Sensagri

Sentinels Synergy for Agriculture

Copernicus for agri-environmental applications

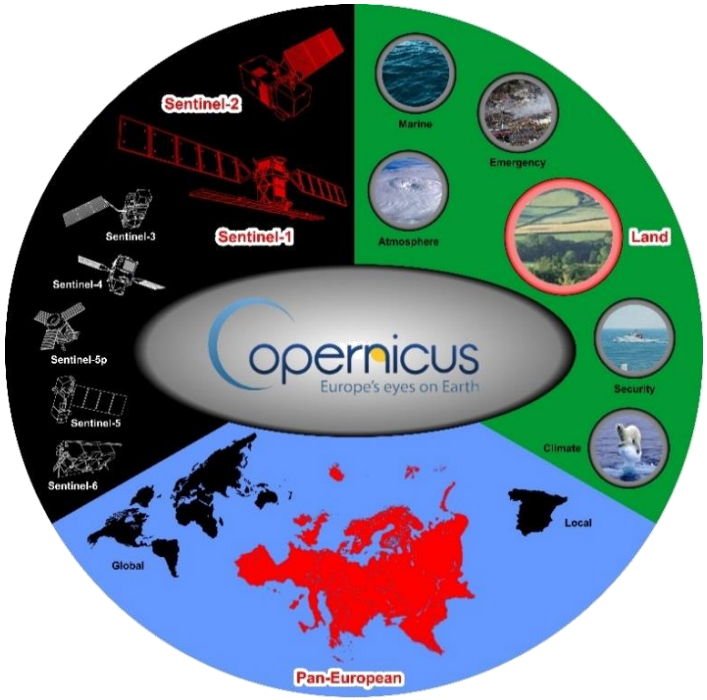
17 October 2019, Madrid, Spain

HORIZON 2020 Copernicus

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

SENSAGRI goals

- Produce **prototypes** for improved and novel Copernicus upstream services combining **Copernicus Sentinel-1 radar with Sentinel-2 optical** and in-situ data, to develop new EO applications for the European agricultural sector
- **Validate delivered services** and establish **service demonstration cases** to show the large application potential of the new upstream data products



Sentinels Synergy for Agriculture

H2020 EO-3-2016: Evolution of Copernicus services

GA 730074

Start: Nov 2016

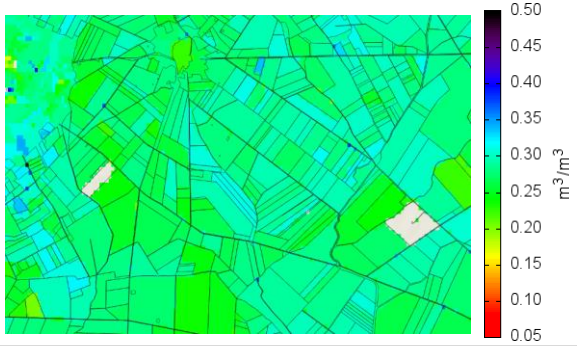
End: Oct 2019

SENSAGRI team

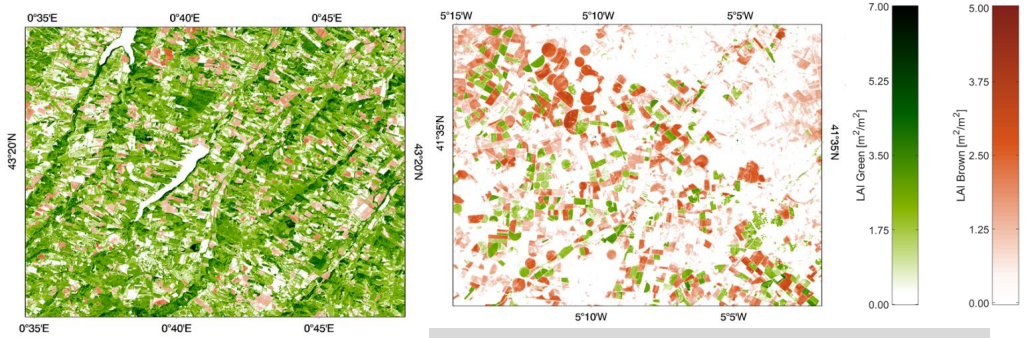
- Three Research centers with solid background and previous developments (SMOSAR, ARTMO, Sen2Agri)
- Three technological centers with experience in EO applications in agriculture and tight links with stakeholders
- One CAP paying agency

SENSAGRI services

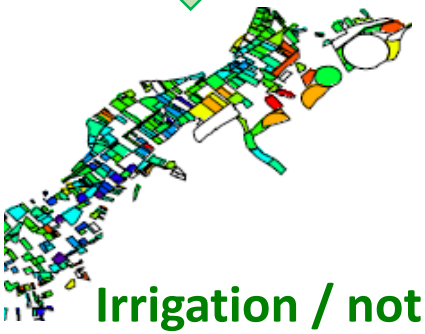
- Targeted for agricultural applications (CLMS Pan-European)



Soil Surface Moisture (SSM)

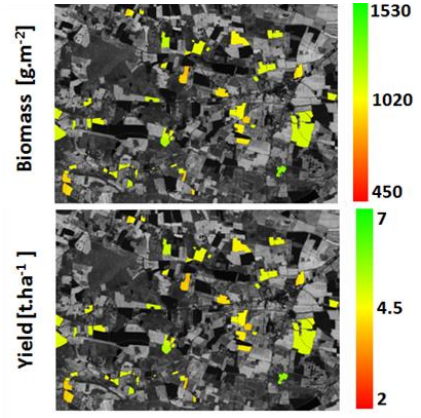


Green & Brown Leaf Area Index (LAI)



Irrigation / not irrigation

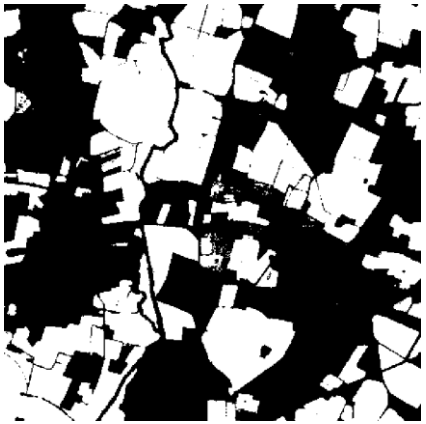
Tillage change



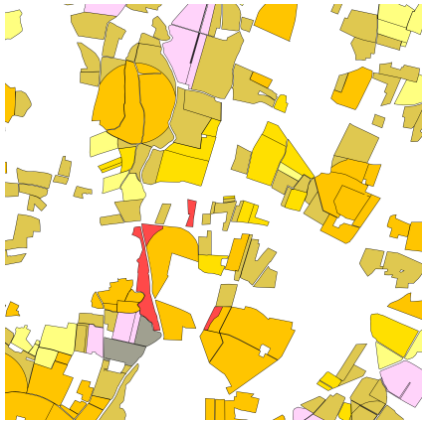
Biomass / Yield model

SENSAGRI services – Seasonal Crop Map

- Integrating **Sentinel-1** and **Sentinel-2** data
- **Binary crop mask** and **crop type map**
- **2 or 3 times** per year
- Tested with **different training datasets** (including LPIS-IACS and ancillary data)
- **Early in the season map** based only in information from previous year(s)



France 2017
Crop Mask



France 2017
Crop Type

Spain 2018
Land cover map

Validation strategy

Four European agricultural test sites

Spain: ITACYL - Duero River-basin
France: UPS-CESBIO - OSR Auradé and Lamasqère
Italy: CREA/CNR - Apulian Tavoliere
Poland: IPP/NRI – Winna Góra

Services	Ground Variable	Time
SSM	Volumetric Soil Moisture at 0-5 cm depth	• Continuous monitoring • 3 measurement campaigns at critical stages and during irrigation season
LAI	Leaf Area Index, with LAI-2000 Plant Canopy Analyzer	3 measurement campaigns at critical stages and during growing season
Seasonal Crop Mapping	Crop types	3 measurement campaigns in March, June and September
Irrigated areas	Irrigated and not irrigated fields	3 measurement campaigns in March, June and September
Tilled areas	Tilled and not tilled fields	
Yield	Commercial yield	1 measurement campaign at crop harvest
Intermediate crops	Crop types	2 measurement campaigns in March and July

CLC agricultural classes. Source: EEA

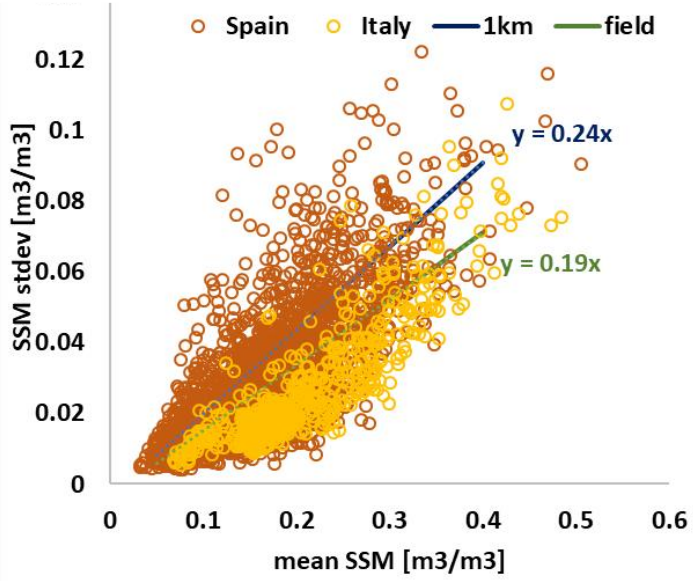
Three non-European test sites

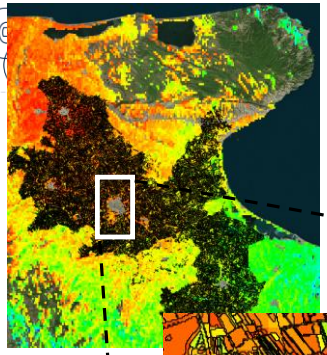
Argentina: INTA – Hilario Ascasubi
Two JECAM sites (South Africa and Ukraine)

Soil Surface Moisture (SSM)

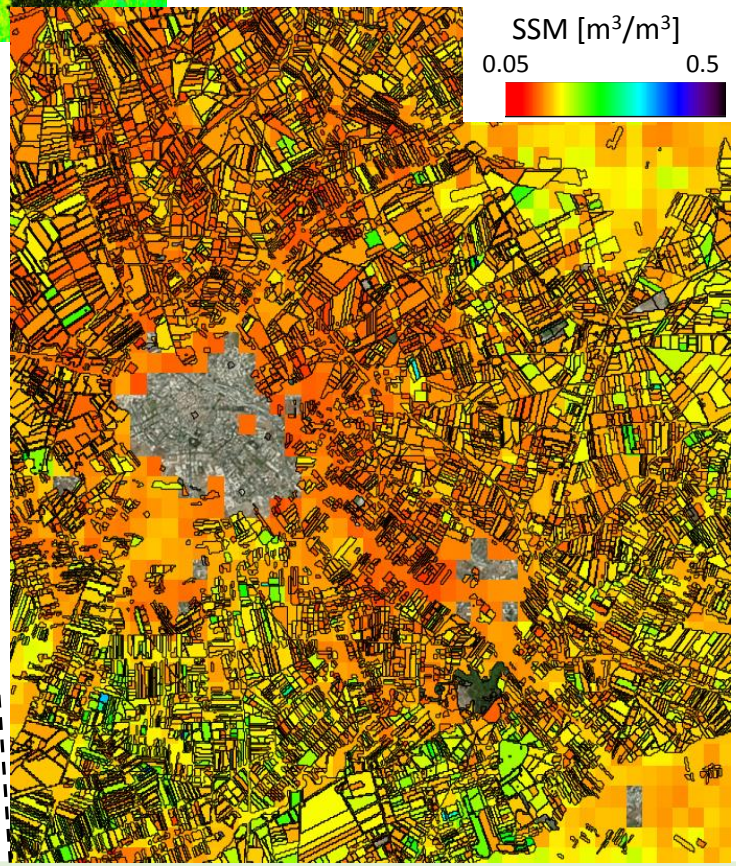
- SMOSAR processor. Algorithm based on Short Term Change Detection (STCD) approach using S1
- S2 (NDVI) allows masking abrupt changes (harvest, fire…)
- At 1 km spatial resolution. Up to 100 m or higher if parcel map is available

Retrieved vs observed SSM [m3/m3] at field scale



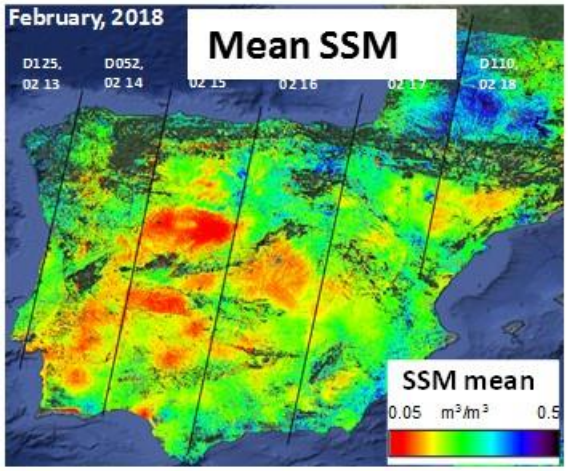


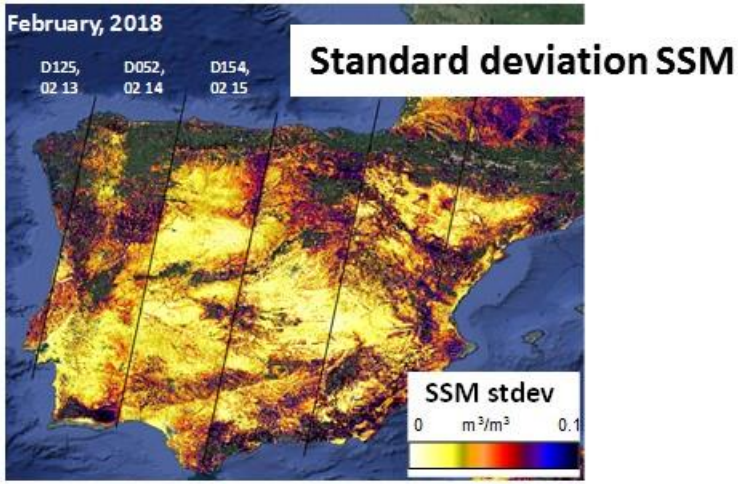
Apulian Tavoliere (Italy) Sensagri SSM (mean) on April 4, 2018



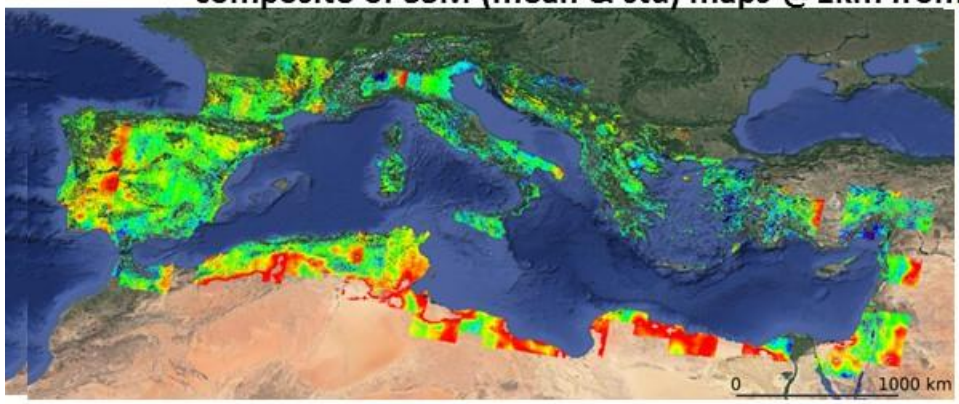
SSM: mean & std @1km

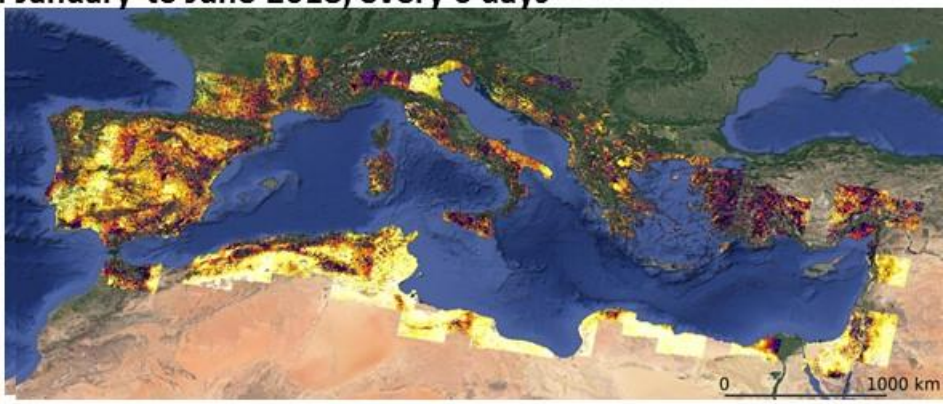
mosaic of 6 S1 RONs - over a 6-day period





composite of SSM (mean & std) maps @1km from January to June 2018, every 6 days



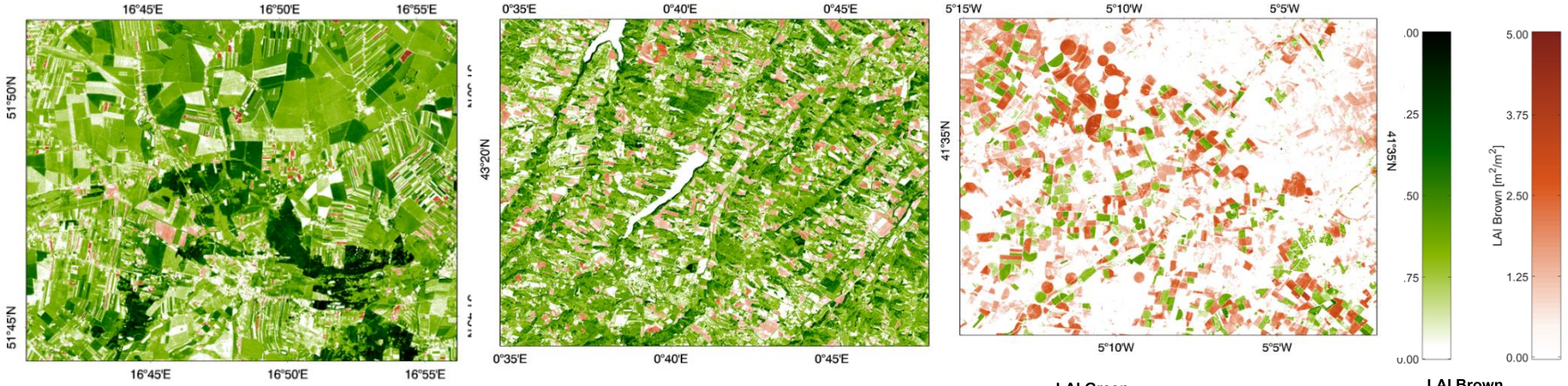


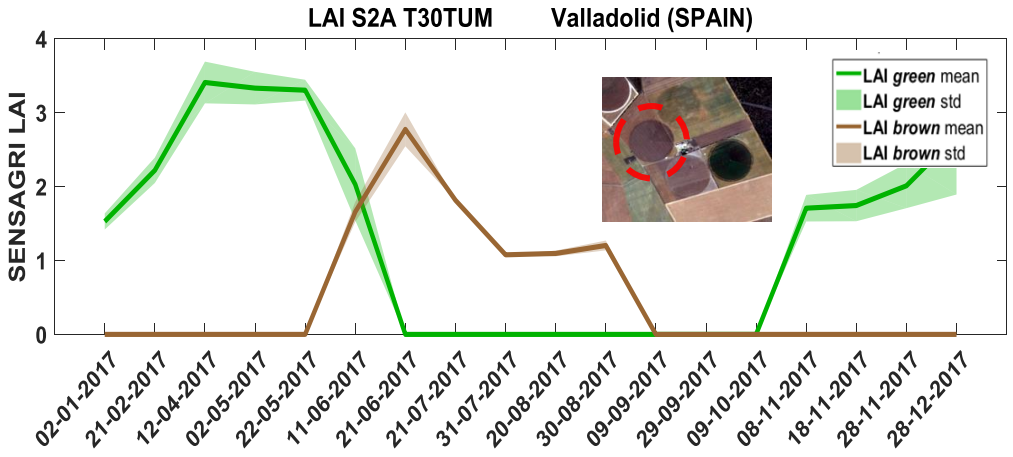
0.05 m³/m³ 0.5

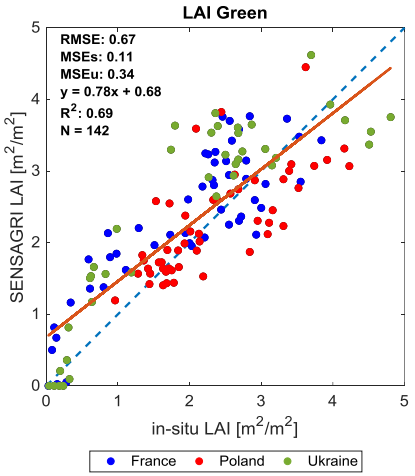
0 m³/m³ 0.1

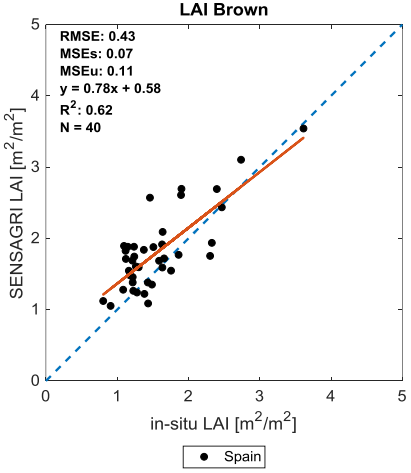
Leaf Area Index (LAI)

- **LAI** (**green & brown**) processor based on Gaussian processes regression (GPR)





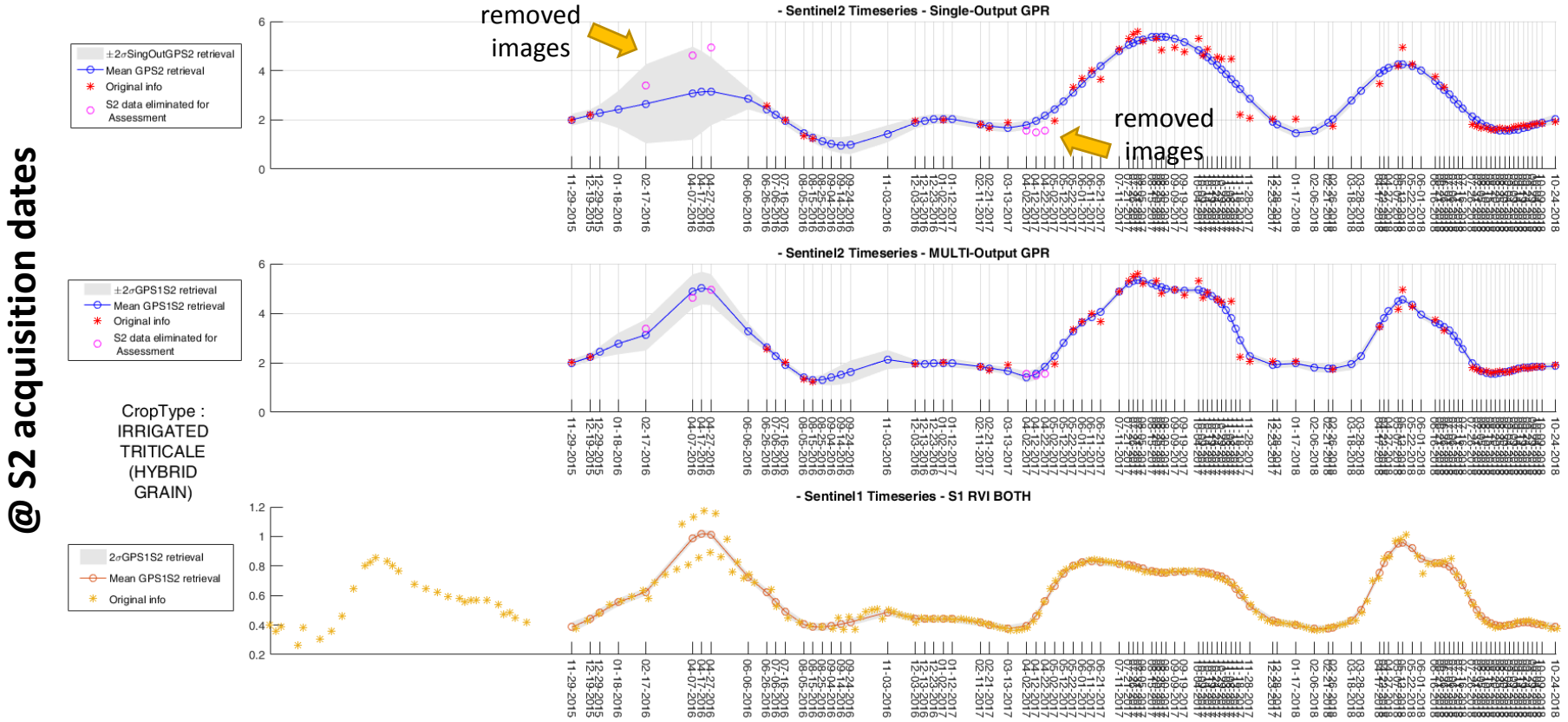




Fused LAI retrieval algorithm using Sentinel-1

- Time series reconstruction from the synergy S1 + S2 data
- Multi-Output Gaussian Process[1] Gap-filling
- LAIG temporal profile reconstruction over a homogeneous crop

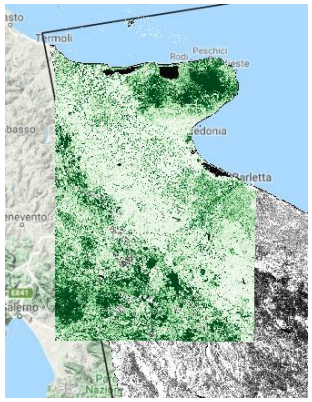
Crop area

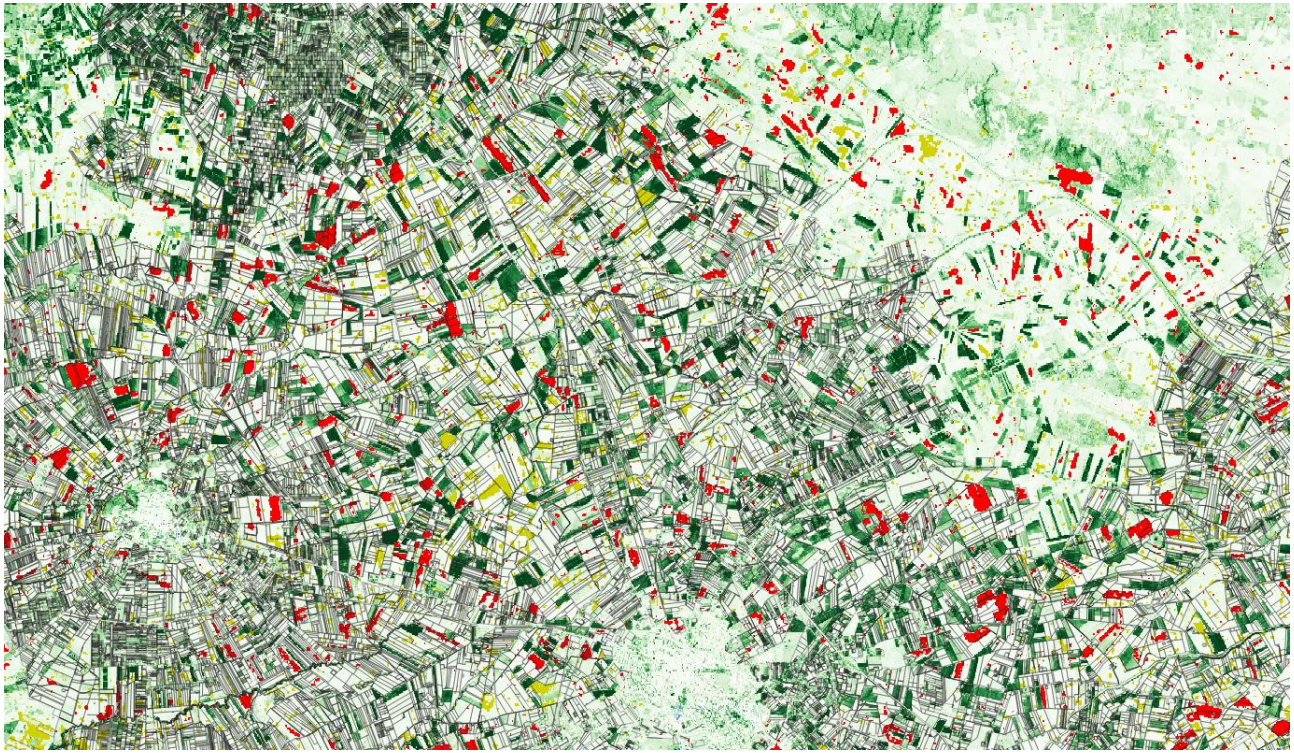


[1] M.A. Álvarez, L. Rosasco, N.D. Lawrence, "Kernels for Vector-Valued Functions: a Review, *Foundations and Trends in Machine Learning* 4, pp 195-266. Library available at https://github.com/SheffieldML/GPy

Tillage change detection

- Multiscale thresholding approach applied to the temporal change of VH S1 backscatter of bare or scarcely vegetated fields (i.e. S2 NDVI < 0.3)
- 40 m spatial resolution





Tillage change

ΔVH(-)

ΔVH(+)

ndvi

0.1

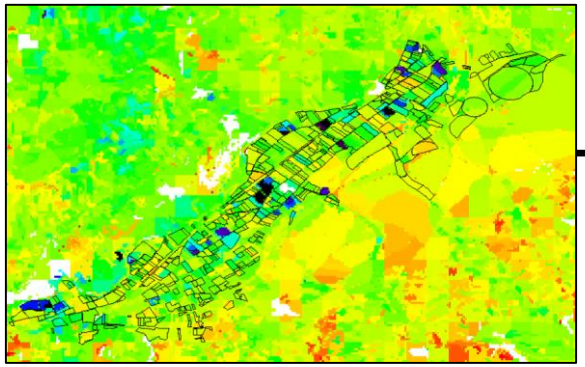
0.3

0.5

0.7

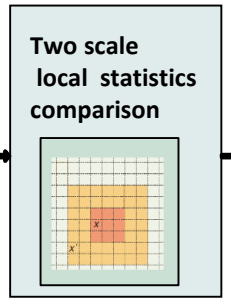
0.9

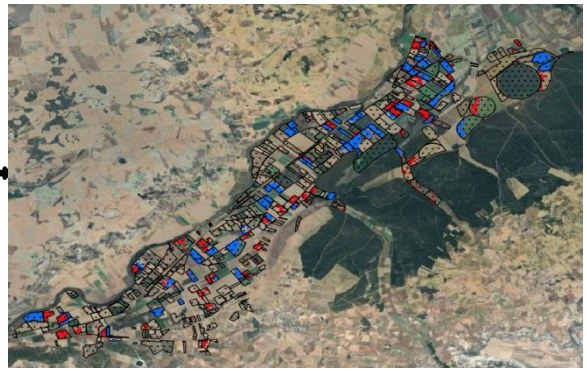
Irrigated/not irrigated area



0.03 m^3/m^3 0.25

S1&S2 SSM map (09/04/2017)





Irrigated/ not-irrigated map

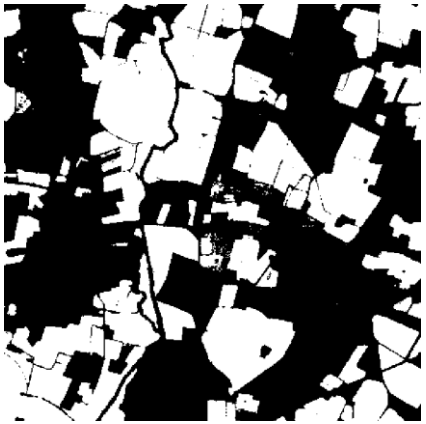
Classified as irrigated :
- irrigated in ground data
- not irrigated in ground data

- Methodology: **unsupervised** thresholding classification method, based on the exploitation of local statistics computed at different scales (n1 < n2)
  - Automatic threshold value & multi window approach
- Input: S1& S2 SSM at the highest resolution, i.e. $\sim 40\ m$ pixel size ($\sim 100\ m$ resolution).
- Output: binary map, eventually aggregated at field scale, using the parcel borders information.

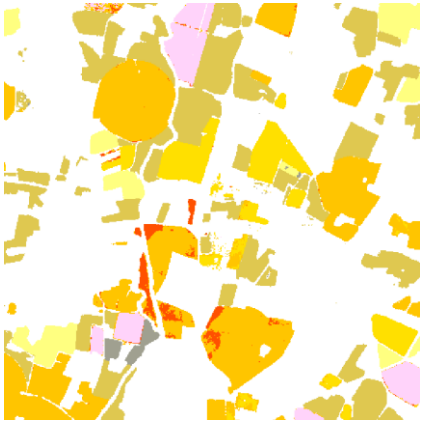
Crop map Products

- Two products : A **binary crop mask** and a **crop type map**
- Spatial resolution 20m (**10m resolution**)
- Confidence map
- Temporal resolution **2 or 3 times** per year
- Pan-European hierarchical nomenclature based on JECAM

Straw Cereal
Maize
Sorghum
Soybeans
Vetch
Grain leguminous
Horse bean
Chickpea
Peas
Beet
Potatoe
Asperagus
Brocoli
Raspseed
Sunflower



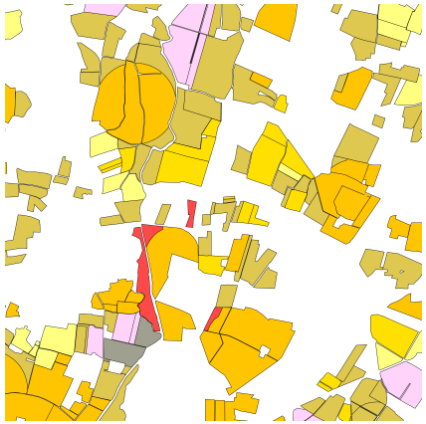
France 2017
Crop Mask



France 2017
Crop Type

Confidence
0% 25% 50% 75% 100%

France 2017
Crop Type confidence



France 2017
Crop Mask (Vector format)

Comparison between exisiting Sentinel's classification system

- S12 : The crop type map product produced by SenSAgri
- S2A: The ESA S2Agri crop classification processing chain by incorporating Sentinel-1 as input feature

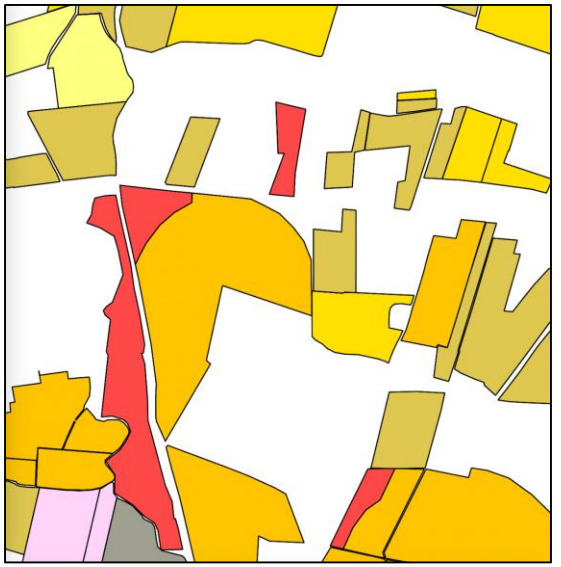
	1-Mar				5-Jul				2-Nov			
Class	S1	S2	S12	S2A	S1	S2	S12	S2A	S1	S2	S12	S2A
Straw Cereal	76.8	87.7	**89.9**	84.9	97.2	97.1	**97.7**	97.1	97.3	97.3	**98.0**	97.7
Maize	79.7	79.1	**82.8**	78.2	92.9	95.5	**95.9**	95.1	95.6	96.9	**97.3**	96.2
Sorghum	**18.8**	14.9	17.5	13.2	68.5	66.5	**75.4**	64.9	72.9	81.7	**82.9**	75.6
Soya beans	**10.0**	7.5	9.6	9.6	33.4	37.8	**44.7**	39.7	68.1	78.1	**79.8**	70.4
Peas	34.1	33.8	**40.6**	34.6	90.2	87.7	**91.1**	88.8	90.8	86.7	**91.5**	88.7
Rapeseed	64.2	74.0	**81.2**	68.7	96.9	91.6	**97.3**	95.9	96.9	91.0	**97.2**	95.5
Sunflower	57.4	68.3	**71.6**	67.2	92.9	93.1	**94.7**	94.3	95.6	96.5	**96.7**	96.3
OA	67.8	74.0	**77.9**	72.0	92.3	93.3	**94.6**	93.1	94.8	95.7	**96.5**	95.2
95 CI	0.53	0.45	0.55	**0.86**	**0.41**	0.34	0.38	0.38	**0.32**	0.28	0.28	0.29

Object-based crop maps

If reference parcel boundaries exist, they can be used to apply a majority-vote rule

SensAgri crop type map

Reference parcel boundary

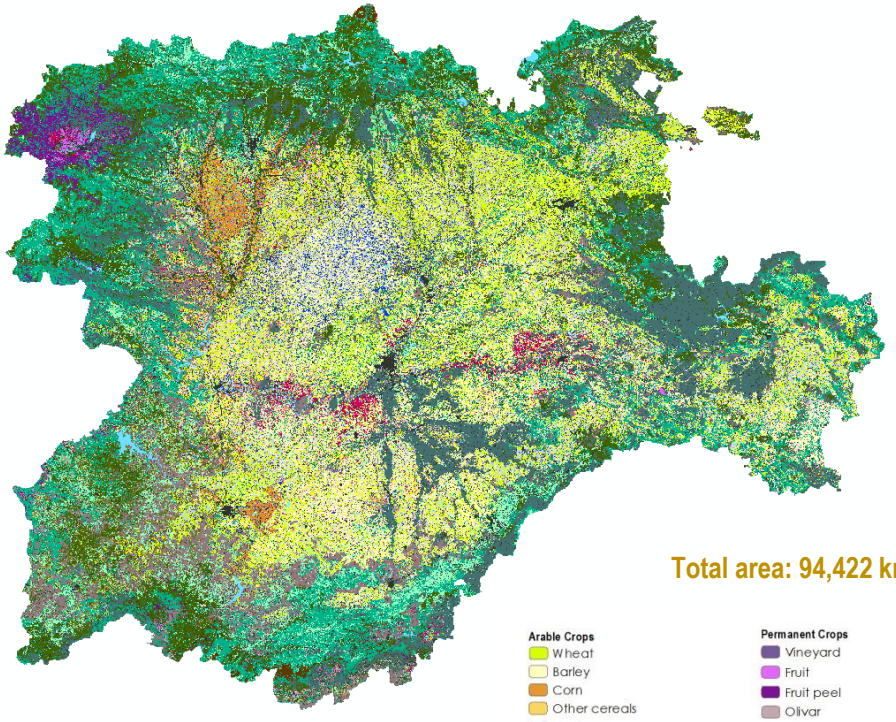


Majority – vote map

Application in Castile and Leon

- Very detailed legend and overall accuracy
- Intense use of LPIS-IACS information

Classification land cover map 2017

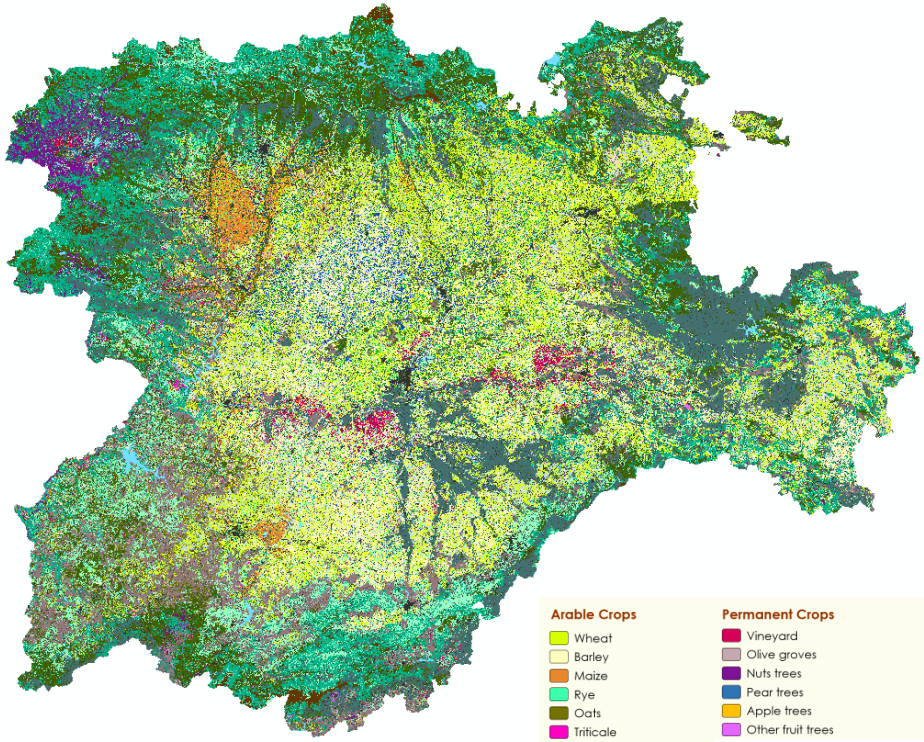


Total area: 94,422 km^2

Accuracy metrics

2017	Jul	Dec
Overall Accuracy	72.55	76.66
Kappa index	0.67	0.72

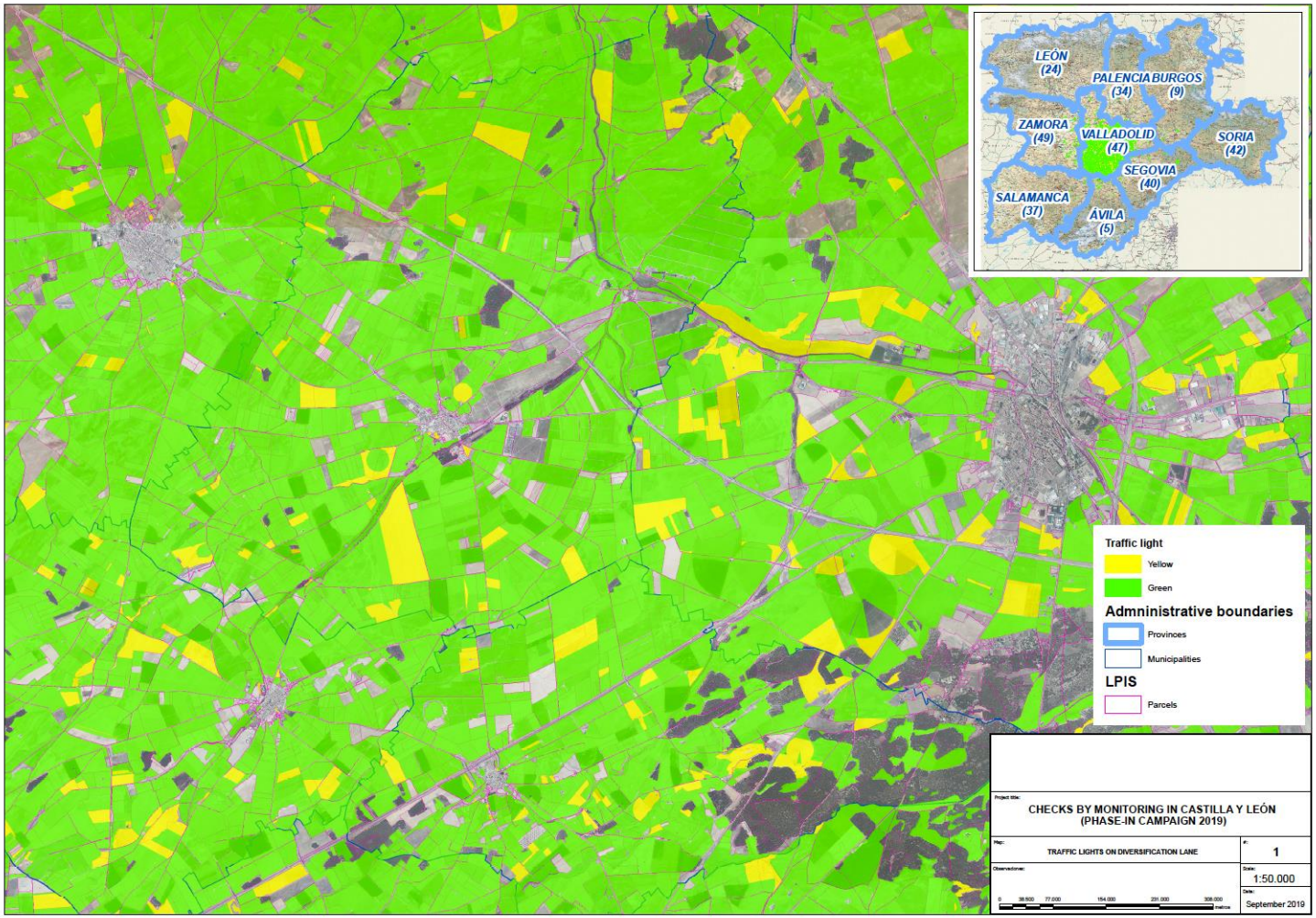
Classification land cover map 2018



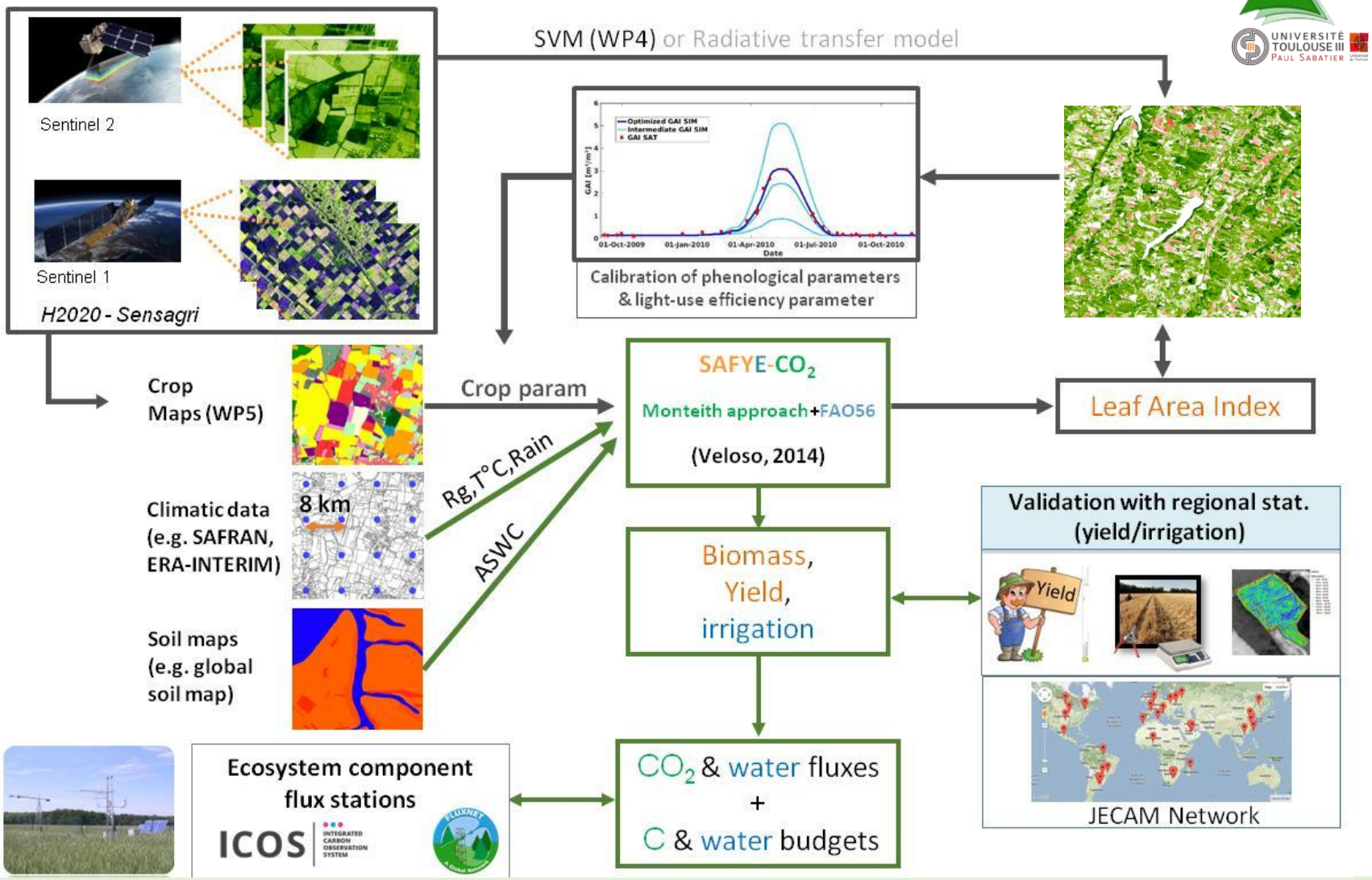
Accuracy metrics

2018	Jul	Dec
Overall Accuracy	79.89	86.33
Kappa index	0.75	0.83

Object-based approach used for real check monitoring



Dry biomass and Yield model



Project status. October 2019

- Improved versions of the algorithms **combining S1 and S2**
  - S2 provides LAI / NDVI for masking S1 radar products (SSM, tillage, irrigation)
  - S1 for gap-filling of S2-based time series
  - S1 and S2 together in crop classification
- Comprehensive **set of products over European test sites** available
- Products accessible through **web GIS** (www.sensagri.eu)
- OGC **WMS services** - to display the data in user GIS solution: http://osr-cesbio.ups-tlse.fr/geoserver_sensagri/SENSAGRI/wms
- **Validation campaigns** finalized
- Final validation of prototypes performed. Good overall results.

Major achievements of the project

- Mature and validated prototypes, able to be integrated in operational processing chains
- High potential for use in CAP monitoring
- Improvements with respect to current and incoming Copernicus Land Services (SSM delivered with std, LAIG, SCM)
- Novel and/or innovative products (LAI Brown, tillage change, irrigation events' detection, early crop maps without current year reference data)
- Huge effort in validation. Very valuable field dataset obtained
- Successful Living Lab implementation and transfer
- Comprehensive set of products over European test sites available
- Products accessible through web GIS

Perspectives for future exploitation

Two complementary directions for the potential exploitation of SENSAGRI prototypes:

- Generation of **pan-European layers**
  - General application and consistent products
  - Homogeneous approach
  - Similar accuracy and level of detail all throughout the European territory.

- Response to the **new monitoring requirements of the Common Agricultural Policy (CAP)**:
  - Focus on **agricultural practices** and in **markers** of land use
  - Requires more flexible and locally tuned methods
  - Fits with the use of **DIAS** and with the **combination of several products** to derive added value data.

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Copernicus for agri-environmental applications

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