La venue de ce conférencier a été rendue possible grâce au soutien financier du ministère de l’Agriculture, des Pêcheries et de l’Alimentation.
Explaining Variability in Yield Response to Nitrogen

New Opportunity for Soil and Crop Variability Management, Quebec, Canada

Peter Kyveryga, PhD
Operations Manager-Analytics
Iowa Soybean Association
Outline

• Temporal patterns of corn N deficiency and mid-season N recovery.

• Variability in yield response and reducing uncertainty in economic optimal N rates.

• On-farm approaches: Decision support systems to quantify and manage risk in N management.
Common Risks in N Management

- N loss
- Yield loss
- Reduced N availability due to lack of moisture

In normal rainfall conditions:
Under or over N applications or large unexplained variability.
In-Season N Adjustments Using SPAD Meters

- Chlorophyll Meter Readings (CMR)
- 4 sites
- 0, 56, 122, 224 kg N/ha sidedress UAN at V2-V3
Convergence of Chlorophyll Meter Readings

Dribbled UAN at V10-V13

- Site 1 and 3:
  56 and 112 kg N/ha

- Site 2 and 4:
  56 N/ha

Only treatments with yield reduction >5% from the highest rate.

Only treatments that had yields <5% of that of the highest (reference) N rate.

These graphs mimic situations when N rates are well established and there is concern that farmers apply more N than it is needed.

CMRs tended to converge with those from the highest rate.

In-season N applications caused CMR to converge during reproductive stages with those that have the adequate supply of N.

Solid dots indicate statistically significant increases.

• Chlorophyll meters can detect easily severe N deficiencies (> 10% yield reduction) but unlikely mild mid-season N deficiencies.

• Corn canopy greenness could partially recover from short periods with inadequate N.

• In-season increases in N rates tended to produce increases in CMR but without significant yield response.
Challenges in Developing N Recommendations

Dr. Alfred Blackmer, professor of Iowa State University, had this poster in his office and told me that he could not develop reliable after-the-fact N recommendations across all trials.
Example of “Model bias” and estimating 68% Confidence Bands for EONR calculated by different models.

Small changes in slopes produce significant differences in EONR.

How to solve this problem?
Discrete Marginal Analysis of Yield Response

Discrete marginal product- is yield response per unit of N.

\[ DMP_i = \frac{Y_{N1} - Y_{N2}}{N1 - N2} = \frac{\Delta Y_i}{\Delta N_i} \]
Discrete Marginal Analysis

1 kg N costs 5 kg grain

Marginal cost

No response

Corn after corn
Corn after soybean

54 trials

Rates of N fertilization (kg N ha$^{-1}$)

DMPs of N (kg grain kg$^{-1}$ N)

Improving After-the-Fact N Recommendations

• Using Discrete Marginal Analysis (i.e., analyses of model slopes).

• Using other benchmarks for EONR such as rates that produce different % return on the last unit of N.

• Using management categories across many trials to reduce variability in yield response.

• After-the-fact EONR are required to make predictions for the future.
Needs To Estimate Risks in N Management

**After-the-Fact**
Description

**For-the-Future**
Prediction and Prescription

Uncertainty and Risk

LOW

HIGH

Risks and uncertainty in soil spatial variability, weather, differences in management, market prices, technological constraints and etc.
ISA On-Farm Network®

• On-Farm Network organizes farmers to use precision ag. technologies to evaluate management practices in crop production.

• We work annually with ~ 400 farmers in Iowa and provide technical assistance to similar groups in Minnesota and Indiana.
• A process of evaluating and improving management by:

✓ conducting on-farm studies and collecting critical management, soil and weather information;

✓ sharing and discussing results with other farmers, agronomists, crop consultants, and scientists;

✓ and making adjustments for the future.
Post Season Feedback in Corn N Status

• Tools to collect feedback in N status:

1. Late-season digital aerial imagery.
2. Corn stalk nitrate test (CSNT).
3. On-farm replicated strip trials (RST).

Iowa State Univ. PM 1584
All Results of On-Farm Evaluations Are On-Line

Imagery Guided Stalk Nitrate Survey

2013 Stalk Nitrate Results

GSS2013ACD018

On-Farm Network

NRCS

Advancing Agricultural Performance®

Two-Treatment Replicated Strip Trials

Strip Trial Summary Statistics

ST201MA113B

Yield By Treatment and Soil Map Unit

<table>
<thead>
<tr>
<th>Soil Map Unit</th>
<th>East</th>
<th>West</th>
<th>North</th>
<th>South</th>
<th>Yield (bushel)</th>
<th>Yield Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheaton 5B Soils, 0-7%</td>
<td>776</td>
<td>86.5</td>
<td>36.9</td>
<td>146.7</td>
<td>153.6</td>
<td>5.1</td>
</tr>
<tr>
<td>Wheaton 5B Soils, 0-2%</td>
<td>91.5</td>
<td>4.9</td>
<td>3.6</td>
<td>144.5</td>
<td>143.6</td>
<td>0.9</td>
</tr>
<tr>
<td>Dorrinson Soils, 0-2%</td>
<td>99.8</td>
<td>6.5</td>
<td>6.4</td>
<td>150.2</td>
<td>146.6</td>
<td>-0.4</td>
</tr>
<tr>
<td>Dorrinson Soils, 2-5%</td>
<td>171B</td>
<td>2.4</td>
<td>2.4</td>
<td>158.4</td>
<td>141.9</td>
<td>17.8</td>
</tr>
<tr>
<td>Racter Shale Soils, 2-5%</td>
<td>402B</td>
<td>4.8</td>
<td>1.7</td>
<td>97.4</td>
<td>92.7</td>
<td>4.7</td>
</tr>
</tbody>
</table>

*Yield differences calculated for soil map units that represent a significant change in yield.

Yield Average By Individual Treatment

<table>
<thead>
<tr>
<th>High N Rate</th>
<th>Low N Rate</th>
<th>Yield Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>161.2</td>
<td>181.2</td>
<td>11.0</td>
</tr>
</tbody>
</table>

A randomized test suggested strong evidence of a significant yield difference.
On-Line Database of Replicated Strip Trial Summaries

On-Farm Network® Replicated Strip Trial Database

Instructions

Limit trial results as desired by selecting one or more Years, Crop, Trial Type, Trial Detail, Watershed and County.
Hold the CTRL key and click to select multiple items.
After making all of your selections click Display Results.
If you choose just one crop you will see the average yield difference and also have the option to calculate ROI on the trials.
To reset your selections click Clear Results.

Year
- All Years
- 2013
- 2012
- 2009
- 2007

Crop
- All Crops
- Corn

Trial Type and Detail
- Crop Protection - Seed Treatment
- Equipment
- Management
- Plant Nutrition - Fertilizer
- Plant Nutrition - Manure
- Plant Nutrition - Manure + Nitrogen
- Plant Nutrition - Manure Form
- Plant Nutrition - Nitrogen Form

Location
- All Watersheds
- Boone
- Middle Des Moines
- Greene
- Wright

# On-Line Database of Replicated Strip Trial Summaries

<table>
<thead>
<tr>
<th>Year</th>
<th>Watershed</th>
<th>County</th>
<th>Crop</th>
<th>Trial Type</th>
<th>Trial Detail</th>
<th>Yield Difference bu/A</th>
<th>Trial ID</th>
<th>Trial Report Stalk Nitrate Report Scouting Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>Upper Iowa</td>
<td>Hancock</td>
<td>Corn</td>
<td>Plant Nutrition - Manure + Nitrogen</td>
<td>Manure + N vs Manure</td>
<td>22.3</td>
<td>ST2013A071A</td>
<td>View</td>
</tr>
<tr>
<td>2013</td>
<td>Upper Iowa</td>
<td>Hancock</td>
<td>Corn</td>
<td>Plant Nutrition - Manure + Nitrogen</td>
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<td>2.0</td>
<td>ST2013A072A</td>
<td>View</td>
</tr>
<tr>
<td>2013</td>
<td>Winnebago</td>
<td>Hancock</td>
<td>Corn</td>
<td>Plant Nutrition - Manure + Nitrogen</td>
<td>Manure + N vs Manure</td>
<td>2.0</td>
<td>ST2013A070A</td>
<td>View</td>
</tr>
<tr>
<td>2013</td>
<td>Upper Iowa</td>
<td>Hardin</td>
<td>Corn</td>
<td>Plant Nutrition - Manure + Nitrogen</td>
<td>Manure + N vs Manure</td>
<td>-1.5</td>
<td>ST2013A012A</td>
<td>View</td>
</tr>
<tr>
<td>2013</td>
<td>North Stunk</td>
<td>Jasper</td>
<td>Corn</td>
<td>Plant Nutrition - Manure + Nitrogen</td>
<td>Manure + N vs Manure</td>
<td>22.8</td>
<td>ST2013A121A</td>
<td>View</td>
</tr>
<tr>
<td>2013</td>
<td>Boyer</td>
<td>Monona</td>
<td>Corn</td>
<td>Plant Nutrition - Manure + Nitrogen</td>
<td>Expanded Manure</td>
<td>0.0</td>
<td>ST2013A148A</td>
<td>View</td>
</tr>
</tbody>
</table>

Average Yield Difference of the 7 trials displayed: **10.2 bu/acre**.

90% Confidence Interval for the Average Yield Difference: from **2.7 to 17.7 bu/acre**.

## Return on Investment

To calculate ROI of the selected trials, enter a market price for this crop and the cost per acre.

- Market Price: $4.5
- Cost Per Acre: $25

Average Return on Investment: **$20.90 per acre**.

90% Confidence Interval for the Average Return on Investment: from **$-12.85 to $54.65 per acre**.
Case Study: Soil-Based Variable N Applications

Categorical Analysis of Economic Yield Response?
1) Reducing influence of yield monitor errors;
2) “Yes” or “No” are common decisions to apply additional N.

High-140 kg N/ha
Low-128 kg N/ha
UAN sidedress at V2-3

Profitability Maps, Topography and Soil Attributes

- **Profitability Map**
  - High N rate is profitable
  - High N rate is non profitable

- **Elevation**
  - High ground
  - Low ground

- **Topographic Wetness Index (TWI)**
  - High probability of flooding
  - Low probability of flooding

- **Soil Electrical Conductivity and Soil Map**
  - High conductivity
  - Low conductivity
# Autologistic (Spatial) Regressions

<table>
<thead>
<tr>
<th>Year-Field</th>
<th>Relative elevation</th>
<th>Soil electrical conductivity</th>
<th>Slope</th>
<th>Topographic wetness index</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004-S</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2004-R</td>
<td>![↑]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005-RT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2006-N</td>
<td></td>
<td></td>
<td>![↓]</td>
<td></td>
</tr>
<tr>
<td>2006-R</td>
<td></td>
<td></td>
<td>![↓]</td>
<td></td>
</tr>
<tr>
<td>2007-B</td>
<td></td>
<td></td>
<td>![↑]</td>
<td></td>
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<tr>
<td>2008-S</td>
<td></td>
<td></td>
<td>![↑]</td>
<td></td>
</tr>
<tr>
<td>2009-RT</td>
<td></td>
<td></td>
<td>![↓]</td>
<td></td>
</tr>
</tbody>
</table>

- Increase in variable caused higher probability of profitable yield response.
- Increase in variable caused lower probability of profitable yield response.

We could detect significant effect of spatial soil variables on the probability of profitable yield response only in 8 of 15 sites.

These effects were not consistent over years.
Developing Decision Support System

Content:
P2. Complexity of N management.
P3. Adaptive management to collect feedback.
P5. On-farm replicated strip trials.
P6. Data collection, summarization and interpretation.
P7. Verifying calibration categories of corn stalk nitrate test.
P8. Using feedback in N status to make adjustments for the future.
P11. Establishing relationship between corn N status, management and rainfall.
P11. Concerns and fears of unexpected results.
P12. Farmer group meetings.
Using N Feedback for Future Adjustments in N Management

1. Feld-level site-specific early-season rainfall observations and post-season corn N status.
2. Benchmarking N management against N Rates that Resulted in Optimal N Status across state or watershed.
Early Season Rainfall and Risk of N Loss

Assessing Risk of N Loss using March through June rainfall

Relatively High > 35 cm
Relatively Low < 35 cm

www.mesonet.agron.iastate.edu
Using risk of N loss and post-season corn N status.

<table>
<thead>
<tr>
<th>Field-Average N Status*</th>
<th>After-Fact Risk of N Loss#</th>
<th>Adjustments for Future Management</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deficient</strong></td>
<td>Above Average</td>
<td>No adjustments or in-season testing for possibility to correct N deficiency</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>Increase N availability</td>
</tr>
<tr>
<td></td>
<td>Below Average</td>
<td>Increase N availability</td>
</tr>
<tr>
<td></td>
<td>Very Low (drought)</td>
<td>No adjustments</td>
</tr>
<tr>
<td><strong>Optimal</strong></td>
<td>Above Average</td>
<td>No adjustments</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>No adjustments</td>
</tr>
<tr>
<td></td>
<td>Below Average</td>
<td>No adjustments</td>
</tr>
<tr>
<td></td>
<td>Very Low (drought)</td>
<td>No adjustments</td>
</tr>
<tr>
<td><strong>Excessive</strong></td>
<td>Above Average</td>
<td>Reduce N rate</td>
</tr>
<tr>
<td></td>
<td>Average</td>
<td>Reduce N rate</td>
</tr>
<tr>
<td></td>
<td>Below Average</td>
<td>No adjustments or in-season testing for possibility to reduce N rate</td>
</tr>
<tr>
<td></td>
<td>Very Low (drought)</td>
<td>No adjustments if corn N uptake increased due to moisture stress.</td>
</tr>
</tbody>
</table>

*When geometric mean of 3 stalk samples fall into deficient, optimal or excessive category.

# Above-average; more than 14 inches from March through June rainfall.
Five N Management Categories

1. AA Fall; fall-applied anhydrous ammonia.
2. Swine Fall; fall-injected swine manure.
3. AA Spring; spring-applied anhydrous ammonia.
4. UAN Spring; spring-applied UAN.
5. UAN SD; sidedress UAN

2011. JSWC. 66:373-385
Analysis of Historical Data: 2006-2013

3430 corn fields from 2006 through 2013
Benchmark N Rates Resulting in Optimal Corn N Status

- If farmers do not collect site-specific N feedback and their N rates fall on the right side of the box, then possibility of decreasing N rate or use in-season diagnostic tools.

- If farmers’ N rates fall outside the box but field specific N status or result of replicated strip trial can verify the optimal N status, no changes in N management.
20013: Corn N Status, Rainfall and N Rates

**Corn after Corn in 2013**

- **Fall AA**: 80% Excessive, 20% Optimal
- **Fall SM**: 60% Excessive, 40% Optimal
- **SD UAN/AA**: 40% Excessive, 60% Optimal
- **Spring AA**: 20% Excessive, 80% Optimal
- **Spring UAN**: 0% Excessive, 100% Optimal

**Corn after Soybean in 2013**

- **Fall AA**: 100% Optimal
- **Fall SM**: 100% Optimal
- **SD UAN/AA**: 100% Optimal
- **Spring AA**: 100% Optimal
- **Spring UAN**: 100% Optimal

### Average Monthly Rainfall (cm)

<table>
<thead>
<tr>
<th></th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn after Corn in 2013</strong></td>
<td>22</td>
<td>17</td>
<td>24</td>
<td>28</td>
</tr>
<tr>
<td><strong>Corn after Soybean in 2013</strong></td>
<td>23</td>
<td>21</td>
<td>28</td>
<td>26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn after Corn in 2013</strong></td>
<td>12</td>
<td>9</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td><strong>Corn after Soybean in 2013</strong></td>
<td>14</td>
<td>11</td>
<td>18</td>
<td>15</td>
</tr>
</tbody>
</table>

### N Rate (kg N/ha)

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn after Corn in 2013</strong></td>
<td>224</td>
<td>36</td>
</tr>
<tr>
<td><strong>Corn after Soybean in 2013</strong></td>
<td>192</td>
<td>26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn after Corn in 2013</strong></td>
<td>293</td>
<td>69</td>
</tr>
<tr>
<td><strong>Corn after Soybean in 2013</strong></td>
<td>255</td>
<td>75</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn after Corn in 2013</strong></td>
<td>231</td>
<td>29</td>
</tr>
<tr>
<td><strong>Corn after Soybean in 2013</strong></td>
<td>172</td>
<td>40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Corn after Corn in 2013</strong></td>
<td>196</td>
<td>13</td>
</tr>
<tr>
<td><strong>Corn after Soybean in 2013</strong></td>
<td>170</td>
<td>24</td>
</tr>
</tbody>
</table>

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<tr>
<th></th>
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<th>Std. Dev.</th>
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<tbody>
<tr>
<td><strong>Corn after Corn in 2013</strong></td>
<td>217</td>
<td>38</td>
</tr>
<tr>
<td><strong>Corn after Soybean in 2013</strong></td>
<td>169</td>
<td>38</td>
</tr>
</tbody>
</table>
Reducing Farmers’ N Rates

When and where N reductions are possible and at what risk?

- 2006: 34 on-farm trials
- 2007: 22 on-farm trials
Predictions for Unobserved Situations

Hierarchical and Bayesian Analyses

Predictive Posterior Probabilities as the Risk of Economic Yield Loss from Reducing N.

Regional Process Model
Field Process Model
Data

N categories with lower risks (in blue) are more preferable, especially in years with dry May and June.

These probabilities can be adjusted whether a farmer collects feedback in N status or not.

• Quantifying Risk of: (1) N loss, (2) above or below optimal N status, (3) yield loss or (4) under or over applications using rainfall observations.

• Multi-level estimation of predictive probabilities of economic yield response for different N management categories, including timing, form, placement or within-field-level factors.

• Collecting feedback in corn N status from farmers’ fields and refining estimated predictive probabilities.
Thank you

pkyveryga@iasoybeans.com