EARTH & LIFE INSTITUTE

Belgian Pavilion
Milano 2015

EXPO
MILANO 2015
FEEDING THE PLANET
ENERGY FOR LIFE

Space4Food – Workshop

Why tonight will change agriculture monitoring in the world ?

From JECAM to BELCAM initiatives in preparation to Sentinel-2

Pierre Defourny, Sophie Bontemps, Xavier Blaes, Marie-Julie Lambert, Nicolas Matton, and François Waldner

UCLouvain - *Geomatics*

UCL UNIVERSITÉ CATHOLIQUE DE LOUVAIN

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~~11 June 2015~~
22=>23 June 2015

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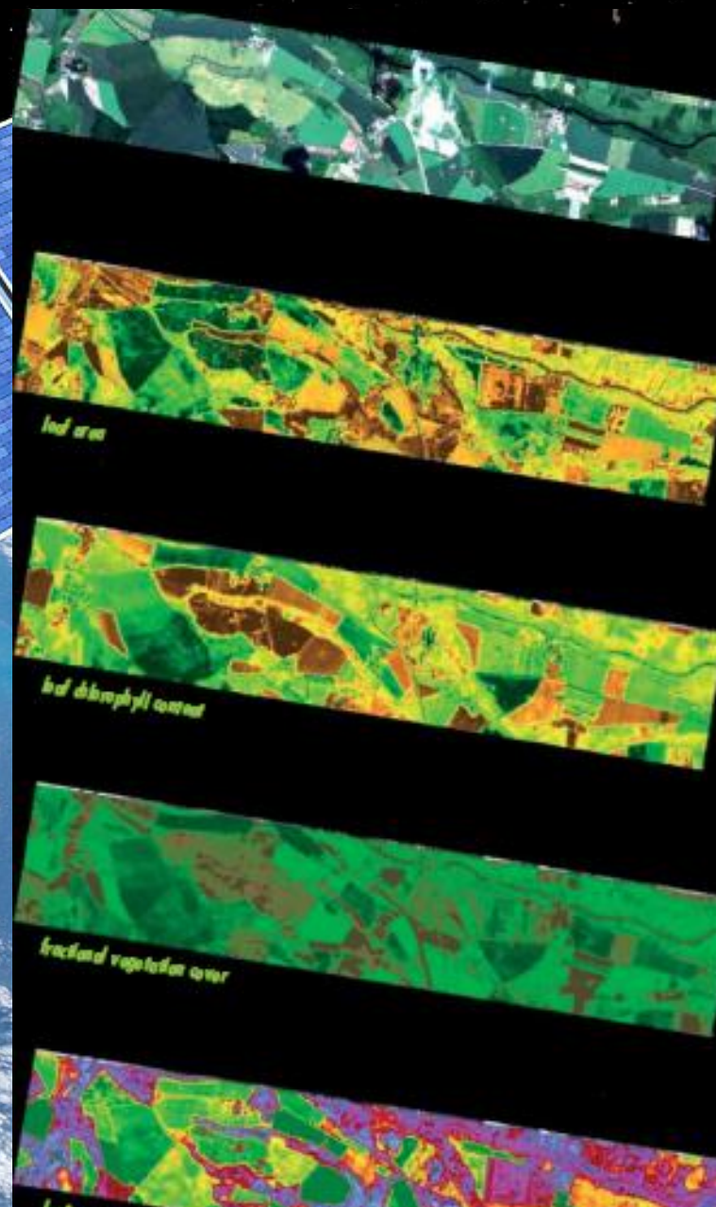
Copernicus Sentinel-2 satellites

Multispectral High Resolution Optical Imager

- Launch: June 2015, Nov. 2016, ...
- **13 bands (VIS, NIR & SWIR)**
- **290 km swath at 10, 20 and 60 m**
- **Free, open and continuously delivered data**
- **Systematic acq.** of all land and coasts
- **5 days repeat cycle with 2 satellites**
- 7 years design lifetime (max. 12 yrs)



CEOS - GEOGLAM EO missions requirements

Major Sentinel-2 contribution to agriculture monitoring

Req#	Spatial Resolution	Spectral Range	Effective observ. frequency (cloud free)*	Sample Type	Field Size	Target Products: Crop Mask	Crop Type Area and Growing Calendar	Crop Condition Indicators	Crop Yield	Crop Biophysical Variables	Environ. Variables	Ag Practices / Cropping Systems
	Coarse Resolution Sampling (>100m)											
1	500 - 2000 m	thermal IR + optical	Daily	Wall-to-Wall	All			X		L		
2	100-500 m	optical + SWIR	2 to 5 per week	Cropland Extent	All	X	X	X	L	L		L
3	5-50 km	microwave	Daily	Cropland Extent	All			X	X	X	X	
	Moderate Resolution Sampling (10 to 100m)											
4	10-70m	optical + SWIR + TIR	Monthly (min 2 out of season + 3 in season). Required every 1-3 years.	Cropland Extent	All	X	L/M					X
5	10-70m	optical + SWIR + TIR	Weekly (min. 1 per 16 days)	Sample	All	X	X	X	X	X	X	X
6	10-100m	SAR	Weekly (min. 1 per 2 weeks)	Cropland Extent of persistant cloudy areas/Rice	All	X	X	X	X	X	X	X

100 m daily global coverage – follow up of PROBA-V needed

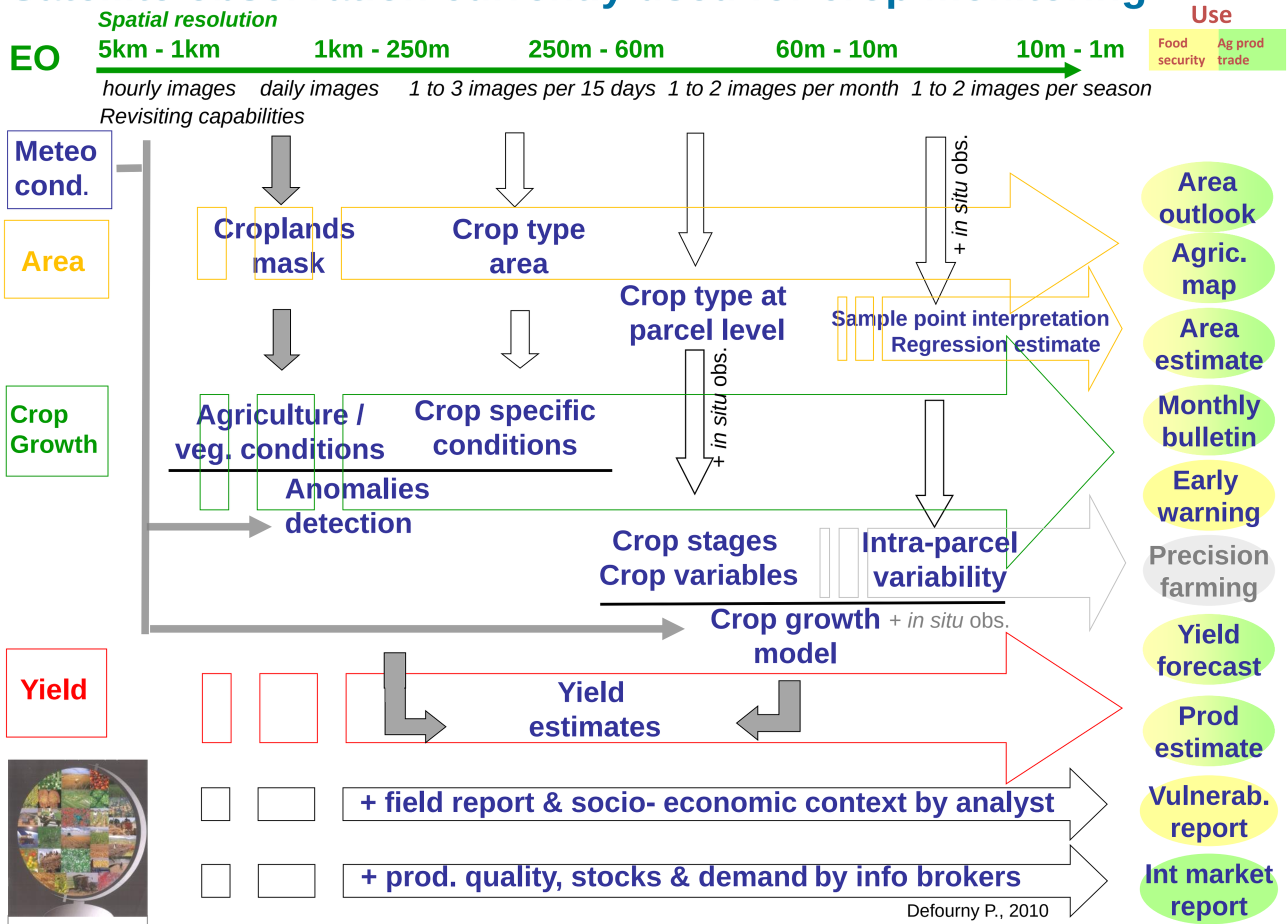
Sentinel-2 A & 2B

Sentinel-2 A & 2B

Sentinel-1 A & 1B

Source: CEOS ACQUISITION STRATEGY FOR GEOGLAM PHASE 1

Satellite observation currently used for crop monitoring

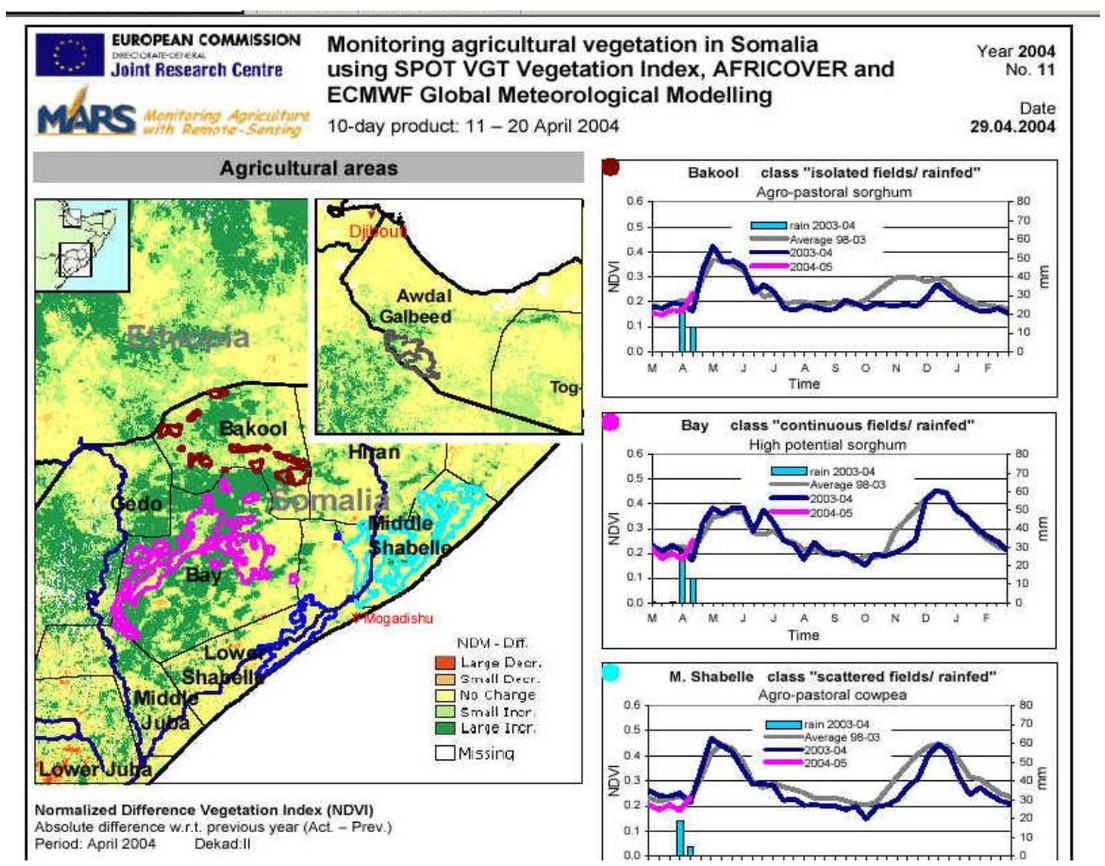


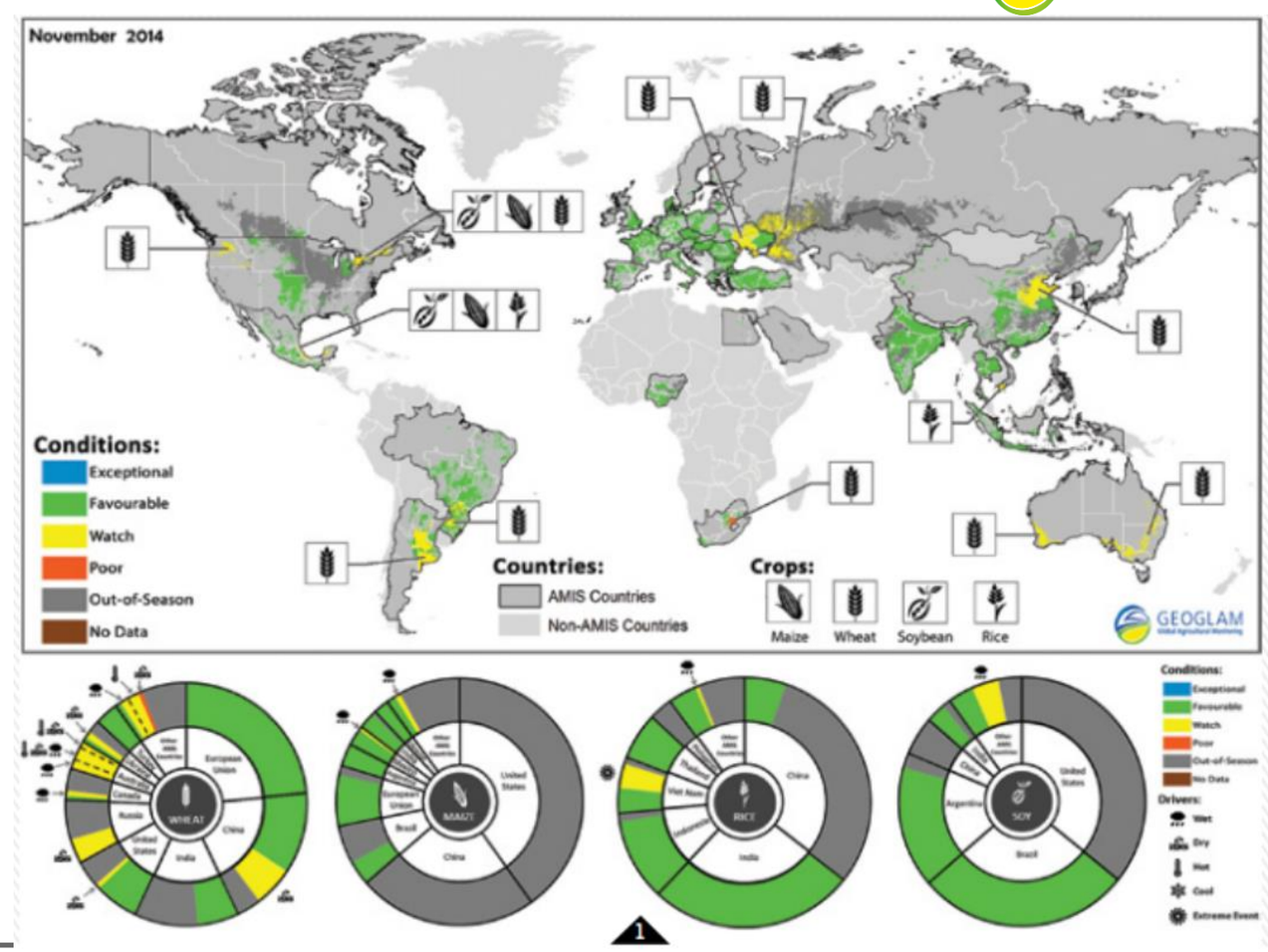
Defourny P., 2010

1 km NDVI time series
to detect anomalies in the growing season

- Monitor the vegetation growth but no focus on croplands
- Only qualitative information by inter-annual comparison (anomalies)
- No crop specific assessment

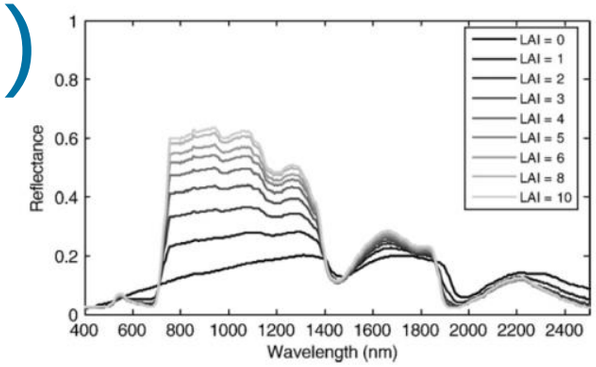
=> only general overview of the growing season condition





From NDVI to crop biophysical variables

Leaf Area Index (LAI or GAI)



Jacquemoud et al. 2009

Spectral reflectance observation by satellite

+ *sun angle*

+ *viewing angle*

Crop canopy structure

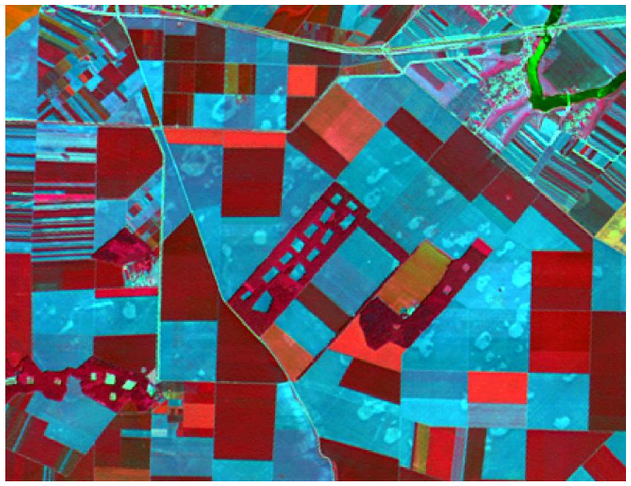
- *Leaf Area Index*
- *Leaves distribution*
- *Foliage angles*

Leaf structure

- *Chlorophyll a & b*
- *Water content*

Atmospheric effects

- *Pressure*
- *Water vapor*
- *Aerosols*



SATELLITE IMAGE

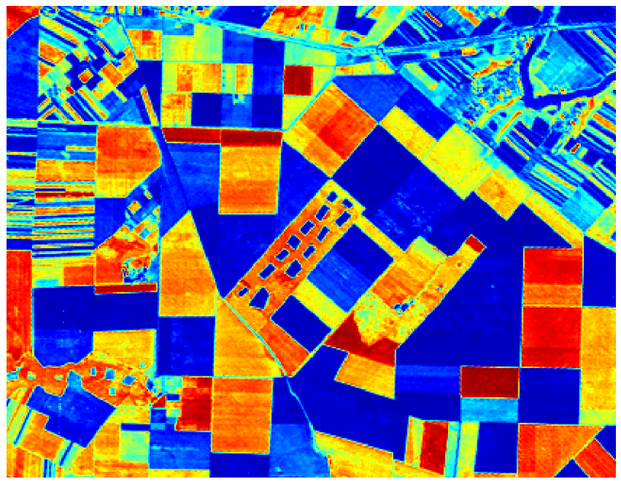
Calibration

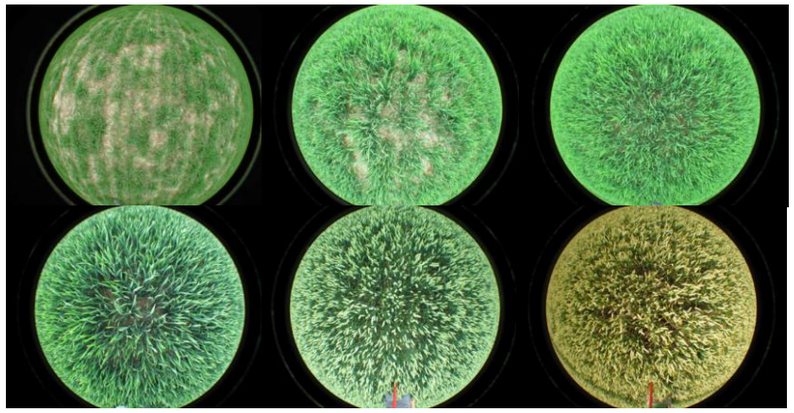
Inversion

Pinty et al. 2001

RADIATIVE TRANSFER MODEL

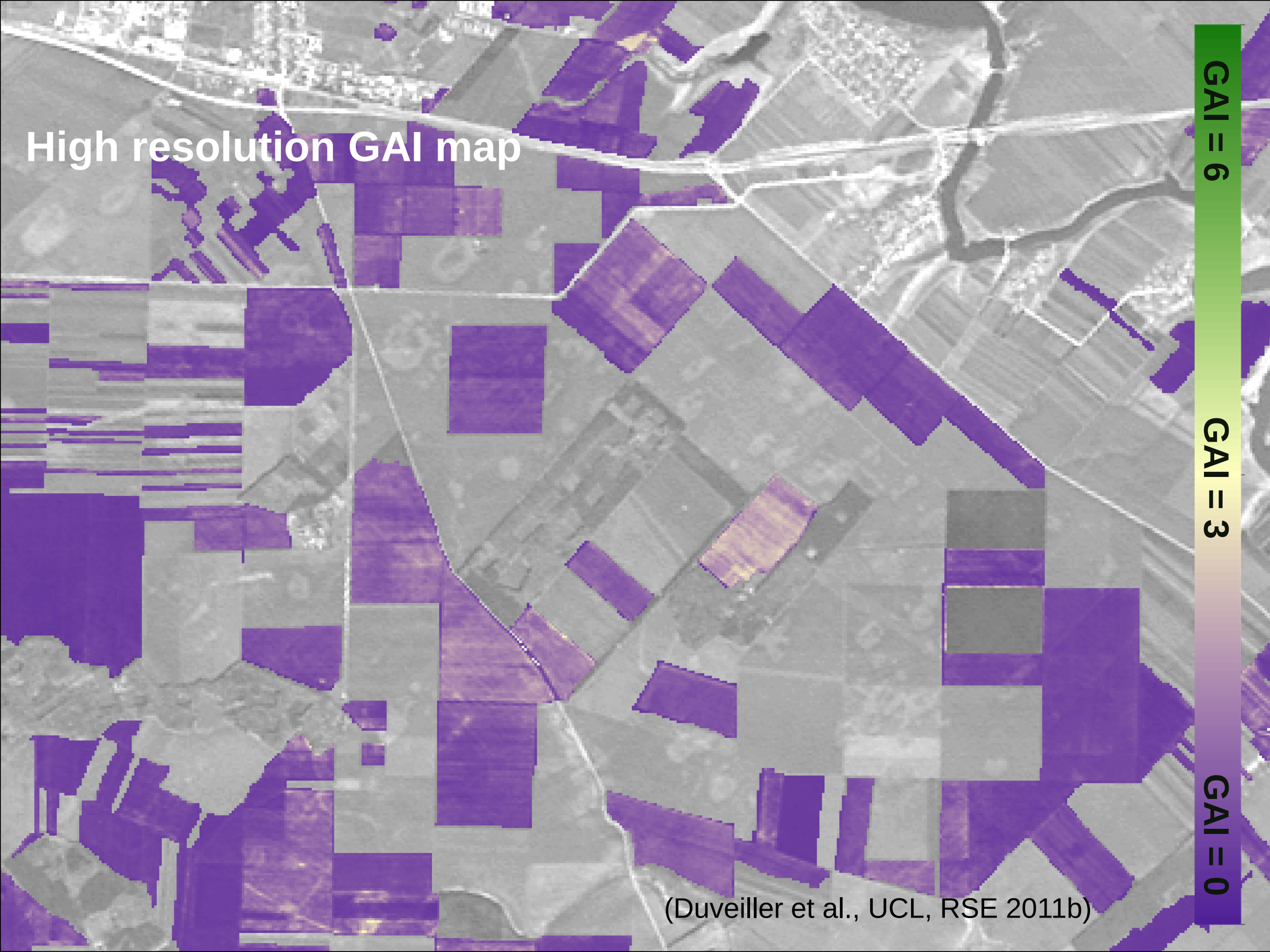
LEAF AREA INDEX MAP





Ground GAI obtained from Digital Hemispherical Photography

High resolution GAI map

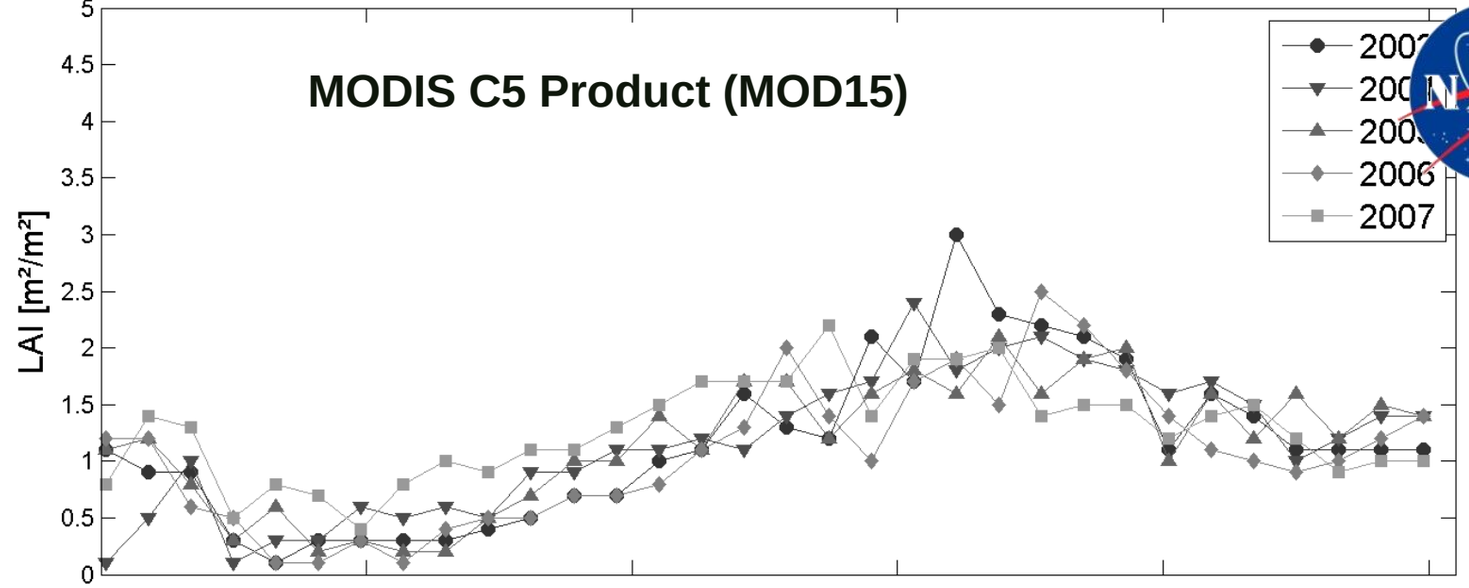


(Duveiller et al., UCL, RSE 2011b)

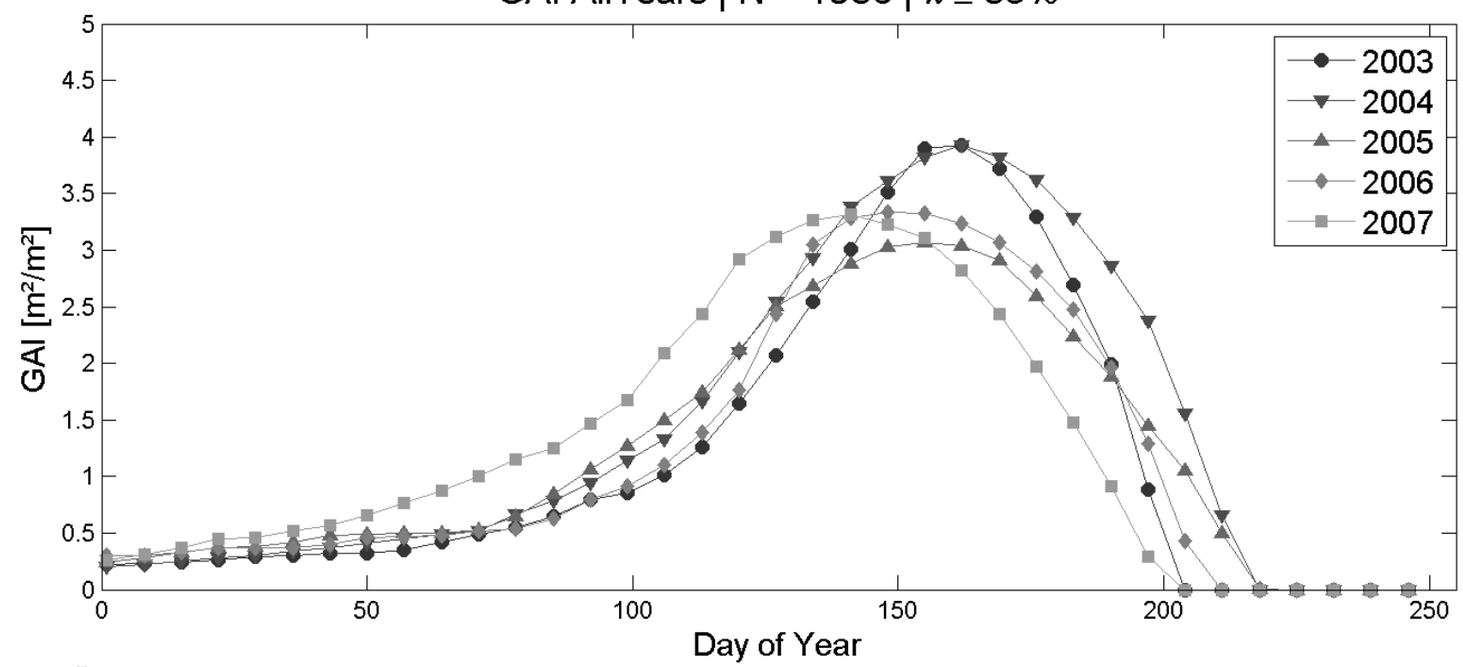
Can LAI time series detect the inter-annual variability for a given region ?

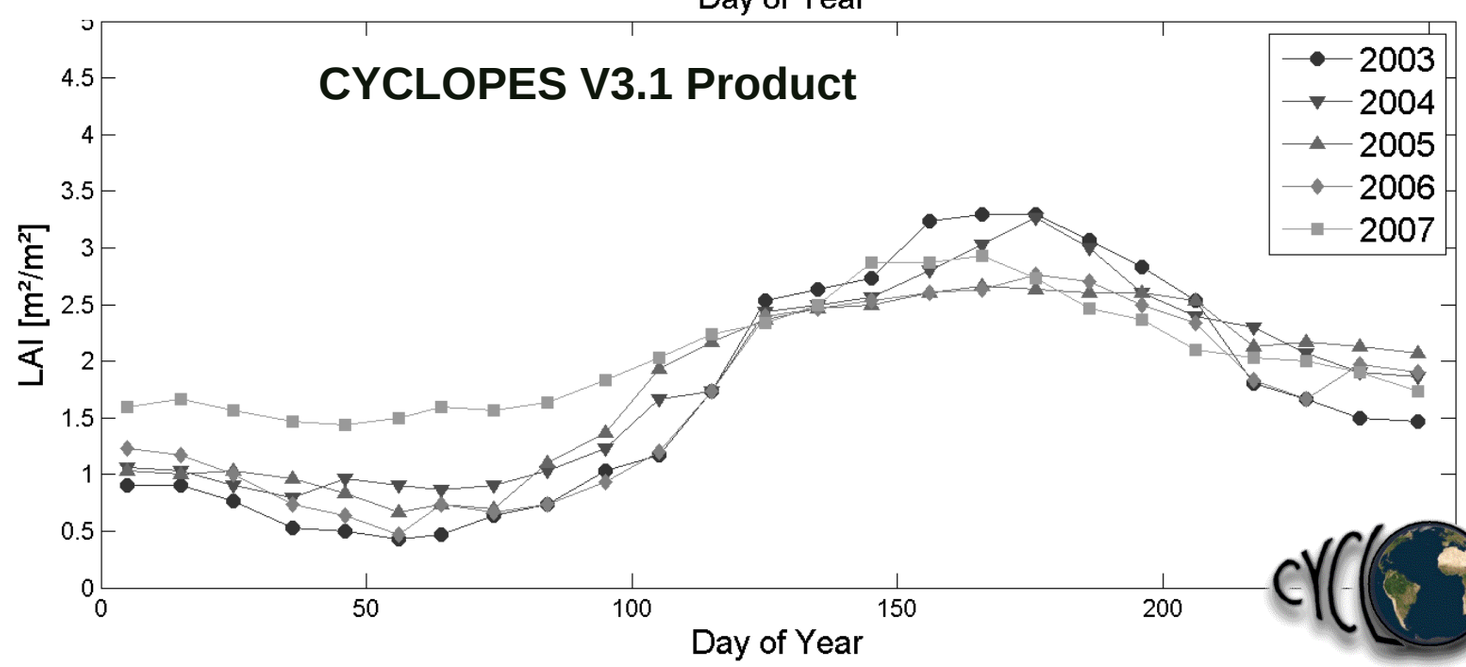
Inter-annual variability better grasped by crop specific focus

Winter wheat LAI at 250 m



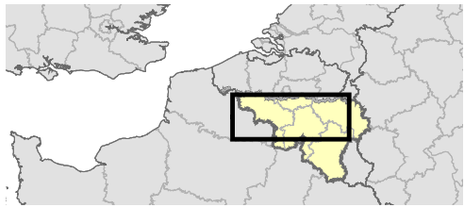
GAI AllYears | N = 1986 | $\pi \geq 85\%$



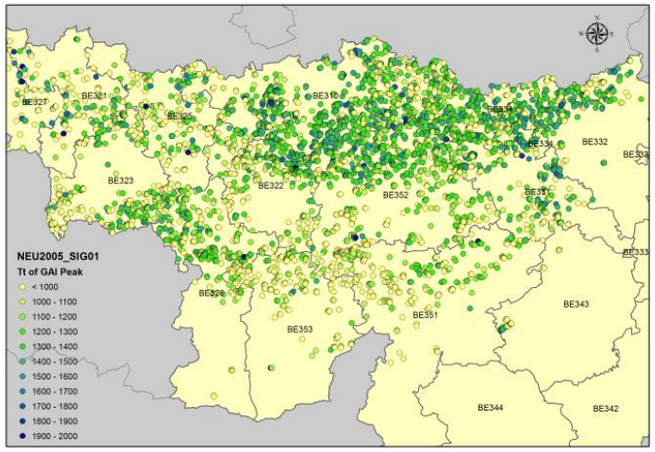


GLOBAM (BELSPO)
Duveiller et al., RSE2011

Better yield estimate thanks to assimilation of LAI in crop growth model



GLOBAM : WOFOST model
optimized for winter wheat using LAI derived from 250-m EO for 6 different years



Yield Estimations

< 5.0 t/ha	6.5 - 7.0 t/ha	8.5 - 8.5 t/ha
5.0 - 5.5 t/ha	7.0 - 7.5 t/ha	9.0 - 9.5 t/ha
5.5 - 6.0 t/ha	7.5 - 8.0 t/ha	9.5 - 10.0 t/ha
6.0 - 6.5.0 t/ha	8.0 - 8.5 t/ha	> 10. t/ha

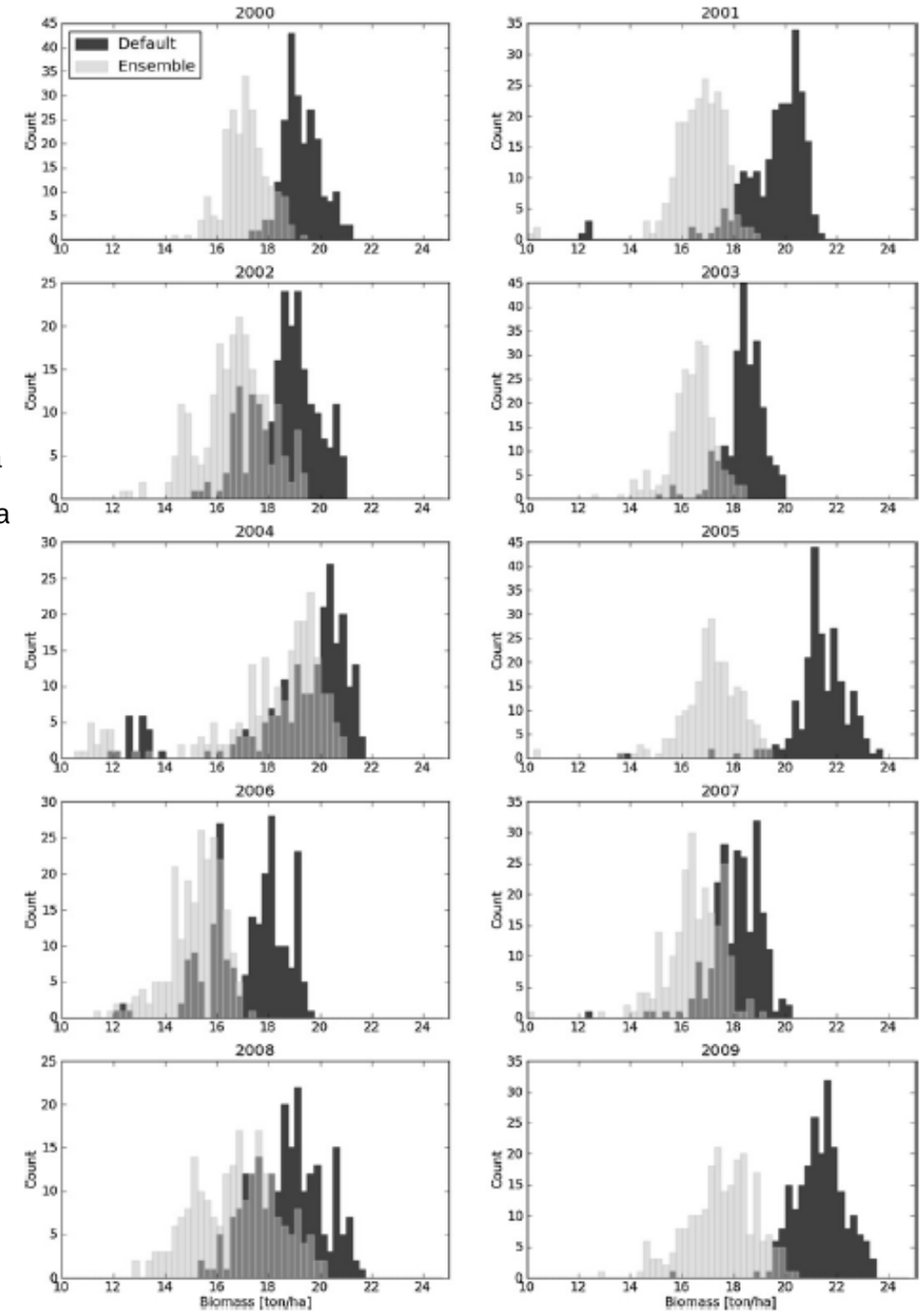


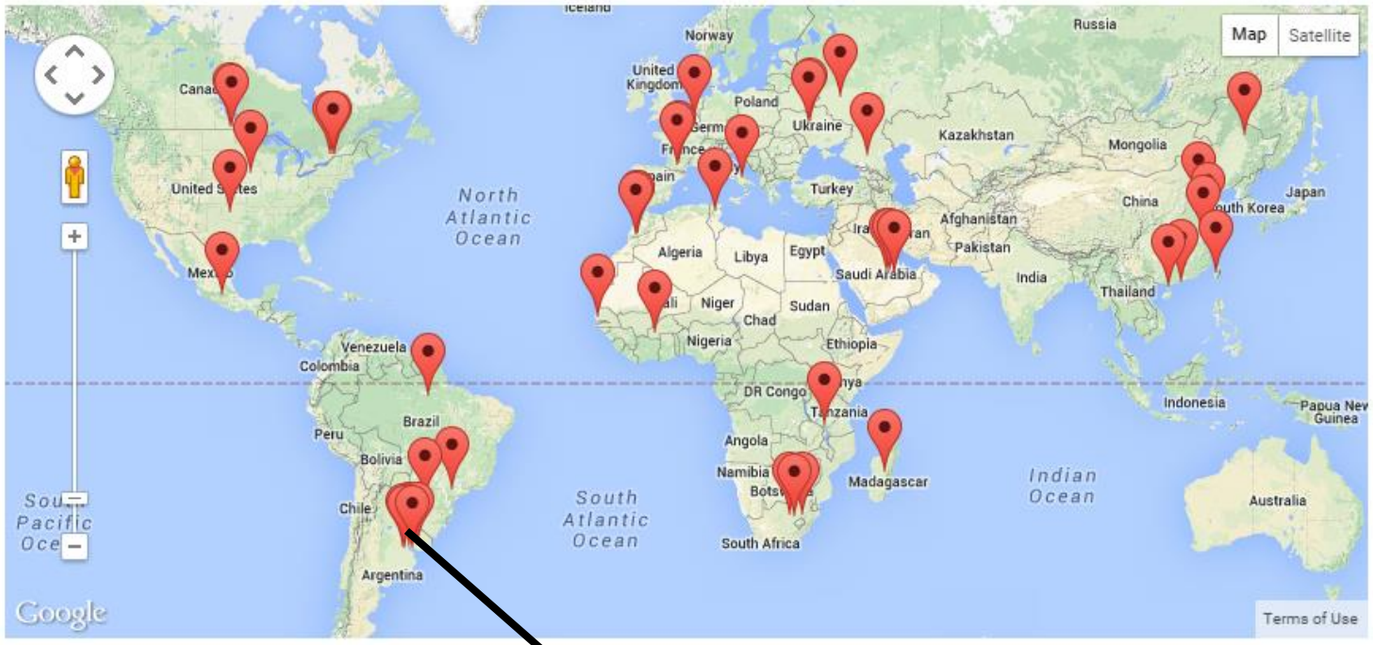
Fig. 8. Histograms of the end-of-season simulated total aboveground biomass for all 10 × 10 grids in Wallonia for the default model run (black) and the ensemble ave (light grey). Overlap between the histograms is indicated in dark grey.

EO data assimilation provided

- Improved results for 3 years
- No impact for 2 years
- Worse results for 1 year

GLOBAM (BELSPO)
Duveiller et al., AFM2012

Challenge 1: High resolution time series over large areas need automated method valid for various regions



JOINT EXPERIMENT FOR CROP ASSESSMENT AND MONITORING

JECAM – global network of ag. sites to develop and test EO new methods much faster !!!

Special focus for EO acq.by space agencies

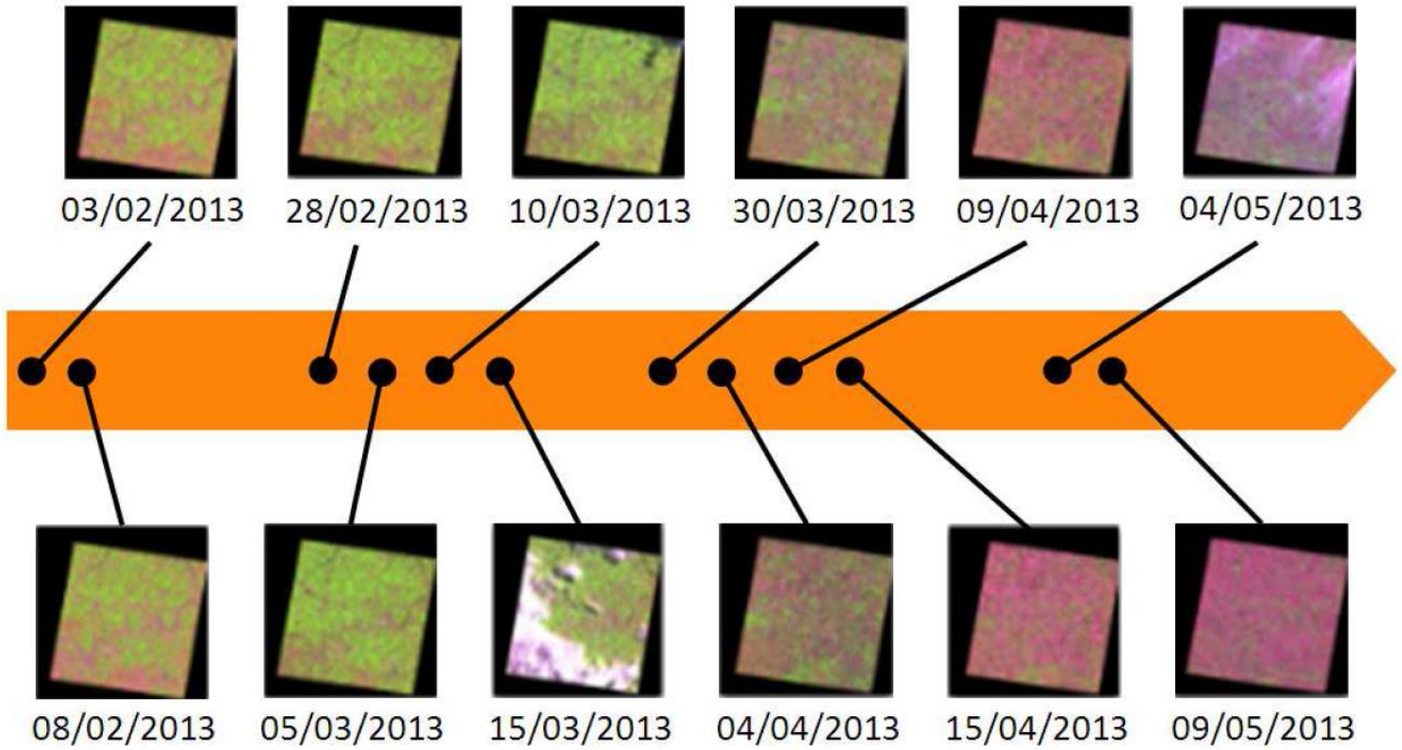
SPOT 4 TAKE 5

FEB. TO MAY 2013

JECAM ARGENTINA

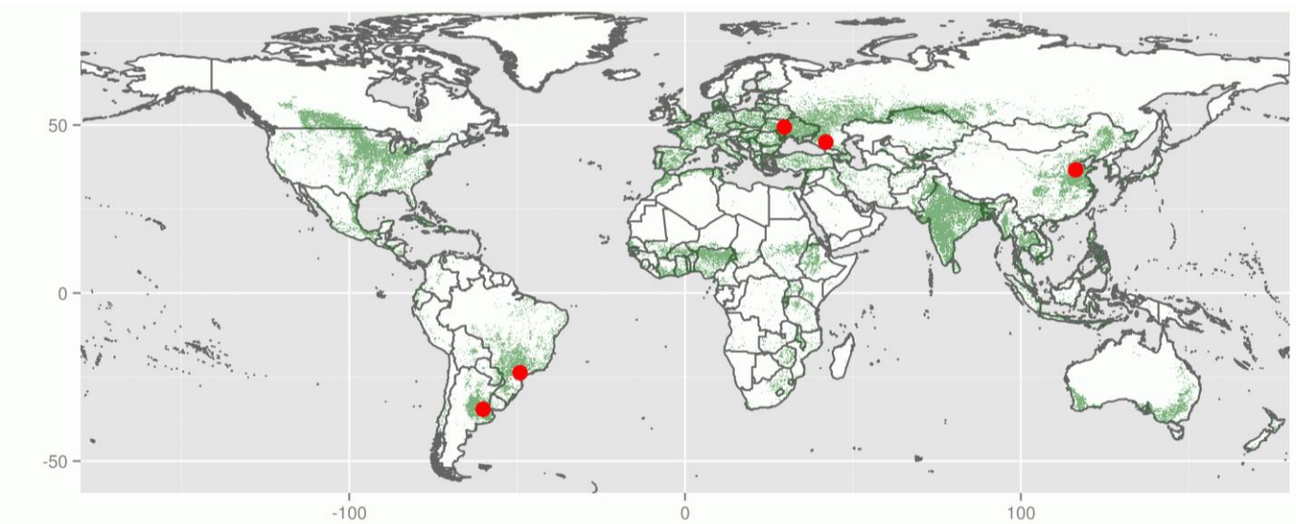
SPOT 5 TAKE 5

APR. TO AUG. 2015

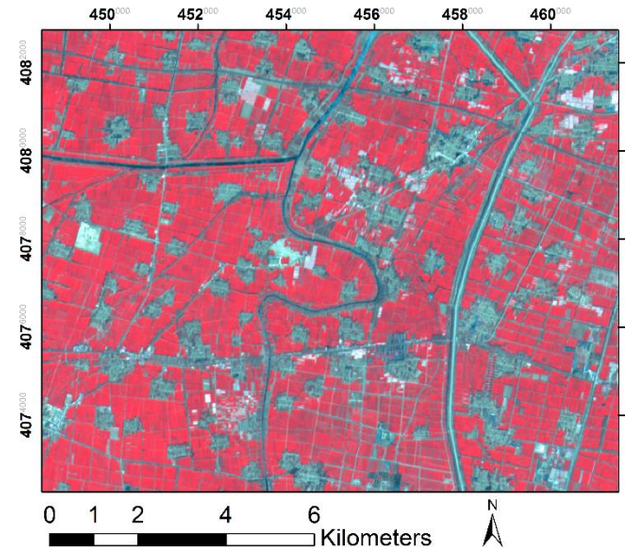


JECAM – SIGMA methods benchmarking :

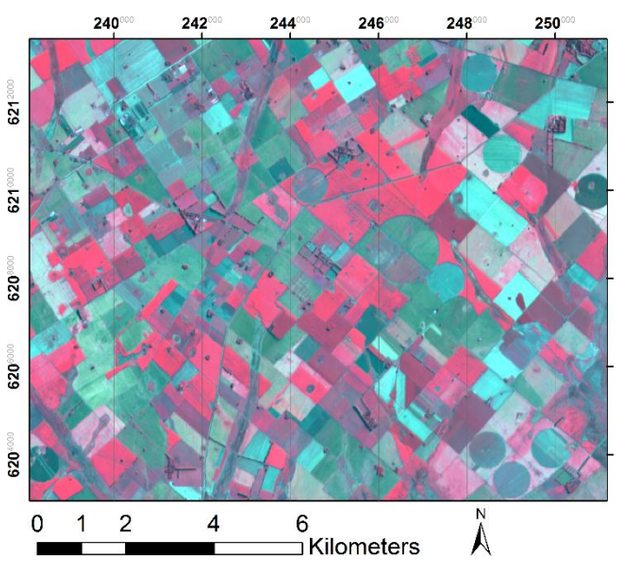
5 partners to map cropland in 5 sites over the world using 5 different methods and the same MODIS data



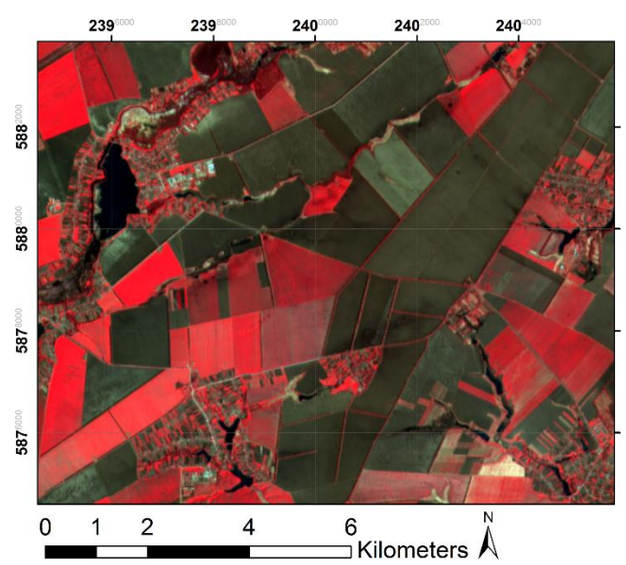
Field observations provided by each partner for validation



China

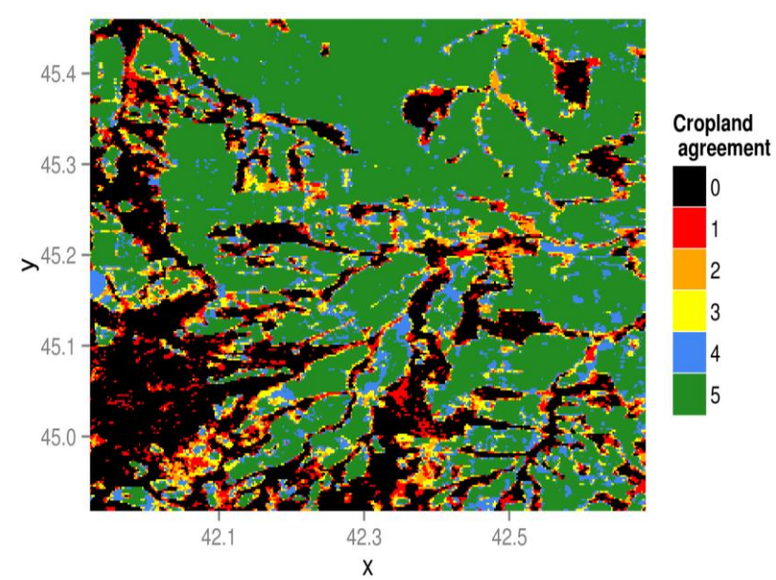


Argentina



Ukraine

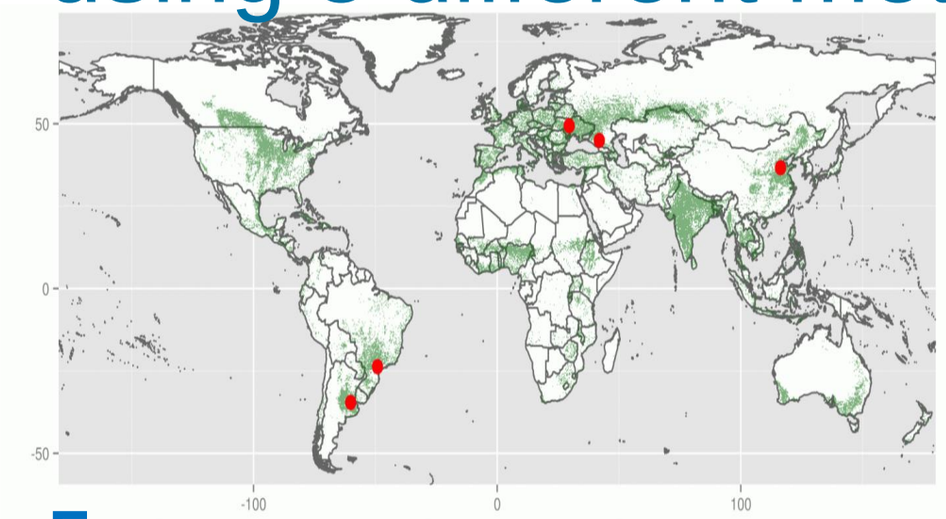
Russia – Methods agreement



Waldner et al. (submitted 2015)

JECAM – SIGMA methods benchmarking :

5 partners to map cropland in 5 sites over the world using 5 different methods from the same MODIS data



site	method	OA
Ukraine	iki	93.62
Ukraine	inta	96.58
Ukraine	radi	95.91
Ukraine	sri	98.04
Ukraine	ucl	97.58
Argentina	iki	90.74
Argentina	inta	92.66
Argentina	radi	90.52
Argentina	sri	95.49
Argentina	ucl	85.33
Brazil	iki	90.26
Brazil	inta	89.54
Brazil	radi	84.45
Brazil	sri	91.60
Brazil	ucl	91.15
China	iki	90.58
China	inta	91.23
China	radi	90.58
China	sri	90.58
China	ucl	88.31
Russia	iki	98.19
Russia	inta	95.40
Russia	radi	94.48
Russia	sri	98.38
Russia	ucl	95.21

Each method has different contraints

- Input requirement (EO time series)
- Delivery time
- Fully automated or not
- Need for training areas or not

=> Similar method accuracy performances !

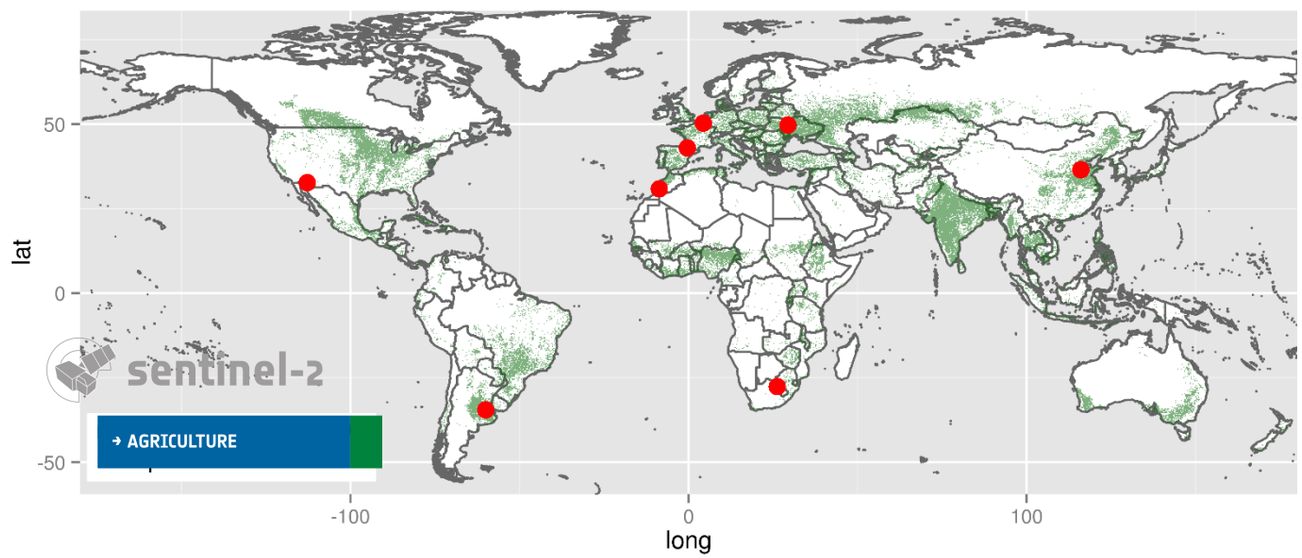
=> Major impact of the agricultural landscape

=> Influence of the input data quality

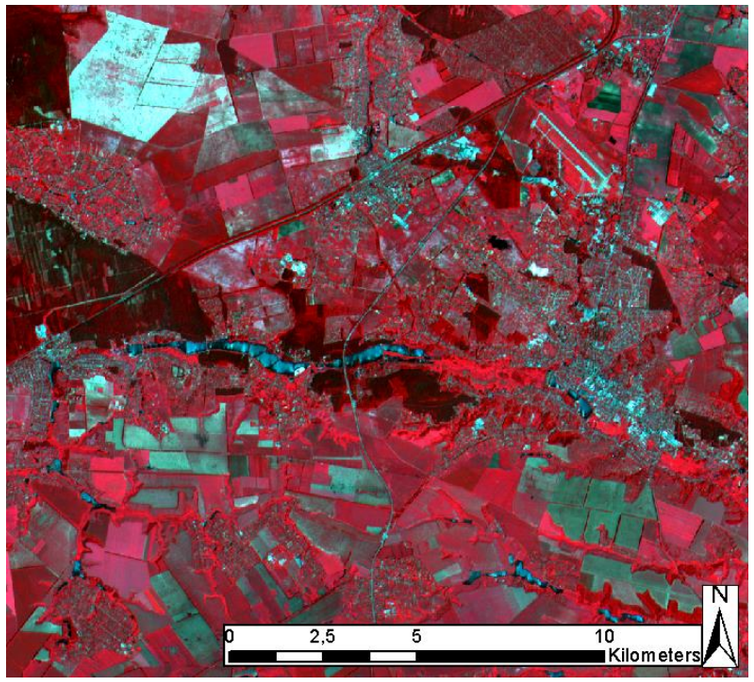
Waldner et al. (submitted 2015)

JECAM – ESA Sen2Agri methods benchmarking:
efficient annual cropland mapping along the season

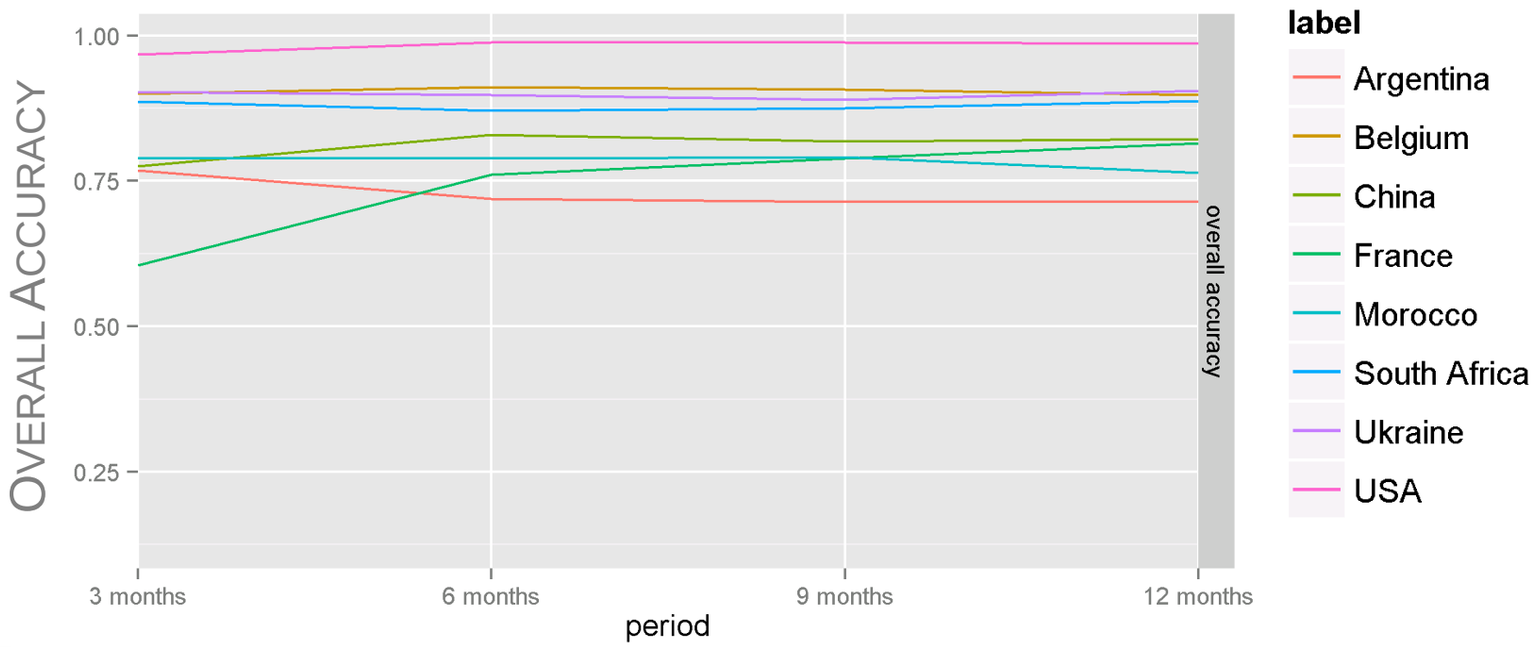
FOR MOST OF THE 8 SITES WIDELY DISTRIBUTED AROUND THE WORLD

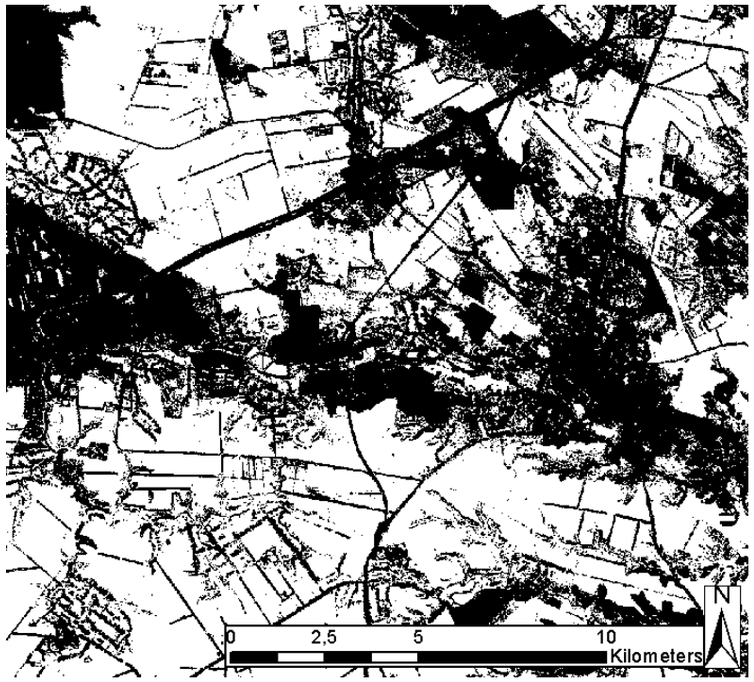


11/06/2013



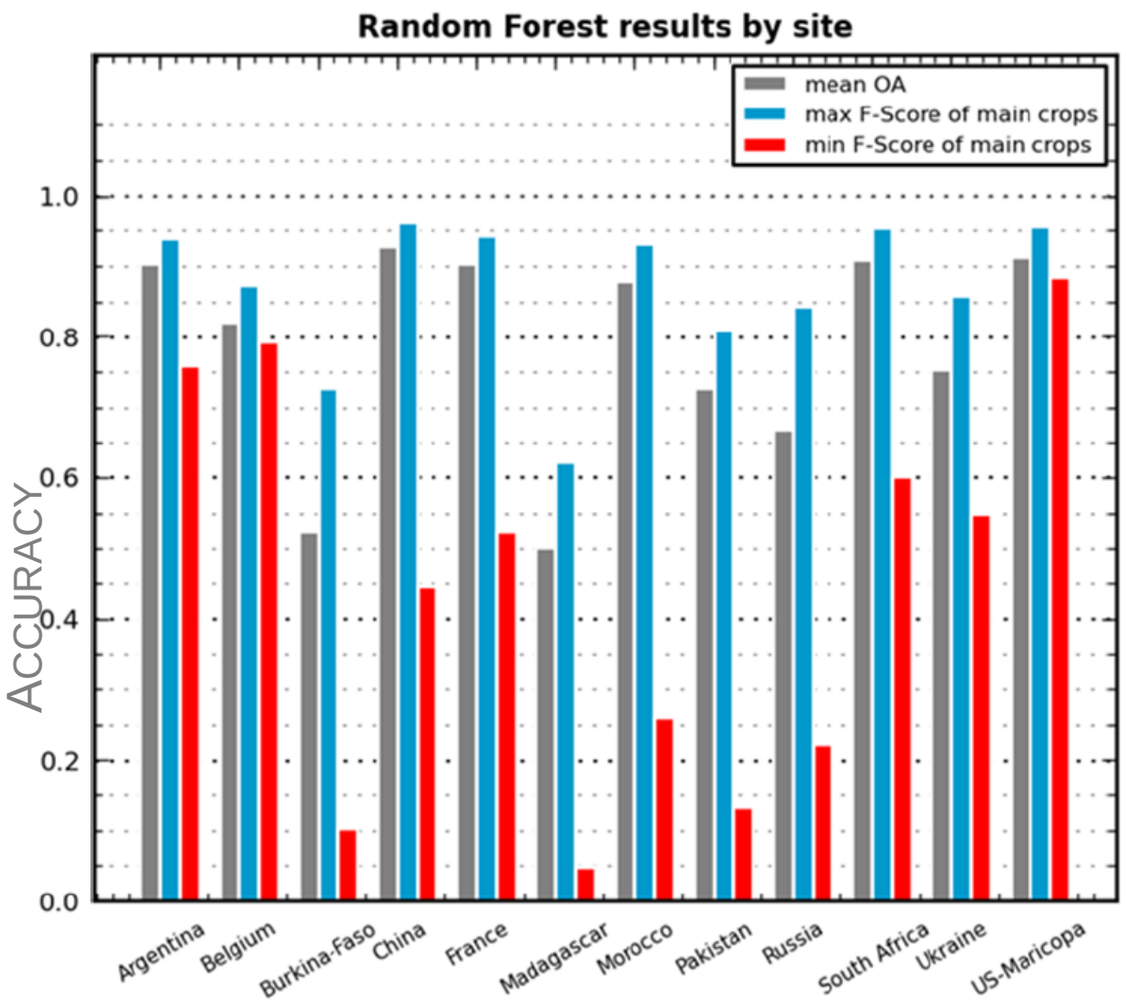
6 MONTHS OF OBSERVATION TO REACH THE FINAL CROPLAND ACCURACY



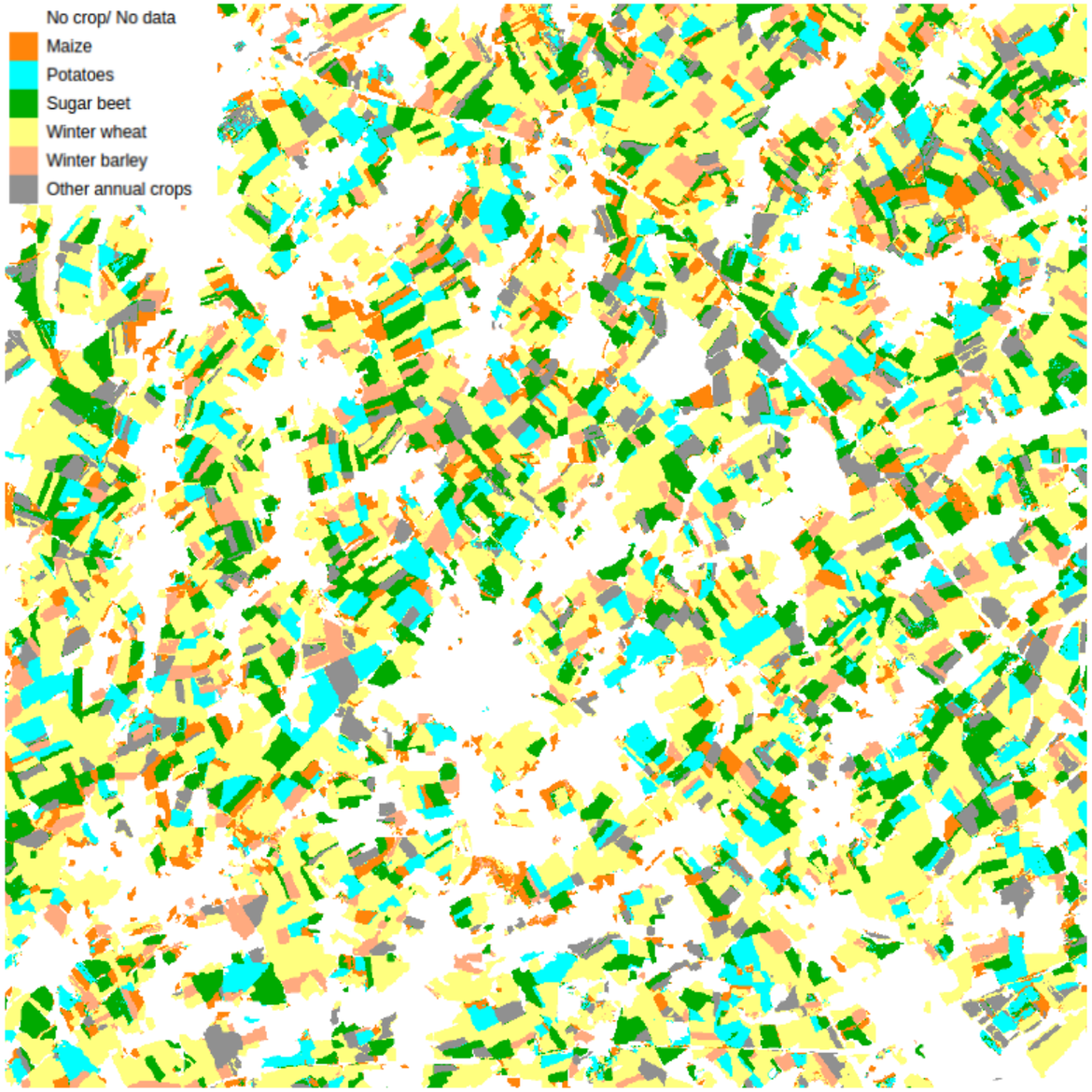


ESA Sen2Agri methods benchmarking : good accuracy for 5 main crop types mapping

FOR MOST OF THE 12 SITES WIDELY DISTRIBUTED AROUND THE WORLD



Overview of main quality criteria for the whole test dataset



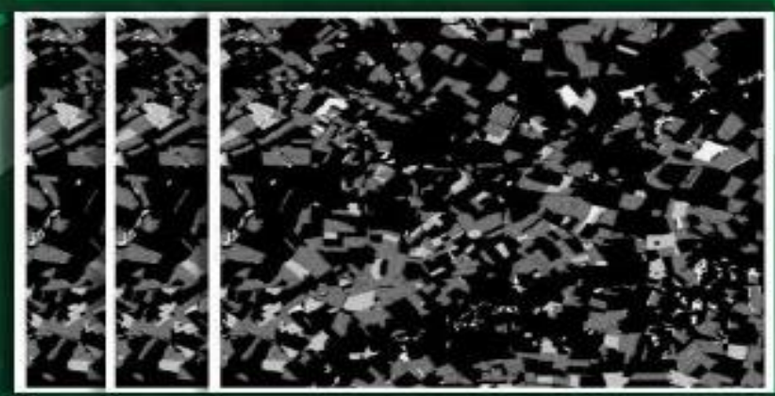
Spot 4 (left) and Landsat-8 (right) scenes over Belgium and corresponding crop type product derived using the RF classifier after regular temporal sampling of input image series

SUCCESSFUL DEVELOPMENT THANKS TO JECAM COLLABORATIVE NETWORK

ESA Sen2Agri : development of toolbox to derive 4 products from Sentinel-2 data

esa

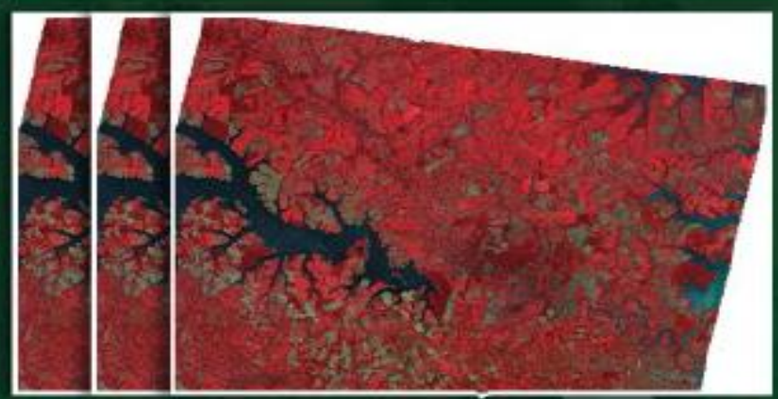
DYNAMIC CROPLAND MASK



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

Monthly cloud free surface reflectance composite at 10 m

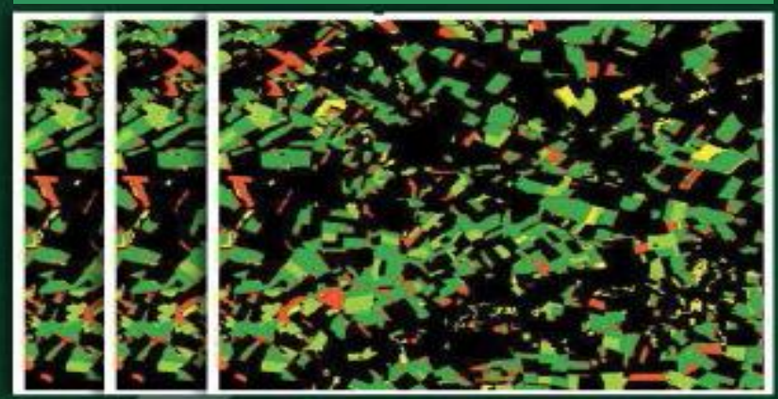
CLOUD FREE SURFACE REFLECTANCE COMPOSITES



Open source toolbox
Capacity building and training

CULTIVATED CROP TYPE MAP

EARLY AREA INDICATOR



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

VEGETATION STATUS

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

sentinel-2

→ AGRICULTURE

www.esa-sen2agri.org

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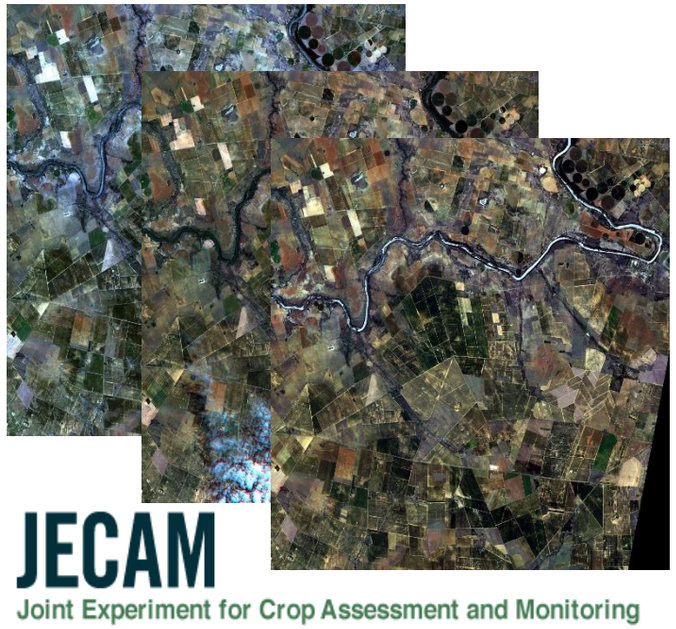
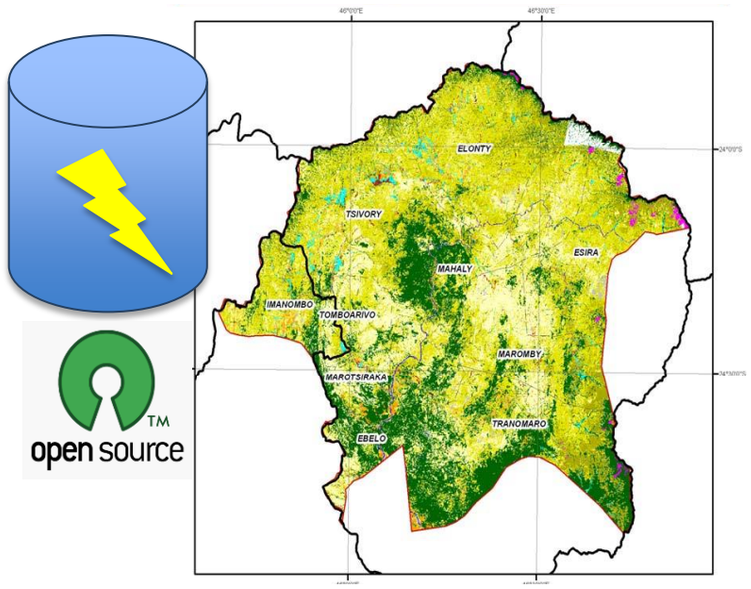
Sen2Agri project : forthcoming plan

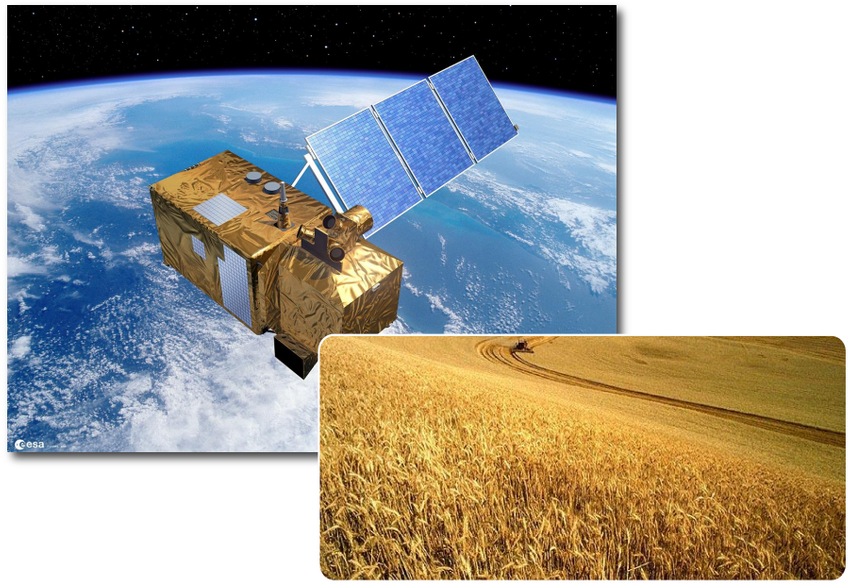
Algorithm Development 2014

Prototypes of EO products 2015

Demonstration & Validation 2016







✓ **Design** :

- User Requirements
- EO product specification
- Algorithm Development

❑ **Processing System**:

- Testing & validating of EO prototypes (12 sites) in 2015 agriculture season

GEOGLAM
Global Agricultural Monitoring

Use cases:

- 3 national cases
- 5 local cases
- Transfer to national users

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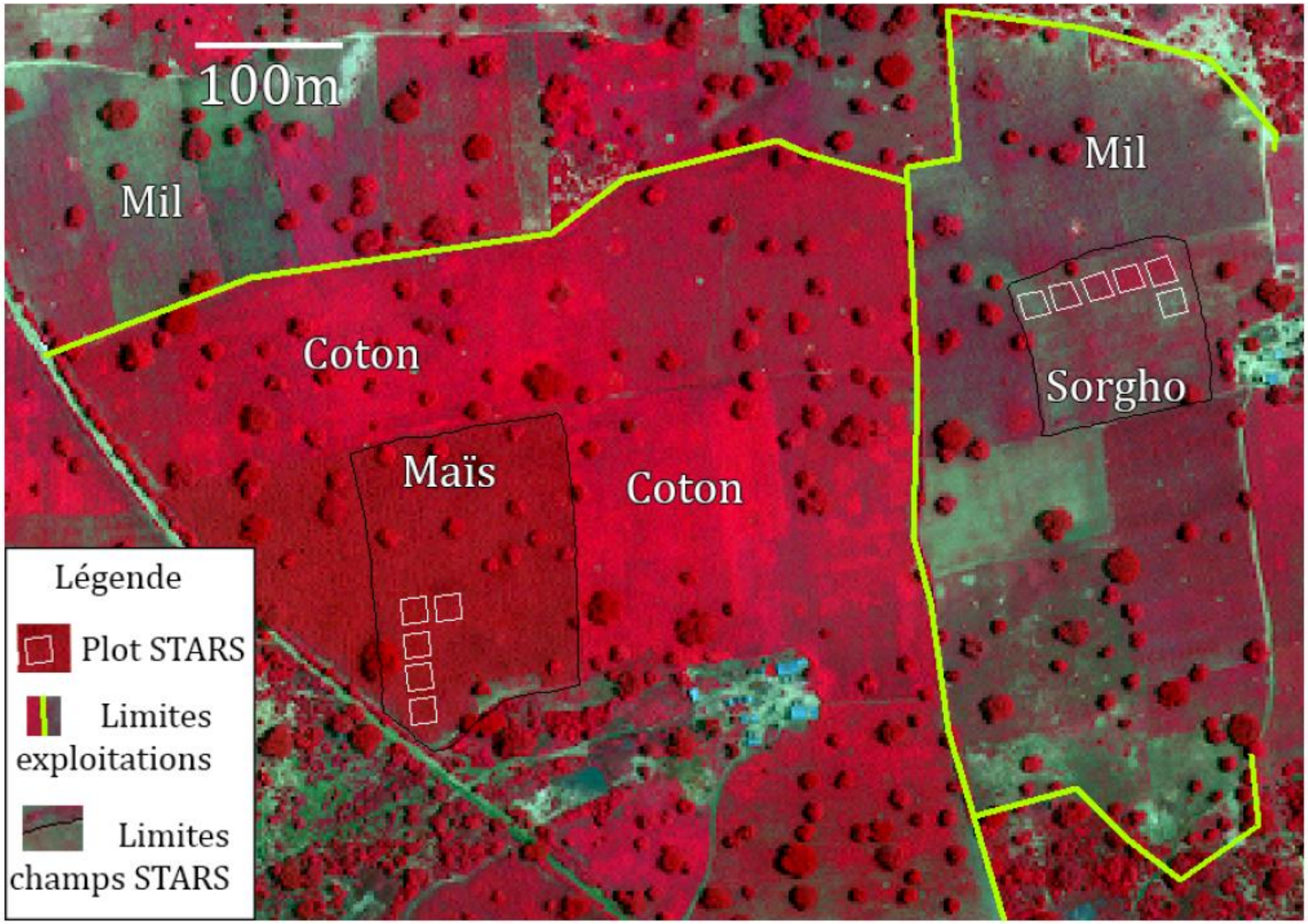
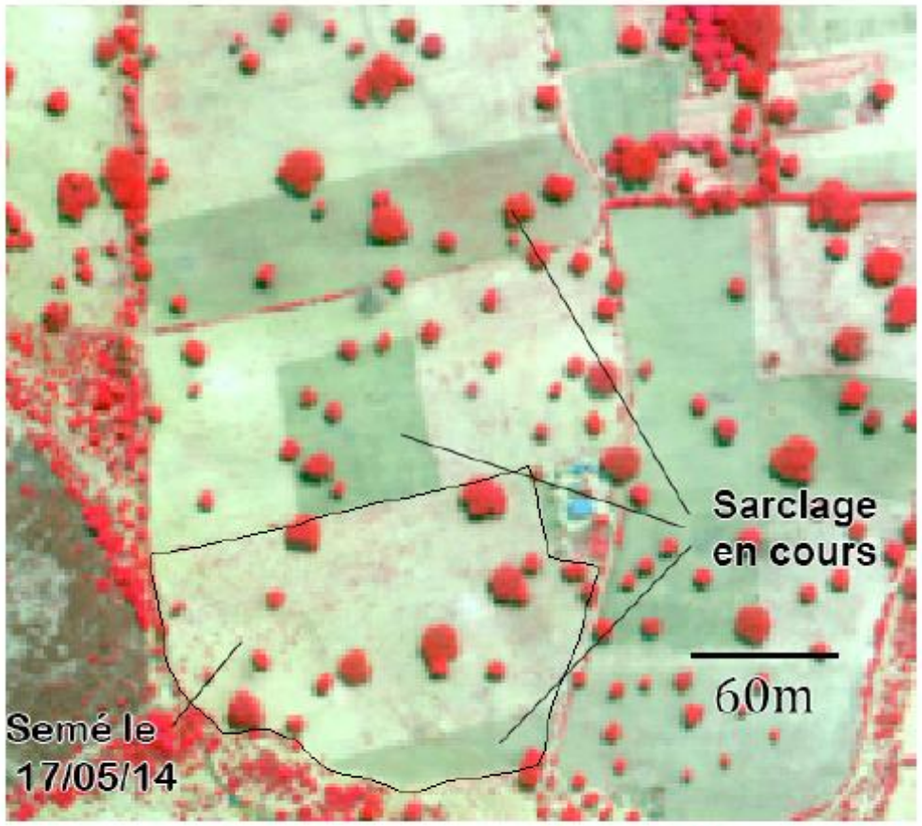
Challenge 2: EO monitoring for smallholder farmers in heterogeneous agrosystems

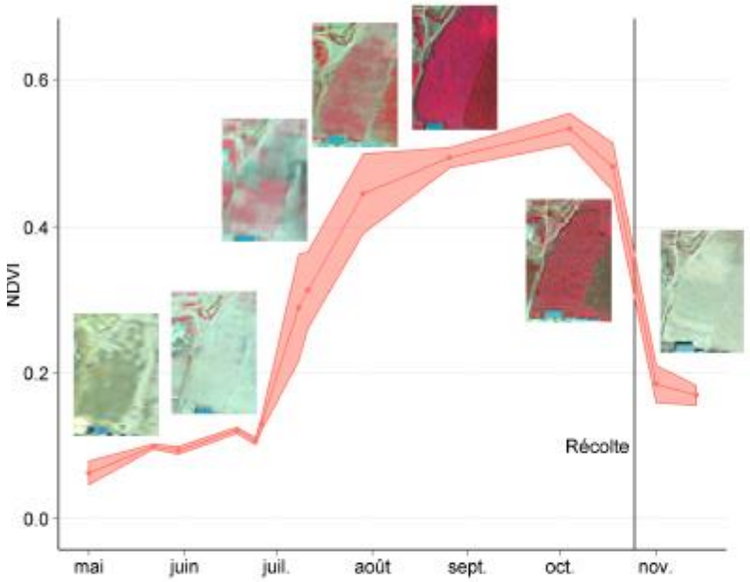


2-m resolution time series to capture fields

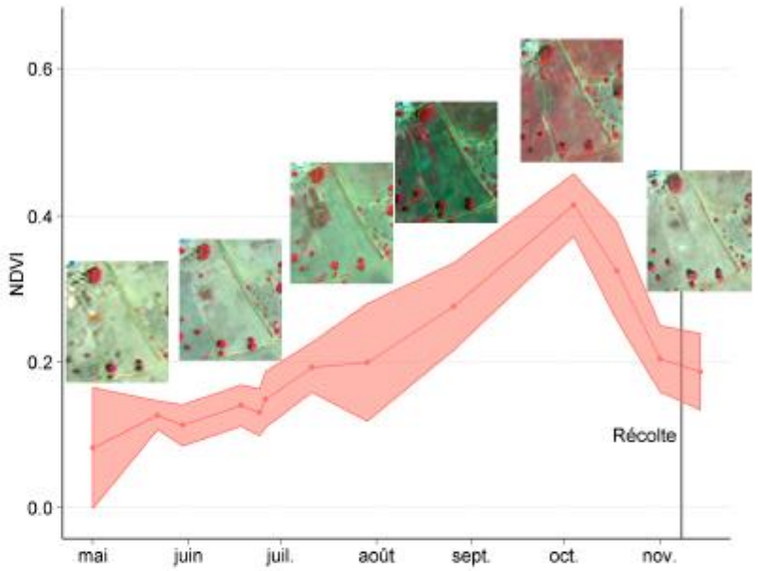
High heterogeneity within and inter-fields from EO time series point of view



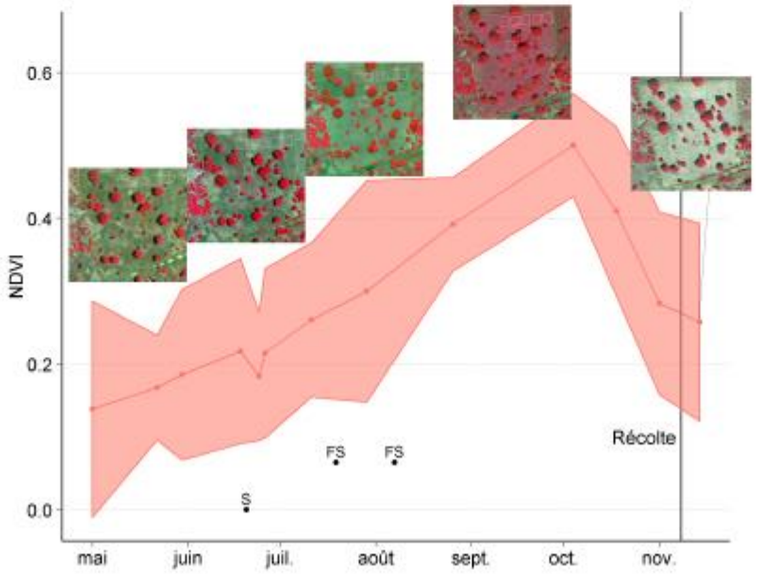
Region of Koutiala (Mali) – 26/06/2014



a) Parcelle proche du village, hâtive et homogène - plaine lluviale



(b) Parcelle en bordure de plateau, sans rattrapage du retard - croissance en conditions d'hydromorphie



(c) Parcelle en bordure de plateau, rattrapage du retard et production (S : semi, FS : fertilisation des plots STARS)

BMGF – STARS experiment
Chomé G., 2015 & ICRISAT

It seems possible to detect different levels of fertilizers in spite the high local heterogeneity

but landscape stratification is required

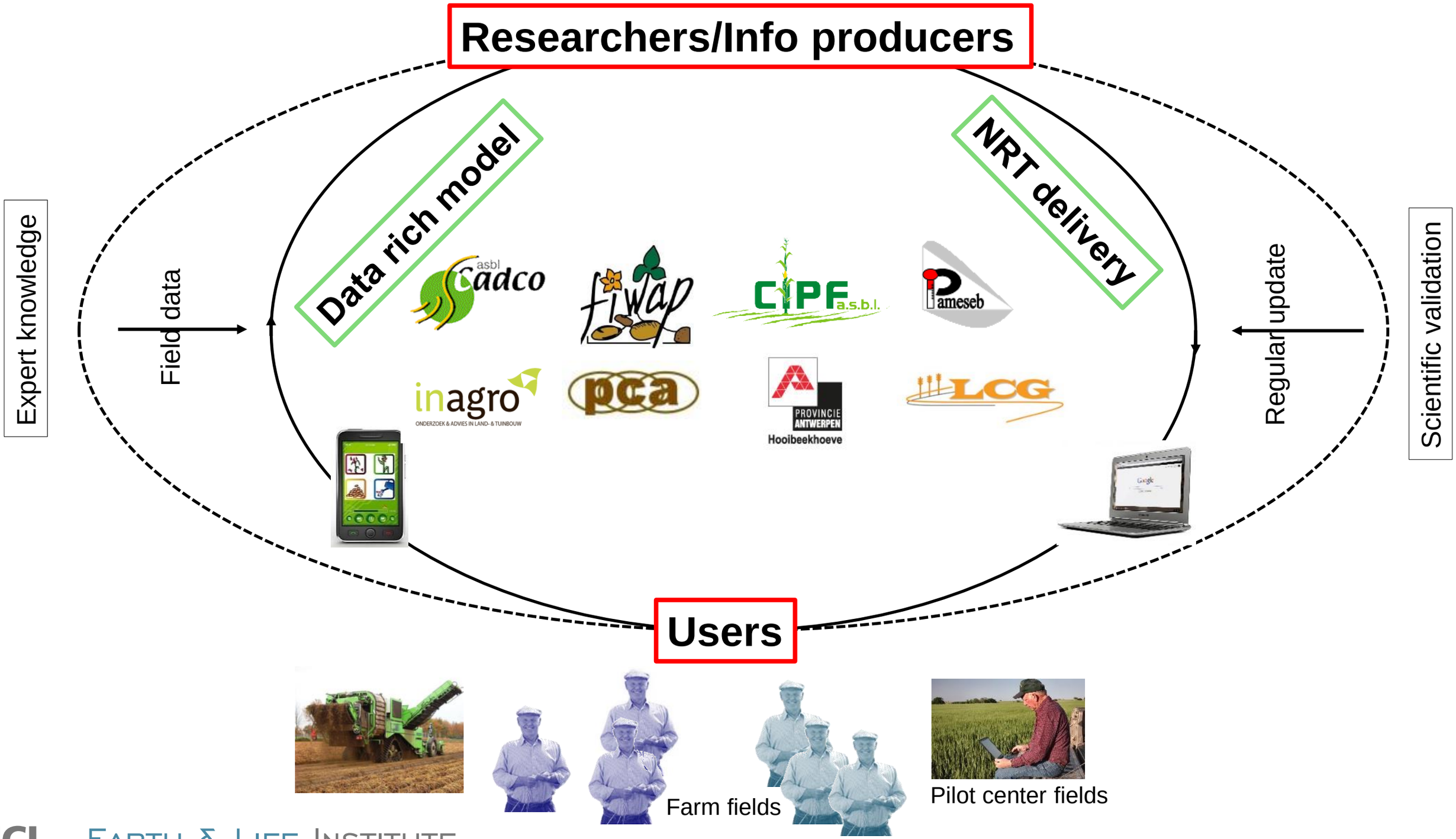
(a) Effet plot - Mil (image GeoEye 26/08/14)

(b) Effet plot - Sorgho (image GeoEye 26/08/2014)

BMGF – STARS– 5 plots of different fertilization in farmer field for 2014 (5 crops)
Chomé G., 2015 & ICRISAT

Challenge 3: take advantage of data rich environment and multi-stakeholders collaboration

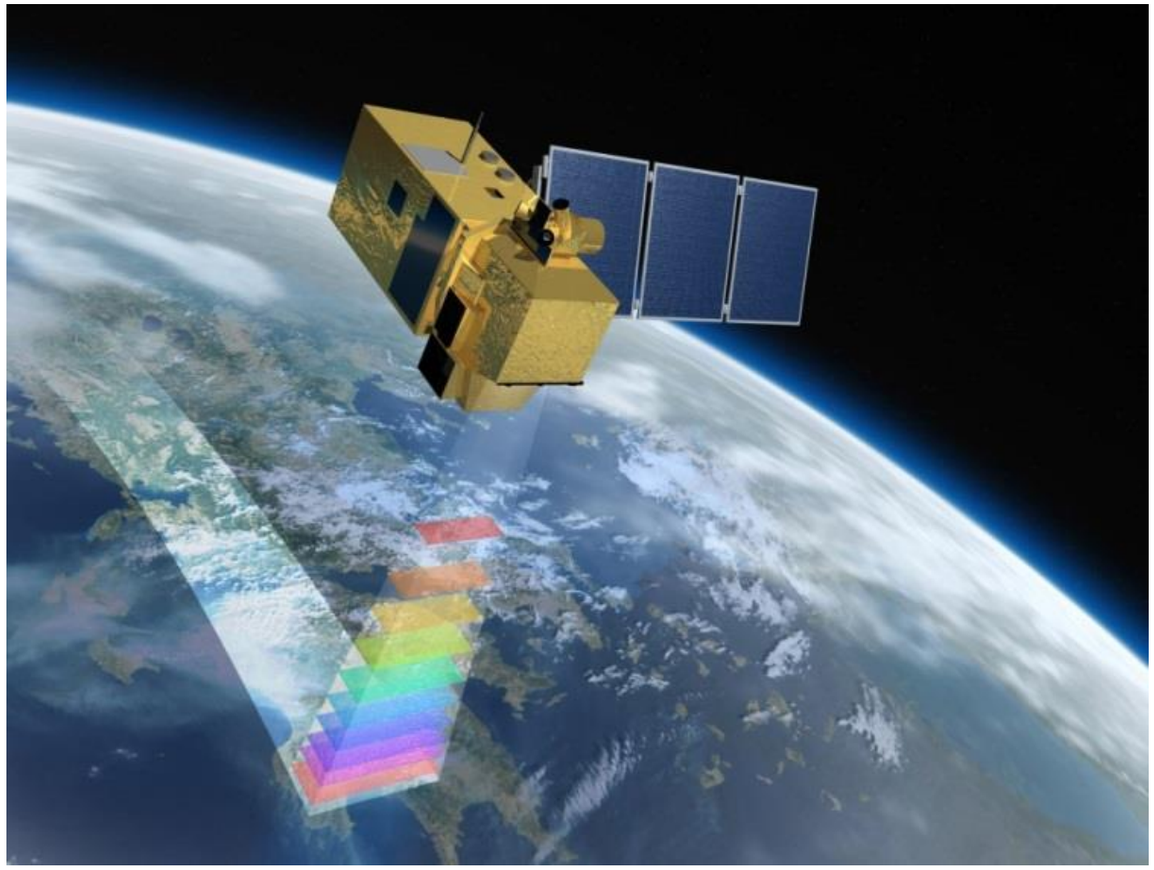
(new data acquisition, crowdsourcing, sensors, etc.)



belspo

belcam

December 2014 to March 2019



BELgian Collaborative Agriculture monitoring at parcel level for sustainable cropping systems

UCL Université catholique de Louvain
Earth and Life Institute - Geomatics

Université de Liège

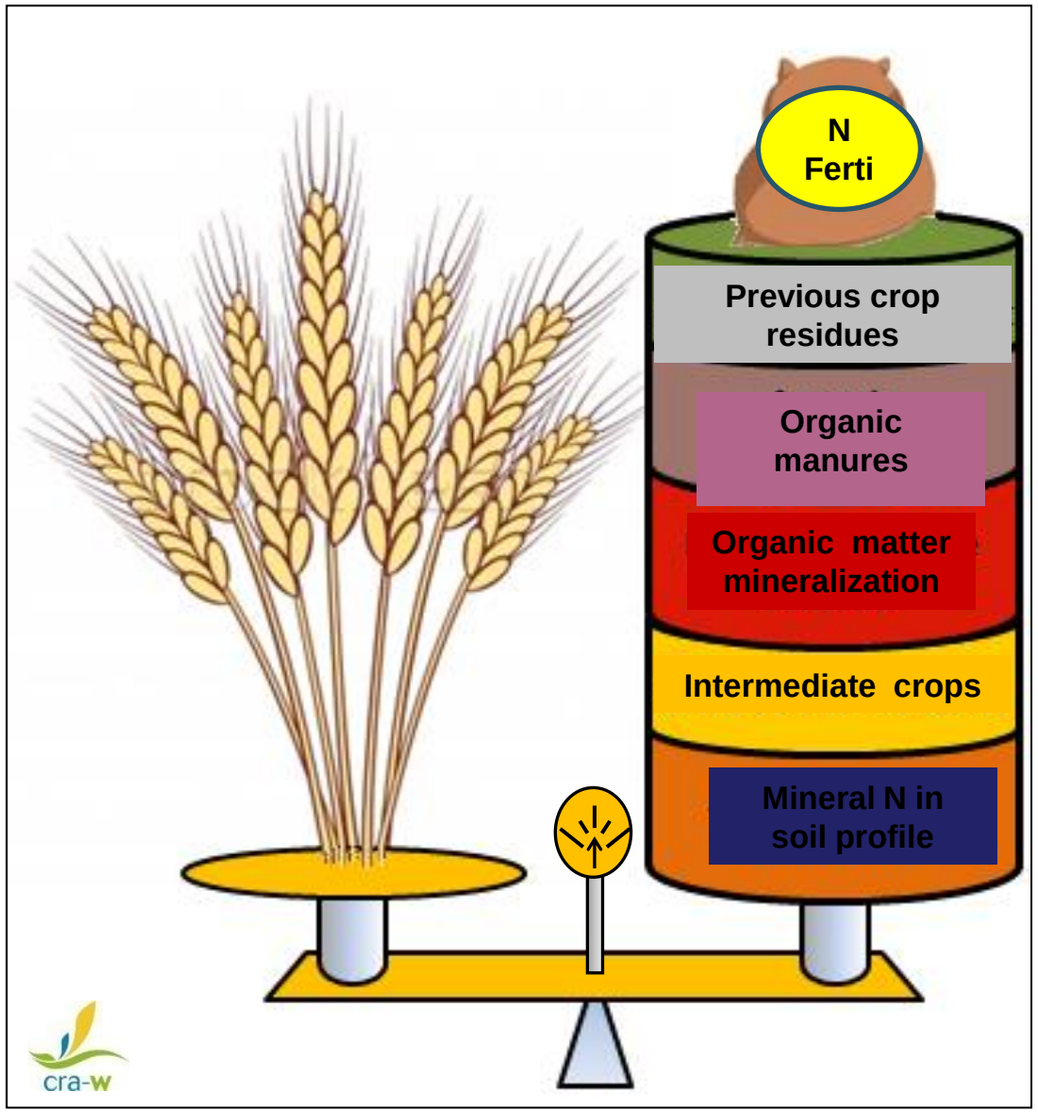
vito vision on technology

cra-w

INRA SCIENCE & IMPACT

BELCAM example : field provisional N balance-sheet for N fertilization advice

Crop nitrogen total needs | **Sources of nitrogen supply**



Current practices

Sources of N supply mainly based on

- farmers info on field cropping practices and characteristics
- standardized table of parameters

Large UNCERTAINTY for such farmer-based information !

BELCAM expected outputs

Info from RS and auxiliary sources to improve the accuracy

- previous crop type
- intermediate crop biomass
- crop residues
- soil texture
- *organic manures applicat.*

+ **parcel zoning** derived from RS to better integrate **local heterogeneity** leading to modulated N advice within the field

Field provisional N balance-sheet to be established in February/March

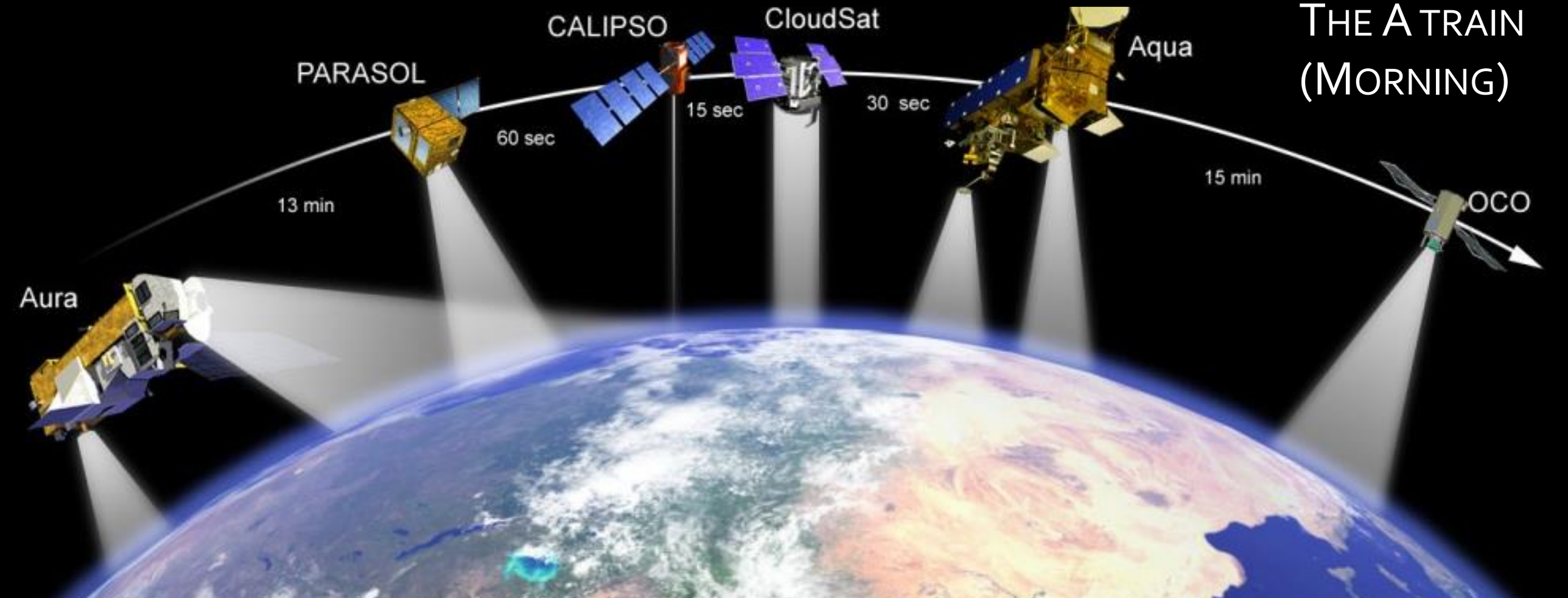
(Abras, M., Goffart, et al. CRAW, BASE 2013)

Perspectives

- Sentinel-2 : first operational non commercial satellite designed for agriculture monitoring

  (100 m daily still required in particular for cloudy regions)

- Successfull collaborative efforts (JECAM, GEOGLAM) but more needed between space agencies (S2 + L8) and between reserachers and users



Thank you for attention