sentinel-2

esa

→ AGRICULTURE

JECAM / SEN2AGRI cross-sites benchmarking for cropland

Bontemps S., Arias M., Bellemans N., Dedieu G., Guzzonato E., Hagolle O., Inglada J., Matton N., Morin D., Rabaute T., Savinaud M., Sepulcre G., Valero S., Defourny P., Koetz B.

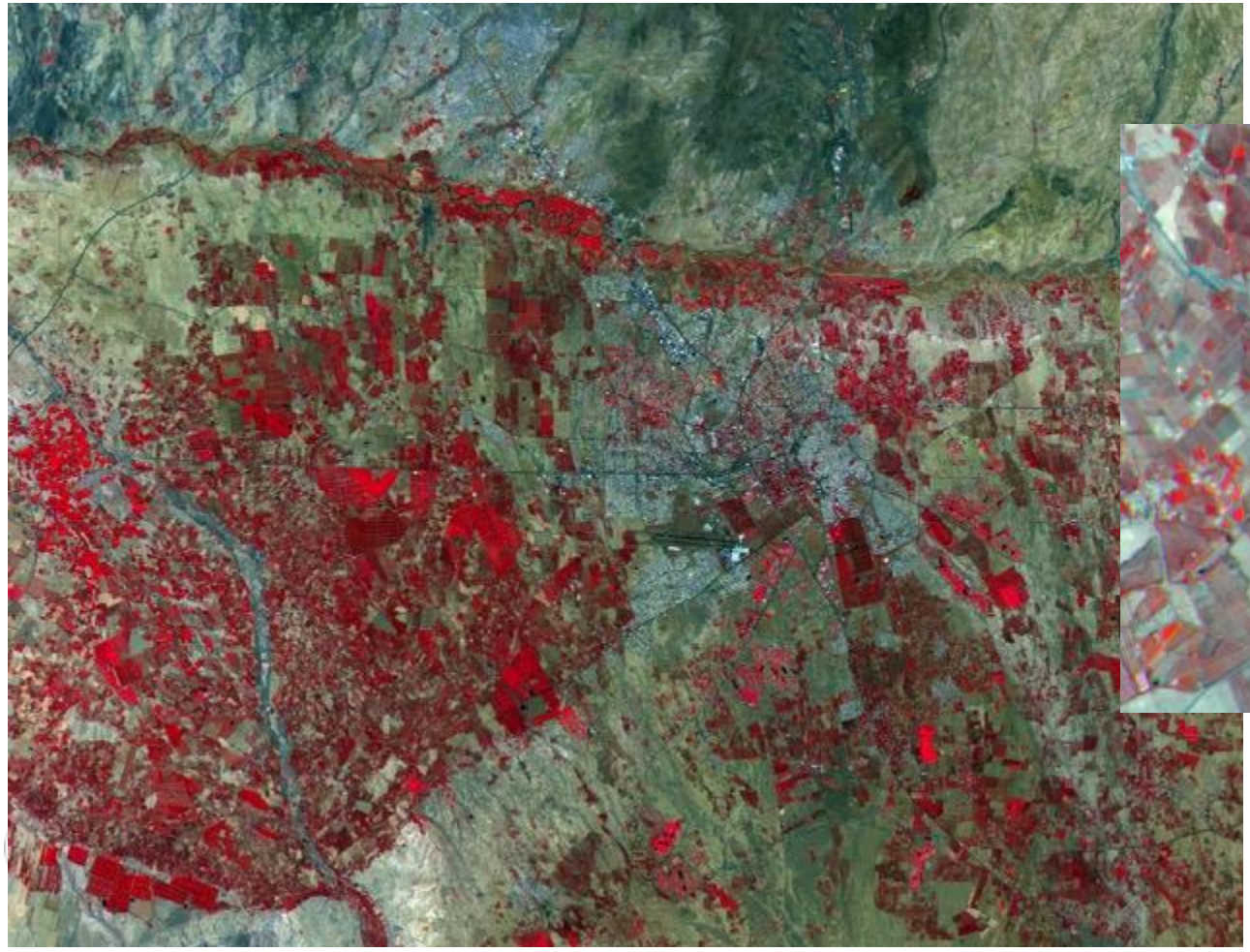
Unique momentum for satellite remote sensing in agriculture

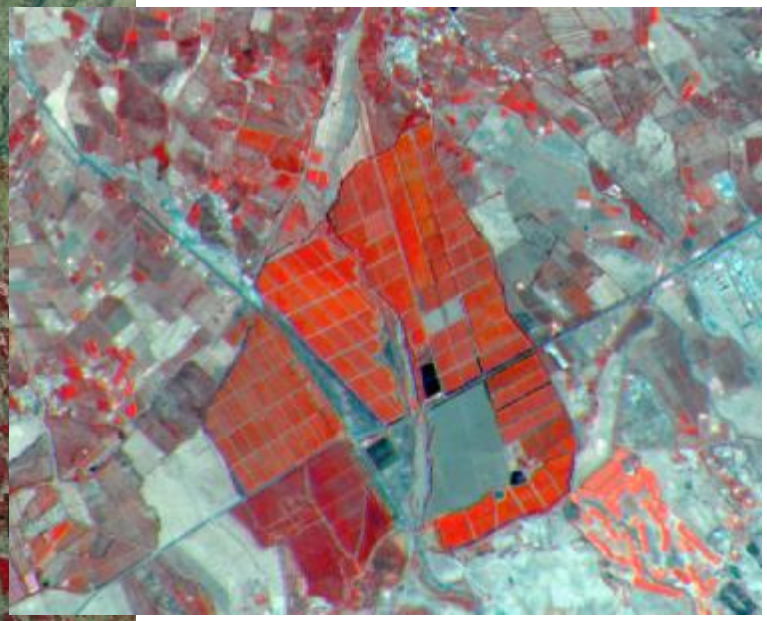
- EO response to operational agricultural applications:
  - Emerging collaborative initiatives endorsed by G20 in the context of GEO (AMIS, GEOGLAM)
  - JECAM initiative opening the door to move from local experiments to global solutions
  - CEOS support to global agriculture users requirements
  - US and Chinese efforts on 30-m global croplands mapping
  - **Sentinel-2 mission to finally reach agriculture expectations (jointly with Landsat-8 and Sentinel-1)**

Sentinel-2 spatial resolution
Irrigation monitoring at field scale

Marrakesh (Morocco) - Sentinel-2 - 12 July 2015

Water consumption for irrigation of summer vegetation (in red)





Copernicus data (2015)

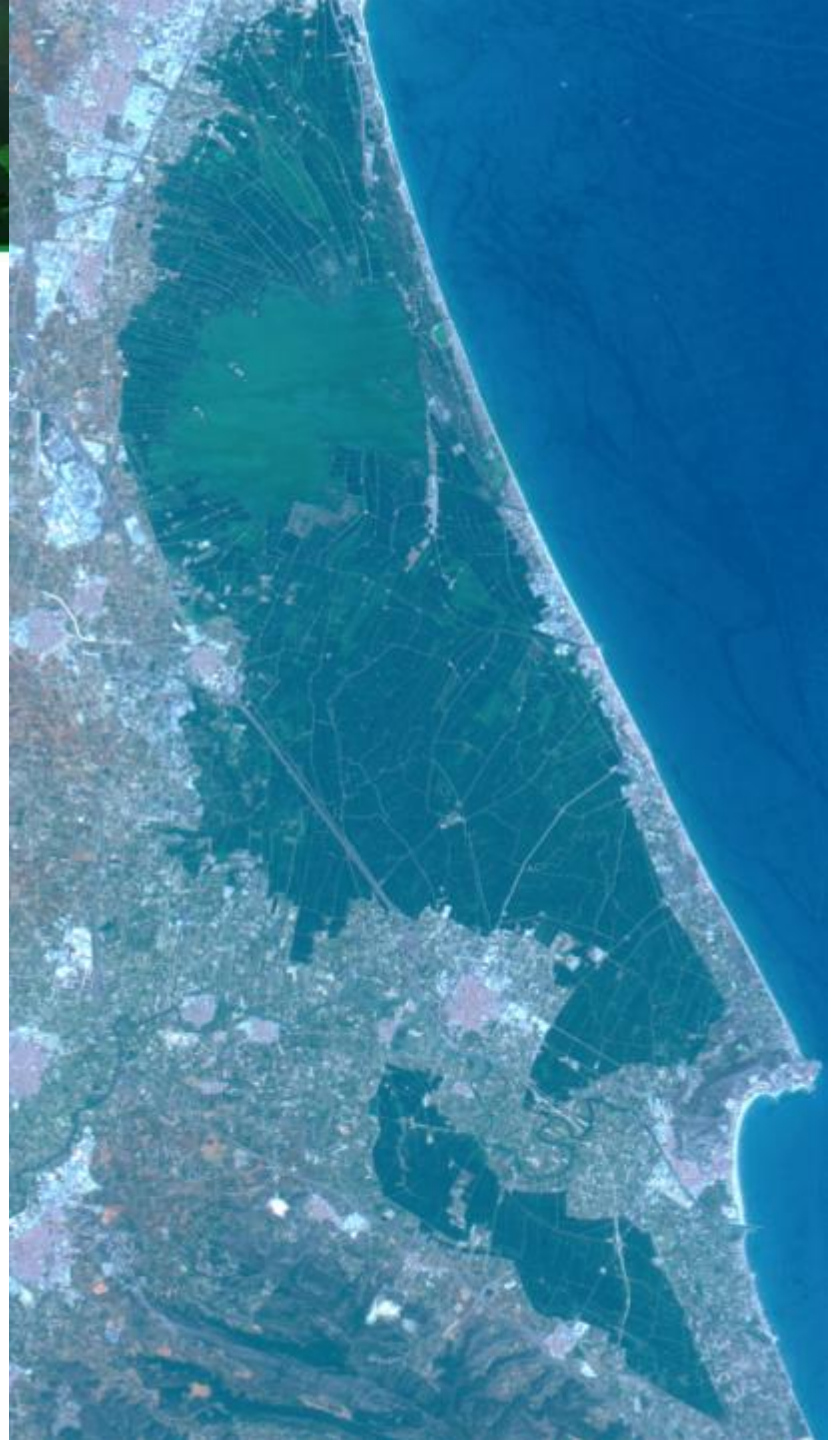
5-day revisit for NRT agriculture monitoring

Valencia (Spain) – April – June 2015
flooding dynamic of rice field and monitoring the start of growing season

20 April 2015
30 April 2015
10 May 2015
15 May 2015
20 May 2015
25 May 2015
04 June 2015
09 June 2015
14 June 2015
19 June 2015

Simulation of Sentinel-2 (2 satellites) 5 days revisit frequency with SPOT5-Take5

16 July 2015 by Sentinel-2a



sentinel-2

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Sentinel-2 for Agriculture
Launched by ESA in Feb. 2014

Objective:

- **Preparation for national to regional agricultural monitoring based on Sentinel-2**
- **Consolidate best practices for EO agricultural monitoring**
- **Strengthening national capacity for agricultural monitoring**

3-phase project over 3 years

Algorithm Development 2014 → Prototypes of EO products 2015 → Demonstration & Validation 2016

User-driven approach

1st User Consultation organized by ESA in 2012

2nd User Consultation during the first months of the project through surveys

1 user workshop each year + training / capacity building activities

18 Champion Users + 13 Sites Managers

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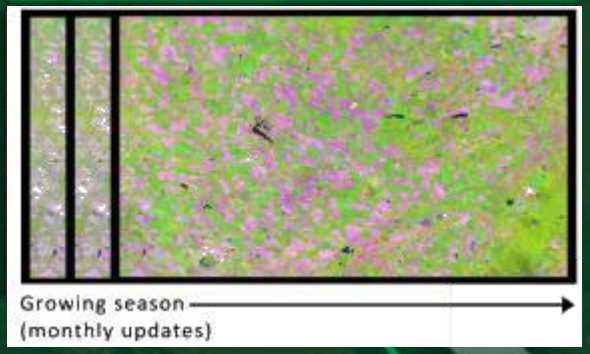
Toolbox for 4 S2-based products in line with the GEOGLAM core products

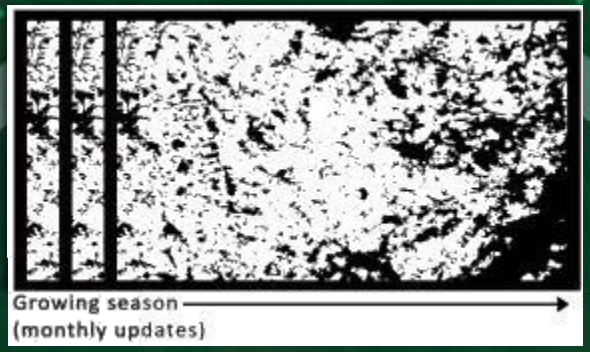
esa

Monthly cloud free surface reflectance composite at 10-20m

CLOUD FREE SURFACE REFLECTANCE COMPOSITES



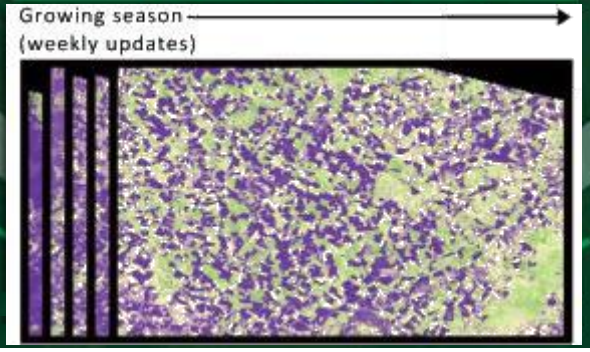
DYNAMIC CROPLAND MASK



Binary map identifying annually cultivated land at 10m updated every month

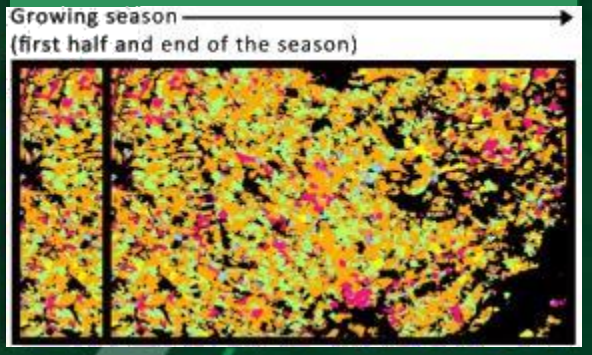
Open source toolbox
Capacity building and training

VEGETATION STATUS



Vegetation status map at 20m delivered every 10 days (NDVI, LAI, pheno index)

CULTIVATED CROP TYPE MAP



Crop type map at 10m for the main regional crops including irrigated/rainfed discrimination

Benchmarking for a transparent and objective algorithms selection

Literature review

Test Data Set (EO + in-situ data)

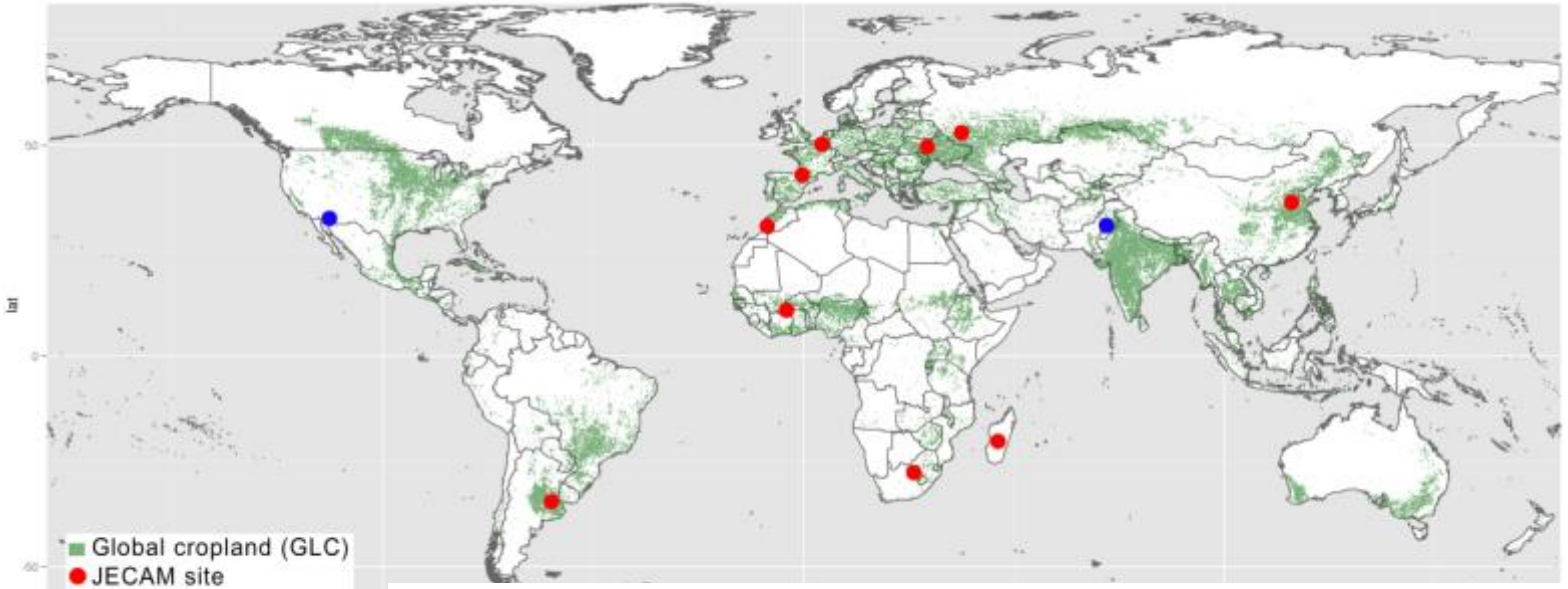
Scientific analysis

Select 5 suitable algorithms

Run the algorithms over 12 sites globally distributed

Compare results between algorithms and sites

Identify the best algorithms



12 test sites, relying on JECAM network, spread over the world, which represent more than 17 major crop types

sentinel-2

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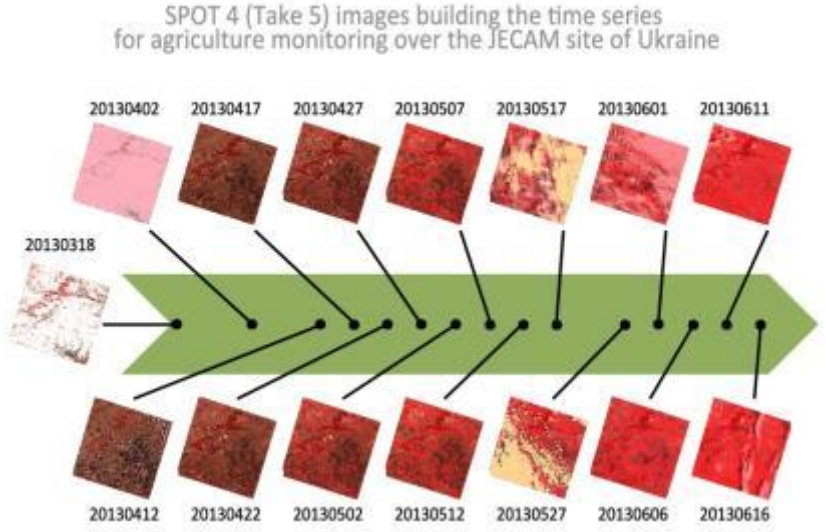
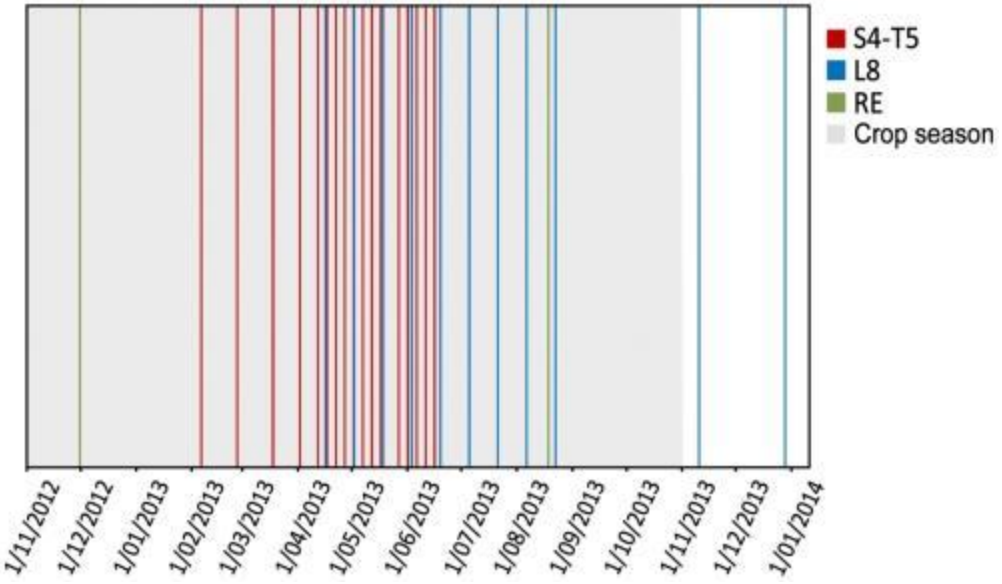
A unique dataset made of Sentinel-2 like EO time series and in-situ data

Site	S4-T5	L8	RE	Total
Argentina	12	11	15	38
Belgium	8	3	-	11
Burkina Faso	-	9	1	10
China	18	10	-	28
France	32	8	-	40
Madagascar	12	15	2	29
Morocco	24	16	-	40
Pakistan	-	13	1	14
Russia	-	5	6	11
South Africa	23	15	26	64
Ukraine	17	11	2	30
Maricopa (US)	54	15		69
Total of dates	200	131	53	384





Sentinel-2

AGRICULTURE

A unique dataset made of Sentinel-2 like EO time series and in-situ data

Site	In-situ (2013)	Reference map
Argentina	Crop (108); No crop (39)	Global land cover GLC30
Belgium	Crop (31244); No crop (78156); GAI, PAI, FAPAR, FCOVER	SIGEC 2012, Land Cover CCI
Burkina Faso	Crop (496); No crop (101)	Global land cover GLC30
China	Crop (54); No crop (22)	Global land cover GLC30
France	Crop (1500); No crop (7659); GAI, PAI, FAPAR, FCOVER	RPG 2012, Land Cover CCI
Madagascar	Crop (221); No crop (101)	Global land cover GLC30
Morocco	Crop (636); No crop (500); LAI	Land Cover CCI
Pakistan	Crop (228); No crop (54)	Global land cover GLC30
Russia	Crop (205); No crop (56)	Fields delineation based in Landsat provided by the site manager, Land Cover CCI
South Africa	Crop (120); No crop (44)	Water bodies SRTM-SWBD, SADC Landcover Dataset (2000), Land Cover CCI
Ukraine	Crop (221); No crop (56); GAI, PAI, FAPAR, FCOVER	2010 classification map (30 m) provided by site manager
United States	Crop (4907); No crop (11351)	USDA data layer

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Dynamic cropland mask

- Binary map, updated every month, identifying the annual cropland according to JECAM definition*

The annual cropland is a piece of land of minimum 0.25 ha (minimum width of 30 m) actually sowed/planted and harvestable at least once within the 12 months after sowing date, which produces an herbaceous cover possibly combined with a tree cover*

*** the herbaceous fCover should reach at least 30 % and a maximum woody (height > 2 m) fractional cover of 20% is considered**

There are 3 known exceptions:

1. **the sugarcane plantation and cassava crop which are included in the cropland class although they have a longer vegetation cycle and are not yearly planted;**
2. **taken individually, vegetables consisting as contiguous small plots do not meet the minimum size criteria of the cropland definition. However, when considered as a continuous heterogeneous field, they should be included in the cropland;**
3. **the greenhouse crops that cannot be monitored by remote sensing and that are thus excluded from the definition.**

*Definition presented at the JECAM meeting of July 2014, with general agreement

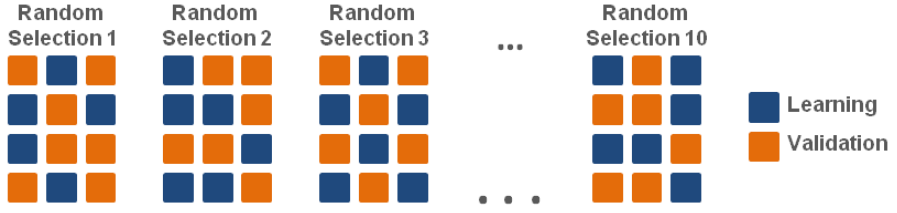
L4 dynamic cropland mask

Properties	User Requirement	Product specification
Spatial coverage	Local (over sites) to regional	✓
Time period	Current	✓ with 6 months before the 1st delivery
Temporal frequency	1 month	✓ 1 month with a 12-month moving window (fully operational after 23 months)
Delivery time	3 days after the end of each month	✓
Spatial resolution	10 meters	✓
Legend	Binary (crop – no crop)	✓ focusing on annual croplands
Geometric accuracy	Sub-pixel location error	L1C geometric accuracy
Thematic accuracy	10 % (maximum error of omission and commission of annual cropland mask)	F1-Score of 50% at the middle of the season and 80% at the end of the season
Quality flags	(i) the number of valid observations (ii) the status of the pixel (valid, cloud, cloud shadow, snow, gaps and filled values)	✓ Info split in 4 flags (obs. number, validity, status, gap filled)
Format	Standard raster format (e.g. GEOTIFF)	✓ GEOTIFF
Projection	UTM and WGS84	✓ UTM-UPS/WGS84
Metadata	Clear metadata, standard data formats	✓ XML file
Products distribution	Open and freely available product (+ documentation and validation)	✓

Benchmarking set-up

- 2 modes:
  1) With in-situ data: supervised algorithm based on SVM / RF classifiers
  2) Without in-situ data:
     a) K-mean classification + labelling based on an existing map
     b) Cleaning of an existing map using a trimming process, to derive training dataset to feed a supervised algorithm (ML / RF)
- Per-pixel vs per-object approach (objects used before or after the classification)

- Assessment criteria:
  - Overall accuracy + crop / no-crop F-Scores (threshold of 50%/80% at the middle/end of the season)
  - Computation time
- Validation based on in-situ:
  - 1/3 for algorithm training, 2/3 for validation
  - Split by field
  - Split made 10 times to reduce variability (mean OA and F-Scores)



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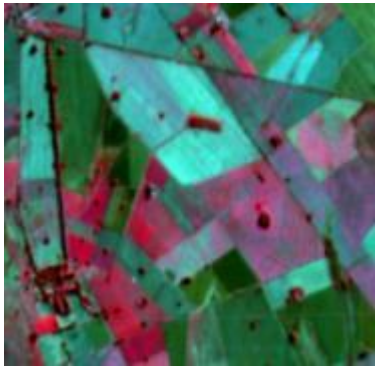
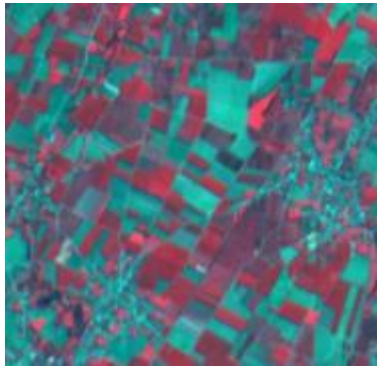
Wide range of agricultural systems

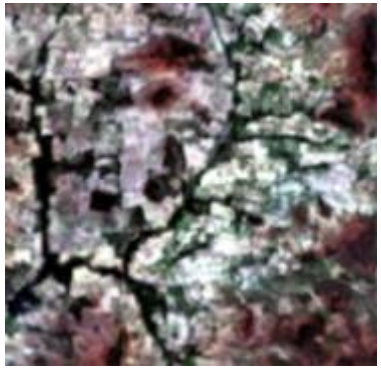
Argentina



Belgium

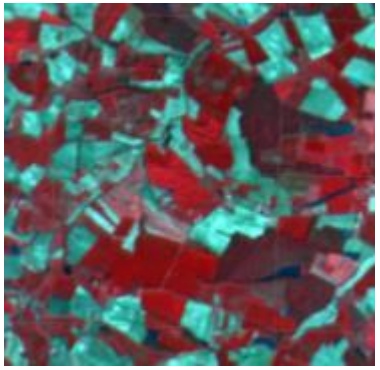


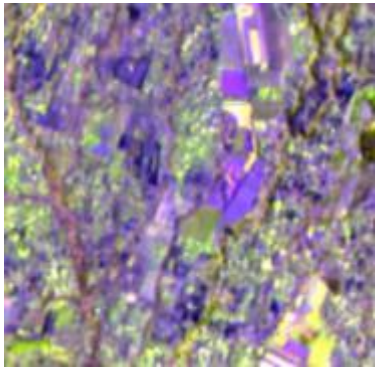
Burkina Faso



China

France

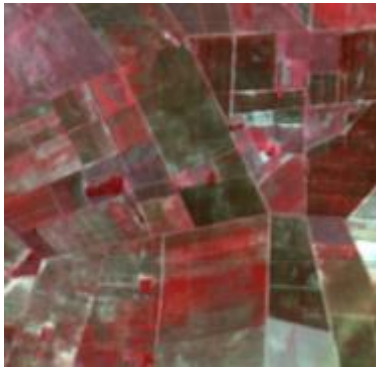




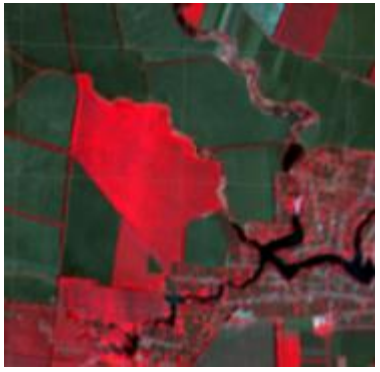
Madagascar

Morocco

Russia



South Africa



Ukraine

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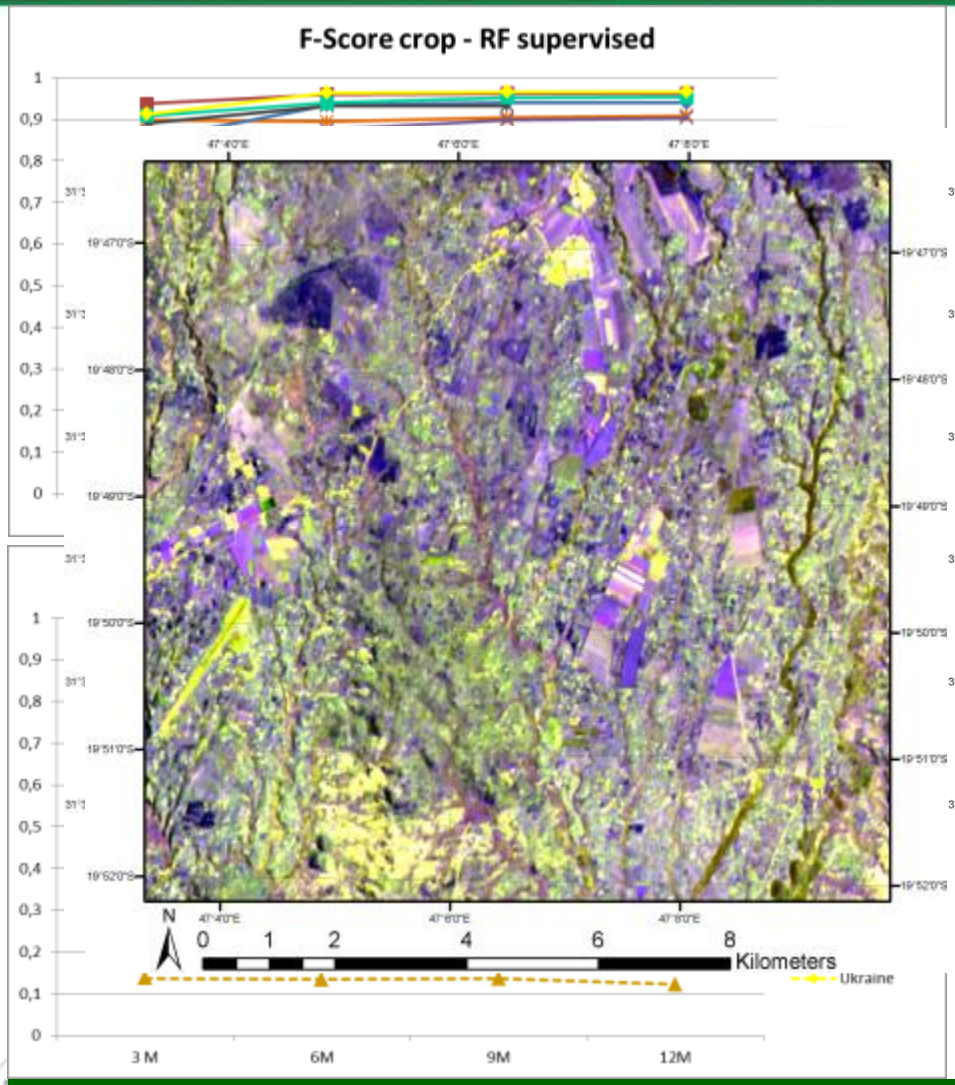
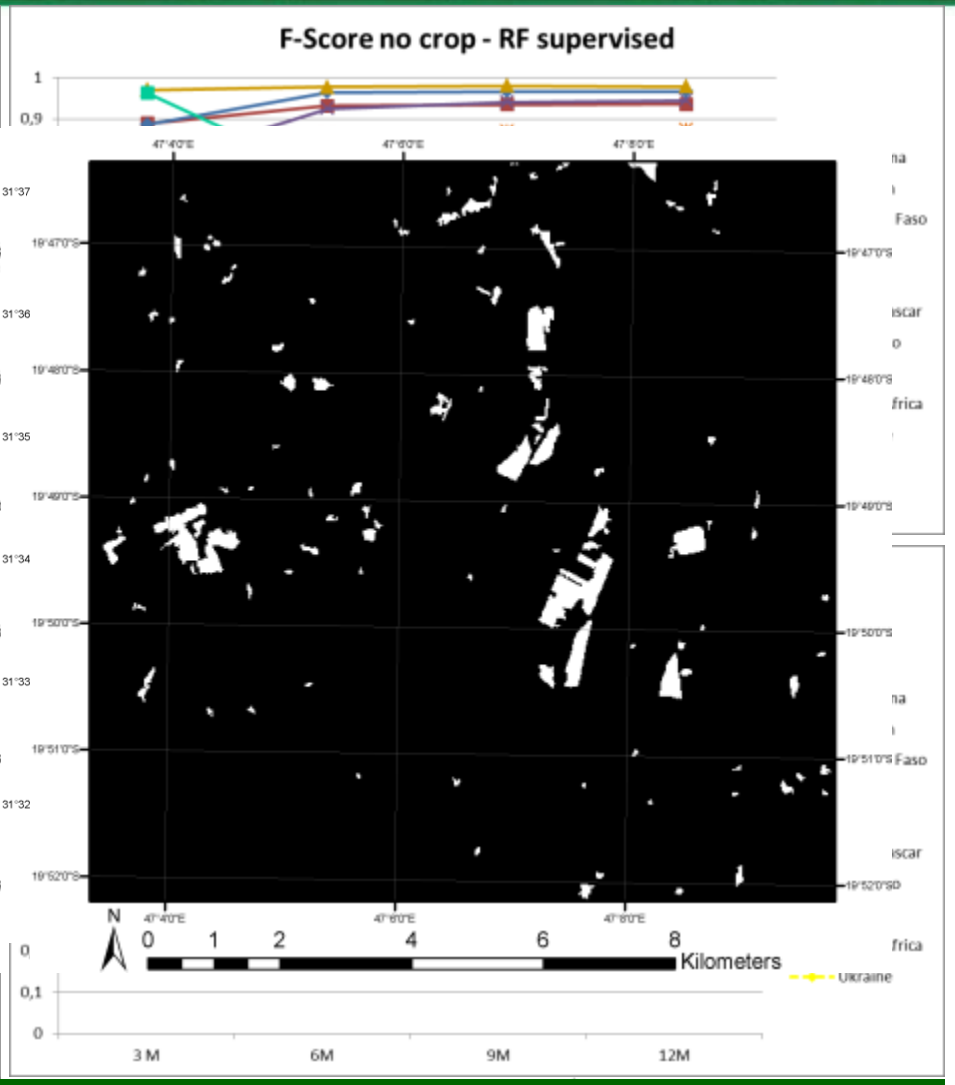
Accuracy assessment (1/2)

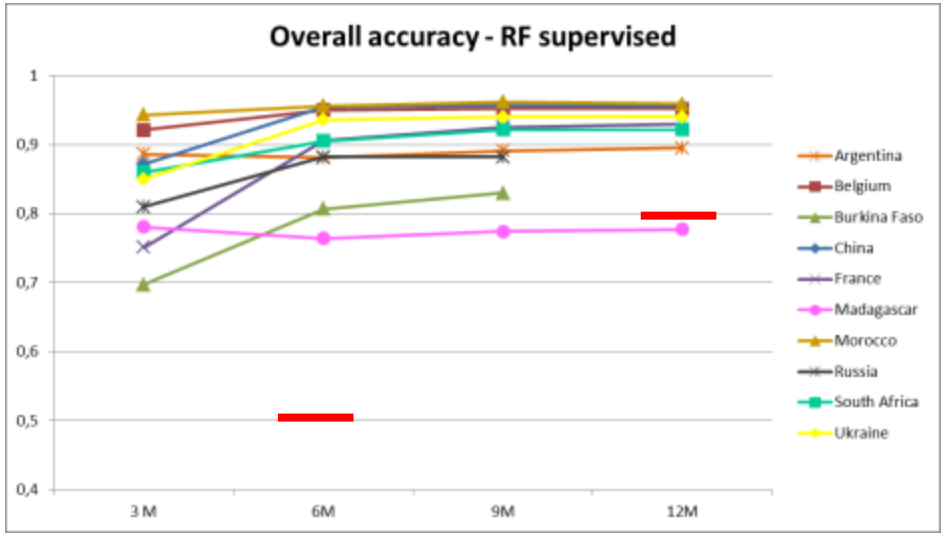


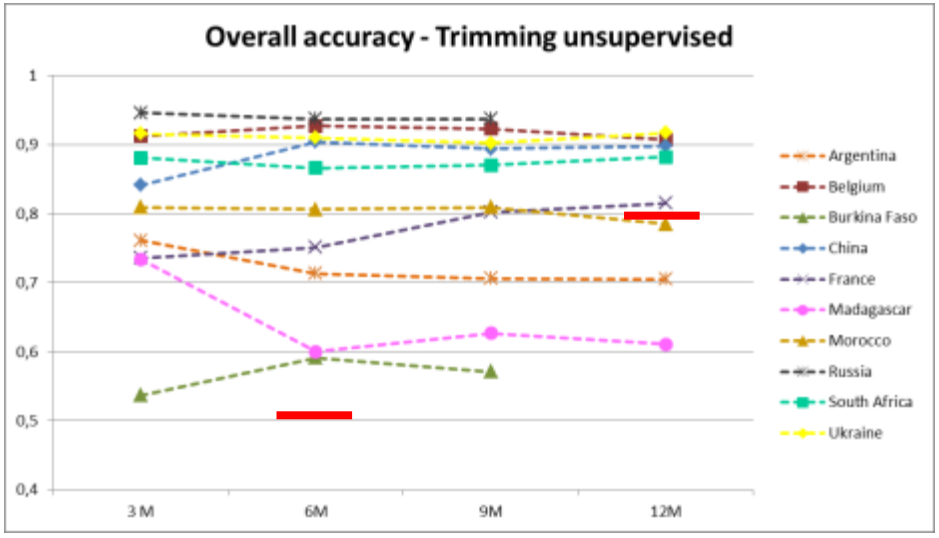


CROP: same trends observed for sup. and unsup. methods

NO-CROP: Unsupervised approaches have more difficulties to detect no crop pixels

Accuracy assessment (2/2)



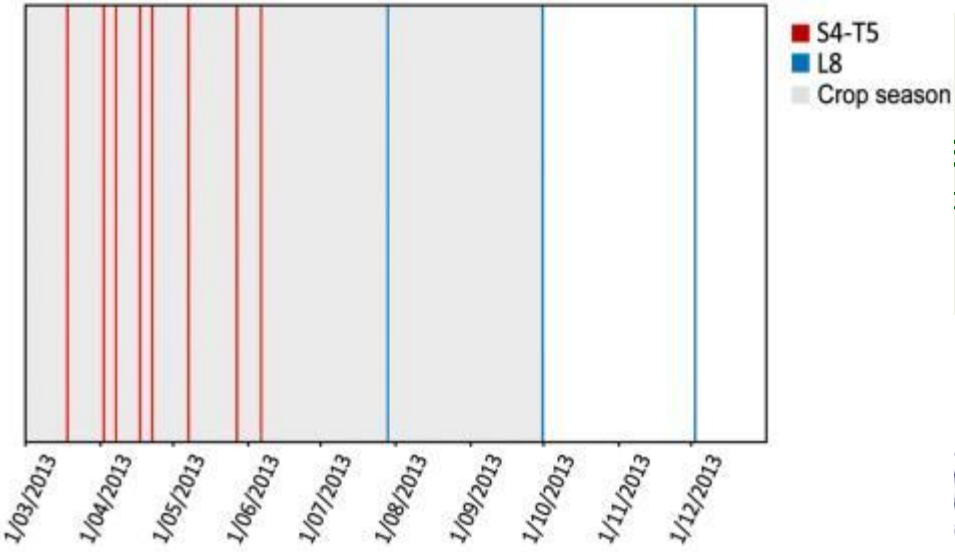


Supervised app

Unsupervised c

situations wher

food insecure c



esting as many

year of activity,

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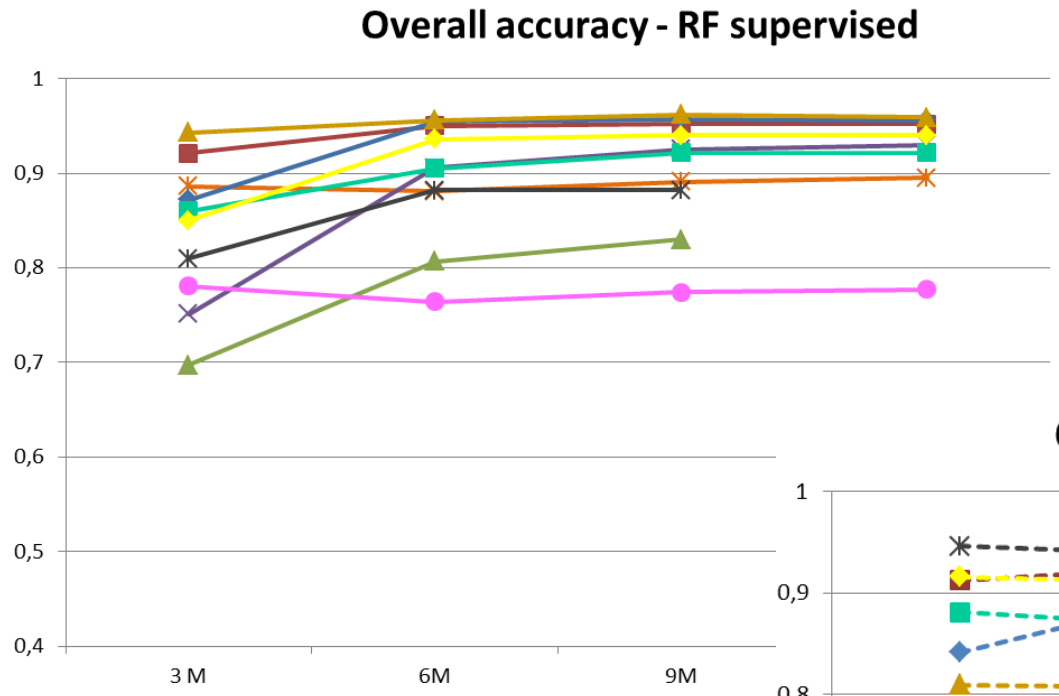
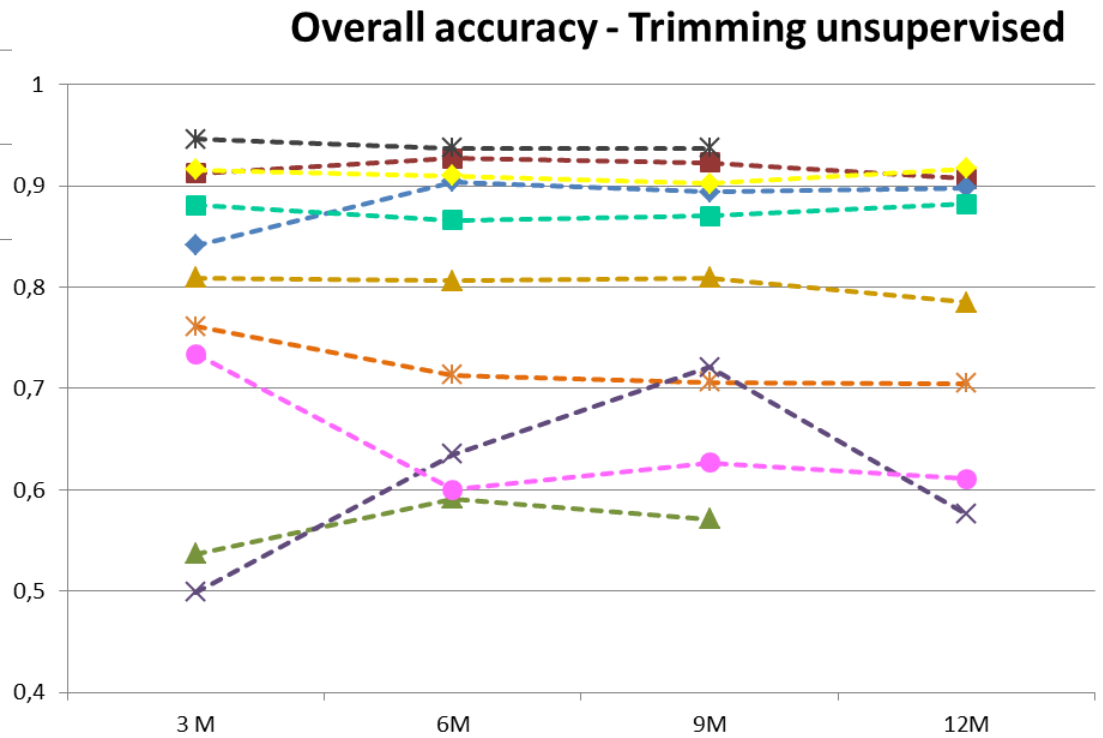
Efficient annual cropland mapping along the season



6 months of observations enough to reach the final cropland accuracy



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Sensitivity of unsupervised approach to the reference map

Trimming per pixel method re-run over the sites with HR references using the 300m CCI land cover map

	Overall Accuracy		F-Score crop		F-Score no crop	
	HR	CCI 300m	HR	CCI 300m	HR	CCI 300m
Belgium*	0.898	0.909	0.901	0.932	0.982	0.871
South Africa*	0.905	0.911	0.931	0.924	0.589	0.677
Ukraine*	0.986	0.982	0.913	0.860	0.993	0.995
Argentina**	0.714	0.695	0.676	0.674	0.965	0.797
Burkina Faso**	0.570	0.838	0.936	0.842	0.324	0.794
Madagascar**	0.627	0.8314	0.557	0.8276	0.667	0.8836
Morocco**	0.707	0.869	0.055	0.116	0.999	0.999
Russia**	0.935	0.937	0.941	0.945	0.740	0.742

* Local (national) reference map
** Global reference map (GLC30)

Matton et al. (2015)

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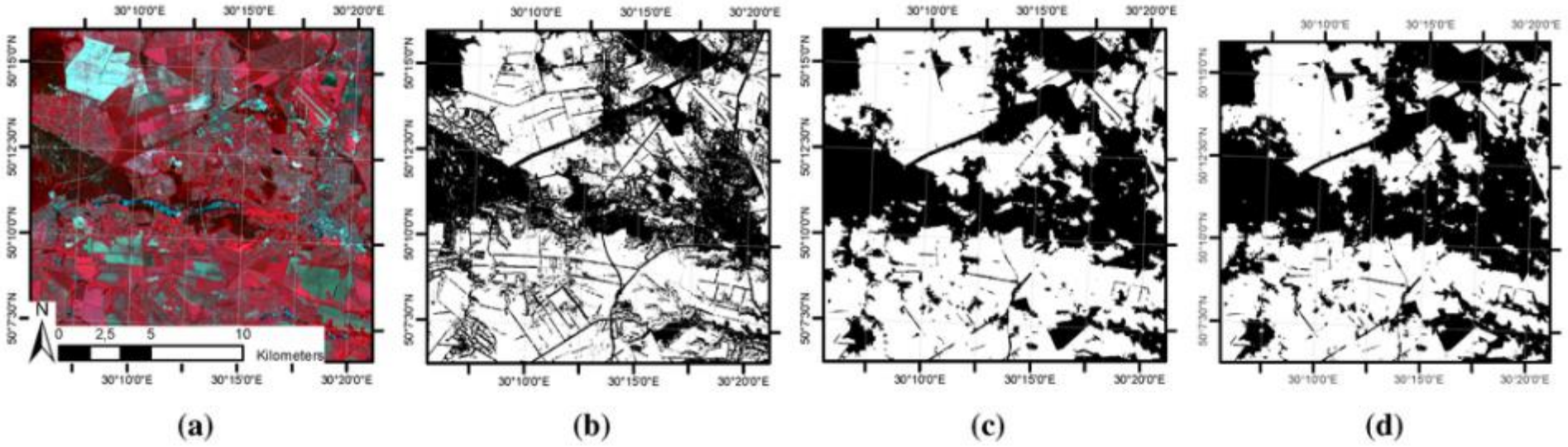
Similar results with HR or 300m reference map

Object-based approach for a posteriori filtering

Objects resulting from mean-shift segmentation, applied to 6 first components (PCA on full NDVI times series)



a) SPOT 4 (Take 5) image, 11 June 2013
b) Pixel-based classification: salt and pepper effect preventing sharp field delineation
c) Object post-filtering approach: dual approach combining both aspects
d) Object-based classification: higher spatial consistency

Matton et al. (2015)

Objects don't increase OA, but improve spatial consistency of maps

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Benchmarking conclusions

- Supervised approach leads to higher OA than unsupervised, but performance of unsupervised not bad
- Increased OA over time but already ~ 80% after 6 months
- Per-object approach most efficient for a-posteriori filtering

Implementation in the Sen2-Agri system

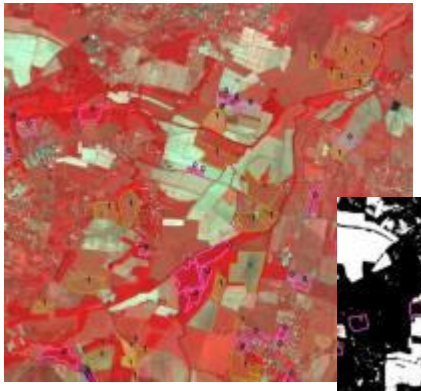
- 2 chains implemented to deal with presence/absence of in-situ data
- RF supervised algorithm
- Trimming to clean an existing map -> training -> RF supervised algorithm
- A posteriori smoothing based on a per-object approach

Successful development thanks to JECAM collaborative network

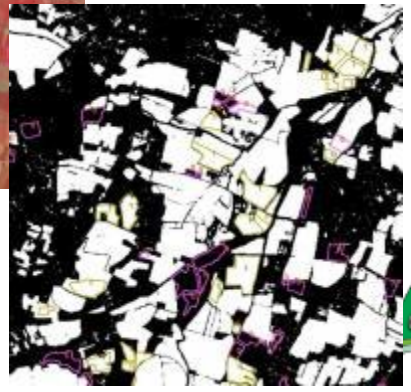
Next steps

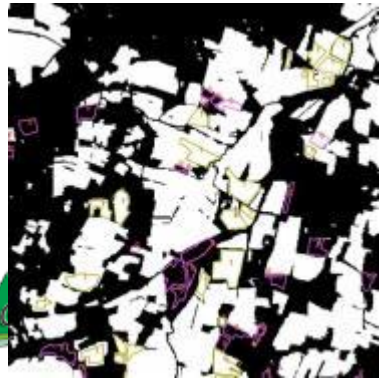
- Cross sites assessment allows testing methods robustness and relevance in different agricultural conditions
- Same assessment in progress with SPOT 5 Take 5 data (8 sites)
- Demonstration of the system (i.e. of the selected algorithms and developed system) from February 2016 in real-life conditions, with S2 data in NRT (presentation Tuesday 2PM)

Mali JECAM site



France (SudMiPyO) JECAM site





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Thank you for your attention

www.esa-sen2agri.org

Remote Sens. **2015**, *xx*, 1-x; doi:10.3390/rs70x000x

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Technical Note

Building a data set over 12 globally distributed sites to support the development of agriculture monitoring applications with Sentinel-2

Sophie Bontemps [1,*], Marcela Arias [2], Cosmin Cara [3], Gérard Dedieu [2], Eric Guzzonato [4], Olivier Hagolle [2], Jordi Inglada [2], Nicolas Matton [1], David Morin [2], Ramona Popescu [3], Thierry Rabaute [4], Mickael Savinaud [4], Guadalupe Sepulcre [1], Silvia Valero [2], Ijaz Ahmad Bhutta [5], Agnès Bégué [6a], Wu Bingfang [7], Diego de Abelleyra [8], Alhousseine Diarra [9,14], Stéphane Dupuis [6a], Andrew French [10], Ibrar ul Hassan Akhtar [5], Nataliia Kussul [11], Valentine Lebourgeois [6b], Michel Lepage [7,14], Terry Newby [12], Igor Savin [13], Santiago R. Verón [8], Benjamin Koetz [14] and Pierre Defourny [1]

Remote Sens. **2015**, *7*, 13208-13232; doi:10.3390/rs71013208

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Article

An Automated Method for Annual Cropland Mapping along the Season for Various Globally-Distributed Agrosystems Using High Spatial and Temporal Resolution Time Series

Nicolas Matton [1,*], Guadalupe Sepulcre Canto [1], François Waldner [1], Silvia Valero [2], David Morin [2], Jordi Inglada [2], Marcela Arias [2], Sophie Bontemps [1], Benjamin Koetz [3] and Pierre Defourny [1]

Remote Sens. **2015**, *xx*, 1-x; doi:10.3390/——

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remote sensing

ISSN 2072-4292

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Article

Production of a dynamic cropland mask by processing remote sensing image series at high temporal and spatial resolutions

Silvia Valero [1,*], David Morin [1], Jordi Inglada [1], Guadalupe Sepulcre [2], Olivier Hagolle [1], Marcela Arias [1], Gérard Dedieu [1], Sophie Bontemps[2], Pierre Defourny[2], Benjamin Koetz[3]

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UCL Université catholique de Louvain

CESBIO

ROMÂNIA