USING NDVI Images for Predicting Yield and Protein in Wheat
Digital Agriculture

The use of tools that use electronic data and its analysis to informed processes and management decisions in order to improve productivity and efficiency. Common examples are GPS guidance, variable rate fertilizer applications, yield maps from yield monitors.
NDVI – Normalized Difference Vegetation Index (example of digital data)

- The ratio of the near-infrared (NIR) and red light reflected back from an object

\[
\text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{Red} + \text{NIR})}
\]

- Higher values = higher levels of green color but more diagnostic than just green

- High NDVI values may equate to:
  - More ground cover early in the season
  - Better plant health
  - More biomass
  - More chlorophyll
  - Greater N content of tissue
  - Greater yield potential
Can NDVI data be useful in wheat production?

• Potentially many uses but one use is to aid in decisions of N fertility management
  – N status affects leaf color
  – N is often the most costly input
  – N loss from and supply by the soil is impacted by the environment
  – Can guide in-season applications of N and improve NUE
Active NDVI sensors inform in-season N rates

- Variable N rates are applied based on data from tractor mounted active sensors (have their own light source)
- Often use an N-rich strip as reference for adequacy of N
- NDSU has published algorithm for use of NDVI in corn. Areas of low value get more N
Previous work with NDVI in wheat

- Prediction of N need for yield and protein with NDVI from handheld sensors variable
  - Early season N deficiencies hard to detect (small plant growth)
  - Separation extreme differences (10% protein from 14%) documented but not more likely differences (i.e. 12% and 14%)
  - NDVI becomes saturated before reaching yield and protein levels where N might be limiting
  - Adoption of NDVI to guide in-season N in spring wheat is low

\[
y = 28.017x - 15.039 \\
R^2 = 0.591
\]
Can NDVI be used to guide development of prescription maps for N rates in HRSW?

- Research undertaken in 2018 and 2019
- NDVI collected from drone-mounted sensors multiple times during growing season in farmers’ fields with N-rich (1.2 to 1.5 X) and N-limited strips (0.75X)
- Data compared to:
  - satellite NDVI images from previous season
  - yield maps from 2019 harvest
- NDVI was compared to yield and protein maps in a few locations
Why N-rich and N-limiting strips?

• References for adequacy or excess N
• Provide a greater range of potential NDVI values to sample
• To determine the diagnostic value of these “strips”
• Question #1. What did we learn from N strips?
Yield of N strips, 5 locations, 2019

- N-limited
- Grower's Rate
- N-Rich

Yield (bu/acre)

Campbell
Walcott
Colfax
Breckenridge
E. Grand Forks
Yield variability within fields and as influenced by N application
Comments on N-rich and N-limited strips

• Variable N strips have potential for informing of adequacy or excessive level of N

• Placement in the field is critical (uniform, average yielding, crossing productivity zones?)

• When disease and other factors like lodging limit yield, not a good measure of soil productivity
When is the best time to collect NDVI?
Effect of N treatment and crop stage on NDVI values, Walcott, 2019

June 25
Effect of N treatment and crop stage on NDVI values, Walcott, 2019
Effect of N treatment and crop stage on NDVI values, Walcott, 2019
## Correlations between NDVI and yield, 2019

<table>
<thead>
<tr>
<th>Date</th>
<th>Walcott (63 bu/a)</th>
<th>East GF (86 bu/a)</th>
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<tr>
<td>26-Jun</td>
<td>0.20</td>
<td>0.02</td>
<td>-0.45</td>
<td>0.56</td>
<td>0.47</td>
<td>0.62</td>
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<tr>
<td>2-Jul</td>
<td>0.28</td>
<td>-</td>
<td>-0.22</td>
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<td>11-Jul</td>
<td>0.11</td>
<td>0.66</td>
<td>0.09</td>
<td>0.49</td>
<td>0.55</td>
<td>0.74</td>
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<tr>
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<td>0.23</td>
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Best timing?

- Merging NDVI data collected over multiple dates or later in the season, slightly more predictive than single early data.
Other comments about NDVI

• NDVI inconsistently predicted yield. May be the most useful in situations when soil factors limit yield
  – high yield, no disease, or lodging
  – Large variability in the field (when low areas and field borders included)

• In such situations can be a start in creating production zones if yield maps are lacking
Production zones based on NDVI values collected in 2019
### What about historic NDVI maps?

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<td>Prev. Year NDVI</td>
<td>-0.09</td>
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<td>0.08</td>
<td>0.34</td>
<td>0.22</td>
<td>0.43</td>
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Other lessons learned

• Given variability of yield, managing some inputs by production zone has merit (at a minimum don’t fertilize the ditches)

• NDVI maps of previous season (satellite derived) may be useful but less so than in-season from wheat

• Resolution of drone-derived data is far more than needed for zone mapping
Lessons learned (continued)

• Drones and sensors are relatively inexpensive, but -

• Data collection and analysis slow:
  – To cover 160 acres - 2 hrs (six flights) at 200 ft, 45 mins (2 flights) at 400 ft
  – ~12 to 48 hours and expensive software to stitch images

• Software or third party to develop production zones from NDVI image
Challenge of drone flight

• Internal compass in the drone may override flight plan
• Batteries can burn and drones can crash
• Use contract providers or satellite images
• Drones may still have value for scouting
What about NDVI predicting protein?
Conceptual model of grain yield and grain protein relationship

Part A: Protein changes very little
Part B: Protein change begins to increase, yield begins to slow
Part C: Protein changes rapidly, grain yield very little

Adapted from Mason, 2007
Relation between yield, protein & NDVI

Yield (bu/acre)

Grain Protein (%)

NDVI 6-21-18

- ≤0.932787
- ≤0.941452
- ≤0.947229
- ≤0.950117
- ≤0.973225
- N-rich strip
Preliminary observations

• Protein was generally negatively associated with yield

• To the extent we can predict yield with NDVI we can predict protein (there are important exceptions)

• Extra N in zones likely to be high yielding may be best strategy for optimizing N for protein and yield
Conclusion

• Substantial variability in yield suggest benefits from variable rates of N

• NDVI inconsistently predicted yield, but could be a start in defining zones in absence of yield maps or to augment yield map info

• Predicting protein with NDVI directly not possible, but indirectly by predicting yield