Approaches to characterize chlorophyll/nitrogen status of crop canopies

Klaus Schelling, RapidEye AG

DGPF Workshop “Auswertung von Fernerkundungsdaten“
Hannover, 18. November 2010
Agenda

- Introduction: Why assessing nitrogen and chlorophyll status of crops?
- How to “measure” chlorophyll?
- Information content of RapidEye satellite data
- “Measuring” chlorophyll with remote sensing
- Chlorophyll sensitive spectral parameters
- Challenges
Why assessing nitrogen and chlorophyll status of crops? (1)

- Crop growth and yield strongly depend on an adequate supply of nitrogen (N)
- In many crops application of N-fertilizer is the single most important management action to boost crop growth and yield
- N-fertilizer represents one of the biggest input cost factors in the cultivation of many important crops (e.g. corn, wheat, rice)
- Assessing the N-status is critical for optimum fertilizer management
- **Undersupply** of N results in yield losses.
- **Oversupply** of N has negative effects on crops (e.g. lodging) and the environment
Why assessing nitrogen and chlorophyll status of crops? (2)

> “Intelligent” N-fertilizer management (Precision Farming) is being applied more widely worldwide ==> Information about N-nutrition status is crucial information

> Nitrogen ”processes” (transformation, uptake, distribution) in soils and plants are very dynamic ==> this causes large spatial and temporal variations of the N-status within and between fields

> The N-status of crops can be assessed through chlorophyll measurements

> Chlorophyll is a strong indicator of the N-nutrition status of (green) plant canopies

> Different ways exist to “measure” chlorophyll...
How to “measure” chlorophyll?

**Chemical Analysis**
- time consuming
- expensive
- Chl-measurement possible for different plant organs
- point measurement
- 'real' biophysical values

**SPAD**
- fast
- easy use
- leaf Chl-measurement (only)
- point measurement
- no biophysical measurement
- dimensionless values

**Online-Sensor**
- operational
- Chl-measurement based on spectral reflectance
- mapping of entire fields
- canopy Chl-measurement
- different systems available

... and remote sensing
Chlorophyll (and other pigments) are strong absorbers of blue and red light.

The Red Edge Inflection Point (REIP) is indicative of chlorophyll.
Information content of RapidEye satellite data

Wavelengths of the RapidEye spectral bands:
- Blue: 440-510 nm
- Green: 520-590 nm
- Red: 630-685 nm
- Red-Edge: 690-730 nm
- NIR: 760-850 nm
“Measuring” chlorophyll with remote sensing

- Chlorophyll (and other pigments) are strong absorbers of light in certain wavelengths ==> chlorophyll can be detected with remote sensing

- Certain spectral features that are indicative of chlorophyll (e.g. the location of the Red Edge Inflection Point) require information from narrow spectral bands

- The RapidEye spectral bands are broad spectral bands (typical for most spaceborne sensors) ==> REIP analyses are not possible

- A number of chlorophyll sensitive vegetation indices and combinations of indices based on broad spectral bands have been developed and tested in recent years

- Remote sensing based approaches can aim at “measuring” chlorophyll content or chlorophyll concentration
(Some) Chlorophyll sensitive spectral parameters

- 'Single' chlorophyll indices (including Red Edge band information)
  - NDRE (Normalized Difference Red Edge Index)
  - MCARI (Modified Chlorophyll Absorption in Reflectance Index)
  - TCARI (Transformed Chlorophyll Absorption in Reflectance Index)
- Combined indices (combining a chlorophyll index with a structural index)
  - NDRE/NDVI
  - TCARI/OSAVI
  - MCARI/MTVI2
- Distance indices
  - relatively new approach, using the distance to a trendline in scatterplots as indicators for chlorophyll
'Single' chlorophyll indices

Relationships between chlorophyll measurements (SPAD-readings) and 'single' vegetation indices

\[ R^2 = 0.1791 \]

\[ R^2 = 0.5206 \]

*Normalized Difference Vegetation Index = (NIR-Red)/(NIR+Red)
**Normalized Difference Red Edge Index = (NIR-RedEdge)/(NIR+RedEdge)

Example: Winter wheat in South Africa, 2009 cropping season, comparison of SPAD - measurements with RapidEye-spectral data (acquisition date 8 August 2009, app. 14 weeks after planting)

RapidEye proprietary information
Combined indices

The use of combined vegetation indices can result stronger relationships between spectral parameters and chlorophyll measurements.

Example: Winter wheat in South Africa, 2009 cropping season, comparison of SPAD -Measurements with RapidEye-spectral data (acquisition date 8 August 2009, app. 14 weeks after planting)

*Normalised Difference Red Edge Index (NDRE)/Normalised Difference Vegetation Index (NDVI)

**Modified Chlorophyll Absorption in Reflectance Index (MCARI)/Second Modified Triangular Vegetation Index (MTVI)

See also:
Distance indices (1)

Using the distance to a trendline in 2-D scatterplot of a chlorophyll sensitive and a structural vegetation index as indicator for chlorophyll

Distance values
Distance indices (2)

Using the distance to a trendline in 2-D scatterplot of a chlorophyll sensitive and a structural vegetation index as indicator for chlorophyll (SPAD)

Example: Winter wheat in South Africa, 2010 cropping season, comparison of SPAD - measurements with RapidEye-spectral data (acquisition date 21 July 2010, app. 12 weeks after planting)
Relative chlorophyll map
Challenges (1)

- Atmospheric effects in satellite remote sensing data
- Effects of soil background (especially when ground cover is low)
- Wide spectral bands do not allow accurate determination of REIP
- RapidEye spectral bands may not be 100% ideal for chlorophyll measurements
- Red Edge band includes composite information on both canopy structure (biomass, leaf area) and chlorophyll => difficult to decouple these two effects
- There is no 100% relationship between chlorophyll and nitrogen in plants (influence of other pigments, other causes for chloroses)
Challenges (2)

- Relationships between spectral information and chlorophyll are weaker than with biomass ==> biomass variations 'overshadow' chlorophyll variations
- No 'single best approach' to determine chlorophyll appears to exist
- Finding the best approach for the specific conditions to estimate the desired chlorophyll parameter is the challenge