Uncertainty With Weather and Soil Interactions: The Source of Fickle Correct Corn Nitrogen Rates

Newell R. Kitchen
USDA-ARS
Cropping Systems and Water Quality Res. Unit
Columbia, Missouri
Nitrogen watch for poorly- and somewhat poorly-drained soils

Accumulated Precipitation (in)
May 1, 2018 to July 1, 2018

Nitrogen watch for well- and moderately well-drained soils

Accumulated Precipitation (in)
April 1, 2018 to July 1, 2018

Courtesy of Dr. Peter Scharf, U. of MO
Near Trimont, MN July 15, 2018
Crop N Need

- 250 lb N ac\(^{-1}\)
- 210 lb N ac\(^{-1}\)
- 180 lb N ac\(^{-1}\)
- 150 lb N ac\(^{-1}\)

(Adapted from Richie, et.al, 2005, How a Corn Plant Develops)
Fertilizer N Uptake (lb N ac\(^{-1}\))

- Grain
- Tassel, Cob, Husk Leaves
- Stalk and Leaf Sheaths
- Leaf Blades

Soil Nitrogen
- 30-50 lb N ac\(^{-1}\)
- 60-80 lb N ac\(^{-1}\)
- 90-150 lb N ac\(^{-1}\)

GDD\(_F\) - Growth Stage

(Adapted from Richie, et.al, 2005, How a Corn Plant Develops)
Accumulated Precipitation (in)
May 1, 2018 to July 1, 2018

Soil Nitrogen Loess
5-30 lb N ac⁻¹
40-80 lb N ac⁻¹
90-120 lb N ac⁻¹

Growth Stage

(Adapted from Richie, et.al, 2005, How a Corn Plant Develops)
180 lbs/A  

40 lbs/A
Within-field corn N fertilizer need from numerous Missouri fields demonstrated that:

- The average range in within-field EONR was 88 lbs N/acre.
- 32% of fields had within-field EONR that varied by more than 100 lbs N/acre.
Crop N Need
- 250 lb N ac⁻¹
- 210 lb N ac⁻¹
- 180 lb N ac⁻¹
- 150 lb N ac⁻¹

Fall or Pre-plant Application
Side-Dress Application

(Adapted from Richie, et.al, 2005, How a Corn Plant Develops)
• Grower surveys often list N fertilizer management among the more challenging decisions of modern corn production
What happens if we are not close to the right rate?

- When applications are >30 lbs N/ac over EONR, every lb N applied = N lb lost
- 20-40% of US corn acres have N over-application >30 lbs N/ac
- 90 m US corn ac/year
- Mean over-application of 60 lbs N/ac
- ~405 K tons of N annually available for loss

Chris Bandura
University of Wisconsin
585 barges of urea-N
Which is the Most Reliable Corn Nitrogen Recommendation Tool?

Crop Growth Models

- Encirca N Service
- Maize-N
- Climate: Nitrogen Advisor
- Adapt-N

Soil Tests

- PPNT: Pre-Plant Soil Nitrate Test
- SDNT: Side-Dress Soil Nitrate Test

Empirical-Based Models

Canopy Sensing
Maximum Return to Nitrogen (MRTN)

Finding the Maximum Return To N and Most Profitable N Rate
A Regional (Corn Belt) Approach to Nitrogen Rate Guidelines

This website provides a process to calculate economic return to N application with different nitrogen and corn prices and to find profitable N rates directly from recent N rate research data. The method used follows a regional approach for determining corn N rate guidelines that is implemented in several Corn Belt states.
35 on-farm trials Soy-Corn 2015

Yield, bu/acre

N rate, lb N/acre

On-Farm N Rate Trials Soy-Corn 2016

Yield, bu/acre

N rate, lb N/acre

Accurate

Not Precise

Accurate

Precise

Not Accurate

Not Precise

Courtesy of Emerson Nafziger, UI
Public-Private Partnering for Improving Performance of Corn Nitrogen Fertilization Tools

David Franzen
North Dakota St. University

Fabián Fernández
University of Minnesota

John Sawyer
Iowa State University

Carrie Laboski
University of Wisconsin

Richard Ferguson
University of Nebraska

Emerson Nafziger
University of Illinois

Newell Kitchen
USDA-ARS
University of Missouri

James Camberato
Purdue University

Paul R. Carter
Evaluate DuPont Pioneer proprietary products and decision aids

Evaluate public-domain decision aid tools, develop agronomic science for improved crop N management, train new scientists, and publish results
Research Locations (2014-16) 16 Locations/Yr: Total 49
.... a wide array of weather and soils conditions.
## Standardized Design

### N Treatments (lbs/acre)

<table>
<thead>
<tr>
<th>Planting</th>
<th>Split (plt+V9)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>40+40</td>
</tr>
<tr>
<td>40</td>
<td>40+80</td>
</tr>
<tr>
<td>80</td>
<td>40+120</td>
</tr>
<tr>
<td>120</td>
<td>40+160</td>
</tr>
<tr>
<td>160</td>
<td>40+200</td>
</tr>
<tr>
<td>200</td>
<td>40+240</td>
</tr>
<tr>
<td>240</td>
<td>80+80</td>
</tr>
<tr>
<td>280</td>
<td>80+160</td>
</tr>
</tbody>
</table>

### Measurements

#### Climate
- Precipitation
- Temperature
- Solar radiation

#### Soil
- EC mapping (Veris™)
- Soil sampling (3x)
- Soil moisture (TRT 3+16)

#### Crop
- Plant N (VT & R6)
- Canopy reflectance (V9)
- Grain yield and moisture
What was the correct N rate?

Best-fit model for Economic Optimal N Rate (EONR)
Variation in Economic Optimal N Rate

![Graph showing variation in Economic Optimal N Rate for different states and years (2014, 2015, 2016). Each state (IA, IL, IN, MN, MO, ND, NE, WI) has two categories: High and Low. The graph represents the Economic Optimal N Rate (EONR) in lbs N/Acre.](image-url)
Which Tool Performs the Best?

**Empirical-Based**

**Crop Growth Models**

- Encirca
- Maize-N
- Climate: Nitrogen Advisor
- Adapt-N
- SCAN

**Proximal Canopy Sensing**

**Soil Tests**

- **PPNT** Pre-Plant Soil Nitrate Test
- **PSNT** Side-dress Soil Nitrate Test
- **LSNT** Late Spring Nitrate Test
Tools’ Ability to Match EONR

Negative Relationship

$r^2 = 0.13$
At-Planting

- Good
  - ± 30 lbs N ac⁻¹ of EONR
- Mediocre
  - ± 60 lbs N ac⁻¹ of EONR
- Bad
  - Everything Else

% of Sites Close to EONR
At-Planting

<table>
<thead>
<tr>
<th>Category</th>
<th>Good</th>
<th>Mediocre</th>
<th>Bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRTN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WI PPNT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmer NR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MN PPNT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General PPNT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MN YG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NE YG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State-Specific YG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maize-N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ND PPNT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MO YG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General YG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IN YG</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% of Sites Close to EONR

0 10 20 30 40 50 60 70 80 90 100
Crop Growth Models

Empirical-Based

Proximal Canopy Sensing

Soil Tests

PPNT Pre-Plant Soil Nitrate Test

PSNT Side-dress Soil Nitrate Test

Encirca Maize-N online: Nitrogen Advisor

Fusion
Farmer knowledge Assessment of soil N Assessment of plant N

Yield Goal PSNT Canopy Reflectance Sensing

Decision Tree Tool Fusion
Split Decision Tree

$r^2 = 0.37$
Sites close to EONR = 45%

Decision Tree

Canopy Reflectance < 89
- yes
  - IA PSNT 0 < 124
    - yes
      - 70
        - n=7
    - no
      - 129
        - n=14

- no
  - General YG ≥ 183
    - yes
      - 144
        - n=8
    - no
      - 218
        - n=20

- General YG < 227
  - yes
    - 173
      - n=7
  - no
    - 218
      - n=20

Decision Tree, lbs N ac$^{-1}$
Elastic Net Regression Tool Fusion

Yield Goal

Farmer knowledge

Assessment of soil N

Canopy Reflectance Sensing

Assessment of plant N
How Close to EONR?

<table>
<thead>
<tr>
<th></th>
<th>Good</th>
<th>Mediocre</th>
<th>Bad</th>
</tr>
</thead>
<tbody>
<tr>
<td>YG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PSNT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canopy Ref.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

% of Site Close to EONR
• How do they work?
  - Collect and compare light reflected from an N-rich crop canopy to that of a N-deficient crop canopy
  - Coupled with an algorithm, the reflectance measurements are used to calculate a recommended split application N rate

Many sensors and algorithms have been developed.
Crop N Need

- 250 lb N ac⁻¹
- 210 lb N ac⁻¹
- 180 lb N ac⁻¹
- 150 lb N ac⁻¹

N Uptake (lb N ac⁻¹)

Side-Dress Application

Growth Stage

(Adapted from Richie, et.al, 2005, How a Corn Plant Develops)
Unadjusted 2014

\[ \text{Unadjusted} = 29\% \]

\[ \begin{align*}
0 & \quad 50 & \quad 100 & \quad 150 & \quad 200 & \quad 250 & \quad 300 \\
EONR \ (\text{lbs N ac}^{-1}) & \\
\end{align*} \]
Which tool to use?

• Many of the current publicly-available N recommendation tools don’t work well when EONR is low (< 100 lbs N/ac) or high (> 220 lbs N/ac).

• Tools that use soil and/or crop measurements on the fields of interest (e.g., PPNT/PSNT, canopy reflectance) generally work better, and performance improves when tools are fused.

• Fields that historically show within-field greenness variation on wet years (see Google Earth), deserve a tool that address spatial variation.

• Tool development and validation are needed that are adaptive to weather and soil interactions (e.g., modeling, canopy reflectance).

• Using on-farm strip trials over several years is an excellent way to judge your current tool (e.g., strips with current ± 30 lbs N/ac).
Acknowledgements