MAPPING OF BIOPHYSICAL PARAMETERS BASED ON HIGH RESOLUTION EO IMAGERY FOR JECAM TEST SITE IN UKRAINE

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Abstract

In this paper, we propose an approach for estimation biophysical parameters, namely LAI effective, FAPAR, and FCOVER, based on in-situ and satellite measurements. In-situ data were collected during 2013–2014 within several field campaigns at the JECAM test site in Ukraine. We have built 30-meter resolution crop specific maps of biophysical parameters based on regression dependencies between ground measurements and NDVI derived from high resolution imagery (Landsat, SPOT) and Proba-V (100 m) . In this paper, we discuss the best model selection for LAI effective, FAPAR and FCOVER mapping as well as selection of optimal source of satellite images. Obtained results are compared to available coarse resolution global biophysical products such as MODIS and SPOT-Vegetation.

Index Terms — *biophysical parameters, LAI, FAPAR, FCOVER, agriculture, remote sensing, JECAM, Ukraine.*

1. INTRODUCTION

Crop state assessment is an important component of agriculture resources monitoring. Such information allows identification of crop phenological indicators [1] and could be used as a proxy for crop yield [2] and production prediction [3]. Remote sensing images are valuable source of information for estimating crop state at regional, national and global scale [4]-[5]. Globally available products on crop state provide extremely important input to food security within, for example, the Global Agriculture Monitoring (GLAM) initiative [6].

Leaf area index (LAI), fraction of absorbed photosynthetically active radiation (FAPAR) and fraction of vegetation cover (FCOVER) are variables that characterize the crop state [7]. Coarse resolution images acquired by SPOT-VEGETATION, MODIS, and PROBA-V are used to provide regular products on biophysical parameters at global scale. In order to provide consistent and reliable information these products should be validated using ground measurements. Direct comparison of low resolution imagery at 1 km pixel size and point ground measurements is not possible since a 1 km pixel represents a mix of different vegetation types and states [8]. Therefore, an up-scaling protocol using high-resolution satellite imagery should be established as proposed by the CEOS Land Product Validation sub-group [9]. With the availability of large amount of optical images from Landsat-8, oncoming Sentinel-2, SPOT satellites, it becomes possible to provide high-resolution biophysical maps at detailed scale and regular basis. However, the effect of different high-resolution instruments usage and its spatial resolution should be further assessed in a quantitative manner in order to provide consistent high-resolution biophysical maps that should be also consistent with those from coarse resolution imagery. Hence, the particular objectives of this study are: (i) to assess coherence between biophysical maps derived from different high-resolution satellite images, namely Landsat-8, SPOT-4, and SPOT-5 as well as Proba-V; (ii) to study crop specific relationships between biophysical parameters and EO based indicators.

2. STUDY AREA AND DATA DESCRIPTION

All surveys on JECAM test site in Ukraine were performed at two scales: local sub-site (Pshenichne test site) of 3 km × 3 km and medium site (NUTS3 level) of area near 1000 sq. km [10].

Three field campaigns in 2013 (14-17 May, 12-15 June and 14-17 July) and two field campaigns in 2014 (12 Jun and 31 Jul) to characterize the vegetation biophysical parameters at the Pshenichne test site were carried out in the framework of the JECAM (Joint Experiment for Crop Assessment and Monitoring) initiative. Digital Hemispheric Photographs (DHP) images were acquired with NIKON D70 camera. Hemispherical photos allow calculation of LAI and FCOVER measuring gap fraction through an extreme wide-angle camera lens (i.e. 180º) [11]. The hemispherical images acquired during the field campaign were processed with the CAN-EYE software (http://www.avignon.inra.fr/can_eye) to derive LAI effective, FAPAR and FCOVER estimations. The in situ biophysical values were used for producing LAI, FCOVER and FAPAR maps from optical satellite images, and provide cross-validation and validation of global remote sensing products.

EO images acquired from Landsat-8 (at 30 m spatial resolution), SPOT-4 (20 m) and SPOT-5 (10 m) satellites were used to support ground observations and provide high-resolution biophysical maps. Satellite imagery was atmospherically corrected to derive surface reflectance values for each pixel. MOD15A2 and Copernicus Land Service GEOV1 products are validated with high resolution reference maps derived in this study.

3. METHODOLOGY

Ground observations followed the VALERI protocol in which the measurements were made for the elementary sampling units (ESUs) [12, 13]. A pseudo-regular sampling was used within each ESU of approximately 20×20 m. Within the 2013 campaign 30, 34, and 37 ESUs were collected while for 2014 28 and 25 ESUs were collected.

The largest dataset was collected for maize (up to 85 measurements for 2013-2014). Dataset for winter wheat was much smaller and distributed over 2013-2014 in a irregular way (most of measurements are made in 2014).

The NDVI vegetation index was used as a main variable to derive biophysical values (LAI, FAPAR, and FCOVER). We investigated two kinds of models: general for all crops and crop specific regressions for winter wheat and maize. The following metrics were used to assess efficiency of the models: (i) root mean square error (*RMSE*); (ii) cross-validation RMSE with a leave-one-out method (*RC*); (iii) model's adjusted coefficient of determination R^2.

Additionally, for maize and wheat as the main crops in the area of study crop specific models were built. For model assessment the same criteria have been used as in the first approach (*RMSE*, *RC*, R^2).

4. RESULTS

Relationships between satellite derived NDVI values and ground measurements of biophysical parameters were built using linear and exponential models and the best model was selected in terms of *RC* value. Statistical properties of all models were good enough in terms of *F-statistics* (Fisher's statistics - the measure of statistical model adequacy), and NDVI parameter was statistically significant which was confirmed by the hypothesis test *p-value that determines the significance of regression model coefficients* (predictor with p-value <0.05 is likely to be a meaningful addition to the model).

The obtained results showed that there was a good correspondence between biophysical parameters derived from different high resolution satellites.

For maize, the best results were achieved for campaigns of 2014 only with Landsat 8 data with a single factor exponential model for LAI (up to R^2=0.94), and linear single factor model for FAPAR (up to R^2=0.95) and FCOVER (up to R^2=0.92). Similar results are obtained for wheat from 2014 campaigns and Landsat 8 data: for LAI (up to R^2=0.9), for FAPAR (up to R^2=0.91), for FCOVER (up to R^2=0.63).

The 30-meter resolution maps of LAI for maize and winter wheat at JECAM test site were compared with available 1 km Copernicus and MODIS products. Comparison results are shown in Fig. 1 and Fig. 2 respectively.

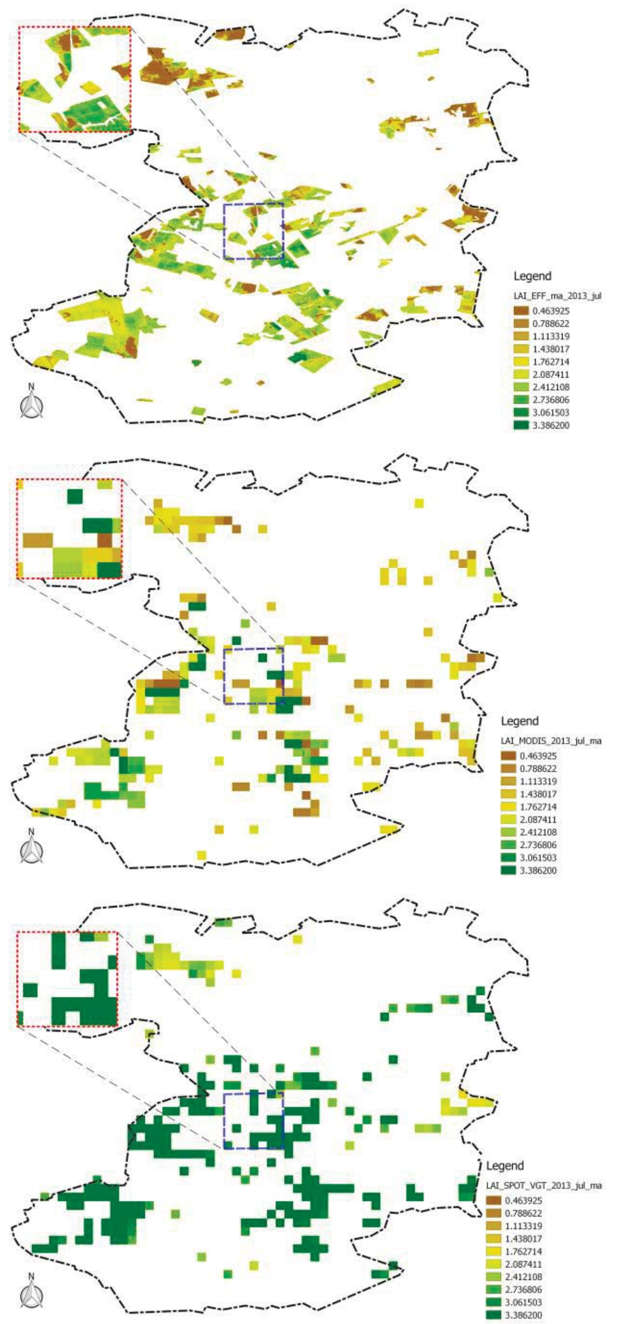

Fig. 1 Maize LAI comparison (July, 2013): modelled on Landsat 8 and ground data (top), MODIS MOD15A2 product (middle), SPOT-VGT Copernicus product (bottom).

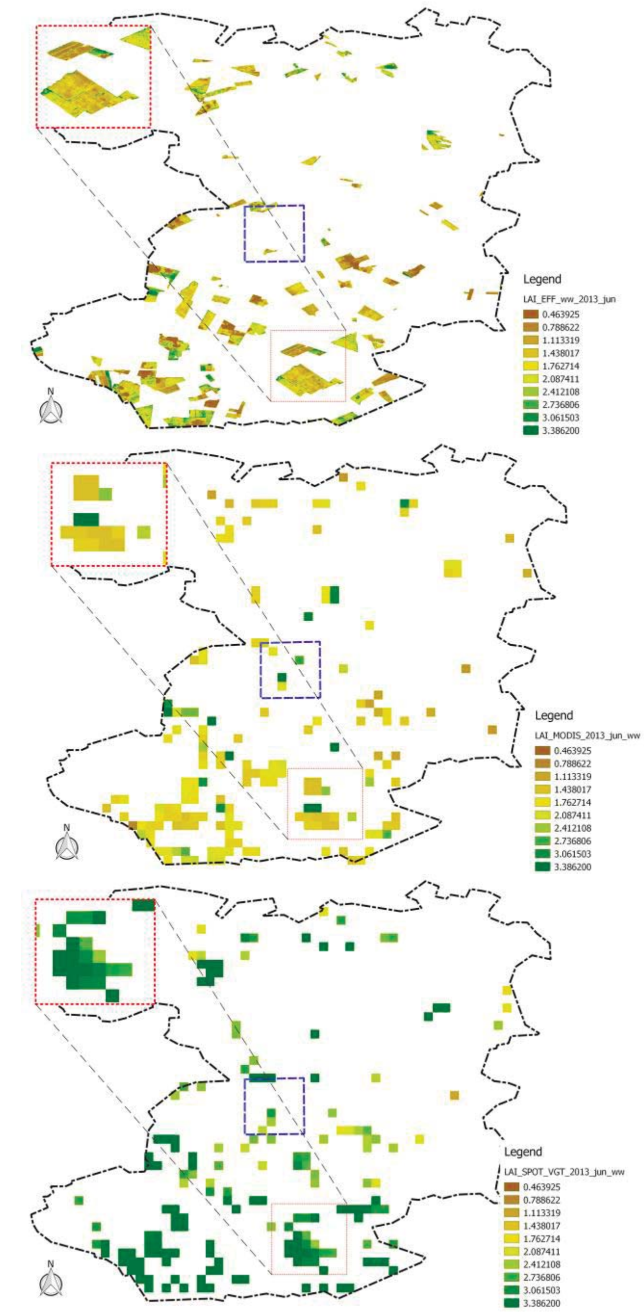

Fig. 2. Winter wheat LAI comparison (June, 2013,): modelled on Landsat 8 and ground data (top), MODIS MOD15A2 product (middle), SPOT-VGT Copernicus product (bottom).

In order to select the optimal source of satellite data for high resolution biophysical parameters mapping several sources of information were investigated: Landsat-8, SPOT-4, and PROBA-V. Statistical parameters of corresponding models in terms of R^2, *F-stat* and *p-val* are presented for comparison of SPOT-4 to Landsat 8 (Table 1) and PROBA-V to Landsat 8 (Table 2). Selected models for biophysical parameters mapping are statistically significant.

Table 1. Quality of regression models for maize, Landsat 8 vs SPOT-4, 2013

LAI				
	Landsat 8		SPOT-4	
Stat	Single lin.	Single exp	Single lin.	Single exp
R^2	*0.65*	*0.8*	0.65	0.78
F-stat	*82.9*	*221.5*	61.9	121
p-val	*1.7e-12*	*2.2e-16*	3.6e-9	9.6e-13
RMSE	*0.64*	*0.51*	0.42	0.51
FAPAR				
R^2	*0.74*	*0.79*	0.76	0.75
F-stat	*156.4*	*213.5*	107.5	97.5
p-val	*2.2e-16*	*2.2e-16*	4.6e-12	1.6e-11
RMSE	*0.14*	*0.37*	0.12	0.42
FCOVER				
R^2	*0.61*	*0.67*	0.65	0.58
F-stat	*83.7*	*110*	64.6	47.1
p-val	*5.7e-3*	*1.2e-14*	2.3e-9	6.7e-8
RMSE	*0.13*	*0.46*	0.1	0.53

Table 2. Quality of regression models for maize, Landsat 8 vs PROBA-V, 2014

LAI				
	Landsat 8		PROBA-V	
Stat	Single lin.	Single exp	Single lin.	Single exp
R^2	*0.87*	*0.94*	0.81	0.87
F-stat	*192.3*	*415.3*	114.3	176.2
p-val	*8.5e-14*	*2.2e-16*	3.3e-11	2.4e-13
RMSE	*0.34*	*0.2*	0.43	0.29
FAPAR				
R^2	*0.95*	*0.91*	0.88	0.85
F-stat	*467.7*	*288*	190.2	156.6
p-val	*2.2e-16*	*6.2e-16*	9.7e-14	9.5e-13
RMSE	*0.06*	*0.13*	0.08	0.18
FCOVER				
R^2	0.92	*0.88*	0.86	0.82
F-stat	307.5	*198.4*	161.3	126.2
p-val	1.3e-5	*5.9e-14*	6.7e-13	1.1e-11
RMSE	0.07	*0.17*	0.09	0.21

To compare our crop-specific maps for wheat and maize with global biophysical products at lower spatial resolution the following approach is proposed. Several fields for maize and wheat were selected within the JECAM test site (NUTS-3) and averaged values of corresponding products for these fields were compared (5-7 low resolution pixels per field). For winter wheat LAI (Fig. 3), Copernicus biophysical product showed steady overestimation while MODIS product was quite close to the results of this study (8-22% of difference for LAI, 3-15 % for FAPAR – both at mid of Jun, 2013). Similar results were obtained for maize (in July 2013 6 – 38 % for LAI, 0- 42 % for FAPAR).

5. DISCUSSIONS AND CONCLUSION

In the paper crop specific regression dependencies between measured in-situ biophysical parameters (LAI, FAPAR and FCOVER) and high resolution satellite data (Landsat, Spot-

4) as 100-m Proba-V are proposed and investigated. We developed single factors regression models that relate LAI effective, FAPAR and FCOVER for winter wheat and maize at JECAM Ukraine test-site with NDVI, extracted from satellite data, as a predictor and built correspondent maps. According to our study LAI is related to NDVI with exponential single factor regression model, while FAPAR and FCOVER — with single factor linear model.

In order to select the optimal source of satellite data for high resolution biophysical parameters mapping several sources of information were investigated: Landsat-8, SPOT-4, and PROBA-V.

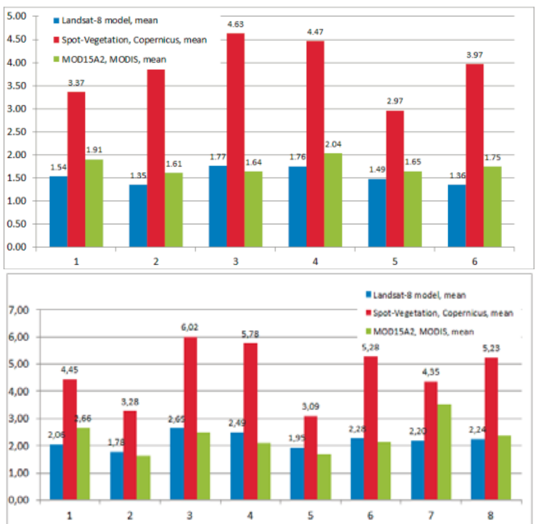

Fig. 3- LAI validation (2013): modelled on Landsat 8 and in-situ data, MODIS MOD15A2 product and SPOT-VGT Copernicus product: wheat for June (top), maize for July (bottom)

Due to rather good spatial and temporal resolution Landsat-8 could be considered as the optimal source of satellite data for high resolution biophysical parameters mapping.

The validation of global low resolution products with crop specific maps showed a good agreement of the MODIS LAI products. At the same time Copernicus SPOT/VGT GEOV1 products overestimate the biophysical parameters and more close to LAI true than to LAI effective.

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