Comparison of different methods for estimates of vegetation biophysical parameters applying in-situ data and Sentinel-2, Proba-V data

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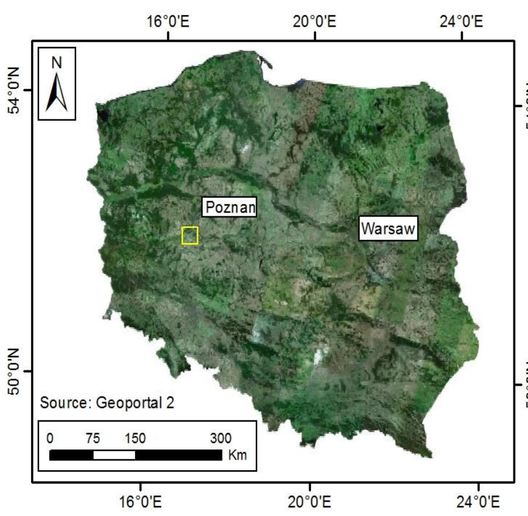
INTRODUCTION

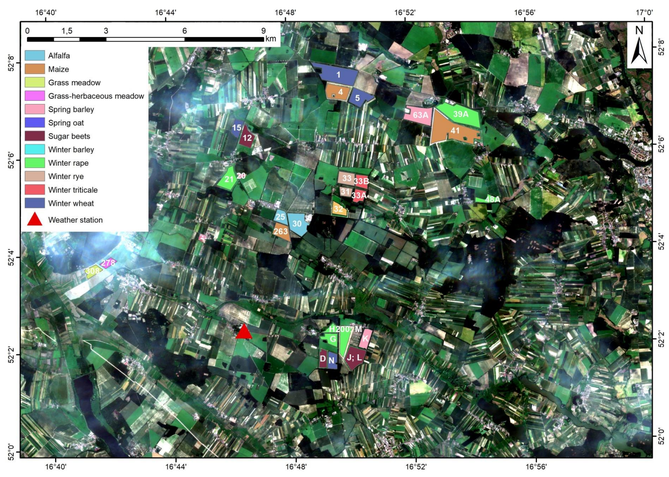
The presented work is performed and designed to be executed under the PhD studies. The work is application of the data for **ESA Project "Land Products Validation and Characterisation in support to Proba-V, S-2 and S-3 missions".**

The goal of the PhD thesis is to compare two methods for estimates of vegetation biophysical parameters, namely: statistical methods and PROSAIL radiative transfer model. The source data is composed of the in-situ data and satellite data acquired from Sentinel-2 and Proba-V satellites (2016-2017).

Wielkopolska agriculture test site in Poland



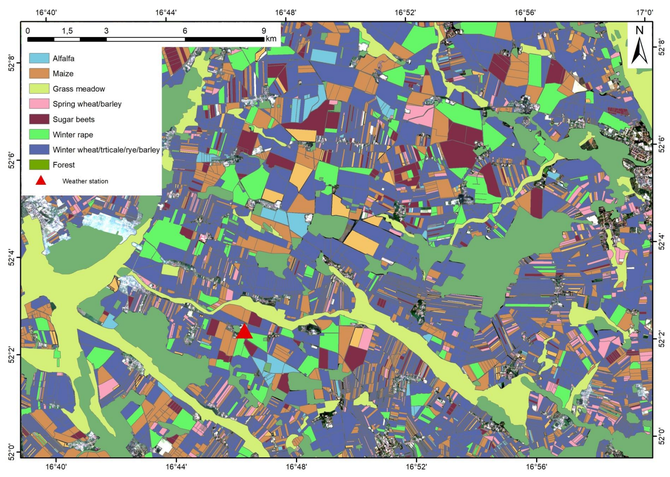
Test fields in Wielkopolska agriculture –
Sentinel-2 Image after Sen2Cor Correction



Sentinel-2 2017-06-20 RGB432

Map of crop classification in Wielkopolska 2017

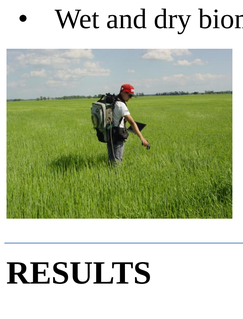
based on Sentinel-2: 2017-04-01; 2017-06-20; 2017-07-30; 2017-08-24

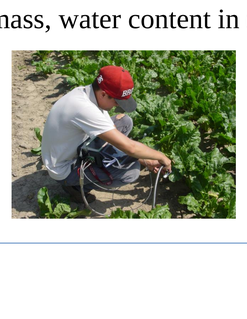


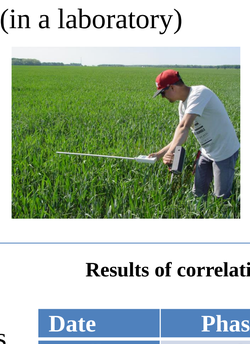
Overall accuracy: 85% Kappa coefficient:0.81

GROUND MEASUREMENTS

- Spectral responses by the ASD FieldSpec4 Hi-Res
- Chlorophyll fluorescence (with OSP5p+)
- Leaf Area Index (with LAI 2200 Plant Canopy Analyser)
- Soil moisture (with TRIME Field Measurement Devices)
- APAR (with AccuPar 80 instrument)
- Carbon balance (with chamber method)
- Radiance temperature (with EVEREST AGRI-THERM II)
- Chlorophyll (with FieldScout CM 1000 Chlorophyll Meter)
- Type of vegetation cover and its development stage
- Wet and dry biomass, water content in (in a laboratory)

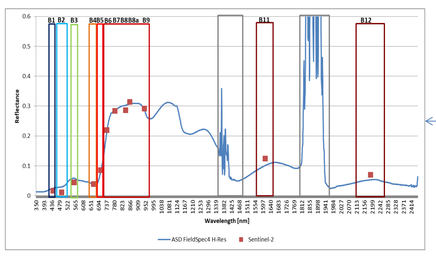






Reflectance by ground measurements and Sentinel-2

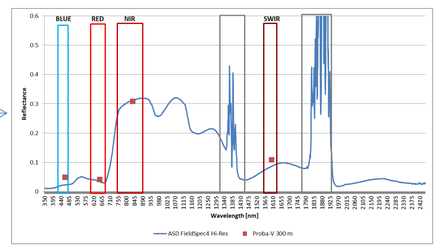
Winter wheat 2016-06-25



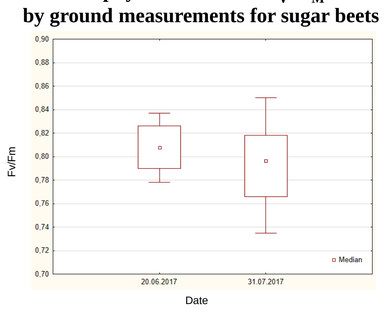
Milk ripening

Reflectance by ground measurements and Proba-V

Winter wheat 2016-06-25



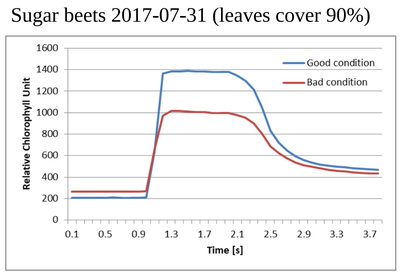
Chlorophyll fluorescence F_V/F_M test by ground measurements for sugar beets



Sugar beets 2017-06-20

Sugar beets 2017-07-31

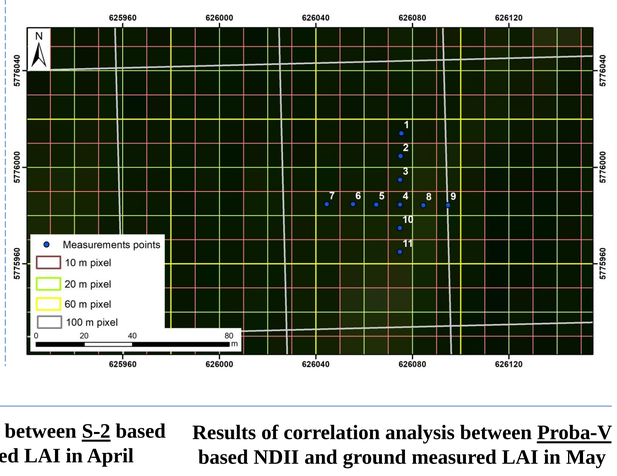
Sugar beets 2017-07-31 (leaves cover 90%)



All ground measurements have been collected during the satellite overpass. The size of the **Elementary Sampling Unit (ESU)** have been **10 m** for single measurements point.

In order to better characterize the whole field **the cross-transects** have been designed.

The scheme of cross-transect.



RESULTS

At the first stage of the work it was decided to make correlation analysis between particular vegetation indices derived from satellite images and **ground measured LAI values**, in order to find if significant relationship exists between these two parameters. The analysis was done separately at each date of the growing season for **winter wheat**.

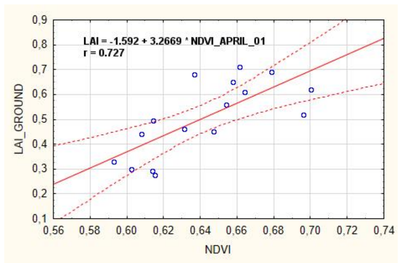
Results of correlation analysis (r coefficient) Sentinel-2

Date	Phase	NDVI	NDII	TVI	SAVI
April 01, 2017	Early tillering	0.727	**0.882**	0.839	0.862
May 01, 2017	Tillering	0.534	0.297	**0.706**	0.518
June 20, 2017	Milk ripening	**0.741**	0.606	0.588	0.652

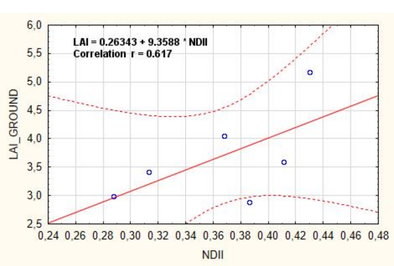
Results of correlation analysis (r coefficient) Proba-V

Date	Phase	NDVI	NDII
May 23, 2017	Heading	0.291	**0.617**
June 01, 2017	Heading	0.243	0.481
June 19, 2017	Milk ripening	0.416	0.332

Results of correlation analysis between S-2 based NDVI and ground measured LAI in April



Results of correlation analysis between Proba-V based NDII and ground measured LAI in May



Normalized Difference Vegetation Index

$$NDVI = \frac{NIR - RED}{NIR + RED}$$

Normalized Difference Infrared Index

$$NDII = \frac{SWIR - NIR}{SWIR + NIR}$$

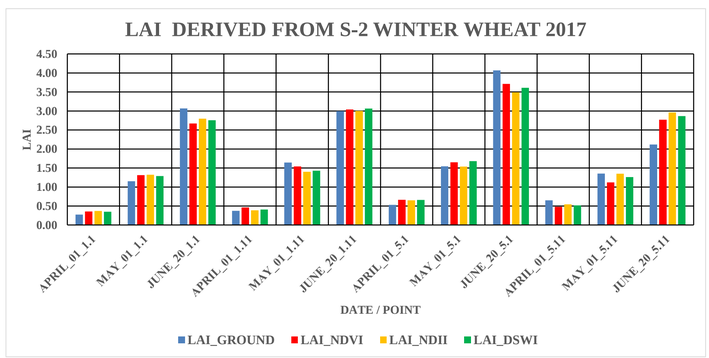
Soil Adjusted Vegetation Index

$$SAVI = 1.5 * \left[\frac{(NIR - RED)}{(NIR + RED)} + 0.5\right]$$

Triangular Vegetation Index

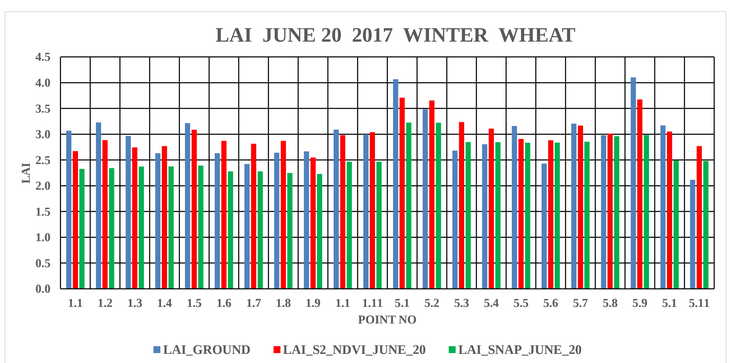
$$TVI = 0.5 * \left[120 * (REDEDGE - GREEN) - 200 * (RED - GREEN)\right]$$

Following approach used for 2017 data the regression equations derived from correlation analysis were applied for **estimating LAI values on the basis of particular vegetation indices.** Next, satellite based LAI values were compared with the ground control data, in order to estimate precision of LAI determination.



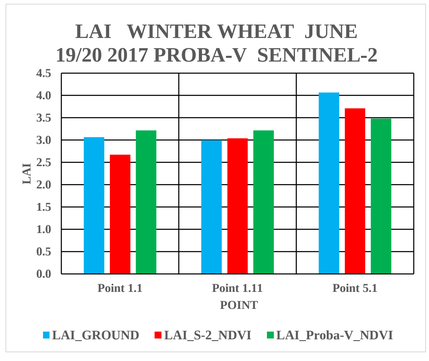
Mean difference between ground measured LAI and LAI derived from Sentinel-2 NDVI at mid-June (milk ripening) is 9 % (for 22 points)

Separate analysis was done for **estimating precision of LAI determination from Sentinel-2 data with the use of SNAP software**. LAI values derived applying this software were compared to ground measured ones.

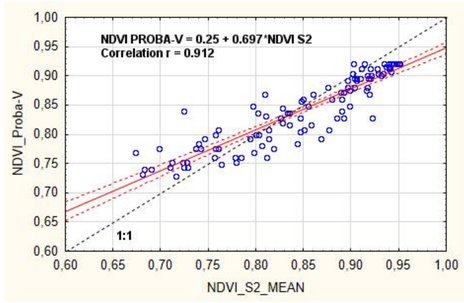


Mean difference between ground measured LAI and LAI derived from Sentinel-2 data using SNAP software at mid-June (milk ripening) is 15 % (for 22 points)

In order to assess **impact of ground resolution on values of vegetation indices** and hence on precision of LAI estimates a separate study has been done, **applying Proba-V data and Sentinel-2** images for this purpose. Within this study over 100 pixels from Proba-V at 100 m resolution were selected within various **wheat fields** and next Sentinel-2 pixels at 10 m resolution were precisely matched with them.



Results of correlation analysis between S-2 based and Proba-V based NDVI



Results of using the PROSAIL model in comparison of in-situ data and Sentinel-2 data for winter wheat 2016-06-25

Bands\Sensor	Sentinel-2 MSI	ASD FieldSpec4 DIFF [%]	PROSAIL model DIFF [%]
B1 (443 nm)	0.0078	-88	-133
B2 (490 nm)	0.0119	-39	-49
B3 (560 nm)	0.0387	2	-28
B4 (665 nm)	0.0233	18	29
B5 (705 nm)	0.0743	24	-21
B6 (740 nm)	0.2941	7	-12
B7 (783 nm)	0.4389	4	11
B8 (842 nm)	0.463	3	20
B8a (865 nm)	0.4728	3	23
B9 (945 nm)	0.4763	14	56
B11 (1610 nm)	0.1462	22	92
B12 (2190 nm)	0.0728	31	89

A preliminary analysis was made using the **PROSAIL model**. PROSAIL combines the leaf optical properties model **PROSPECT** with the canopy radiative transfer model **SAIL**. The models are coupled so that the simulated **leaf reflectance and transmittance** from PROSPECT are fed into the SAIL model, completed with information about soil optical properties and illumination/observation geometry.

Model	Input variable	Units
PROSPECT-5	Chlorophyll content	µg/cm2
	Carotenoid content	µg/cm2
	Brown pigment content / fraction brown leaf area	-
	Equivalent Water Thickness	cm
	Dry matter content	g/cm2
	Leaf structure parameter / structure coefficient	-

+

Model	Input variable	Units
4SAIL	Leaf Area Index	m2/m2
	Average leaf angle / mean leaf inclination angle	degrees
	Soil factor / soil brightness parameter	-
	Ratio of diffuse to total incydent radiation	%
	Hot spot size parameter	m/m
		-
	Solar zenith angle	degrees
	Observer zenith angle	degrees
	Azimuth / Relative azimuth angle	degrees