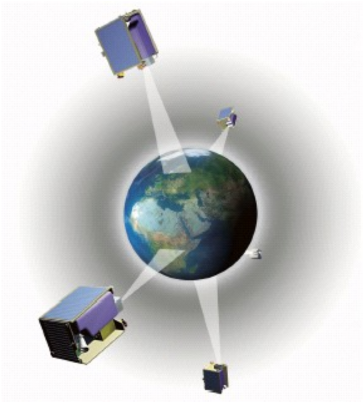

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Approaches to characterize chlorophyll/nitrogen status of crop canopies

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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

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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...

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How to “measure” chlorophyll?

Chemical Anaylsis

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

SPAD

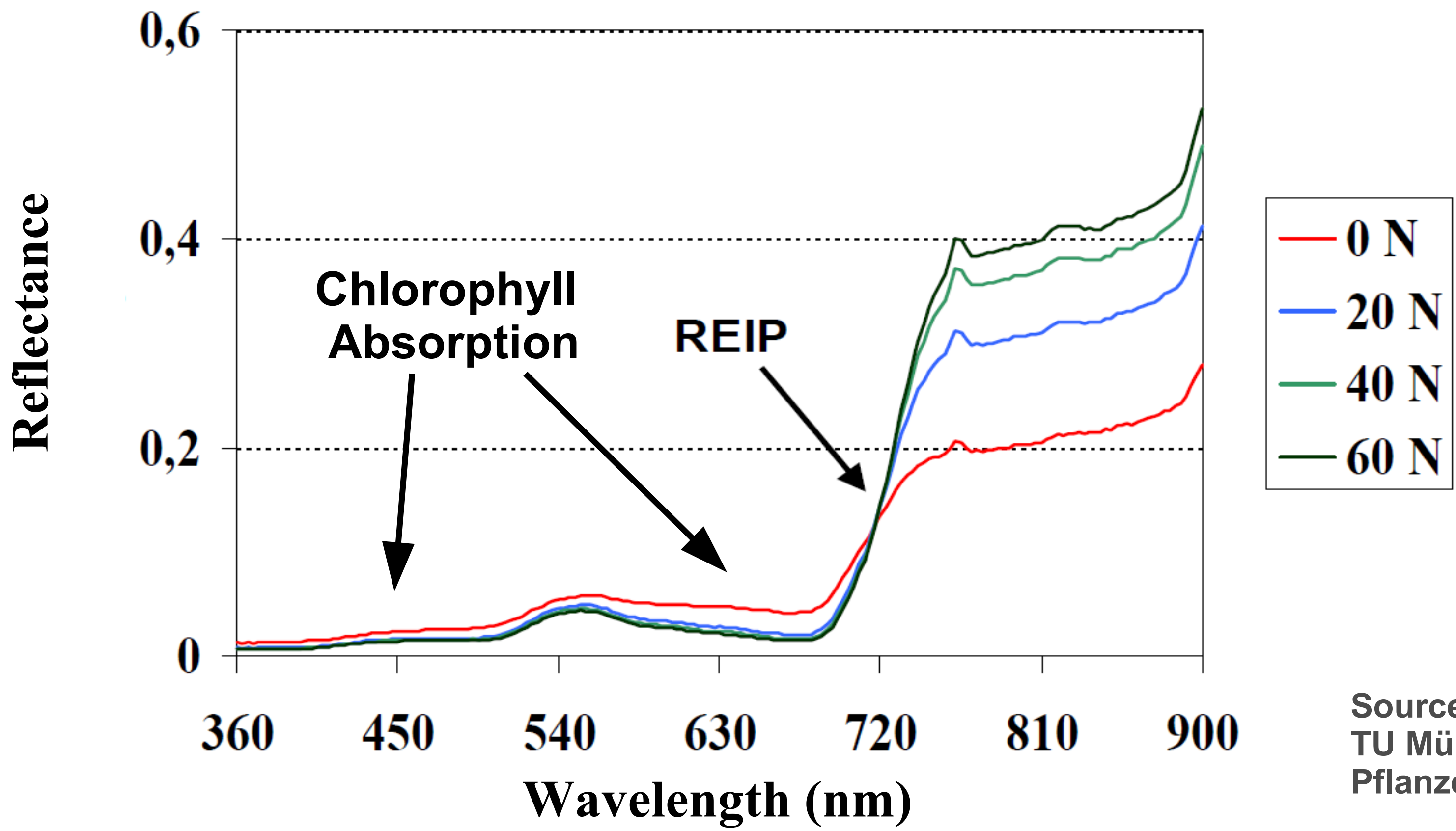
- fast
- easy use
- leaf Chl-measurement (only)
- point measurement
- no biophysical measurement
- dimensionless values

Online-Sensor

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

... and remote sensing

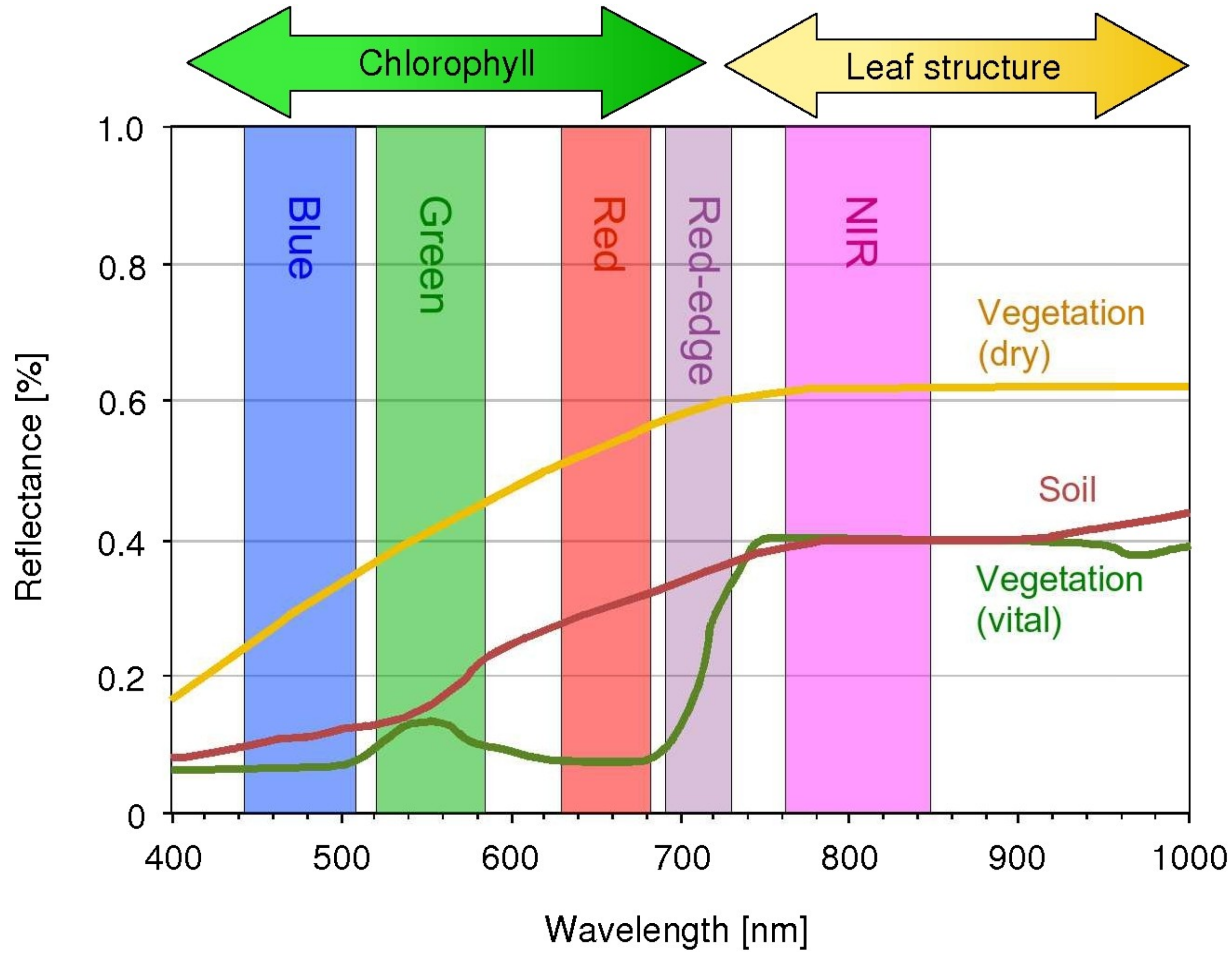
Spectral response of chlorophyll



Source:
TU München, Department
Pflanzenwissenschaften

- 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**
Geen:	**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 chlorphyll sensitive vegetation idices 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**

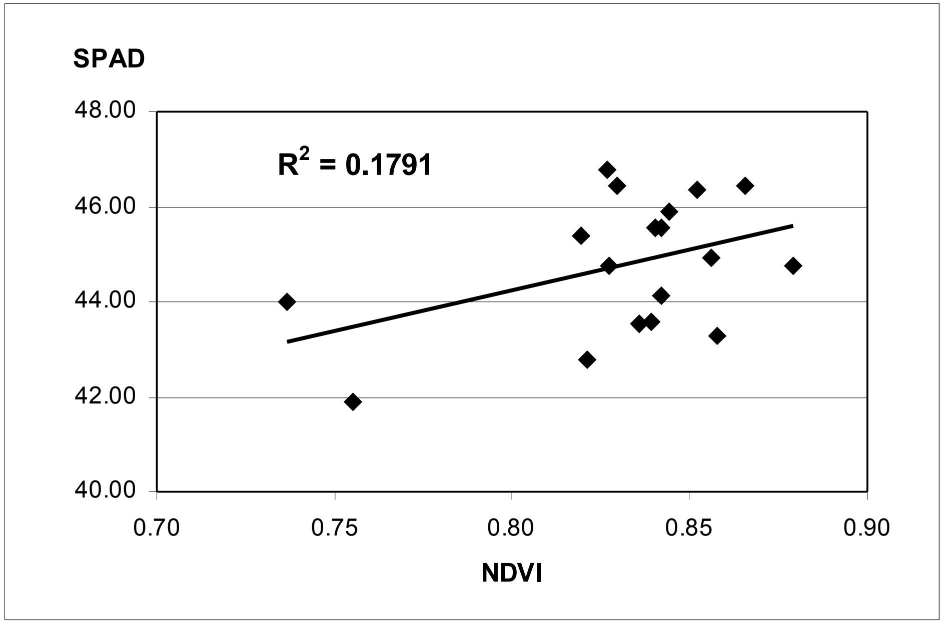
(Some) Chlorophyll sensitive spectral parameters

- '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

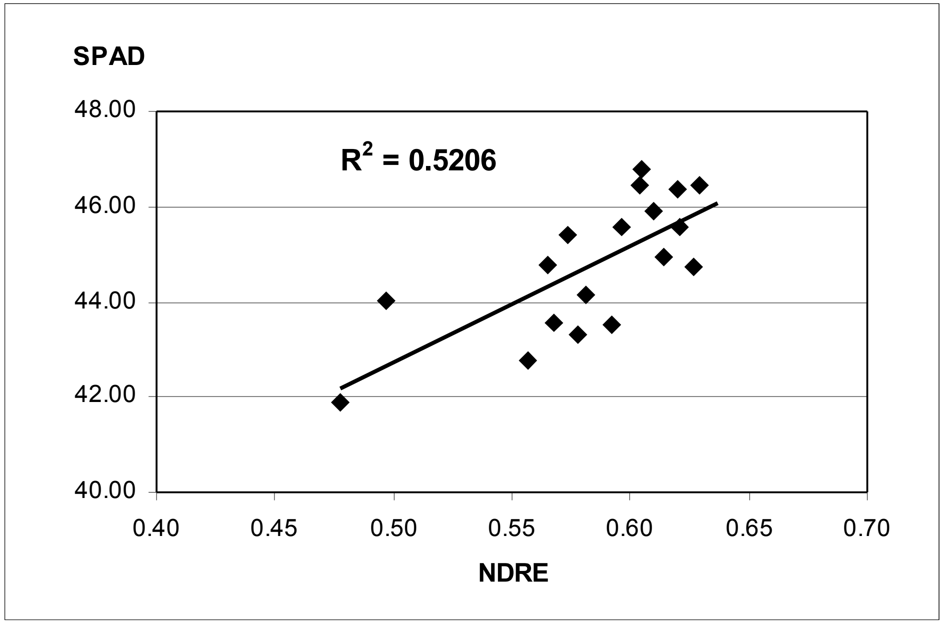
'Single' chlorophyll indices

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

SPAD - NDVI*



SPAD - NDRE**



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

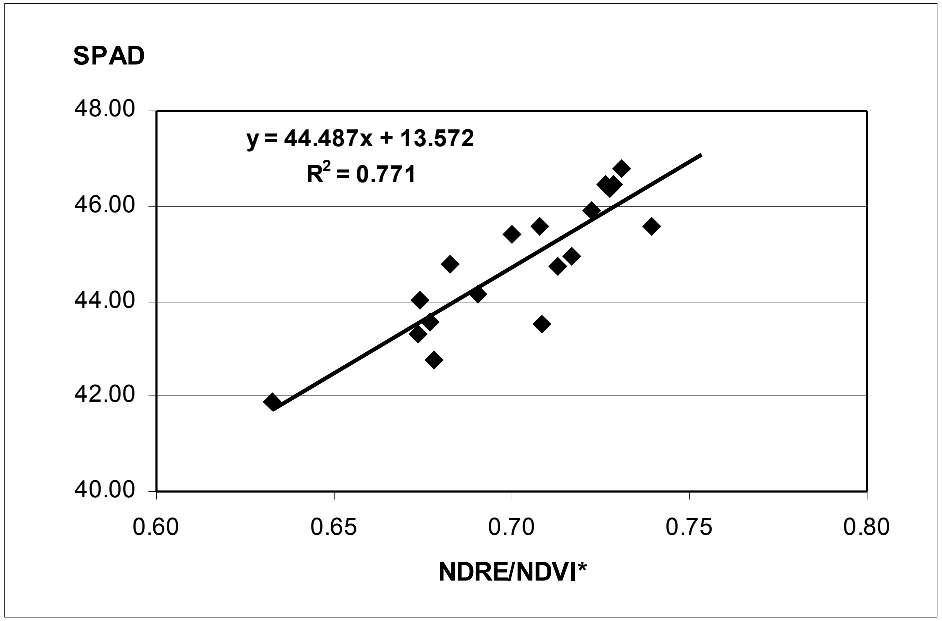
**Normalized Difference Red Edge Index = (NIR-RedEdge)/(NIR+RedEdge)

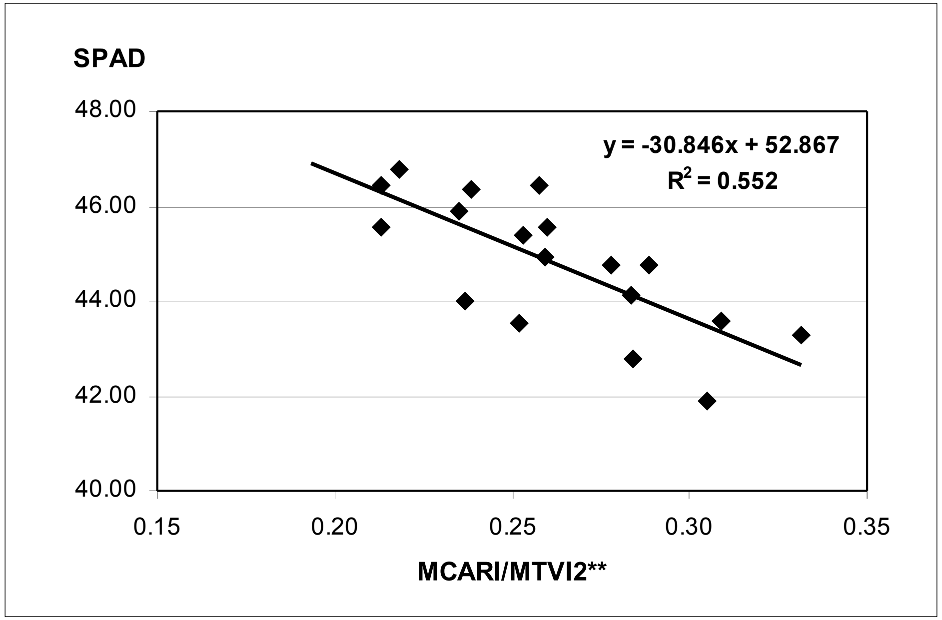
Example: Winter wheat in South Africa, 2009 cropping season, comparison of SPAD - measurements with RapidEye-spectral data (acquisition date 8 August 2009, app. 14 weeks after planting)

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)





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

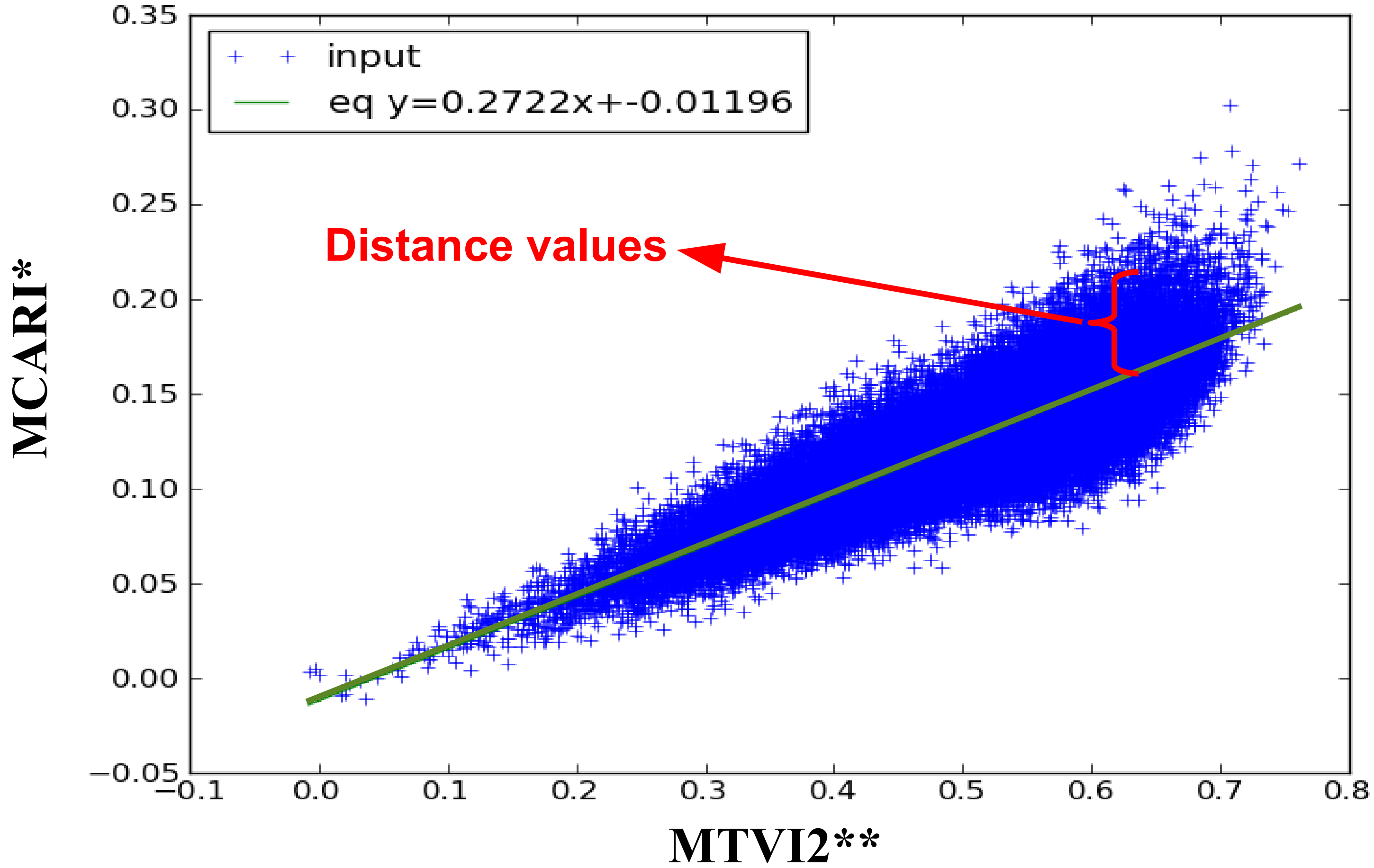
**Modified Chlorophyll Absorption in Reflectance Index (MCARI)/Second Modified Triangular Vegetation Index (MTVI)

See also:

Eitel, J.U.H., Long, D.S., Gessler, P.E., Hunt Jr., E.R., Brown, D.J.: Sensitivity of Ground-Based Remote Sensing Estimates of Wheat Chlorophyll Content to Variation in Soil Reflectance. Soil Sci. Soc. Am. J., 73, S. 1715-1723, 2009

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

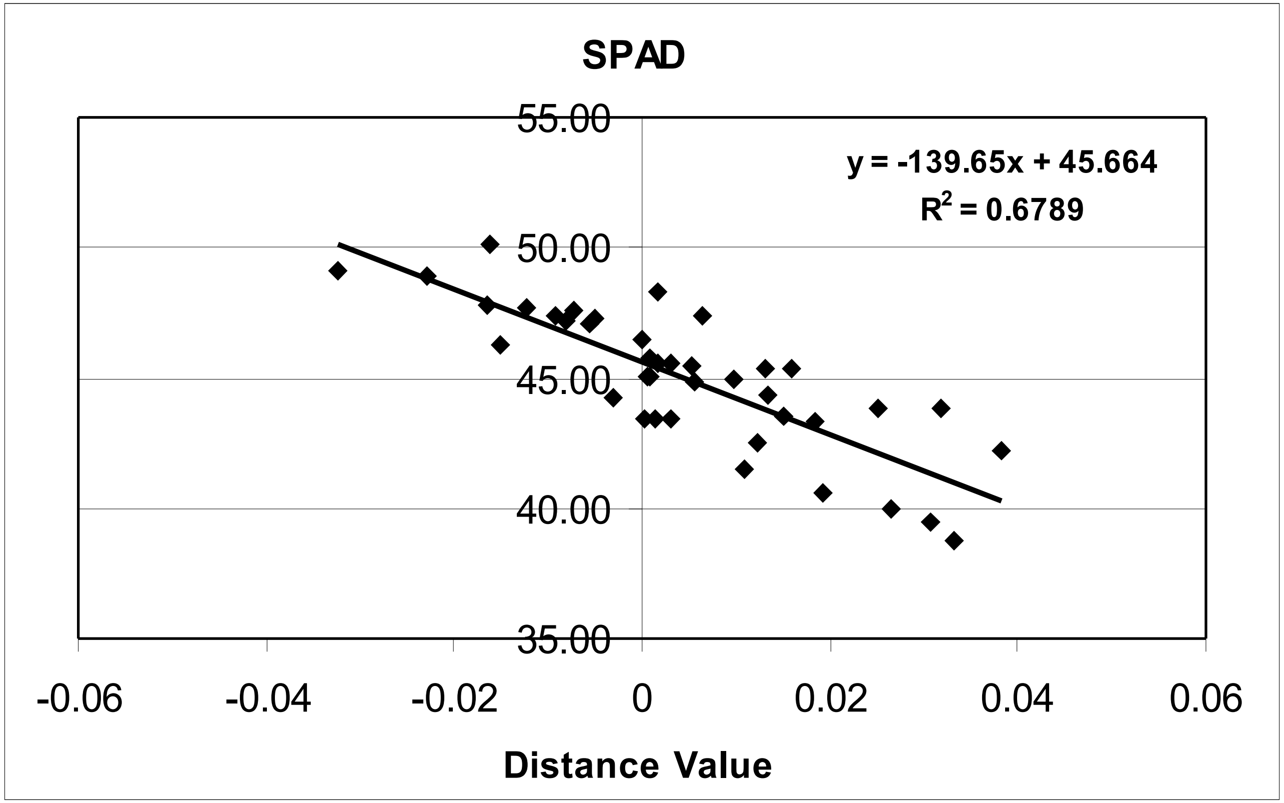


*Modified Chlorophyll Absorption Ratio Index (chlorophyll sensitive)

**Second Modified Triangular Vegetation Index (sensitive to canopy structure)

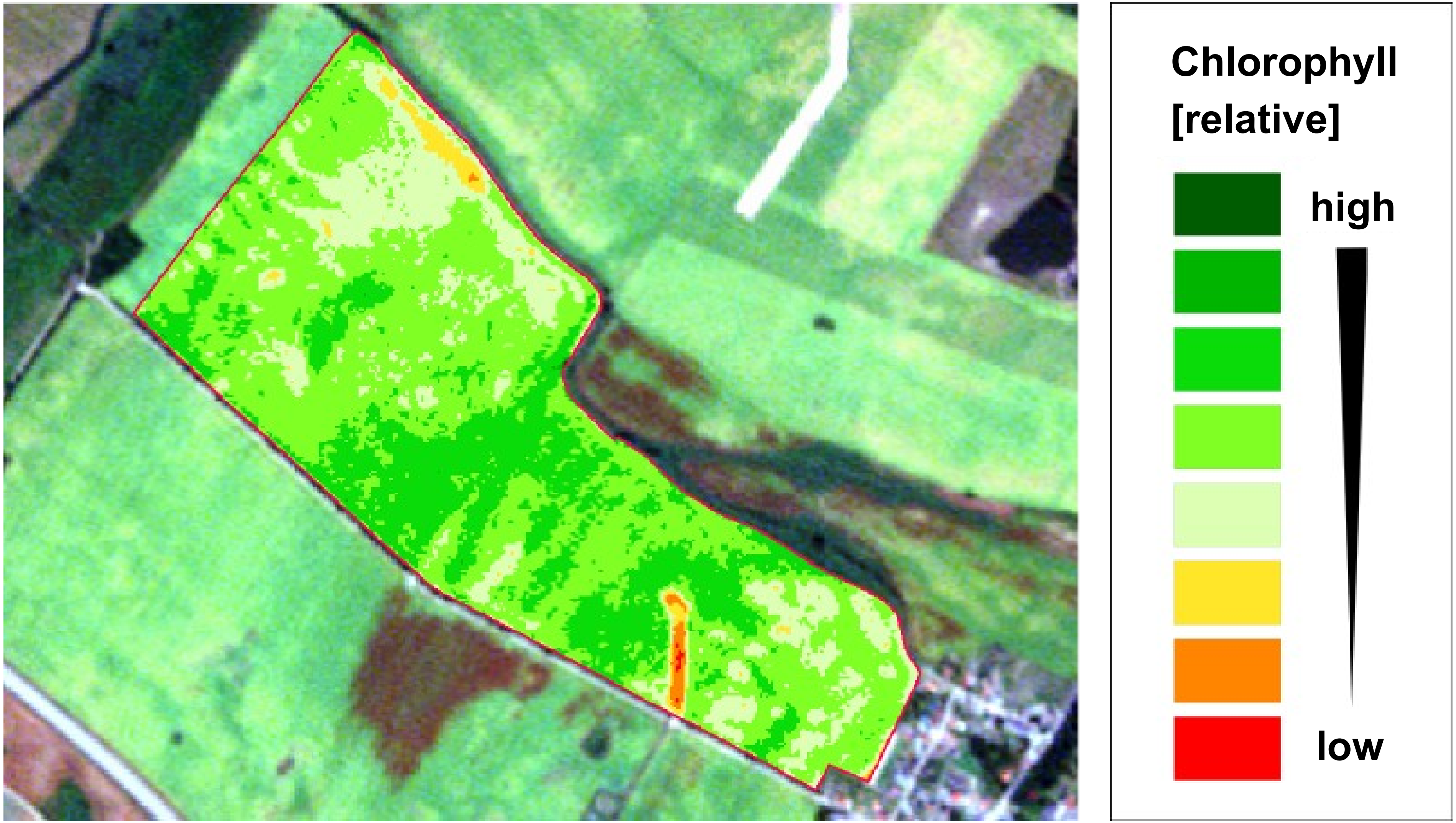
Distance indices (2)

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