Combined Spectral Index for Sensing the Nitrogen Status of Dryland Wheat

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Introduction
Optical sensors are now used on ground-based applications to sense the crop and trigger nitrogen (N) applications according to the crop's potential yield response. This advanced technology relies upon the NDVI, which contrasts the reflectance in chlorophyll-absorbing red wavelengths (650 – 660 nm) with internal leaf-scattering NIR wavelengths (780 – 1350 nm). For example, vegetation indices are used to measure crop growth and detect stress such as drought. However, N has been measured through NDVI, the most common vegetation indices, which may result from spatial patterns in N deficiency, vegetation cover, leaf area index (LAI), and chlorophyll a/b content. In water-limited environments, variations in LAI and cover are often linked to soil moisture rather than plant available N, which makes crop N status more difficult to assess. Chlorophyll indices, which utilize the spectral region between red and NIR reflectance, or red edge (680–730 nm), have been developed that are highly responsive to a wide range of chlorophyll values. These indices have proven useful for remote sensing of crop N status primarily under non-limiting water conditions because biomass is positively correlated with plant available N. However, because leaf chlorophyll indices are determined from reflectance at red and NIR wavelengths, these indices have some sensitivity to variations in LAI and cover caused by variations in soil moisture content.

Study Sites
Hard red spring wheat was grown within three commercial dryland wheat fields, F1 near Palisades, ID, and F2 and F3 near Pendleton, OR. Within each field, smaller areas of the crop were visually identified that differed in degree of greenness–locations for sampling the crop and measuring crop reflectance were chosen randomly within dark or light colored field areas.

Field Measurements
Text measurements of crop reflectance were obtained in each field with an ASD FieldSpec Pro radiometer.

Canopy Reflectance Modelling

Prospect-SAIL radiative transfer model was used to simulate leaf reflectance and transmittance spectra between 300 and 1000 nm at a spectral resolution of 1 nm. Model input parameters included:

- Reflectance data simulated by Prospect-SAIL were used to compute various single and combined spectral indices.

Results

- Simulated vegetation indices as a function of chlorophyll a and LAI index MCARI/MTVI2 was both sensitive to chlorophyll and resistant to LAI:

Conclusions

- NDVI using NIR, and red or green reflectance will be poorly related with chlorophyll a or flag leaf N in dryland environments.

- This inability is due to sensitivity to LAI which confounds predictions of crop N status, and thus limits usefulness of NDVI-based sensing under dryland conditions.

- Use of these systems would be better undertaken in irrigated fields that offer canopy closure.

- A combined index such as MCARI/MTVI2 will improve multispectral reflectance estimates of wheat N status under dryland field conditions.

- (1) Sensitive to chlorophyll resistant to LAI.

- (2) Accommodate soil variability thereby minimizing need for reference strips.

- (3) Improvements to sensor systems.

References


Location of fields, growing season rainfall, number of plots, and SPAD value with means for plots in dark green and light green colored areas.

Field

<table>
<thead>
<tr>
<th>Location</th>
<th>Wheat Variety</th>
<th>Number of Plots</th>
<th>SPAD Value</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Winter Wheat</td>
<td>625</td>
<td>48.1 ± 2.3</td>
<td>49.1 ± 2.3</td>
</tr>
<tr>
<td>F2</td>
<td>Winter Wheat</td>
<td>380</td>
<td>46.2 ± 2.1</td>
<td>46.4 ± 2.1</td>
</tr>
<tr>
<td>F3</td>
<td>Winter Wheat</td>
<td>350</td>
<td>46.8 ± 1.8</td>
<td>48.7 ± 1.8</td>
</tr>
</tbody>
</table>

Reference measurements of relative chlorophyll were taken using a SPAD chlorophyll meter. Flag leaves were sampled for laboratory analysis of N concentration. Leaf area index was also measured using a LICOR Crop Canopy Analyzer.