NDVI for Variable Rate N Management in Corn

David Mulla, Ph.D.
Director Precision Ag. Center
Dept. Soil, Water & Climate
University of Minnesota
Co-authors: Aicam Laacouri, Tyler Nigon and Jeff Vetsch
What is Precision Agriculture?

• A management practice applied at the right rate, right time and right place
  • Customized field management
  • Nutrients
  • Drainage or Irrigation
  • Pests and Weeds
  • Tillage and Seeding Operations
Benefits of Precision Agriculture

- Increased profitability
- Increased efficiency of inputs
- Reduced environmental pollution
Conventional Agriculture

- Most nitrogen fertilizer in Minnesota is fall applied
- Uniform management based on
  - Average or best field conditions
- Uniform management ignores spatial and temporal variability in crop growth, soil or landscape features and denitrification or leaching losses of N
- It leads to overuse of farm inputs
Variable Rate Side-Dress Nitrogen (VRN)

- Match side-dress N fertilizer application to crop growth patterns
- Use remote or proximal sensing to detect N deficiency in leaves
Study Area
Agricultural Ecology Research Farm, Waseca

Site 2 is used for VRN rate estimation

Sites 1, 4, 6, 8 are uniform N
Sites 3, 5, 7, 9 are VRN
Methods

• Conventional Treatment: EONR (135 lb/ac N in 2016 and 180 lb/ac N in 2017)
  • Corn after soybean in 2016
  • Corn after corn in 2017

• VRN Treatment: 30% of EONR (PP) + VRN Side-dressed based on NDVI with CropCircle ®
Variable Rate N Fertilizer Recommendations Based on CropCircle® NDVI

- Three N Response Zones (2016)
  - Zone 1: high N response (lower OM, lower NDVI)
  - Zone 2: low N response (higher OM, higher NDVI)
  - Zone 3: Average of 1 and 2

\[
\text{NDVI} = \frac{(\text{NIR}-\text{R})}{(\text{NIR}+\text{R})}
\]
EONR Fertilizer Rate based on NDVI (2016)

Estimated Rate (62 lb/ac)

Add 50 lb/ac

Spectrally Optimum rate (112 lb/ac)
VRN Fertilizer Side-Dressing at V6-V7

Raven Controller

Toolbar
## Results

VRN subfields in green received 20-30% less N than uniform subfields, with no significant impact on yield (2017)

<table>
<thead>
<tr>
<th>Subfields</th>
<th>Yield (bu/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>194</td>
</tr>
<tr>
<td>3</td>
<td>199</td>
</tr>
<tr>
<td>4</td>
<td>204</td>
</tr>
<tr>
<td>5</td>
<td>204</td>
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<tr>
<td>6</td>
<td>198</td>
</tr>
<tr>
<td>7</td>
<td>203</td>
</tr>
<tr>
<td>8</td>
<td>212</td>
</tr>
<tr>
<td>9</td>
<td>198</td>
</tr>
</tbody>
</table>
Economics of VRN Fertilizer Management

- Urea fertilizer and market price of $0.35/lb N
- $5/ac cost for variable rate prescription and application

<table>
<thead>
<tr>
<th>VRN Sub-Fields</th>
<th>2016 ROI (Per acre)</th>
<th>2017 ROI (Per acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>$13.5</td>
<td>$15.75</td>
</tr>
<tr>
<td>5</td>
<td>$13.5</td>
<td>$15.75</td>
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<tr>
<td>7</td>
<td>$11.5</td>
<td>$12.5</td>
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<tr>
<td>9</td>
<td>$16</td>
<td>$19</td>
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</table>
Comparison Between NDVI and Other VI

<table>
<thead>
<tr>
<th>Reflectance</th>
<th>Absolute Correlation with N Rate</th>
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<tbody>
<tr>
<td></td>
<td>V6</td>
</tr>
<tr>
<td>NDVI</td>
<td>0.47</td>
</tr>
<tr>
<td>Green NDVI</td>
<td>0.47</td>
</tr>
<tr>
<td>GDVI</td>
<td>0.59</td>
</tr>
</tbody>
</table>

\[ \text{NDVI} = \frac{\text{NIR} - \text{R}}{\text{NIR} + \text{R}} \]

\[ \text{Green NDVI} = \frac{\text{NIR} - \text{G}}{\text{NIR} + \text{G}} \]

\[ \text{GDVI} = \frac{\text{NIR} - \text{G}}{\text{NIR} + \text{G}} \]
## Comparison Between Satellites and Cameras
(all can estimate NDVI)

<table>
<thead>
<tr>
<th>Satellite/Sensor</th>
<th>spatial resolution (ft)</th>
<th>spectral resolution (no. of bands)</th>
<th>pixels per ac</th>
<th>M – Multispectral, SWIR – Short Wave IR, H - Hyperspectral</th>
</tr>
</thead>
<tbody>
<tr>
<td>IKONOS 2</td>
<td>2.69 (P), 13.1 (M)</td>
<td>4</td>
<td>6019, 254</td>
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<tr>
<td>QuickBird</td>
<td>2.0 (P), 13.1 (M)</td>
<td>4</td>
<td>10890, 254</td>
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<tr>
<td>RapidEye</td>
<td>16.4 (M)</td>
<td>4+red-edge</td>
<td>162</td>
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<tr>
<td>GeoEye</td>
<td>5.4 (M)</td>
<td>4</td>
<td>1494</td>
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<tr>
<td>WorldView-3</td>
<td>4.1 (M), 12.1 (SWIR)</td>
<td>8 (M), 8 (SWIR)</td>
<td>2591, 298</td>
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<tr>
<td>Landsat 8</td>
<td>98.4</td>
<td>4 (M), 4 (SWIR)</td>
<td>4.5</td>
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<td>Sentinel 2</td>
<td>33-66 (M), 66-197 (SWIR)</td>
<td>8 (M), 4 (SWIR)</td>
<td>18, 2.5</td>
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<td>AISA Eagle</td>
<td>3.3 (H)</td>
<td>63</td>
<td>4000</td>
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<td>Tetracam MCA6</td>
<td>0.22 (M)</td>
<td>5+red-edge</td>
<td>900000</td>
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</tr>
</tbody>
</table>
Increased Homogeneity of Pixels
Limitations to Satellite Remote Sensing

• Coarse spatial resolution and infrequent repeat coverage for older satellite platforms
• Difficulty obtaining images when needed
• Interference from clouds
• Changes in irradiance on multiple passes
• Slow turn-around time due to image processing for calibration, corrections, and geo-rectification
The Mini Satellite Revolution

• Flocks of miniature (nano) satellites have been launched by Planet ®

• These Dove (radar) and SkySats (MSS) have the capacity to cover the entire earth daily at sub-meter resolution

• Future launches may include mini satellite flocks that provide HS imaging at high spatial resolution and low S/N ratio
Challenges For VRN Implementation

• How much N to apply pre-plant?
  • 30-60 lb N/ac is generally appropriate
  • Applying more than 90 lb N/ac is excessive

• How should N response zones be identified?
  • A combination of soil organic matter and historical crop yields
  • Crop modeling (Adapt-N, Encirca, ClimateCorp)
Comparison Between Airplanes and UAVs

Airplane based FSA-NAIP derived NDVI for Theilman, MN (around V6)
Red colors indicate N deficiency, green colors indicate no N stress
Comparison Between Airplanes and UAVs

UAV based NDVI for Theilman, MN (around V6)
Red colors indicate N deficiency, green colors indicate no N stress
Challenges to Implementation of VRN

• What algorithm should be used to estimate N fertilizer recommendation?
  • UofM is developing algorithms based on many site years of research
  • One alternative is to use a sufficient N reference in the field (180 lb N/ac in corn-soybean rotation)
  • Another alternative is to use a virtual reference N location, the location with highest biomass growth
  • GreenSeeker®, CropCircle® and Yara® have proprietary algorithms not specific to Minnesota
  • Technically no difference between satellite imagery based NDVI and sensor based NDVI except spatial resolution
Conclusions

• VRN side-dressing at V6 reduced nitrogen fertilizer rate by 25-30% without impacting yield

• High ROI even in the absence of yield improvement
The Problem with NDVI

- Current aerial surveillance methods can detect yellow regions in corn fields using NDVI

- Need more information:
  - The exact nature of the stress (e.g. N vs S)
  - The severity of the stress
Nitrogen Deficiency has V-Shape Yellowing
High Resolution Approach

Fly low and pay attention to the details!
Identify V-Shape Yellow Areas

- Skeleton of green
- Skeleton of yellow
- Edge of green
- Edge of yellow
Identify Nitrogen Deficient Leaves

84.2%
Determine Stress Severity
Assess density of nitrogen deficient leaves for N fertilizer recs
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David Mulla
mulla003@umn.edu
(612) 625-6721