:1
Cover Crop Contribution

Legume cover crop

12 inches tall, about 2000 lbs of dry hay @ 18 % protein or 2.9 % N = 58 lbs of N/ton

If left on the soil it will be available for the next crop

If Legume is Grazed, there will be about 46 lbs of N remaining for the next crop
# Cover Crop Nutrients

1.83 tons/acre

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>lbs/acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon, C</td>
<td>1520</td>
</tr>
<tr>
<td>Nitrogen, N</td>
<td>110</td>
</tr>
<tr>
<td>Phosphorus, P2O5</td>
<td>28</td>
</tr>
<tr>
<td>Potassium, K2O</td>
<td>123</td>
</tr>
<tr>
<td>Sulfur, S</td>
<td>16</td>
</tr>
<tr>
<td>Zinc, Zn</td>
<td>0.13</td>
</tr>
<tr>
<td>Calcium, Ca</td>
<td>60</td>
</tr>
</tbody>
</table>

C:N = 13.8
Nitrogen Tie-up or Nitrogen Release

- Legume Cover Crop  C:N = 13.8

\[ \text{Nitrate, ppm} \]

\[ \text{Legume Killed} \]

\[ \text{Mineralization} \]

\[ \text{Maximum Release} \]

Time
Total Organic Carbon

- Food for Microbes, especially recent additions to organic matter
- Nutrient for Plants
- Soil Organic Matter is 58 % C
- Soil Aeration very Important to Form CO2
- Soil Organic Matter test
  - Loss on Ignition (LOI)
Carbon/Organic Matter

- Organic Matter is about 58 % C
- Ratio becomes 170 OM : 10 N : 1.4 S
- 1 % OM in 8 inches of Soil is 24,000 lbs/A
- This Quantity of OM Holds About 1400 lbs of N and 200 lbs of S per Acre.
No-Till Sulfur Deficiency

- Most of the Sulfur in the soil is held in the organic matter portion of the soil
- The idea is to build soil organic matter to improve soil quality and health and increase soil productivity
- C : N : S ratio
- 100C : 10N : 1.4S
Total Carbon, Pounds per Acre

Cropping System

Plow  Chisel  Disk  No-Till

0-4"  4-8"  8-16"  16-32"  32-48"  48-72"
Rogers Memorial Farm

Paul Jasa, Un-L

Total Carbon per acre in 6 ft. of Soil

Tons of Carbon/A 6”

Plow | Chisel | Disk | No-Till

Cultural Practice
Fertilizer Rates for 2010

- Crops do not respond to prices
- Proper rate of nitrogen cannot be reduced without yield loss
- Sulfur may be needed in no-till systems
- Non-mobile nutrients should be applied at rates suggested by soil test. Strive at least to have P at 25 ppm P and K to 200 ppm K
### Nitrogen Requirement

<table>
<thead>
<tr>
<th>Crop</th>
<th>N/Bu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>1.2 lbs</td>
</tr>
<tr>
<td>Wheat</td>
<td>2.4 lbs</td>
</tr>
<tr>
<td>Milo</td>
<td>1.1 lbs</td>
</tr>
<tr>
<td>Grass</td>
<td>40 lbs</td>
</tr>
<tr>
<td>Millet</td>
<td>1.7 lbs</td>
</tr>
</tbody>
</table>
Nitrogen Recommendation

\[ N \text{ lbs/A} = (\text{yield} \times N \text{ req.}) \]
\[ \text{lbs of NO}_3-N \text{ in 24”} \]
Legume credit
Manure credit
Irrigation water credit
<table>
<thead>
<tr>
<th></th>
<th>% Stand</th>
<th>lb. N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alfalfa</td>
<td>100%</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>less than 50%</td>
<td>none</td>
</tr>
<tr>
<td>Sweet Clover</td>
<td>80</td>
<td></td>
</tr>
<tr>
<td>Red Clover</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Soybeans</td>
<td>40-60</td>
<td></td>
</tr>
</tbody>
</table>
Nitrogen Recommendation

• An Example
• Corn after Soybeans
• 200 bu/A X 1.2 = 240 lbs of N required
• Subtract the following
• Soil nitrate = 30 lbs of N
• Past soybeans = 40 lbs of N
• Amount of N to apply = 170 lbs of N/A
<table>
<thead>
<tr>
<th>Soil test ppm P</th>
<th>Rating</th>
<th>lbs P2O5/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5</td>
<td>Very Low</td>
<td>60-140</td>
</tr>
<tr>
<td>6-12</td>
<td>Low</td>
<td>35-75</td>
</tr>
<tr>
<td>13-25</td>
<td>Medium</td>
<td>20-45</td>
</tr>
<tr>
<td>26-50</td>
<td>High</td>
<td>0-30</td>
</tr>
<tr>
<td>51+</td>
<td>Very High</td>
<td>None</td>
</tr>
</tbody>
</table>
Phosphorus—Corn

% or total uptake

Ve V6 V12 V18 R1 R2 R3 R4 R5 R6

May June July August September
## Potassium Recommendations

<table>
<thead>
<tr>
<th>Soil Test ppm K</th>
<th>Rating</th>
<th>lbs K2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-40</td>
<td>Very Low</td>
<td>90-200</td>
</tr>
<tr>
<td>41-80</td>
<td>Low</td>
<td>50-120</td>
</tr>
<tr>
<td>81-120</td>
<td>Medium</td>
<td>25-60</td>
</tr>
<tr>
<td>121-200</td>
<td>High</td>
<td>0-35</td>
</tr>
<tr>
<td>201+</td>
<td>Very High</td>
<td>None</td>
</tr>
</tbody>
</table>
Potassium—Corn

% of Total Uptake

Ve V6 V12 V18 R1 R2 R3 R4 R5 R6
0 20 40 60 80 100 120
May June July August September
## Sulfur Soil Test, Ca-P Extractable

<table>
<thead>
<tr>
<th>Soil Test ppm S</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-4</td>
<td>Very Low</td>
</tr>
<tr>
<td>5-7</td>
<td>Low</td>
</tr>
<tr>
<td>8-11</td>
<td>Medium</td>
</tr>
<tr>
<td>12-15</td>
<td>High</td>
</tr>
<tr>
<td>16+</td>
<td>Very High</td>
</tr>
<tr>
<td>Crop</td>
<td>Yield Unit</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
</tr>
<tr>
<td>Corn</td>
<td>Bushel</td>
</tr>
<tr>
<td>Soybean</td>
<td>Bushel</td>
</tr>
<tr>
<td>Wheat</td>
<td>Bushel</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>Ton</td>
</tr>
<tr>
<td>Grass</td>
<td>Ton</td>
</tr>
</tbody>
</table>
Wheat 80 bu/A Yield Goal
Sulfur Requirement is .28 to .35 lb S/bu
Total S Required is 22 to 28 lbs/A
Sulfate Soil Test is 8 ppm S
  8 ppm X .3 X 8 inches = 19 lbs S/A
Recommendation is 3 to 9 lbs S/A
Sulfur Recommendation Example

Corn 200 bu/A Yield Goal

Sulfur Requirement is .18 to .26 lb S/bu
Total S Required is 36 to 52 lbs/A
Sulfate Soil Test is 8 ppm S
8 X 2.4 = 19 lbs S/A
Recommendation is 17 to 33 lbs S/A
# Zinc Recommendations

<table>
<thead>
<tr>
<th>Soil Test ppm Zn</th>
<th>Corrective Rate lb Zn/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-0.25</td>
<td>3-12</td>
</tr>
<tr>
<td>0.26-0.50</td>
<td>1-7</td>
</tr>
<tr>
<td>0.51-.75</td>
<td>0-6</td>
</tr>
<tr>
<td>0.76-1.00</td>
<td>0-3</td>
</tr>
<tr>
<td>1.01+</td>
<td>None</td>
</tr>
</tbody>
</table>

*Annual rate: Divide Corrective Rate by 6.*
Nutrient Cycle?

1. Nutrients are removed from the land any time grain or forage is transported from the area.
2. How are the nutrients replaced? Higher yields - the more nutrients that have to be replaced.
3. Carbon comes from the air and from microorganisms decomposing organic matter.
4. Others come from soil minerals, decomposition of organic matter, soil microbes including Rhizobia, manures and fertilizer.
# In Furrow Fertilizer

<table>
<thead>
<tr>
<th>Crop</th>
<th>30 “ rows</th>
<th>7 “ rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>8</td>
<td>32</td>
</tr>
<tr>
<td>Milo</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Sunflowers</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>Beans</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Wheat</td>
<td>8</td>
<td>32</td>
</tr>
</tbody>
</table>
The Best Combination:

Banding and broadcasting fertilizer P to build soil fertility levels and to optimize long-term yield potential and profits