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High resolution crop mapping along the growing season: methodological developments towards an operational exploitation of Sentinel-1, 2 and 3

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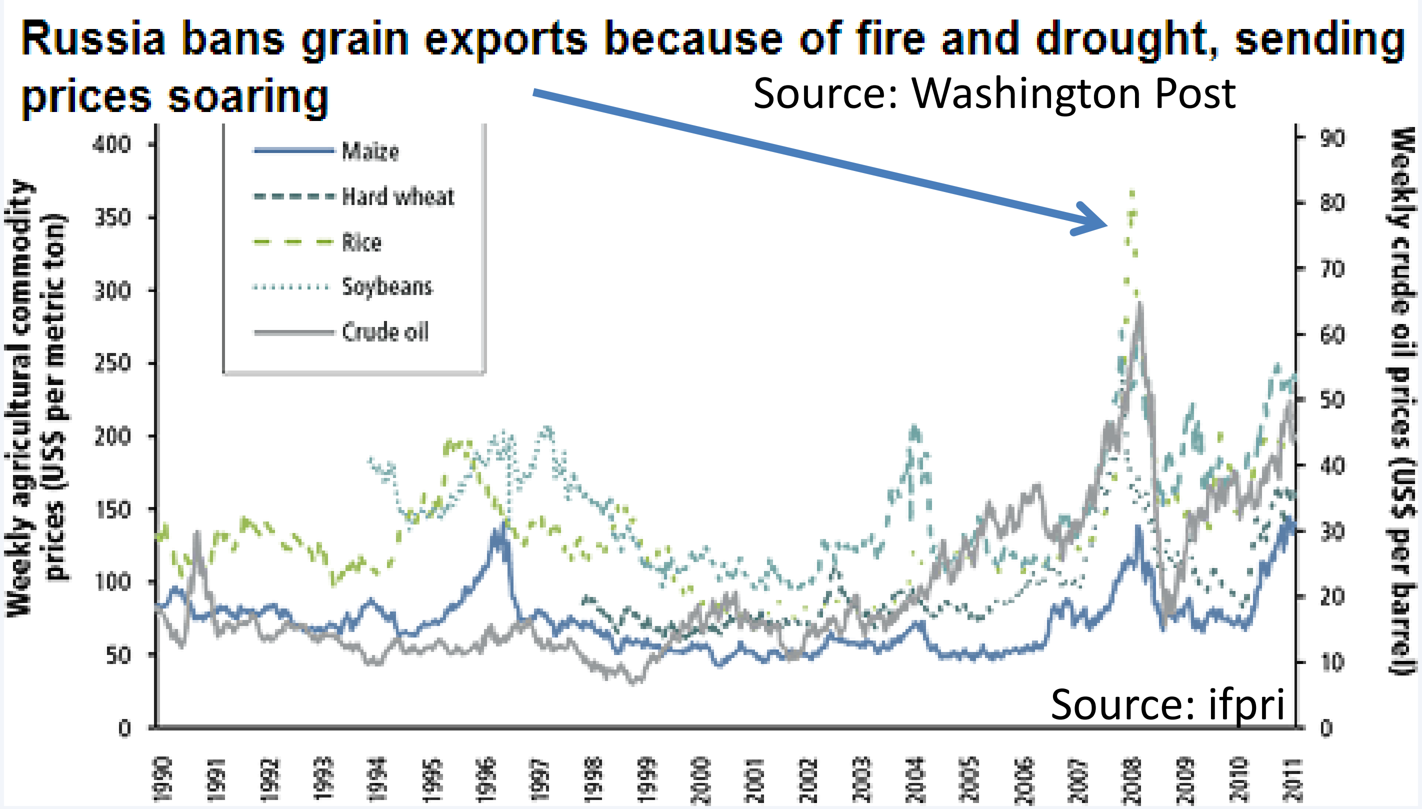
Agriculture monitoring, why?

Agricultural statistics are needed at the regional level and international level by governments, traders and food industries.



G-20 initiatives: AMIS–FAO and GEOGLAM (Global Agriculture Monitoring)

Crop specific information is a prerequisite for monitoring

Need to improve agricultural monitoring

PRODUCTION = **YIELD** **X** **AREA**

Crop specific maps are a **pre-requisite**:

1) Direct area estimation
2) Improved crop growth modeled results

Partial time-series for annual crop specific map

Crop identification exploits differences in:

- spectral responses
- timing of crop development
- crop architecture

Because of rotations and agricultural practices, fields are sown with a different crop each year

→ annual crop specific map

To support monitoring, crop maps need to be available asap

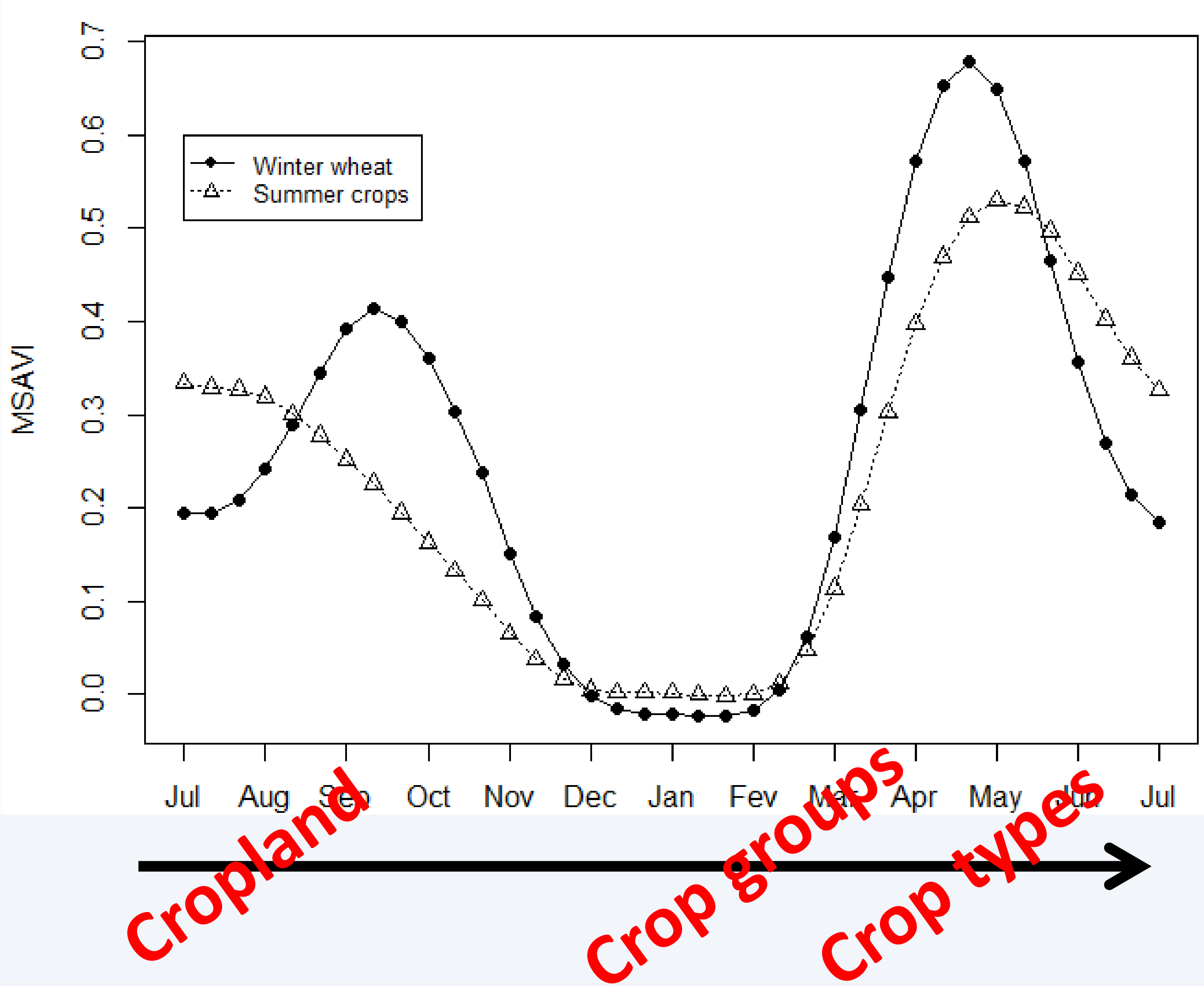
→ partial time-series

An improved level of details as information accumulates

Crop mapping approach with 3 products delivered along the season:

1. *Pre-seasonal cropland layer* based on the previous year time-series
2. *Crop group layer* at the end of the winter
3. *Crop specific layer* updated at each acquisition during the spring and the summer

Three crop products along the season



A multi-sensor approach for high resolution crop mapping

The operational context imposes to reduce the dependency on a single data type:

- Sensor malfunction
- Cloud contamination

→ multi-sensor approach

Combine the temporal consistency of **S-3**, the spatial consistency of **S-2** as well as the complementary data of HR SAR data (**S-1**) to produce high resolution maps

	Sentinel-1 (SAR)	Sentinel-2 (HRO)	Sentinel-3 (MRO)
+	• weather inderpendent • temporal resolution (night acquisitions)	• spatial resolution • number of bands	• temporal frequency • number of bands
–	• number of bands • difficult to interpret	• cloud contamination • temporal resolution	• cloud contamination • spatial resolution

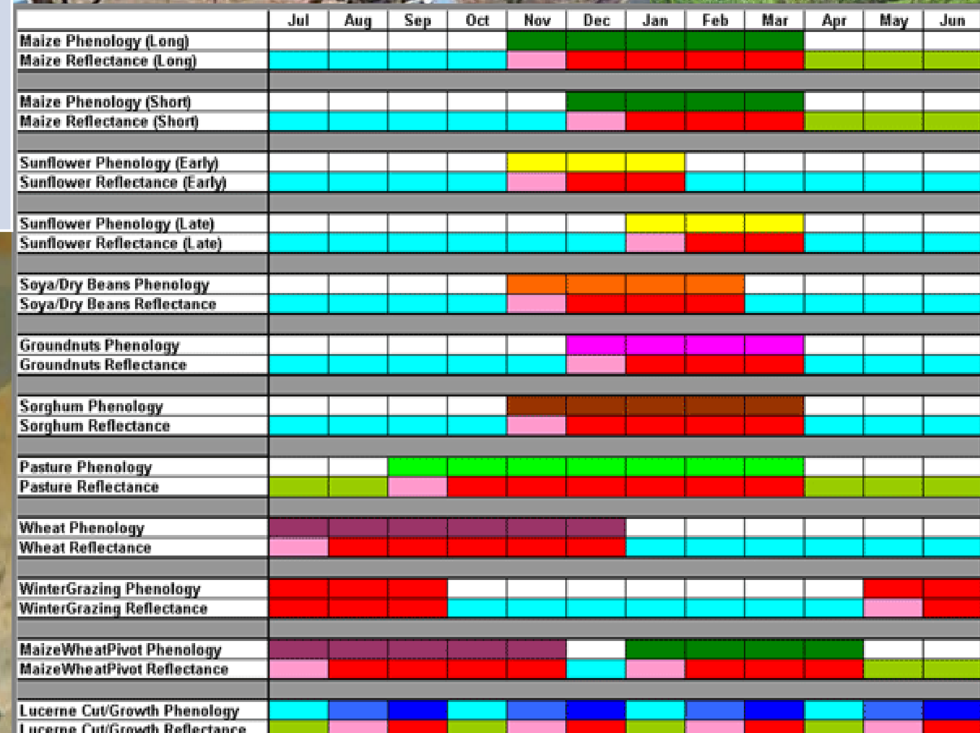
The study focuses on two contrasted areas

South African site

- Free State Province is SA's breadbasket (70% of total grain production)
- sub-humid to semi-arid climate
- Field size: 0,5-40 ha
- Home gardens, small scale and commercial farming
- Continuous growing season
- 129 000 km²



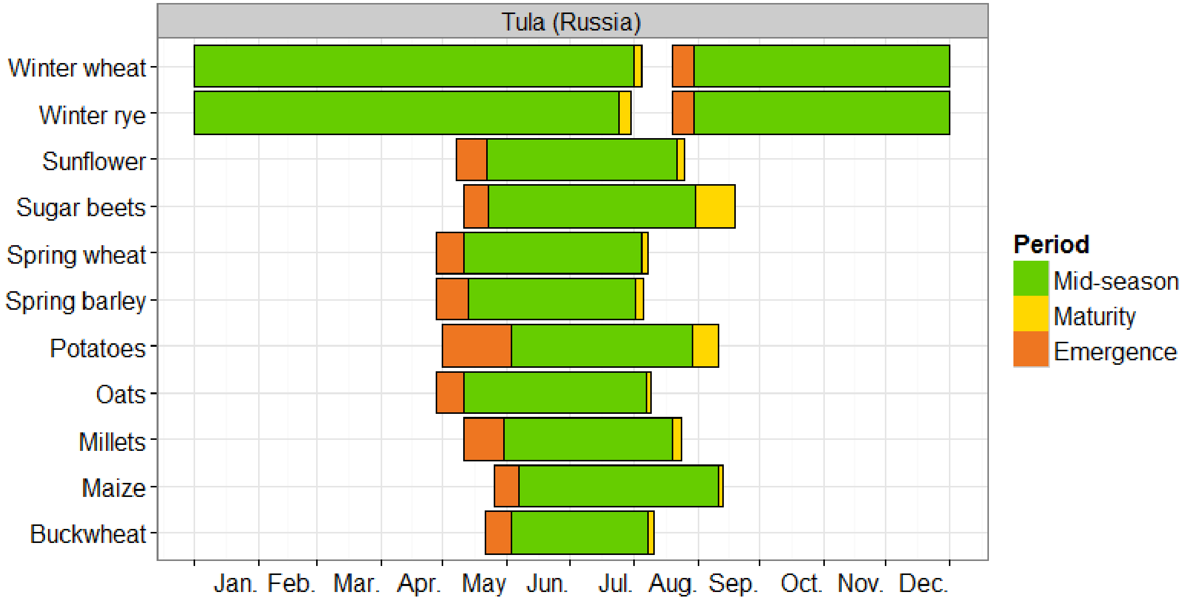




The study focuses on two contrasted areas

Russian site

- Continental climate
- Field size: 70-ha
- Winter crops are planted in August, summer crops in April
- 26 000 km²

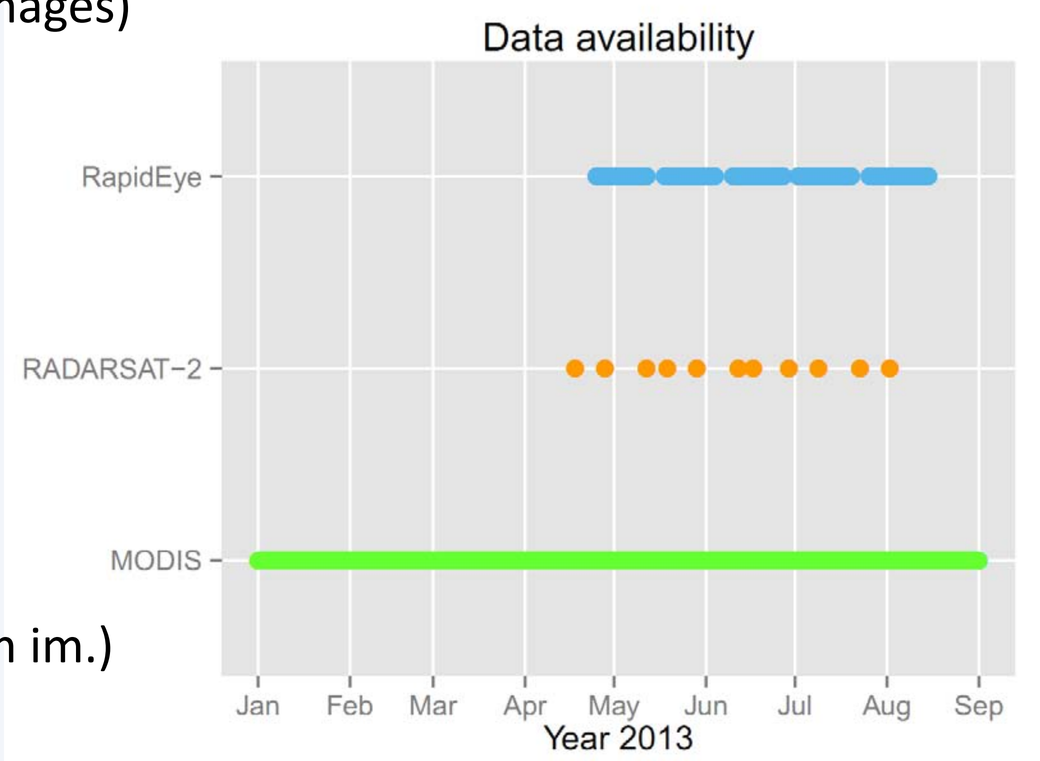


Data acquisition plan

Large sites to simulate the wide swath of sentinel-2 (280-km)
→ integrate the spatial gradient of vegetation conditions across the image

Russia (acquired):
13 Radarsat-2 images (300x300 km)
5 RapidEye coverages (500 25x25 km images)

In-situ data collected in July by the Russian Agrometeorological Institute
→ 600 crop type observations at the field level for the 2013 season
Field boundaries last updated in 2012 manualy digitized on Landsat images



South Africa (in acquisition):
13 RapidEye coverages (4300 25x25 km im.)
13 Radarsat-2 (200 70x150 km im.)

Comparison of the sensors for Russia

	SENTINEL-1	RADARSAT-2	SENTINEL-2	RAPIDEYE	SENTINEL-3	MODIS
Nominal Swath	80-km	300-km	290-km	77-km	1250-km	2330-km
Wavelength (μm)/frequency	C-band	C-band	blue (0.42-0.55), green (0.53-0.59), red (0.63-0.69), red-edge (0.69-0.72, 0.72-0.75, 0.76-0.8, 0.84-0.89), near-infrared (0.72-0.96) and 5 others	blue (0.40-0.51), green (0.52-0.59), red(0.63-0.685), red-edge (0.69-0.73), near-infrared (0.76-0.85)	red (0.6-0.7) , near-infrared (0.88-0.89) and 19 others	red (0.62-0.67), near-infrared (0.84-0.88) and 34 others
Polarization	HH+HV VV+VH	HH+HV VV+VH	NA	NA	NA	NA
Beam Incidence angle	20-41	20-46	NA	NA	NA	NA
Ground resolution	5-m	25-m	10-m	5-m	300-m	250-m
Repeat cycle	2 days using a constellation of satellites	programmable	5 days with a pair	daily with 5 satellites	1-2days with a pair	1-2 days

Cropland mask based on the previous year time-series

Cropland | Crop groups | Crop species

Existing land cover maps contain cropland information

BUT – general maps

– global maps need local tuning

– changes

– how to allocate mixed agricultural classes?

→Image-to-map discrepancy detection to update the land cover map (GlobCover 2009 in this case)

→Easily transposable to other sites

Multi-variate normal iterative trimming to detect outliers

Cropland → Crop groups → Crop species

Image-to-map discrepancy detection using iterative trimming (Radoux and Defourny, 2010)

1. Smoothing and gap filling of MODIS 10-day mean composites MSAVI time-series of the previous year time-series (August 2012 to August 2013)
2. Metric extraction of MODIS time-series (mean, norm, range, sum)
3. Parametric estimation of ‘pure’ class distributions
4. Iterative truncation (5%) of the class distribution
5. Maximum likelihood classification of the outliers and of the mixed agricultural classes

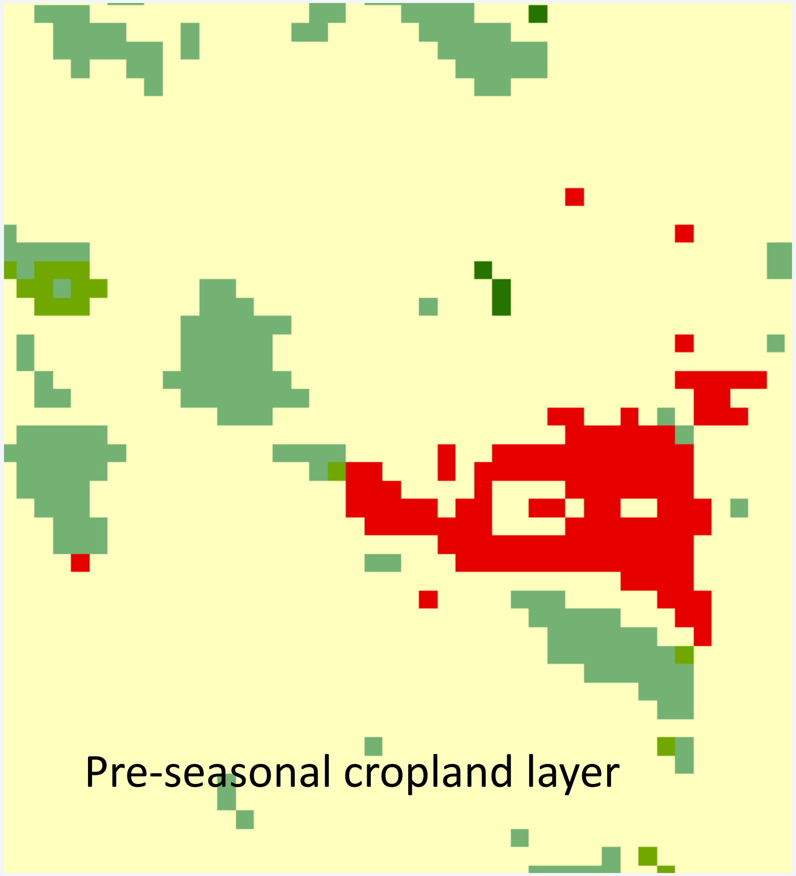
→ Cropland mapped at 250-m at the beginning of the season

Assessment of the pre-seasonal cropland layer

Cropland | Crop groups | Crop species

Visual check

Quantitative validation



Commission errors due to the absence of a natural vegetation class

Crop group map at the end of the winter

Cropland → **Crop groups** → Crop species

1. Smoothing and gap filling of MODIS 10-day mean composite MSAVI time-series from August 2012 to March 2013
2. Fourier transform of the time-series and segmentation on the two first components
3. Automated identification of key events and rule-based classification of the time-series
4. Cross-validation and reclassification using the 25 nearest neighbors

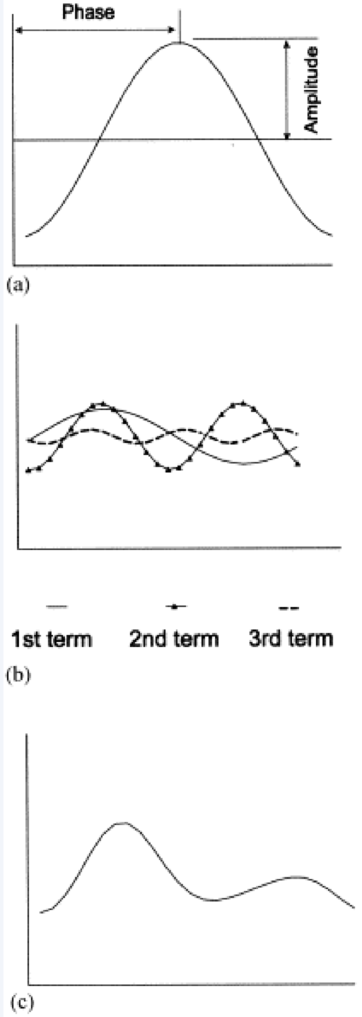
Harmonic decomposition

Cropland | Crop groups | Crop species

- Harmonic analysis transforms an input a temporal input signal into the frequency domain

  →Initial signal to a sum of sines waves
- Each harmonic is defined by a phase and a magnitude
- Pixels of the same Land Cover exhibit the same temporal signature

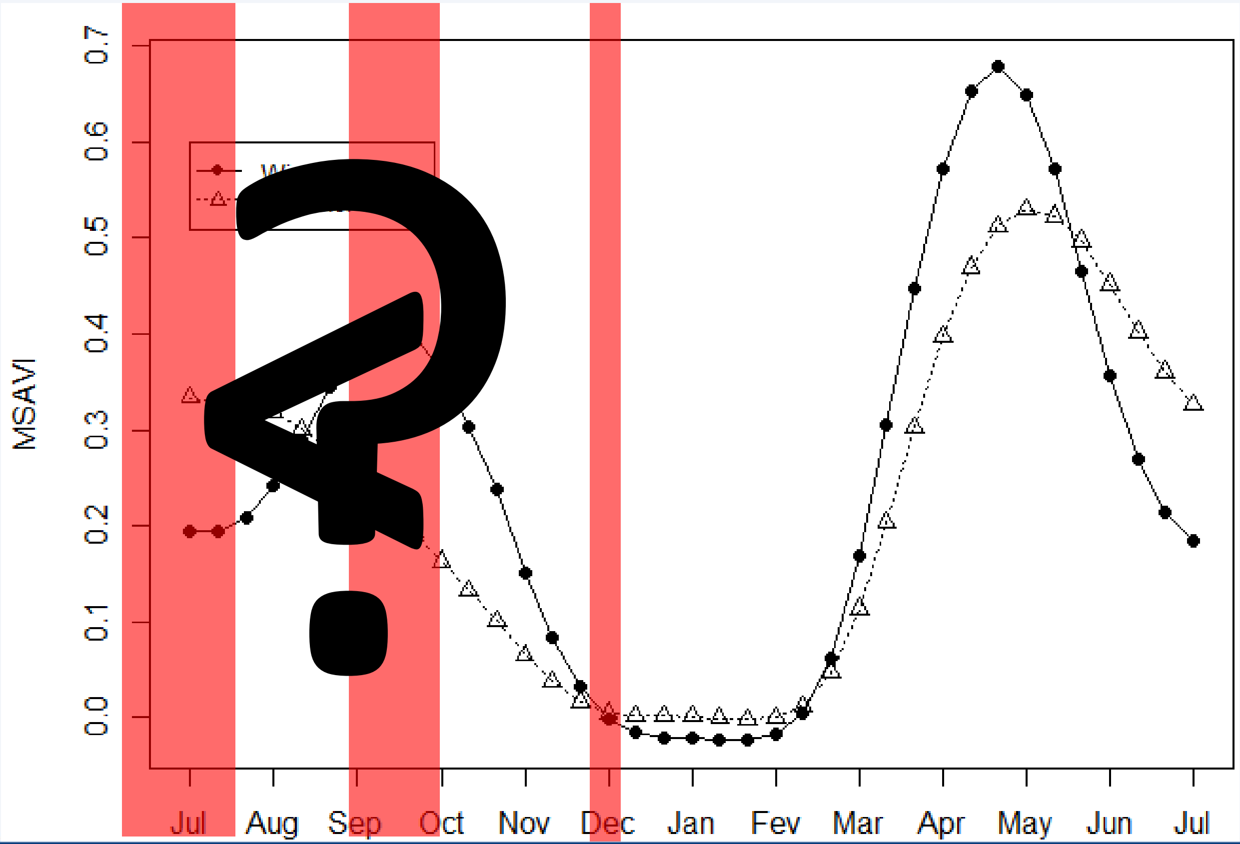
  → They should be defined by similar harmonic components
- No need to identify key dates that can vary on large region for a good multi-date segmentation
- Mutliresolution segmentation on the first two orders and the additive term



Automated decision rule based on feature identification

Cropland → Crop groups → Crop species

No training data → definition of a classification rule based on three features:
1) First snow date, 2) winter growth peak, 3) minimum preceeding it



Assessment of the crop group cropland layer

Cropland | **Crop groups** | Crop species

Visual check

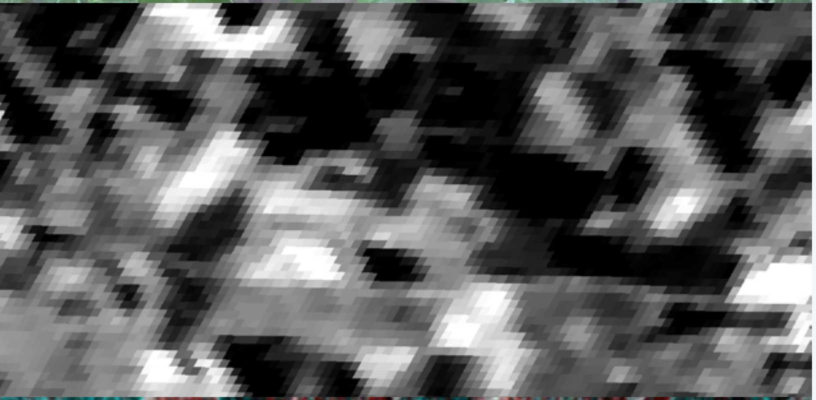
Quantitative validation

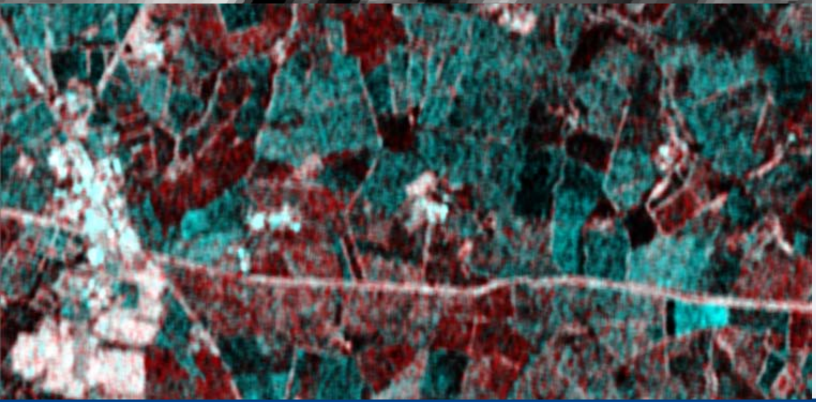
Overall accuracy : 78 %

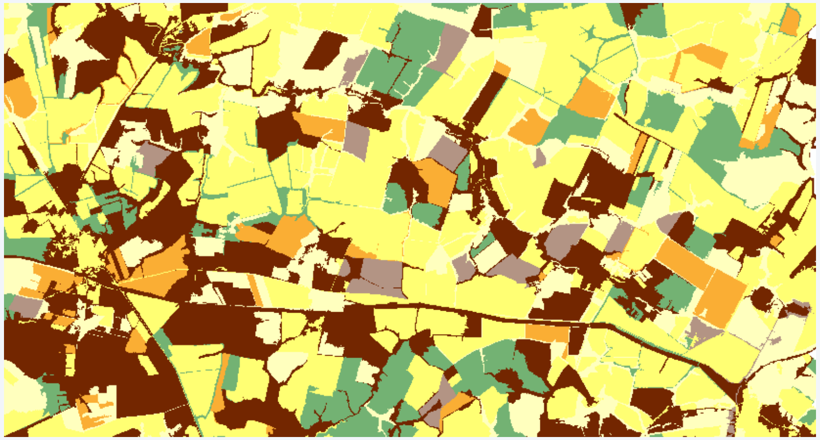
	Reference		
Classification	Other	Winter crops	User Acc.
Other	346	104	0.77
Winter crops	37	143.00	0.79
Producer Acc.	0.90	0.58	
Overall Acc.	0.78		

Omission errors due to the tightening of the decision rule

Combining complementary S1, S2 and S3 data







Crop specific map updated along the season

Cropland → Crop groups → **Crop species**

At each high resolution image acquistion:

1. Pre-processing and coregistration
2. Constrained segmentation and computation of object statistics
3. kNN imputation of missing data
4. Random Forest classification

→ Demonstration on a smaller site (6 images)

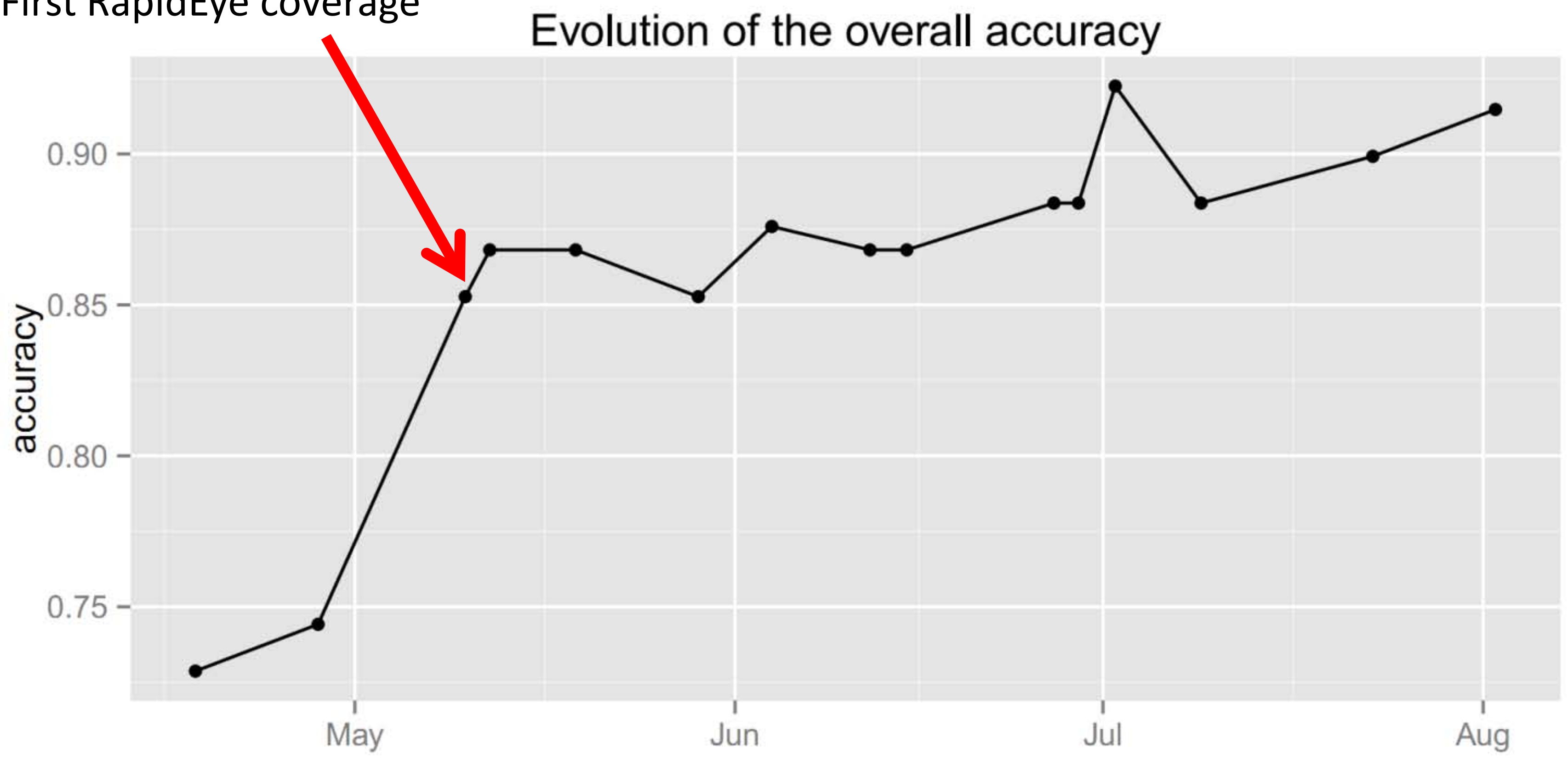
→ Reduced training and validation data sets

pertinence of the data set?

Preliminary results

Cropland → Crop groups → **Crop species**

First RapidEye coverage



Dominance of the winter wheat and the spring barley classes

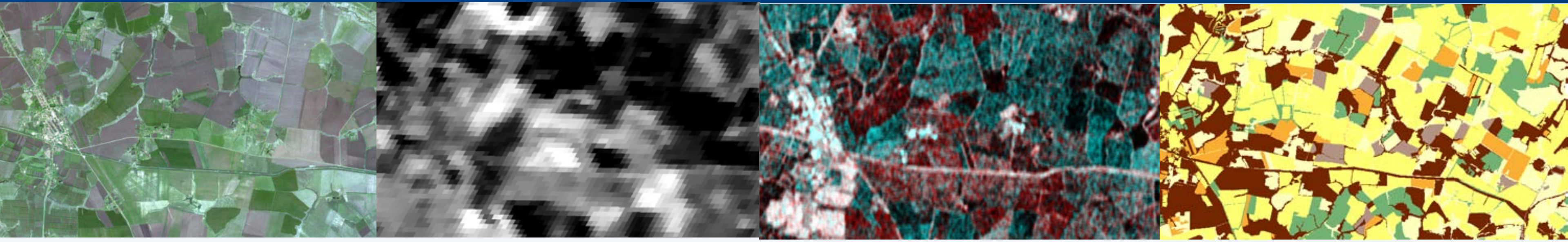
Conclusions

Support agriculture monitoring by providing 3 products along the season using S1, 2 and 3

- Radar data is valuable to provide information if S-2 not available but with less accuracy
- High resolution optical imagery improves both the accuracy and the spatial details
- S-3's frequent revisit capacity allows updating rapidly crop information, even before the spring

Satisfactory accuracy of the within season estimates

BUT need to consider the entire area



Thanks for your attention !

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