Crediting Soil Organic Matter and Cover Crops in a Variable Rate Nitrogen Prescription

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Cover cropping is a key nutrient management strategy

And farmers in the Northeast are doing a lot of it!!

Some regions and crop rotations in PA have even higher cover crop adoption rates

- 52-75% of acreage post-corn was cover cropped in Berks, Lancaster, Lebanon, and York counties in 2013

Hively et al. 2015. J Soil and Water Conservation

Current N fertilizer recommendations don’t take into account N supply from cover crops and soil organic matter.

Experimentally Determined Economic Optimum N Rate (lb/A)

PSU N Recommendation Categories for Corn

130 lb N/A 130 bu/A
160 lb N/A 160 bu/A
190 lb N/A 190 bu/A
220 lb N/A 220 bu/A

Adapted from D. Beegle
Cover crop growth in a field can be highly variable

Climate FieldView satellite NDVI imagery on a smartphone
Calibrating Greenseeker sensors to predict cover crop biomass N content
Soil organic matter content can also vary across a field.

SmartFirmer made by Precision Planting, Inc.

Soil organic matter map from SmartFirmer data courtesy Mike Gardner, Growmark FS.
Soil texture regulates N mineralization and can vary across a field.

Veris 3100 used to map soil electrical conductivity.

Electrical conductivity map of a field at PSU Agronomy Research Farm. Greater EC values correspond to greater clay content.
Understanding and predicting N mineralization

- Carbon
  - ~50% respired as CO$_2$ (Energy gain for the microbes)
  - ~50% assimilated (Building blocks)

- Nitrogen
  - Decomposing Organic Material
  - Inorganic Soil N (NH$_4^+$)
  - Microbial Biomass

- $N_{min} = k \ N_{cc} \left( 1 - \frac{\varepsilon \ (C:N)_{cc}}{(C:N)_m} \right)$
A new set of equations to predict N mineralization from soil organic matter and cover crop residues

\[ \varepsilon = 0.52 + 0.0036 \times \%Clay - 0.0097 \times \%Sand \]  
\[ \text{Eq. 1} \]

\[ \Delta Y_{SOM} = 154 \times \%SOM \times (1 - \varepsilon) \]  
\[ \text{Eq. 2} \]

\[ \Delta Y_{cc} = \alpha \times N_{cc} \times \left(1 - \frac{\varepsilon \times (C:N)_{cc}}{10}\right) \]  
\[ \text{Eq. 3} \]

Where, \( \alpha = 0.55 \) when cover crops are N mineralizing and \( \alpha = 1.8 \) when N immobilizing

\[ Y_T = (\Delta Y_{SOM} + \Delta Y_{cc}) - 0.00094 (\Delta Y_{SOM} + \Delta Y_{cc})^2 - 51 \]  
\[ \text{Eq. 4} \]

Microbial carbon use efficiency

Corn yield supported by N mineralization from soil organic matter

Corn yield supported by N mineralization from cover crop residues

Total corn yield supported by N mineralization of SOM and CC

Google “Charlie White Water Insight Seminar” for a fact sheet with equations

https://agsci.psu.edu/enri/what-we-do/multi-college/water/VariableRateNitrogenCoverCropsandSOMWriteup.pdf
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\[ Y_T = (\Delta Y_{SOM} + \Delta Y_{cc}) - 0.00094 (\Delta Y_{SOM} + \Delta Y_{cc})^2 - 51 \]  
Eq. 4

N fertilizer requirement = \( \frac{[(Yield \, Goal - Y_T) \times 1.2 \, lbs \, N/bu]}{\% \, N \, Efficiency} \)
Testing the new N fertilizer recommendation in a variable rate prescription on 3 production scale fields

On-Farm Exp., Spruce Creek, PA
Cereal Rye to Silage Corn

PSU Agronomy Research Farm, Rock Springs, PA
Cereal Rye to Grain Corn

PSU Farm Services Unit, State College, PA
Triticale to Grain Corn

All photos taken on 5/3/18
Data layers used to make the N fertilizer prescription (Agronomy Research Farm)

- **Electrical Conductivity Map**
- **Cover Crop NDVI Map**

=  

**Soil sample by zone**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Sand %</th>
<th>Clay %</th>
<th>OM %</th>
<th>Cover Crop N (lbs/ac)</th>
<th>Cover Crop C:N</th>
<th>Total N Req.* (lbs/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28</td>
<td>38</td>
<td>2.6</td>
<td>77</td>
<td>19</td>
<td>48</td>
</tr>
<tr>
<td></td>
<td>28</td>
<td>33</td>
<td>2.5</td>
<td>48</td>
<td>23</td>
<td>52</td>
</tr>
<tr>
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<td>27</td>
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<td>23</td>
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<tr>
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<td>45</td>
<td>2.7</td>
<td>42</td>
<td>23</td>
<td>70</td>
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<tr>
<td></td>
<td>22</td>
<td>38</td>
<td>2.2</td>
<td>34</td>
<td>25</td>
<td>101</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>44</td>
<td>2.1</td>
<td>17</td>
<td>25</td>
<td>110</td>
</tr>
</tbody>
</table>

*Assumes 100% recovery of applied N fertilizer; corn yield goal is 185 bu/ac
## Summary of N prescriptions for each field

<table>
<thead>
<tr>
<th></th>
<th>On-Farm Exp. Spruce Creek, PA</th>
<th>PSU Agronomy Farm Rock Springs, PA</th>
<th>PSU Farm Services State College, PA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield Target</td>
<td>250 bu/ac</td>
<td>185 bu/ac</td>
<td>165 bu/ac</td>
</tr>
<tr>
<td>Minimum N Rate*</td>
<td>83 lbs N/ac</td>
<td>48 lbs N/ac</td>
<td>Sufficient N</td>
</tr>
<tr>
<td>Maximum N Rate*</td>
<td>125 lbs N/ac</td>
<td>110 lbs N/ac</td>
<td>Sufficient N</td>
</tr>
<tr>
<td>Area Weighted Average N Rate*</td>
<td>101 lbs N/ac</td>
<td>79 lbs N/ac</td>
<td>65 lbs N/ac used as herbicide carrier</td>
</tr>
<tr>
<td>Agronomy Guide Recommendation</td>
<td>215 lbs N/ac</td>
<td>185 lbs N/ac</td>
<td>145 lbs N/ac</td>
</tr>
</tbody>
</table>

*Assumes 100% recovery of applied N fertilizer
Corn Ear Leaf %N Results

Increasing N Rates

VRN 100% Eff   VRN 75% Eff   VRN 50% Eff   Agronomy Guide Rec

Nitrogen Rate

Normal Sufficiency Range

Spruce Creek, PA
State College, PA
Rock Springs, PA

Increasing N Rates
Corn Stalk Nitrate Results

- optima
- 0
- 1000
- 2000
- 3000
- 4000
- 5000
- 6000
- 7000
- 8000

Increasing N Rates

Optimum Range

Agronomy Guide Rec

Spruce Creek, PA
State College, PA
Rock Springs, PA
Yield Results from Spruce Creek, PA
Yield Results from On-Farm Exp. Spruce Creek, PA

Corn Silage Yields

Nitrogen Rate

N fertilizer rate: 101 lbs N/ac*  135 lbs N/ac*  202 lbs N/ac*  215 lbs N/ac

*Area weighted average across the fertilizer variable rate zones

No significant difference in yields (F-test, P=0.55)
Yield Results from Rock Springs, PA

<table>
<thead>
<tr>
<th>Nitrogen Rate</th>
<th>Grain Yield (bu/ac)</th>
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<tbody>
<tr>
<td>79 lbs N/ac</td>
<td>~120</td>
</tr>
<tr>
<td>105 lbs N/ac</td>
<td>~120</td>
</tr>
<tr>
<td>158 lbs N/ac</td>
<td>~120</td>
</tr>
<tr>
<td>185 lbs N/ac</td>
<td>~140</td>
</tr>
</tbody>
</table>

Yield increase of 5 bushels with ~100 lbs extra N fertilizer is not economical.

*Area weighted average across the fertilizer variable rate zones.

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PennState Extension
Yield Results from State College, PA

N fertilizer rate:

<table>
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<tr>
<th>Grain Yield (bu/ac)</th>
<th>65 lbs N/ac</th>
<th>145 lbs N/ac</th>
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<tr>
<td>VRN 100% Eff</td>
<td></td>
<td></td>
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<tr>
<td>Agronomy Guide Rec</td>
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No significant difference in yields (F-test, P=0.19)
Concluding Thoughts

• Calibrated a biogeochemical equation with agronomic field trials to develop N credits from cover crops and soil organic matter
• Combined commercially available sensor technologies to gather inputs for a variable rate prescription
• Aiming for 100% fertilizer N recovery- how close can we get?
• Further data will help validate and refine the approach
Many Thanks!!

- **Collaborating Farmers**
  - Ed Quigley, Brian Macafee, Don Rill

- **PSU Agronomy Research Farm and Agronomy Extension Team**
  - Hanna Wells, Lucas Stover, Jeff Metz, Scott Harkcom, Ron Hoover

- **Plant Science Dept. Grad Students and Technicians**
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- **Growmark FS**
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- **Helena Agri-Enterprises**
  - Al Cook and Jim Grove

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[Logo of PennState Extension]