Sensagri

Sentinels Synergy for Agriculture

Deliverable D7.12

Second Validation of Leaf Area Index Maps

V 1.0

The research leading to these results has received funding from the European Union's Horizon 2020 Research and Innovation Programme, under Grant Agreement nº 730074

Document information

Project Number	730074	**Acronym**	SENSAGRI
Full Title	Sentinels Synergy for Agriculture		
Project URL	http://sensagri.eu		
Project Coordinator	José F. Moreno. IPL – University of Valencia (Spain)		
EU Project Officer	Massimo Ciscato		

Deliverable	**Number**	D7.12	**Title**	Second Validation of Leaf Area Index Maps
Work Package	**Number**		**Title**	

Date of Delivery	**Contractual**	M34	**Actual**	M35	
Status	Version 1.0		Final ☐		
Type[1]	R ☒	DEM ☐	DEC ☐	OTHER ☐	ETHICS ☐
Dissemination Level[2]	PU ☒	CO ☐	EU-RES ☐	EU-CON ☐	EU-SEC ☐

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Abstract (for dissemination)	This document reports the second validation results of the independent LAI Green and LAI Brown retrieval models developed by UVEG. The retrieval is based on models trained and optimized with LAI ground measurements and Sentinel-2 (S2) data, using Gaussian Processes Regression (GPR).
Keywords	LAI Green, LAI Brown, S2, GPR

Version Log			
Issue Date	**Rev. No.**	**Author**	**Change**
27/09/2019	0.1	Eatidal Amin	First version
27/09/2019	1.0	Antonio Ruiz	First revision

[1] R = Document, report; DEM = Demonstrator, pilot, prototype; DEC = Websites, patent fillings, videos, etc; OTHER; ETHICS = Ethics requirement

[2] PU = Public; CO = Confidential (Consortium and Commission Services); EU-RES = Restreint UE; EU-CON Confidentiel UE; EU-SEC = Secret UE (Commission Decision 2005/444/EC)

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1. Introduction

1.1. Scope of the document

The present document provides the main results of the second validation of the SENSAGRI LAI Green and LAI Brown products, both derived independently with the LAI processor developed by UVEG. The retrieval is based on new improved models that were trained and optimized with and extended LAI ground measurements database and S2 data, using GPR.

1.2. Notations, abbreviations and acronyms

DHP	Digital Hemispherical Photo
ESU	Elementary Sample Units
GPR	Gaussian Processes Regression
LAI	Leaf Area Index
MSEs	Mean squared systematic error
MSEu	Mean squared unsystematic error
NRMSE	Normalized Root-mean-squared error
R^2	Coefficient of determination
RMSE	Root-mean-squared error
S2	Sentinel-2

2. Performance measures

The performance of the product must be evaluated to assess the uncertainty of calibrated S2 derived LAI estimates. The uncertainty metrics calculated are those described by Sexton et al., 2013, based on root mean squared error (RMSE):

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(M_i - R_i)^2}{n}}$$

where M_i and R_i are estimated and reference LAI values at an ESU i in a set of n units, randomly selected among the whole data set of ESUs selected for validation, so to be representative of the LAI variation per each type of crop grown in the study area. After modelling the relationship between M_i and R_i by linear regression, RMSE can be split into components: systematic error (MSE_S) and unsystematic error (MSE_U):

$$MSE_S = \sum_{i=1}^{n} \frac{(\widehat{M}_i - R_i)^2}{n}$$

$$MSE_U = \sum_{i=1}^{n} \frac{(M_i - \widehat{M}_i)^2}{n}$$

where $\widehat{M}_i$ is the LAI value predicted by the linear relationship (Willmott, 1982). Accuracy is quantified by the difference between the trend of the model over reference LAI (MSE_S), whereas precision by the variation around this trend (MSE_U). As MSE_S and MSE_U sum to Mean-Square Error (MSE), it results:

$$RMSE = \sqrt{MSE_S + MSE_U}$$

For consistency, all the errors should be expressed in terms of root mean squared errors.

3. Leaf Area Index products

Leaf Area Index maps are processed from S2 images into multiband GEOTIFF files. Each file contains 8 bands (LAI Green, LAI Brown and other derived parameters, see D4.08). These files are produced according to SENSAGRI proposed algorithm with software v0.2 (D4.7) and retrieval algorithm v0.4 (D4.9). The retrieval is based on new improved models that were trained and optimized with and extended LAI ground measurements database and S2 data, using GPR (D4.09). The spatial resolution is 20m and the spatial reference system is WGS84 in UTM projection (site-specific UTM zone). Note that in this document only LAI Green and LAI Brown bands were validated.

As new field datasets were available for carrying out the second validation report, some data was also used to improve the GPR LAI Green and LAI Brown independent models. For that, the respective training datasets were extended with new field data and thus trained again. On one hand, this step helped to lower the errors and to improve the accuracy of the validation results. Also, a greater LAI values variability is now represented in the respective models. Note that in this document only LAI Green and LAI Brown bands, processed with the latest model release, were assessed. Field data used for validate the LAI Green and LAI Brown models were collected in France, Poland, Ukraine and Spain.

4. Validation in European test sites

The validation here presented consists of comparing the Elementary Sample Unit (ESU) LAI measurement against the SENSAGRI LAI product pixel value, corresponding to the centre coordinates of the sampled ESU. Thus, five LAI measurements were collected in each ESU, according the Figure 1 of the D7.03. (Sampling approach for each ESU). The individual LAI field measurements were done at ESU level using a non-destructive method with the LAI-2000 Plant Canopy Analyser (hereinafter LICOR-LAI), the ceptometer ACCUPAR model LP-80 (hereinafter ACCUPAR) and Digital Hemispherical Camera (DHP). The smallest extent of elementary sampling unit (ESU) is defined as the minimum area compatible with the resolution of the satellite product to be validated. The objective of the sampling strategy is to use the pattern of ESUs, to capture the variability across the site extent, and the repeated measurements within the each ESU, to capture the variability within the high spatial resolution imagery (~20 m). Thus, five LAI measurements were collected in each ESU, according the Fig. 1 of the D7.03. (Sampling approach for each ESU).

5. LAI Green

Next sections present LAI Green latest model's validation statistics. This model was validated using an independent ground measurements dataset, collected in 2017-2018 from three different test sites: France, Poland and Ukraine.

5.1. French test site: 2017/2018

From the French test site, two field data collections are available: (1) wheat/barley and oilseed-rape campaign (from 29/11/2017 to 20/06/2018) and (2) maize/soy campaign (from 28/05/2018 to 11/10/2018). 52 ESUs were used to validate the LAI Green model over Lamasquère region. The LAI measurements were carried out using the DHP (Digital Hemispherical Photo) instrument and processed with the Caneye software. Validation results are shown in Figure 1. In general terms, the SENSAGRI product tends to overestimate the measured LAI, especially at low values, while at mid values, LAI estimation is closer to the measured value. Also, the proportion of the error due to the systematic component is lower than the unsystematic.

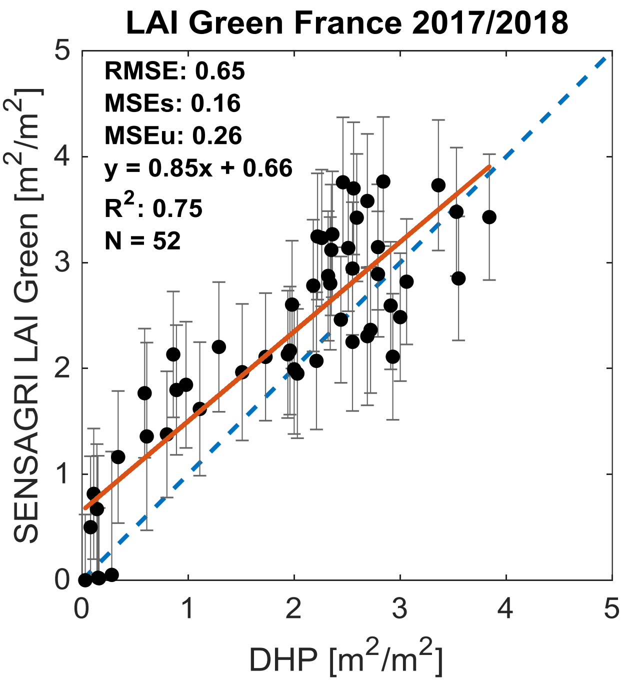

Figure 1. Scatter plot of the SENSAGRI LAI Green estimations against LAI ground data measured with DHP over France. Blue line represents the 1:1 line and the red line corresponds to the linear fit applied. Error bars show the intrinsic standard deviation provided by the GPR retrieval model (y axis).

5.2. Polish test site: 2018

Over the polish test site, several field campaigns took place during the spring- summer season 2018. A total of 50 ESUs were used to validate the LAI Green model performance. LAI values were taken following the procedure by means of LICOR-LAI instrument. Main crops sampled were maize, winter wheat, triticale and oil seed rape. Figure 2 shows the corresponding validation results. According to Figure 2, for LAI values higher than 3, the estimates mainly underestimate the corresponding LAI measures, leading to a worse correlation.

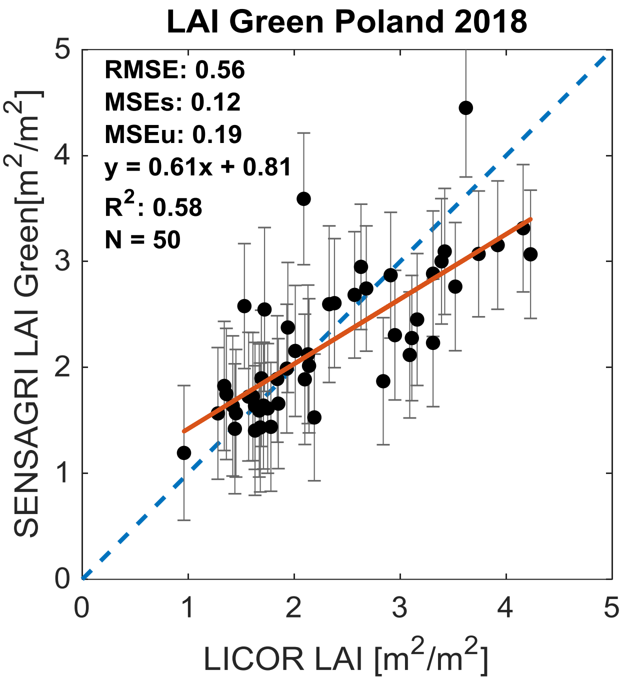

Figure 2. Scatter plot of the SENSAGRI LAI Green estimations against LAI ground data measured with LICOR-LAI over Poland. Blue line represents the 1:1 line and the red line corresponds to the linear fit applied. Error bars intrinsic standard deviation provided by the GPR retrieval model (y axis).

5.3. Ukrainian test site: 2018

For the Ukrainian test site, the validation data consists of 40 ESUs measured from May 2018 to November 2018 using CANON 550D camera. Several crop types were sampled. Mostly, winter wheat, maize, sunflower and soybean crops. Validation results are shown in Figure 3. For this test site, the SENSAGRI product tends to overestimate the measured LAI, while highest values are not accurately retrieved. Although a relative high correlation was obtained, the associated error was also the highest of all test sites.

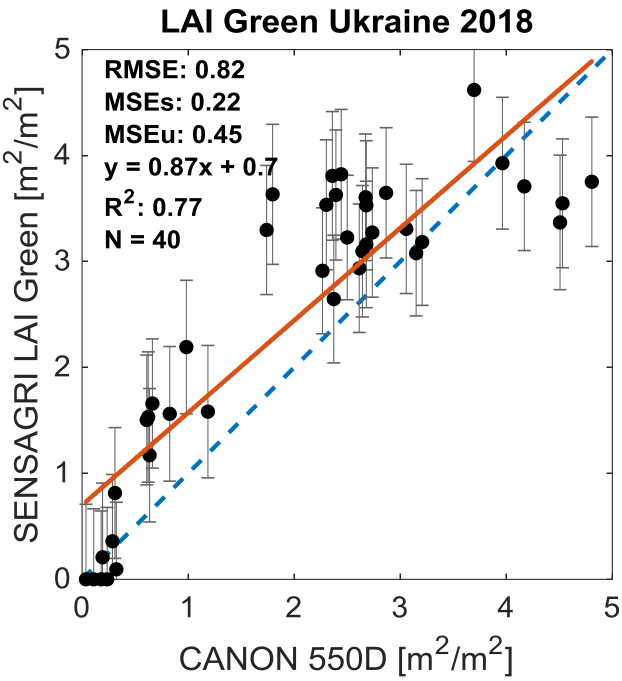

Figure 3. Scatter plot of the SENSAGRI LAI Green estimations against LAI ground data measured with CANON 550D camera over Ukraine. Blue line represents the 1:1 line and the red line corresponds to the linear fit applied. Error bars intrinsic standard deviation provided by the GPR retrieval model (y axis).

5.4. Joint assessment

Finally, Figure 4Figure 4. shows the validation results for LAI Green considering all the SENSAGRI test sites validation datasets together. Statistics calculated evaluate the error on 0.67, and a correlation R^2 = 0.7. No systematic error is observed, and effectively the unsystematic error component is lower than the systematic one. Also, there was no specific site-crop, since similar crops were sampled over all test sites. Particularly, low values are poorly retrieved and are mainly overestimated. From 2 to higher LAI values, there is more dispersion of pair of points and therefore the model is less precise.

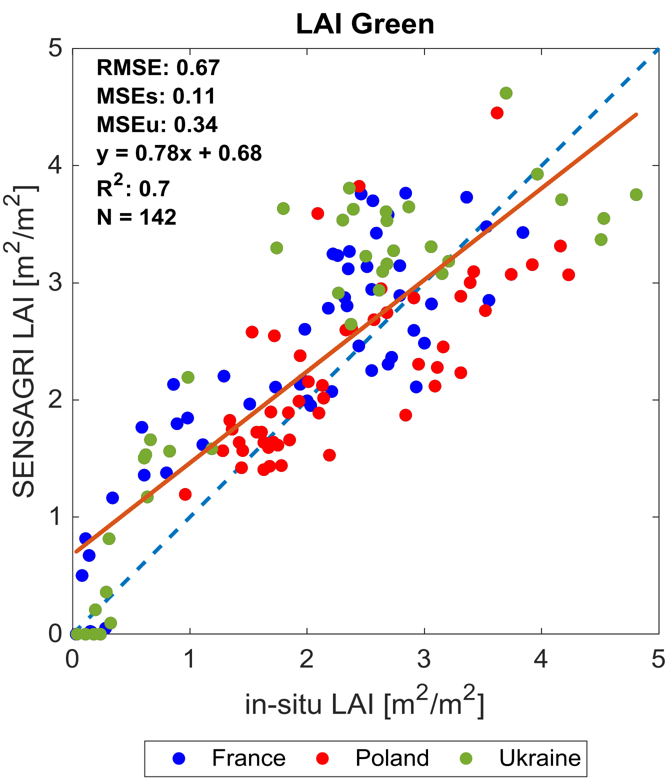

Figure 4. Scatter plot estimated SENSAGRI LAI Green vs LAI collected in-situ for all test sites validation datasets

6. LAI Brown

The LAI Brown GPR model presented in the previous validation report has been improved by adding new field data to the training database, and therefore new model's validation statistics were obtained using new field data from Spain.

6.1. Spanish test site: 2019

New LAI Brown model version was validated using an independent field dataset, which was collected in Valladolid (Spain) from 17/06/2019 to 02/07/2019. A total of 98 ESUs over senescent fields were measured using ACCUPAR instrument, although 58 ESUs were discarded mainly due to cloud cover and geolocation errors. In total 40 ESUs were used for validation. Main crops observed were wheat, barley, rapeseed and oat. It should be mentioned that this model was only validated in the Spanish test site, since there was no other dataset available.

Figure 5 shows the validation results. Overall, all the model performance was improved respect to the first validation report. The RMSE evaluated the model error in 0.43, with a higher unsystematic component (MSEu = 0.11) than the systematic (MSEs = 0.07). On the other hand, the correlation was assessed with R^2 = 0.62. There is more disagreement between estimates and measures within the LAI range between 2 and 3, while at lower and higher LAI Brown values there is a better matching, as they are closer to the 1:1 line.

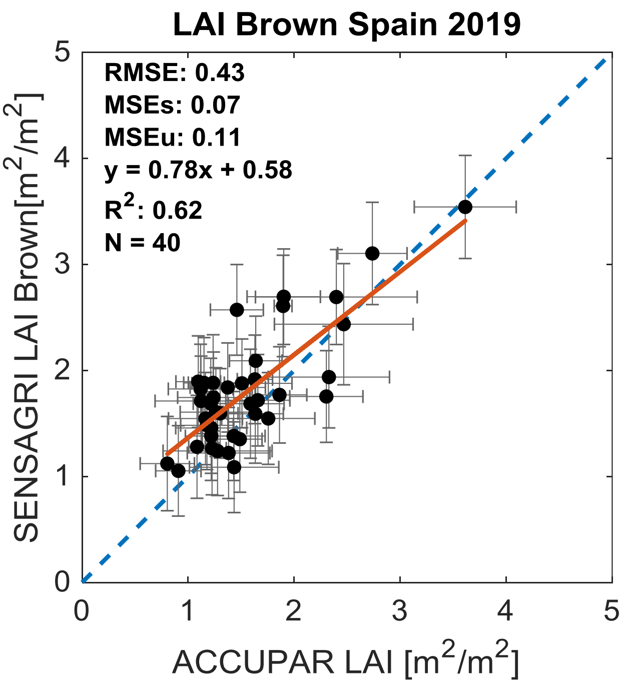

Figure 5. Scatter plot of the SENSAGRI LAI Brown estimations against LAI ground data measured with ACCUPAR. Blue line represents the 1:1 line and the red line corresponds to the linear fit applied. Error bars show the standard deviation of the LAI measured with the ACCUPAR instrument (x axis) and the intrinsic standard deviation provided by the GPR retrieval model (y axis)

7. Conclusions

Overall, all the accuracy and correlation statistics were considerably improved respect to the first validation report (D7.8), applying the same validation strategy. All validation datasets where evaluated independently for each test site.

In the case of LAI Green, validation analysis revealed some differences between test sites. Best correlation was obtained for the Ukrainian dataset, although the RMSE was highest. On the other hand, the Polish test site, presents the lowest error and correlation. It should be noted, that the reference data used for validation over the French and Ukrainian site were measured by a camera and a sampling methodology, which were not used before neither for training nor validation. Also, this was the first time these test sites were evaluated.

Particularly for LAI Green, low and mid LAI values are retrieved more consistently than high values. In view of the results, LAI Green model showed low precision and a saturation effect around 4. In the case of LAI Brown there were less discrepancy between estimated-measured pair of points. However, to better assess the portability and robustness of LAI Brown model, it should be validated in other test sites.

Regarding the error statistics, for LAI Brown the calculated error was lower than for LAI Green, although less ground measurements were used. For all test sites MSEs represents a lower weight compared to the MSEu, meaning that both models do not have an evidence bias.

Finally, it should be stressed that the training datasets with not enough quality may cause biases in LAI retrievals. The LAI measure is affected by several factors: sampling protocol, changes in weather conditions, operator measurer, etc. Also, for several field campaigns, there is a time gap between the LAI measure day and the S2 image acquisition. The field experience reveals that for sparse and low canopies the LAI measure leads to higher errors. Additionally, following the pixel-wise comparison validation strategy, without spatial averaging, some noise might affect the estimation value due to a shift in the pixel geolocation, especially in heterogeneous fields.

Reference documents

SENSAGRI Deliverable D4.07. Software of the final operational LAI prototype

SENSAGRI Deliverable D4.09. Final LAI Algorithm Theoretical Basis Document

Sexton J.O., Song X.-P., Feng M., Noojipady P., Anand, A., Huang C., Kim D.-H., Collins K.M.;, Channan S., DiMiceli C., 2013. Global, 30-m resolution continuous fields of tree cover: Landsat-based rescaling of MODIS vegetation continuous fields with lidar-based estimates of error. Int. J. Digit. Earth 2013, 6, 427–448.

Willmott C. J., 1982. Some Comments on the Evaluation of Model Performance. Bull. Am. Meteorol. Soc., 63, 1309–1369.