



Using the red-edge bands on Sentinel-2 for retrieving canopy chlorophyll and nitrogen content

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Introduction

Chlorophyll and nitrogen play a key role in the biochemistry of plants (e.g., photosynthesis). Optical remote sensing primarily provides integrated information of a plant or canopy, meaning over the IFOV of the sensor. As a result, we may get estimates of the canopy chlorophyll or nitrogen content. For the estimation the so-called red-edge region is very important and the new ESA mission Sentinel-2 carries a sensor (the MSI) incorporating two red-edge bands (at 705 nm and 740 nm). This will make the use of, e.g., the red-edge chlorophyll index feasible at high resolution.

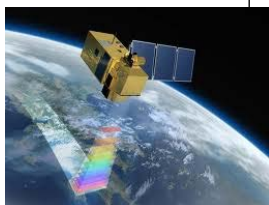
Research objectives:

- Which band setting can best be used in the red-edge chlorophyll index?
- How well does the band setting of Sentinel-2 match the best setting?
- What is the suitability of different vegetation indices in estimating the chlorophyll and nitrogen (N) content based on Sentinel-2?

Methodology

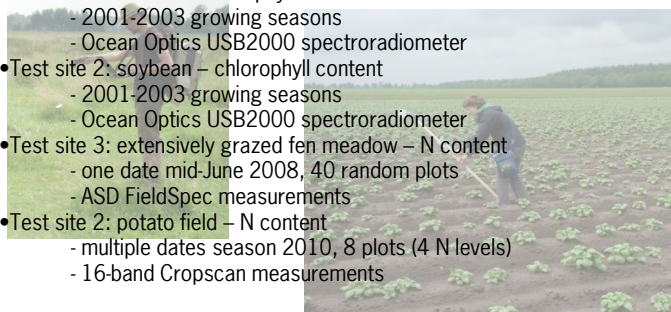
Sentinel-2:

- Polar orbiting satellite
- Launch planned in 2013
- Spatial resolution: 10 m, 20 m or 60 m
- Interesting narrow bands for vegetation studies: 560, 665, 705, 740, 783, 842, 865 nm
- High revisit due two constellation of two satellites



Data sets:

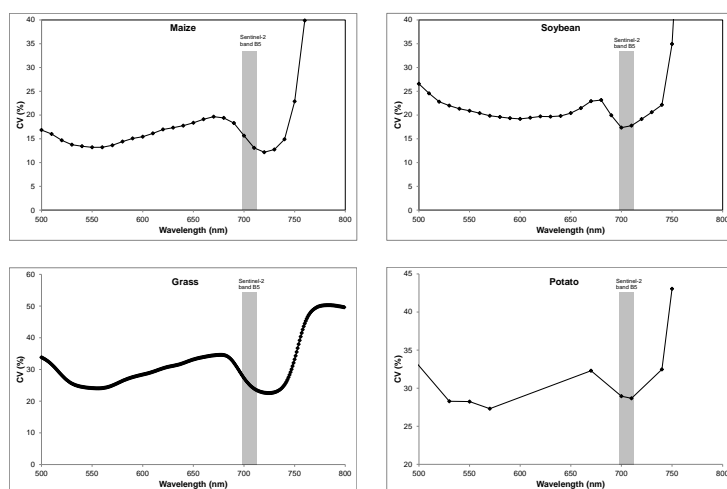
- Test site 1: maize – chlorophyll content
 - 2001-2003 growing seasons
 - Ocean Optics USB2000 spectroradiometer
- Test site 2: soybean – chlorophyll content
 - 2001-2003 growing seasons
 - Ocean Optics USB2000 spectroradiometer
- Test site 3: extensively grazed fen meadow – N content
 - one date mid-June 2008, 40 random plots
 - ASD FieldSpec measurements
- Test site 2: potato field – N content
 - multiple dates season 2010, 8 plots (4 N levels)
 - 16-band CropsScan measurements



Indices tested for chlorophyll and nitrogen estimation:

Index	Formulation
$CI_{red\ edge}$	$(R_{783}/R_{705}) - 1$
CI_{green}	$(R_{783}/R_{560}) - 1$
REP	$705 + 35 \frac{(R_{665} + R_{783})/2 - R_{705}}{R_{740} - R_{705}}$
MTCI	$(R_{740} - R_{705}) / (R_{705} - R_{665})$
MCARI/OSAVI[705,750]	$\frac{[(R_{740} - R_{705}) - 0.2(R_{740} - R_{560})](R_{740}/R_{705})}{(1 + 0.16)(R_{740} - R_{705}) / (R_{740} + R_{705} + 0.16)}$
TCARI/OSAVI[705,750]	$\frac{3[(R_{740} - R_{705}) - 0.2(R_{740} - R_{560})](R_{740}/R_{705})}{(1 + 0.16)(R_{740} - R_{705}) / (R_{740} + R_{705} + 0.16)}$
NDRE1	$(R_{740} - R_{705}) / (R_{740} + R_{705})$
NDRE2	$(R_{783} - R_{705}) / (R_{783} + R_{705})$

Results optimal band setting for $CI_{red-edge}$:



Coefficient of variation (CV %) of canopy chlorophyll content estimation (maize and soybean) or canopy N content (grass and potato) by the R_{800}/R_{xxx} index, with R_{xxx} as the reflectance of a spectral band in the 500 – 800 nm interval.

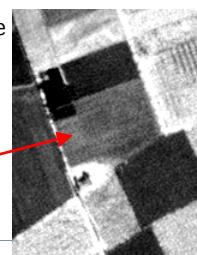
Results Vegetation indices using Sentinel-2 bands:

Summary: R^2 of linear relationship between indices and chlorophyll or N content.

Index	Maize	Soybean	Grass	Potato
Best $R_{800}/R_{xxx} - 1.0$	0.94	0.94	0.80	0.89
$CI_{red\ edge}$	0.92	0.94	0.77	0.89
CI_{green}	0.93	0.92	0.77	0.88
REP	0.92	0.70	0.79	0.85
MTCI	0.92	0.87	0.80	0.86
MCARI/OSAVI[705,750]	0.86	0.92	0.57	0.83
TCARI/OSAVI[705,750]	0.85	0.91	0.75	0.85
NDRE1	0.83	0.81	0.63	0.71
NDRE2	0.83	0.81	0.67	0.73

Conclusions

- The red-edge chlorophyll index is a linear estimator of canopy chlorophyll and N content.
- The best red-edge chlorophyll index uses a band in the range 700 nm – 720 nm in the denominator.
- Sentinel-2 red-edge bands are well positioned for deriving red-edge indices.



Map of canopy N content based on RapidEye data.

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