How Soil Health can Improve Water Quality and Reduce Nutrient Runoff
Agriculture in Lake Erie Basin

- 4.2 Million Acres Maumee Watershed
- 4.9 Million Acres in Lake Erie Basin
- 59.1% cropland
- 72% cropland in Northwest Ohio.
Renewed Concerns about Lake Erie Nutrient Loading

• Issue in 1960-1970’s was Total P Loading
• Issue in 1990-2000’s is Bioavailable or Dissolved Reactive Phosphorous
• Current P Use Efficiency 10% - 50% OR 25%
• 80% of P runoff comes from 20% of land
• 60-90% of P runoff occurs in the 1-2 most intense rainfall events that occur each year!
• While P soil concentration is critical, most P runoff comes from fields close to streams.
Two Key factors:
a) Soil P concentration
b) Transport Factor

Soil P concentration
* Transport Factor
= Pounds of P Lost to Surface Water
Phosphorus Testing

New Info: 70% of PP becomes SRP in water. Dr. Libby Dayton, Ohio State
About 50-75% of the Available P in soil is organic. P stabilizes the OM and forms a bridge to the clay.

Our current P use efficiency is 10-50%. Microbes unlock P chemical bonds and make P plant available.

Islam, 2010
Annual Loads of Total Phosphorus to Lake Erie, 1967-2007

Target load for total phosphorus of 11,000 metric tons set in ~1978

Source: Hiedelberg University
Dissolved Reactive Phosphorus Concentration

Source: Hiedelberg University
Phosphorus Speciation

Plant Available P
- Soluble Reactive (SRP) $P_i$  Inorganic P - $P_i$
- Exchangeable (ExP) $P_o$  Active Carbon- $P_o$

Slowly or Not Plant Available P
- $Ca^{2+} / Mg^{2+}$  Calcium/Magnesium- $P_i$
- $Fe^{3+} / Al^{3+}$  Iron/Aluminum- $P_i$
- Res $P_o$  Humus - Residual $P_o$
- Total P  $= All \ P_o + All \ P_i$
Caused by Saturated Soil Conditions and Lack of Oxygen in soil profile.

Iron is releasing SRP and flows with the water when soils become saturated or flooded.
Clear runoff from no-tilled field

Sediment runoff from conventional-tilled field

Impact of disturbed Aggregates

Conventional-tilled field

No-tilled field

Clear runoff from no-tilled field
Dynamic Properties: Infiltration

- If rainwater runs off field…. It is not available to the crop
  - Dynamic Soil Property greatly influenced by management

<table>
<thead>
<tr>
<th>Tillage System</th>
<th>Water Infiltration Rate after 1 Hour (in/hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plowed, disked, cultivated, bare surface</td>
<td>0.26</td>
</tr>
<tr>
<td>No-tillage, bare surface</td>
<td>0.11</td>
</tr>
<tr>
<td>No-tillage, 40% cover</td>
<td>0.46</td>
</tr>
<tr>
<td>No-tillage, 80% cover</td>
<td>1.04</td>
</tr>
</tbody>
</table>


- Residue cover prevents soil crusts
### Stratification of P by Crop Rotation

<table>
<thead>
<tr>
<th>Crop Rotation</th>
<th>SRP</th>
<th>EP</th>
<th>CaP</th>
<th>Al/FeP</th>
<th>Res P</th>
<th>Total P</th>
</tr>
</thead>
<tbody>
<tr>
<td>c-s-w</td>
<td>0.2c</td>
<td>2.6c</td>
<td>5.1b</td>
<td>6.8c</td>
<td>2.0a</td>
<td>2.3b</td>
</tr>
<tr>
<td>c-c</td>
<td>0.3c</td>
<td>3.4c</td>
<td>11.5a</td>
<td>19.4b</td>
<td>1.6b</td>
<td>2.1b</td>
</tr>
<tr>
<td>c-s</td>
<td>0.3c</td>
<td>0.6d</td>
<td>13.0a</td>
<td>28.1a</td>
<td>1.5b</td>
<td>2.8a</td>
</tr>
<tr>
<td>s-s</td>
<td>0.3c</td>
<td>0.3d</td>
<td>5.7b</td>
<td>24.7a</td>
<td>2.1a</td>
<td>2.6a</td>
</tr>
<tr>
<td>Alfalfa</td>
<td>0.9b</td>
<td>5.7b</td>
<td>6.6b</td>
<td>1.4d</td>
<td>2.0a</td>
<td>2.1b</td>
</tr>
<tr>
<td>Field Grass Waterway</td>
<td>1.7a</td>
<td>7.0a</td>
<td>3.0c</td>
<td>18.3b</td>
<td>1.8a</td>
<td>2.5a</td>
</tr>
<tr>
<td>Forest</td>
<td>1.5a</td>
<td>7.3a</td>
<td>1.6c</td>
<td>1.4d</td>
<td>1.9a</td>
<td>1.8c</td>
</tr>
</tbody>
</table>

Vegetated fields had higher SRP & EP? What happened to the SRP in agricultural fields?
<table>
<thead>
<tr>
<th></th>
<th>SRP</th>
<th>EP</th>
<th>CaP</th>
<th>FeP</th>
<th>Res P</th>
<th>Total P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover Crops + NT</td>
<td>0.34b</td>
<td>1.23a</td>
<td>21.2a</td>
<td>25.7a</td>
<td>147.7b</td>
<td>196.1b</td>
</tr>
<tr>
<td>Control</td>
<td>1.42a</td>
<td>0.14b</td>
<td>18.0b</td>
<td>27.1b</td>
<td>162.8a</td>
<td>209.5a</td>
</tr>
</tbody>
</table>

Cover crops + NT had significantly lower soil concentration of P in the SRP (4.2X less), and Res P, but much higher EP (8.8X).
Cover crops (Red clover) had significantly lower soil stratification of P in the SRP fraction but significantly higher EP and TP fractions.

<table>
<thead>
<tr>
<th></th>
<th>SRP</th>
<th>EP</th>
<th>CaP</th>
<th>FeP</th>
<th>Res P</th>
<th>Total P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cover Crops + NT</td>
<td>0.4b</td>
<td>61.7a</td>
<td>1.6a</td>
<td>1.4a</td>
<td>1.5b</td>
<td>2.0a</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td>9.1X</td>
<td></td>
<td></td>
<td></td>
<td>1.25X</td>
</tr>
<tr>
<td></td>
<td>1.8a</td>
<td>6.8b</td>
<td>1.4a</td>
<td>1.4a</td>
<td>1.6a</td>
<td>1.6b</td>
</tr>
<tr>
<td></td>
<td>4.5X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Forested Watershed

- Soil Organic P = 645 Kg/Ha  
  50% Higher SOM
- Inorganic P = 275 Kg/Ha
- Runoff = 0.3 Kg/Ha

Agricultural Watershed

- Soil Organic P = 314 Kg/Ha  
  50% Less SOM
- Inorganic P = 976 Kg/Ha  
  Mineralization 4x higher
- Runoff = 2.41 Kg/Ha  
  Runoff was 8x higher

Nature and Properties of Soil (Weil & Brady, 2017) page 650
<table>
<thead>
<tr>
<th>P Level Bray P&lt;sub&gt;1&lt;/sub&gt;</th>
<th>Fe/Al-P (mg/kg)</th>
<th>Res-P (mg/kg)</th>
<th>TP (mg/kg)</th>
<th>Ratio Res/Fe Al</th>
<th>SOM (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low (&lt;25 PPM)</td>
<td>108.0</td>
<td>570.5</td>
<td>711.2</td>
<td>5.3</td>
<td>2.9</td>
</tr>
<tr>
<td>Medium (25-75 PPM)</td>
<td>125.1</td>
<td>592.9</td>
<td>740.1</td>
<td>4.7</td>
<td>3.1</td>
</tr>
<tr>
<td>High (75-150 PPM)</td>
<td>286.6</td>
<td>736.3</td>
<td>1052.2</td>
<td>2.6</td>
<td>2.9</td>
</tr>
<tr>
<td>V. High (150-300 PPM)</td>
<td>275.0</td>
<td>473.9</td>
<td>774.4</td>
<td>1.7</td>
<td>1.6</td>
</tr>
<tr>
<td>Ex High (&gt;300 PPM)</td>
<td>345.8</td>
<td>655.1</td>
<td>1052.0</td>
<td>1.9</td>
<td>3.3</td>
</tr>
<tr>
<td>Grass</td>
<td>47.3</td>
<td>449.1</td>
<td>532.5</td>
<td>9.5</td>
<td>8.6</td>
</tr>
<tr>
<td>Woods</td>
<td>36.2</td>
<td>261.1</td>
<td>321.9</td>
<td>7.2</td>
<td>12.9</td>
</tr>
</tbody>
</table>
Has Phosphorus Changed?

No! But Weather and Practices have...

1) **Weather:** Increase number, higher intensity, longer duration rain.

2) We have better environment for cyanobacteria. Warmer weather + more nutrients = Explosion HAB

3) Change in farm size with larger farms. Efficient hybrids

4) More tile spaced closer together with more surface inlets.

5) Fertilizer P chemistry has changed. C-S Rotations. More fall broadcast applications to accommodate farm size.

6) Tri-State Fertilizer Recommendations have safety factor.

7) Vertical tillage + larger farm equipment = soil compaction.

8) Fertilizer Enhancers (Avail/Jumpstart)

9) **Less Soil Organic Matter**

10) **Less Acid Rain, change in P availability.** 4.2pH to 5.2pH Rainwater → SRP
Has increased significantly since 1995 when SRP started Increasing!

THE OHIO STATE UNIVERSITY
COLLEGE OF FOOD, AGRICULTURAL, AND ENVIRONMENTAL SCIENCES
Vertical tillage creates new hard layer at 2-4 inches.

Data from Camp and Lund
No-TILL creates Macropores

ECO Farming & live roots acts like a biological valve to absorb N and P.

Illustrated by Cheryl Bolinger-McKirnan & Jim Hoorman
Fig. 1. Soluble phosphorus transported via runoff from no-tillage and vertical tillage plots. Error bars represent standard error.
Fig. 2. Total phosphorus transported via runoff from no-tillage and vertical tillage plots. Error bars represent standard error.

Smith & Warnemuende-Pappas, 2015
Soil & Tillage Research 153:155-160
Fig. 3. Sediment transported via runoff from no-tillage and vertical tillage plots. Error bars represent standard error.
Fig. 4. Relationship between total phosphorus and sediment mass transported during 30 min of runoff from no-tillage and vertical tillage plots.
Field 1: Conventional

Entering stream/open ditch
Open ditch splitting Field 1. Notice the water level of the ditch.
Field 2: Conventional

Residue covering catch basin at bottom
Field 3: No-till field with terminated cereal rye

Notice the level of water in the ditch!
Field 3: No-till field with terminated cereal rye

Clear water coming off field!
Field 3: No-till field with terminated cereal rye

Clear water coming off Field 3!
Field 3: No-till field with terminated cereal rye clear water entering muddy ditch.
### Cover Crops for Absorbing SRP

**Good Cover Crops**
- Cereal rye
- Annual Ryegrass
- Triticale
- Barley
- Wheat

**Mixtures/Minimize***
- Radish*
- Oats
- Legumes
- Other Issues
- Short pasture
- Alfalfa hay

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**When are the cover crops terminated?**
Benefits of Cover Crops

• Increase water infiltration – Move SRP\textsubscript{i} down into soil profile.
• Decrease bulk density and increase pore space for both air and water – Less saturated soils.
• Live roots absorb soluble nutrients (N & P).
• Increase soil organic matter content which improves soil structure and holds P tighter
  \( \text{SRP}_i < \text{EP}_o \) and \( \text{FeP}_i < \text{Res P}_o \)
• Increased N & P uptake & storage means less runoff of N, P, and less soil erosion.
How Soil Health can Improve Water Quality and Reduce Nutrient Runoff