Sensagri

Sentinels Synergy for Agriculture

# The SENSAGRI Sentinel-2 LAI green/brown product: algorithm development, validation and mapping

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VNIVERSITAT DE VALÈNCIA

IPL

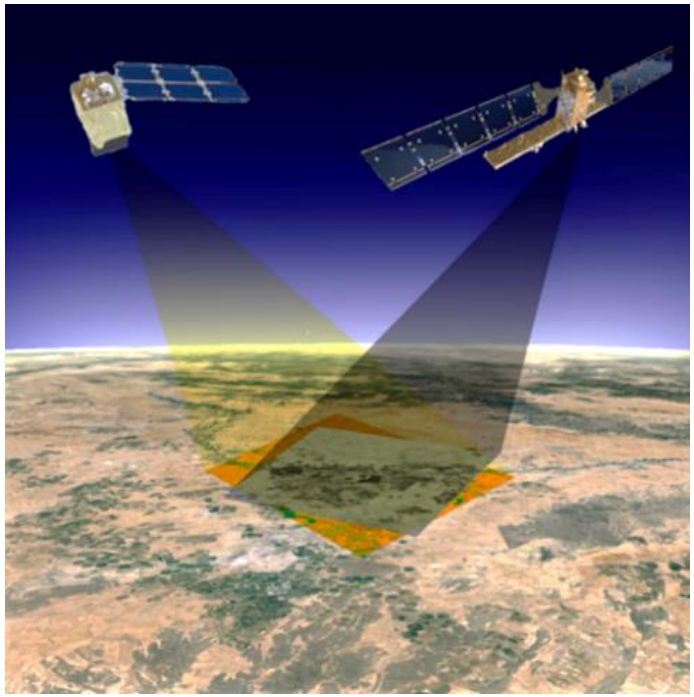
Laboratory for Earth Observation

# Sentinels Synergy for Agriculture

Sensagri

Copernicus

HORIZON 2020



Aims to exploit the capacity of **Sentinel-1** and **Sentinel-2** images to develop an innovative portfolio of prototypes agricultural services:

- Surface Soil Moisture
- Crop type mapping
- **LAI *green* and *brown* retrieval**

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issia cnr

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CESBIO

crea

INSTITUTO TECNOLÓGICO AGRARIO

Junta de Castilla y León

Consejería de Agricultura y Ganadería

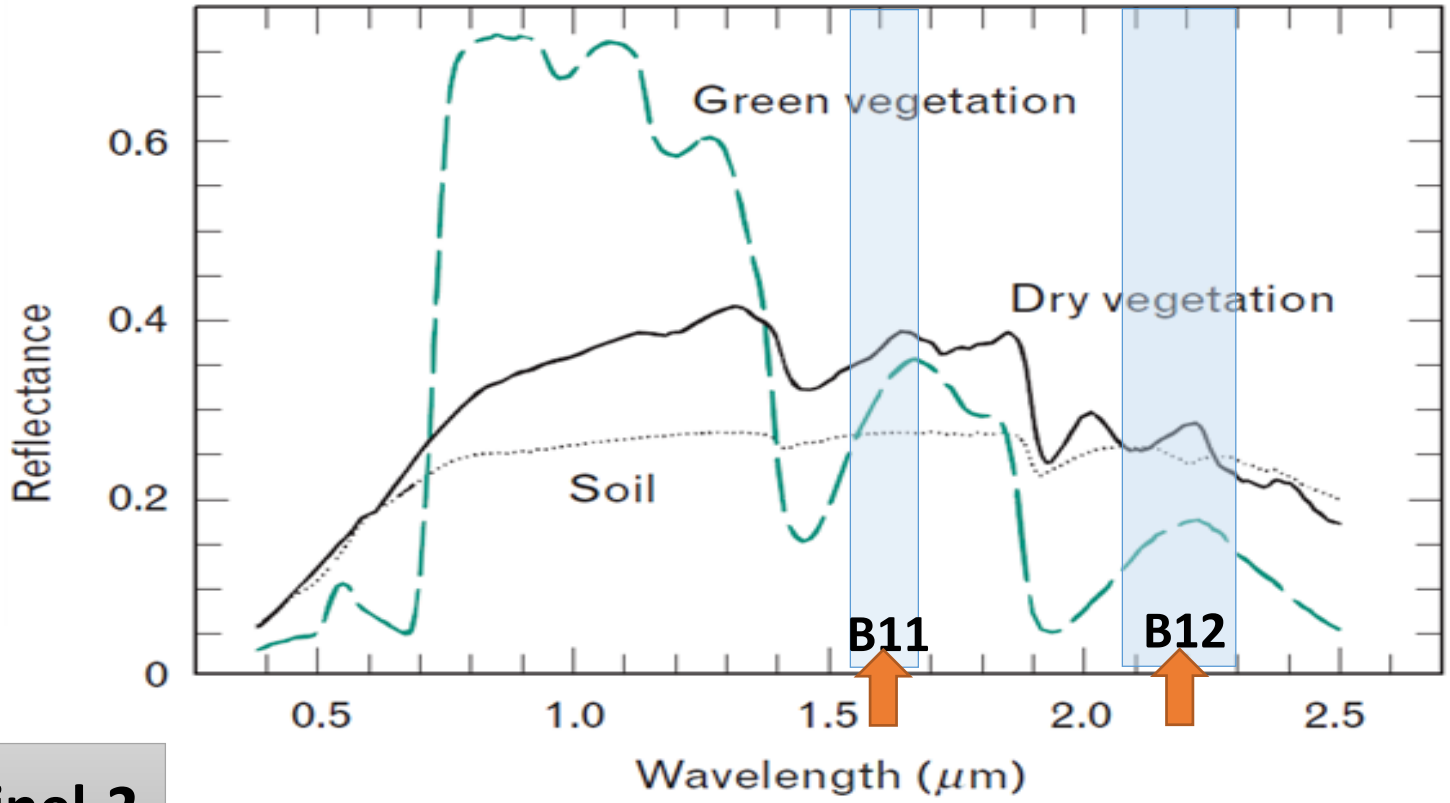
INSTYTUT OCHRONY ROŚLIN PAŃSTWOWY INSTYTUT BADAWCZY

# LAI green/brown

**Green vegetation**
Current operational LAI products focus on vegetation in photosynthesizing stage

**Senescent vegetation**
- ✓ Significant amount of aboveground biomass
- ✓ Key factor in the carbon cycle
- ✓ Crop damage monitoring
- ✓ Fire risk monitoring

# LAI green/brown




**Sentinel-2**

| Band # | B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B8a | B9 | B10 | B11 | B12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Band center (nm) | 443 | 490 | 560 | 665 | 705 | 740 | 783 | 842 | 865 | 945 | 1375 | 1610 | 2190 |
| Band width (nm) | 20 | 65 | 35 | 30 | 15 | 15 | 20 | 115 | 20 | 20 | 30 | 90 | 180 |
| Spatial resolution (m) | 60 | 10 | 10 | 10 | 20 | 20 | 20 | 10 | 20 | 60 | 60 | 20 | 20 |

*Brown and green LAI mapping through spectral indices. Delegido et al. 2015*

# Gaussian Processes Regression (GPR)

- Machine Learning Regression Algorithm **(MLRA)**
- **Training datasets** of Input – Output data pairs

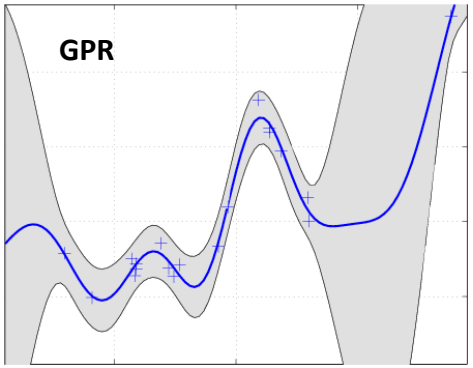
- **Input**: Reflectance observations
- **Output**: Biophysical variable (**LAI**)

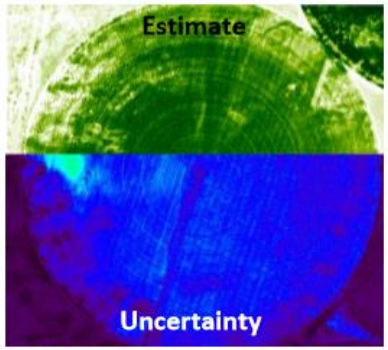
Contents lists available at ScienceDirect
ISPRS Journal of Photogrammetry and Remote Sensing
journal homepage: www.elsevier.com/locate/isprsjprs

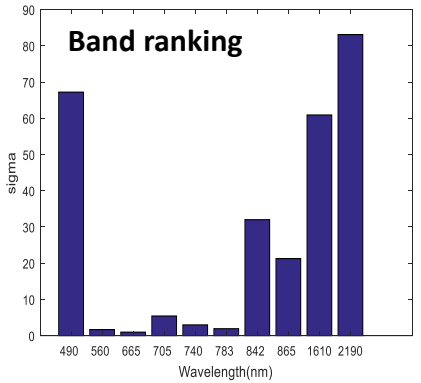
Experimental Sentinel-2 LAI estimation using parametric, non-parametric and physical retrieval methods – A comparison

Jochem Verrelst [a,*], Juan Pablo Rivera [a], Frank Veroustraete [b], Jordi Muñoz-Marí [a], Jan G.P.W. Clevers [c], Gustau Camps-Valls [a], José Moreno [a]

- **Delivery of associated uncertainties**
- **Ranking of the spectral bands relevance**



# GPR model development (v.01)

**LAI green** (164 points)

- **Barrax, Spain**
  12th to 14th July 2003
- **Valencia, Spain**
  7th April 2017
- **Bílý Kříž, Czech Republic**
  31th August 2016

**LAI brown** (50 points)

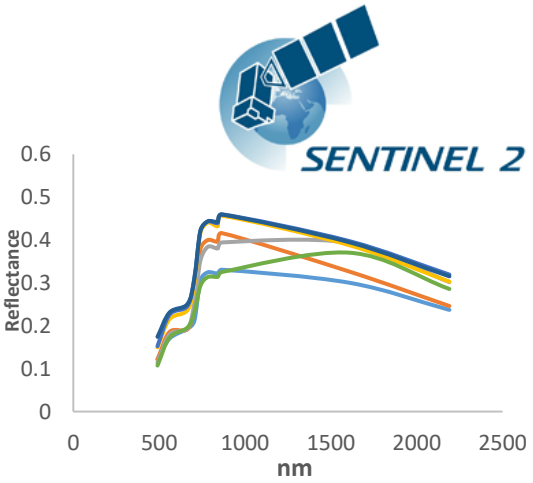
- **Barrax, Spain**
  12th to 14th July 2003
- **Valladolid, Spain**
  20th to 22nd June 2017

**Non-vegetated (LAI=0)**

Bare soil, roads, buildings

**S2 images:**

- Argentina, France, Spain, Poland




**Training database**

MATLAB

ARTMO

**K-Fold cross validation 4k**

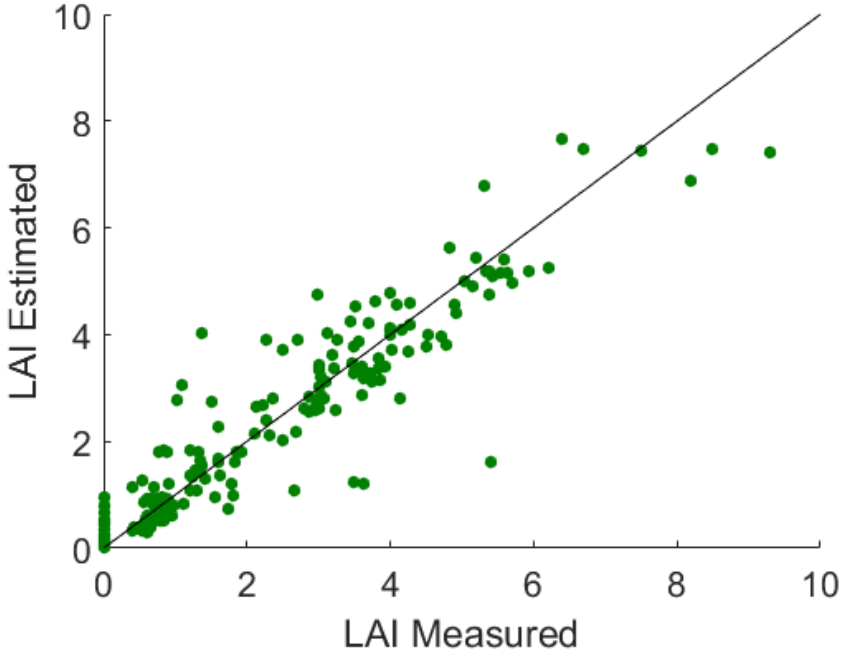
**GPR model LAI *green***

**GPR model LAI *brown***

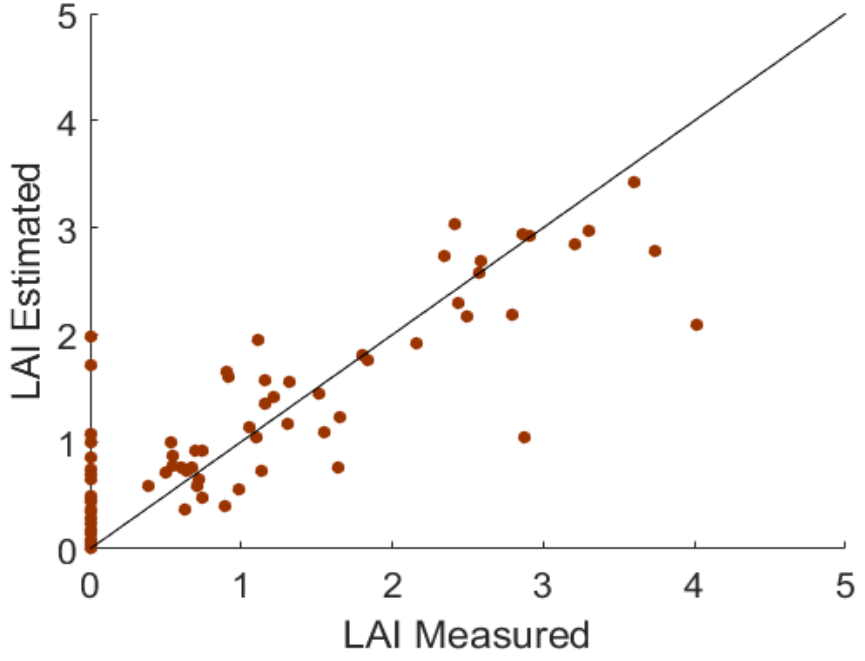
# GPR model evaluation & optimization

| Model | $RMSE_{C-V}$ [$m^2/m^2$] | $NRMSE_{C-V}$ (%) | $R^2_{C-V}$ | Time [s] |
|---|---|---|---|---|
| LAI green | 0.66 | **7.09** | **0.89** | 0.58 |
| LAI brown | 0.55 | **13.66** | **0.75** | 0.35 |

LAI green



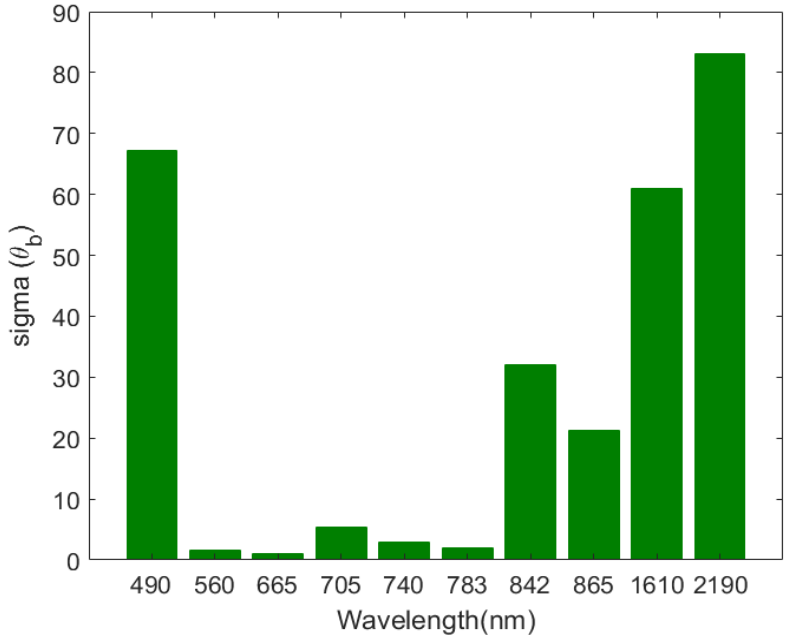

LAI brown



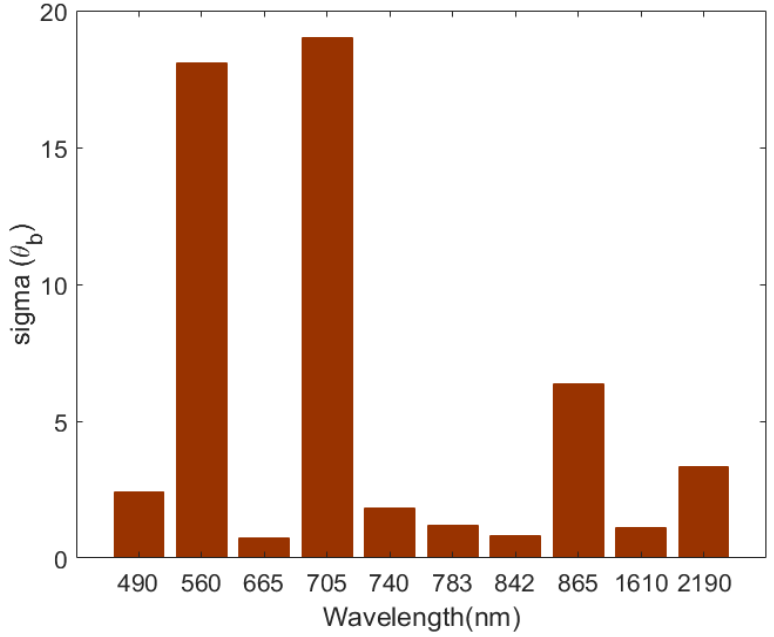
# GPR model evaluation & band analysis

| Model | $RMSE_{C\text{-}V}$ [$m^2/m^2$] | $NRMSE_{C\text{-}V}$ (%) | $R^2_{C\text{-}V}$ | Time [s] |
|---|---|---|---|---|
| LAI green | 0.66 | **7.09** | **0.89** | 0.58 |
| LAI brown | 0.55 | **13.66** | **0.75** | 0.35 |

LAI green




LAI brown

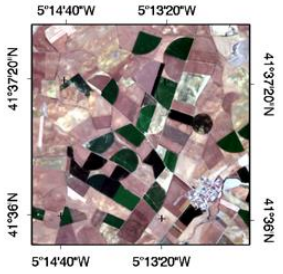



**The lower the sigma the more relevant the band**

$$CV = \left(\frac{SD}{\mu}\right) * 100$$

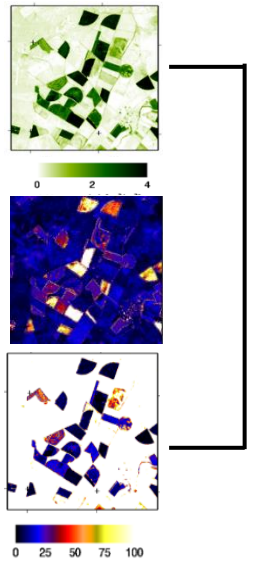
**MASK**
Uncertainty threshold = **CV<50 %**

**S2 image**

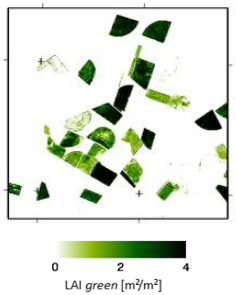



**GPR model LAI green**

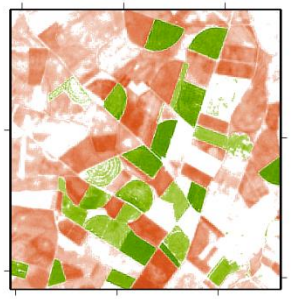
- **μ [m²/m²]**
- **SD [m²/m²]**
- **CV [%]**




**MASK CV<50%**

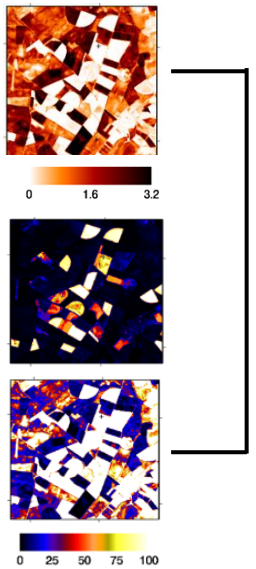



**Composite map**

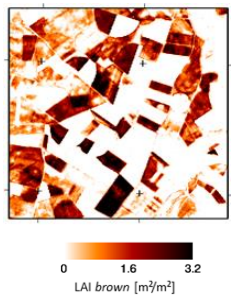


**GPR model LAI brown**

- **μ [m²/m²]**
- **SD [m²/m²]**
- **CV [%]**

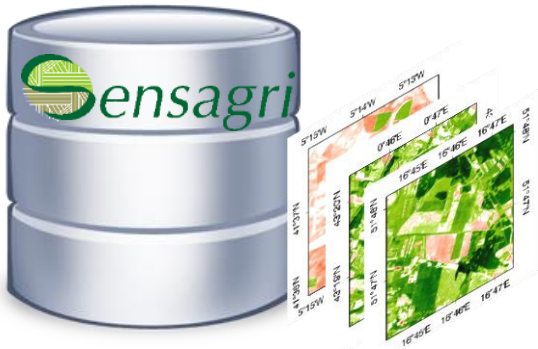



**MASK CV<50%**



# Prototype Software

MATLAB




```
Editor - C:\Users\1\Desktop\SENSAGRI_git_prueba_EDIT\sensagri.m
sensagri.m
1  classdef sensagri
2      %UNTITLED Summary of this class goes here
3      %   Detailed explanation goes here
4
5      properties
6          num_read_lines=100;
7          num_pixel_processing=inf;
8          image_factor_conv=1.000;
9          nonegativo=0.000001
10         resolution=20;
11         mask_option=2;%0=no mask, 1=cloud mask, 2=onl
12         umbralG=50
13         umbralB=50
14         colormapG
15         colormapB
16         colormapT
17         transG_=0.6
18         transB_=0.4
19         winSCP_path='C:\Program Files (x86)\WinSCP'
20     end
```

**INPUTS**

```
>> obj=sensagri('fullpath LAI green GPR model','fullpath LAI brown GPR model')
```

**GPR Models** → **Load GPR parameters and retrieval algorithm** ⇄ class **sensagre_gpr**

```
>> state=obj.retrieval('Input directory of S2 images','Output directory of delivery products')
```

**PROCESSING CHAIN**

**S2 images** → **List and read S2 images in the directory** ⇄ class **artmo_envi**

↓ **Perform LAI *green* and LAI *brown* retrieval**

↓ **Composite map LAI *green/brown***

↓ **Uploading to FTP Server**

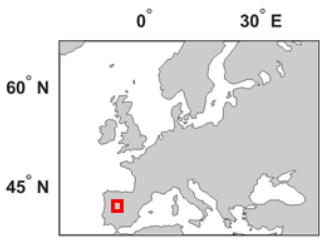
**DELIVERY PRODUCT**

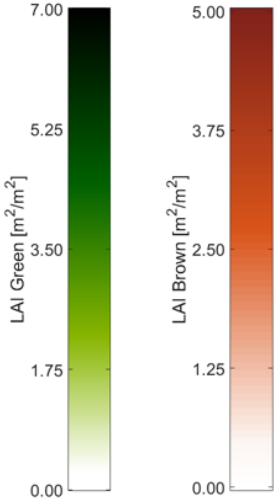
. hdr file:
- Composite LAI *green/brown*
- LAI *green* estimate, LAI SD, LAI CV
- LAI *brown* estimate, LAI SD, LAI CV
- LAI *green/brown* classification band

+ LAI *green/brown* jpg composite map

# Composite LAI green/brown

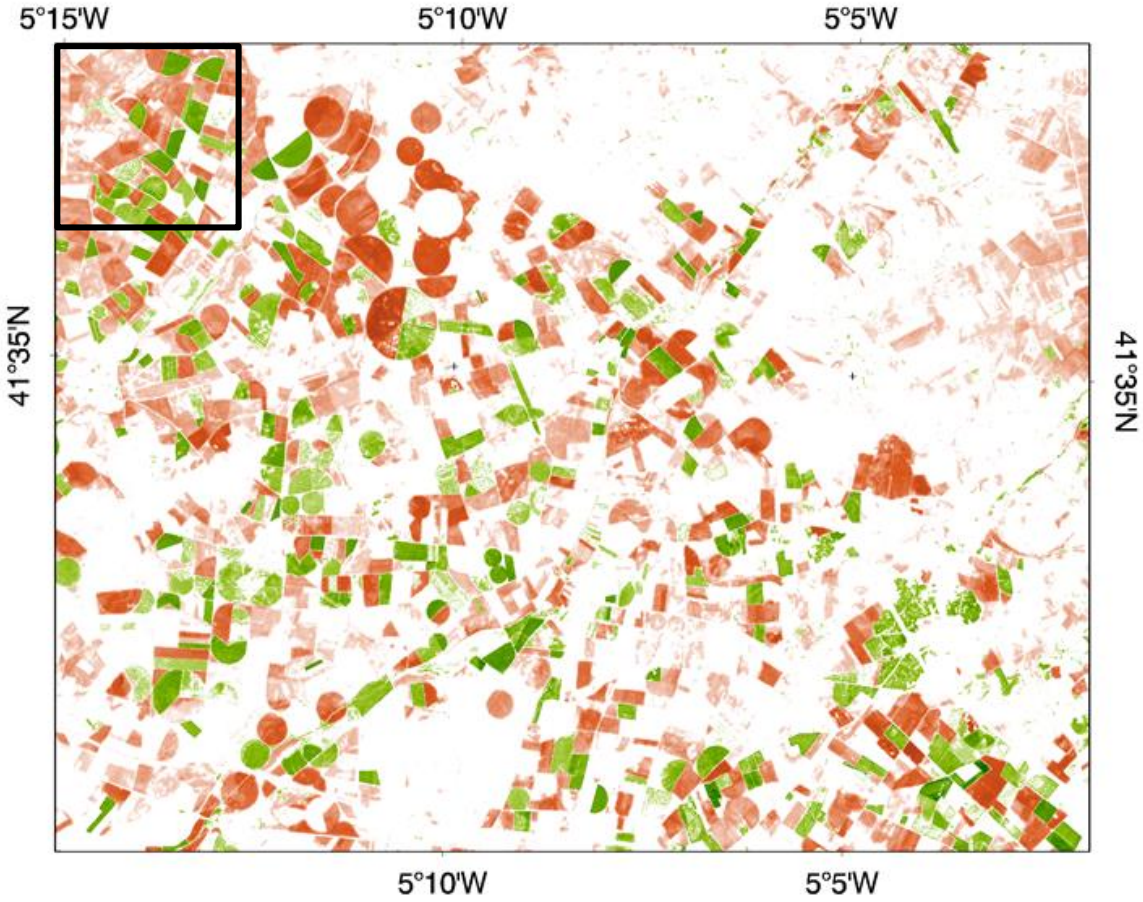
## Valladolid, Spain
## June, 2017

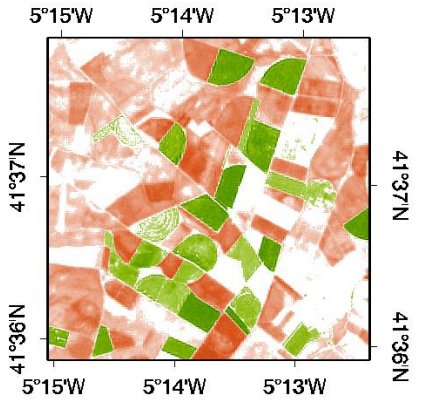




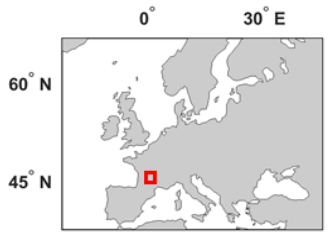


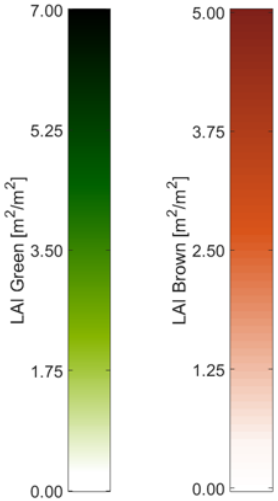


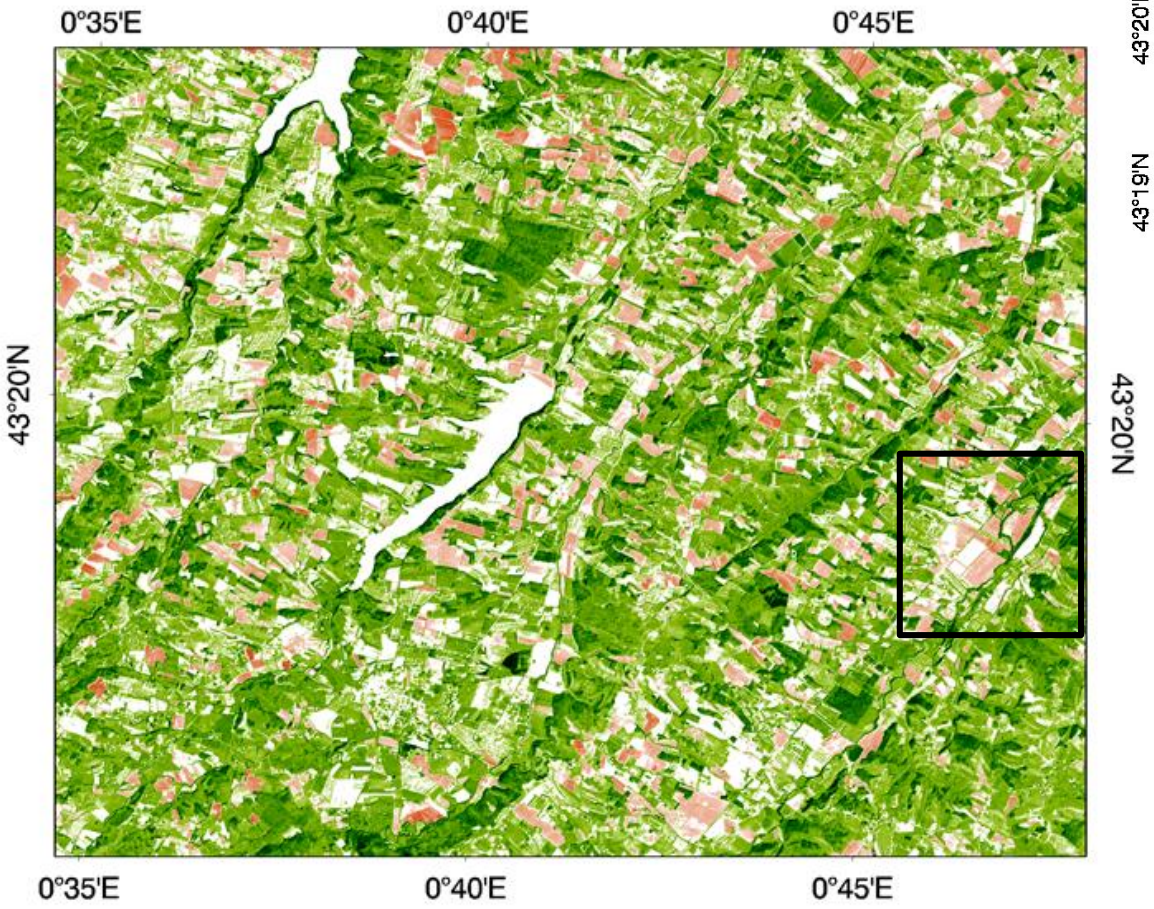



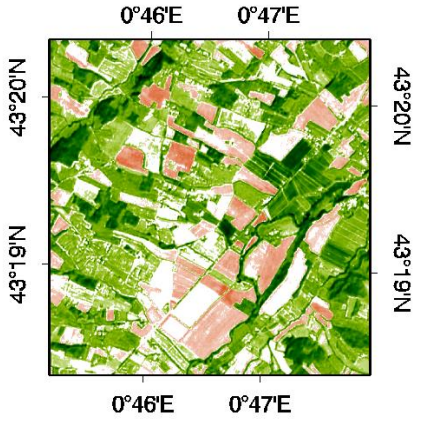
# Composite LAI green/brown

**Toulouse, France**
**July, 2016**



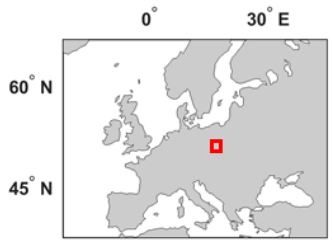



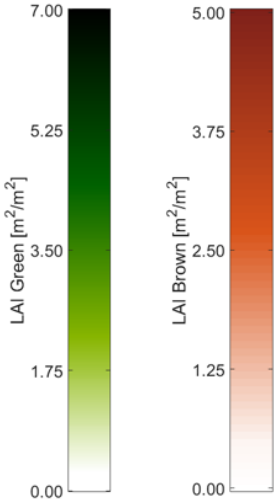



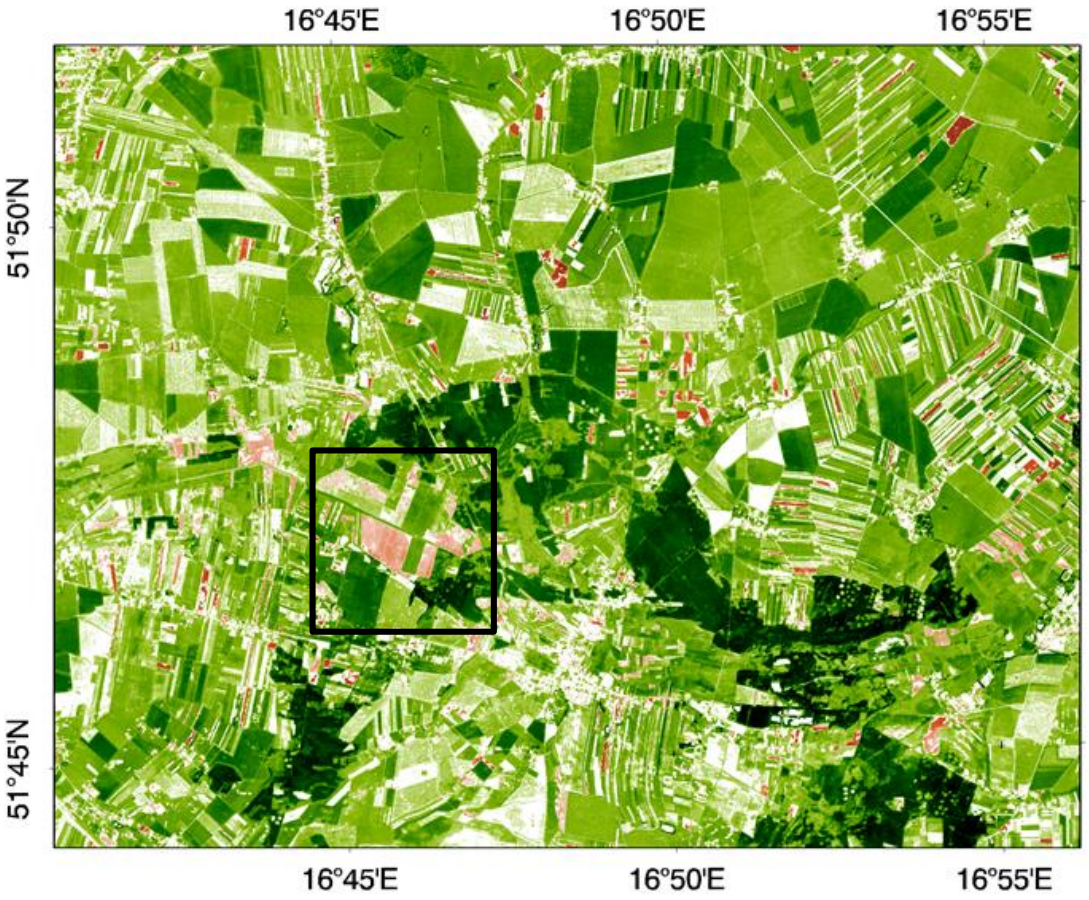



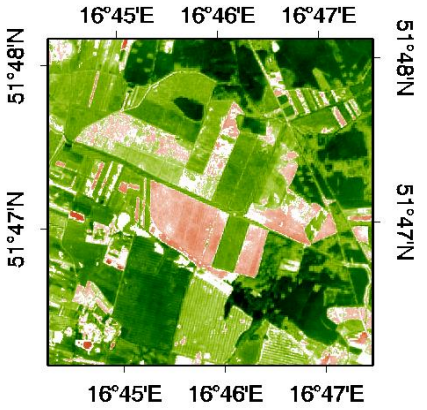
# Composite LAI green/brown

## Poznan, Poland
## June, 2017



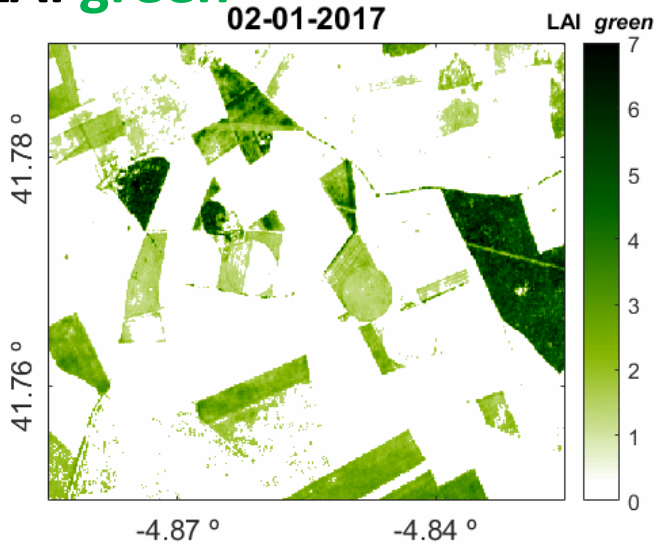



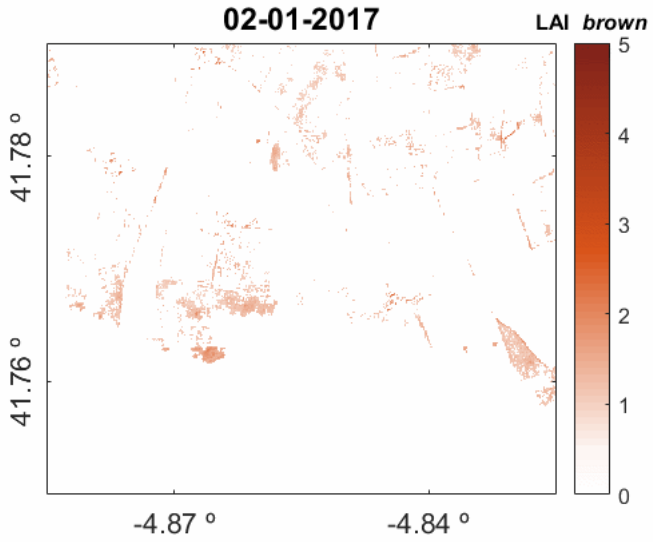



# Valladolid (Spain)

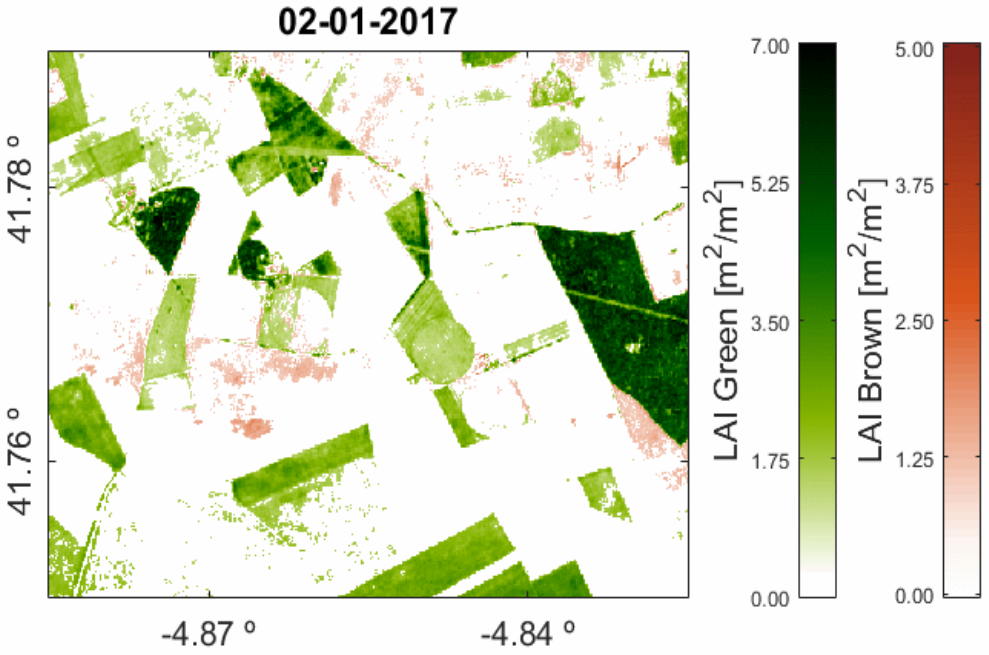
## LAI green




## LAI brown

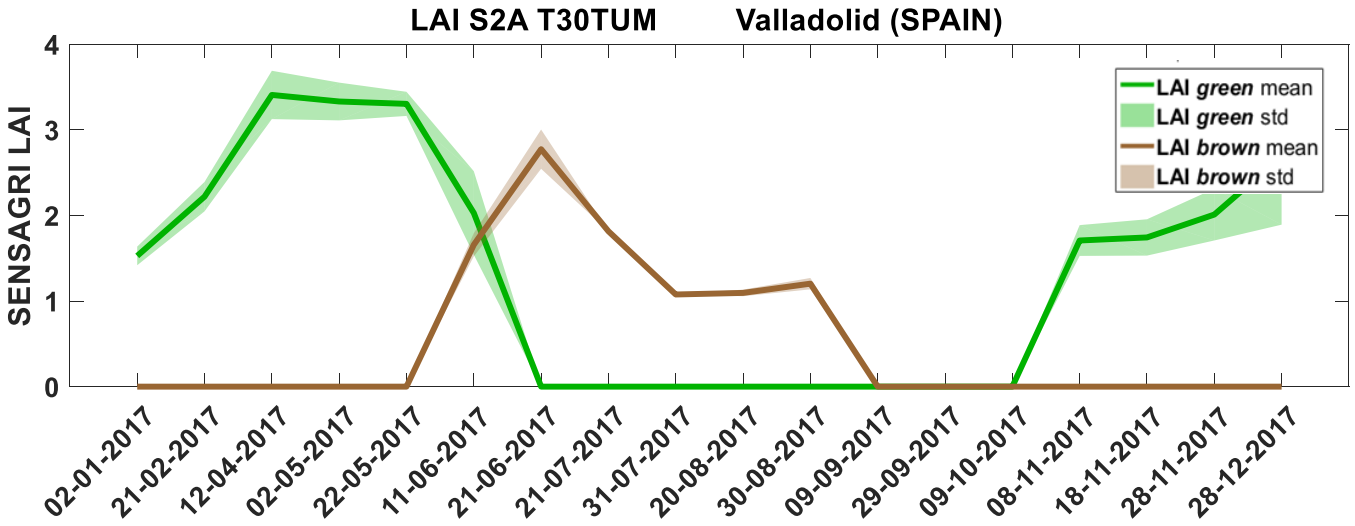


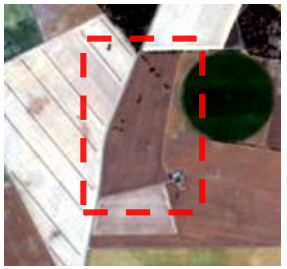

## LAI green/brown

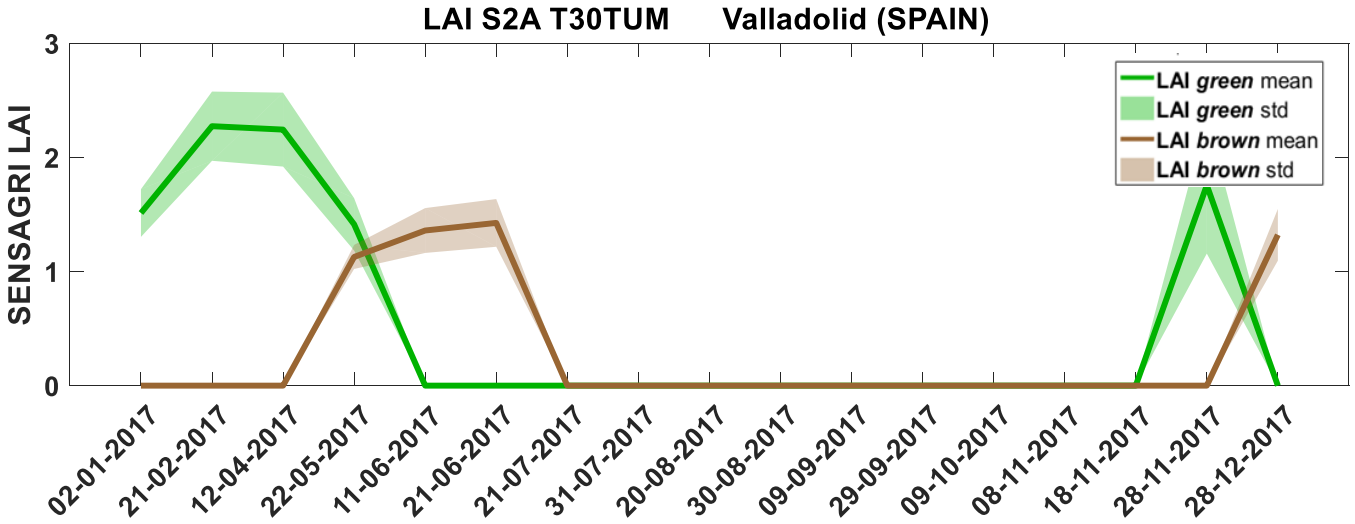


# Valladolid (Spain)

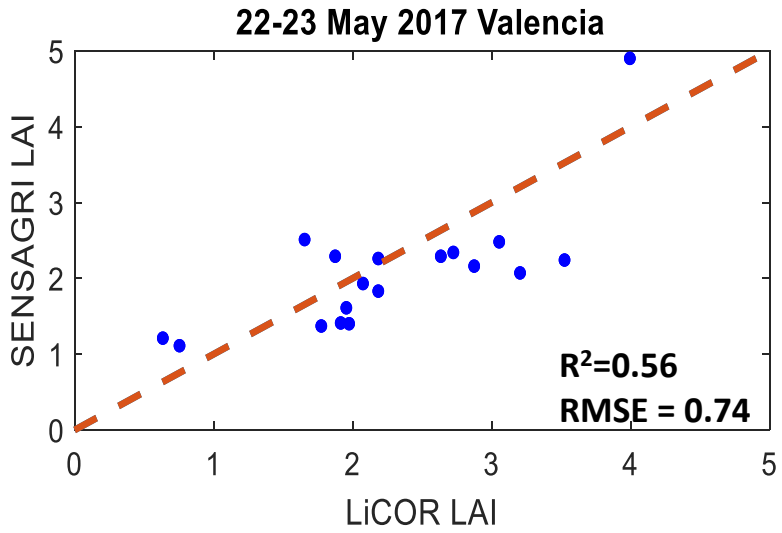
## Wheat

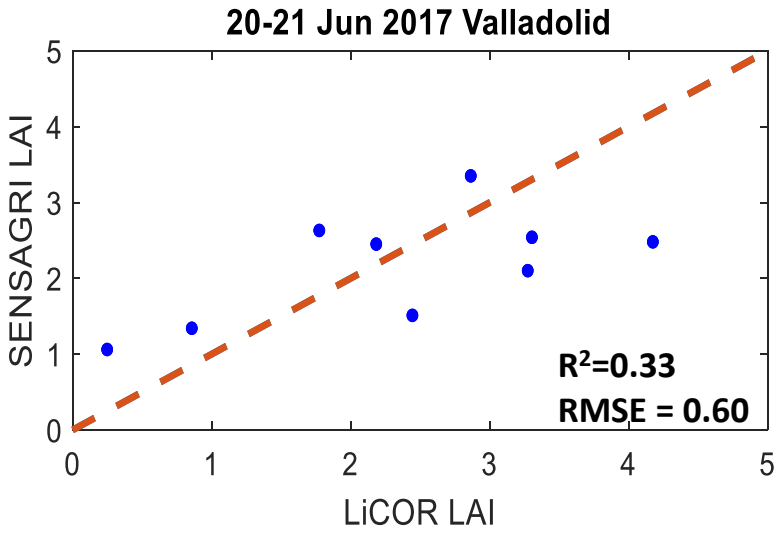


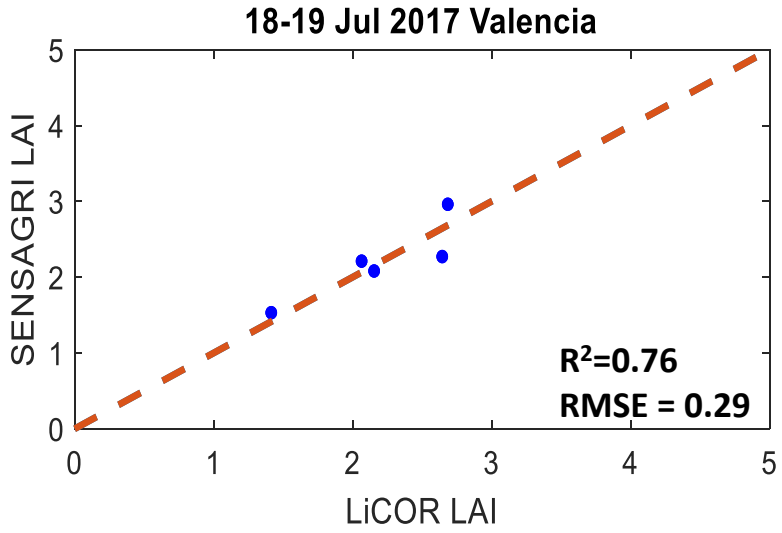



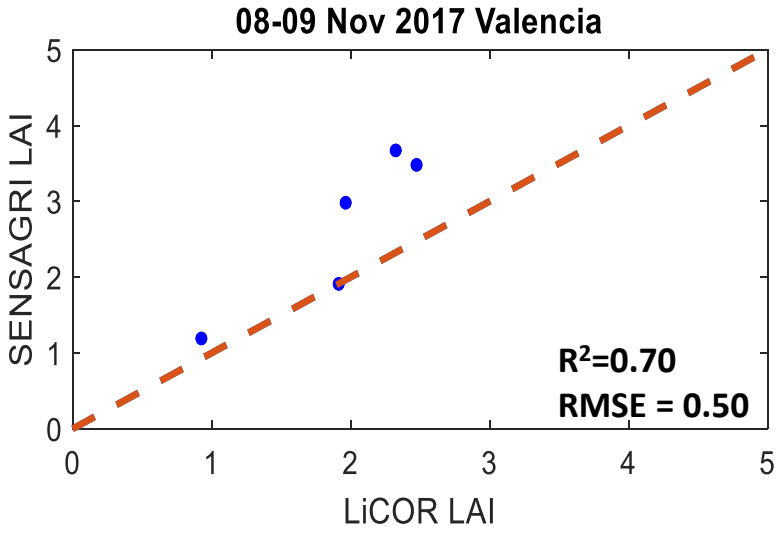


# Validation


22-23 May 2017 Valencia
SENSAGRI LAI
LiCOR LAI
R²=0.56
RMSE = 0.74


20-21 Jun 2017 Valladolid
SENSAGRI LAI
LiCOR LAI
R²=0.33
RMSE = 0.60


18-19 Jul 2017 Valencia
SENSAGRI LAI
LiCOR LAI
R²=0.76
RMSE = 0.29


08-09 Nov 2017 Valencia
SENSAGRI LAI
LiCOR LAI
R²=0.70
RMSE = 0.50

## CONCLUSIONS

- ✓ **GPR** has been **successfully implemented** for independent **retrieval of LAI *green* and LAI *brown*** from S2 images.

- ✓ The **robustness and portability** of the first version of GPR retrieval models have been **positively evaluated** by mapping LAI *green* and LAI *brown* over multiple European locations.

- ✓ **Time series** analysis suggest a **reasonable seasonal LAI evolution**.

- ✓ **More validation results** are foreseen in SENSAGRI schedule.

Sensagri

Sentinels Synergy for Agriculture

# Thank you