

JECAM

Joint Experiment for Crop Assessment and Monitoring



GEO Joint Experiment for Crop Assessment and Monitoring (JECAM):

2016 Progress Report

May 2016

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Executive Summary

This report shows the progress that GEO JECAM (Joint Experiment for Crop Assessment and Monitoring) test sites have made since JECAM started in 2011, with the focus on 2015. The amount and types of Earth Observation (EO) data received are also reported, along with in situ data, analytical results, and future plans. JECAM is the foundation of the Research & Development (R&D) portion of the GEOGLAM (GEO Global Agricultural Monitoring) initiative, and so the R&D results are important for the development and sharing of ‘best practices’ in agricultural monitoring.

A historical background of JECAM is provided, showing how the concept evolved, and how the providers of EO data were engaged to support the initiative.

We have instituted an annual report process to obtain information on JECAM research progress, EO data usage and collaboration activities. The progress of several JECAM sites to February 2016 is presented in this document. There are currently thirty-five JECAM test sites, of which a few appear to be dormant, and a few have just started. Twenty sites submitted progress reports this year. This participation rate is very encouraging.

Our website (www.jecam.org) was launched in 2012. Content from the annual reports will be used to keep the site ‘fresh’, accurate and current.

The data acquisition planning with CEOS Space Agencies and commercial providers went fairly well and most JECAM sites are receiving data. The types of EO data used at each JECAM test site (that reported this year) are shown in Table 1. The entries of this table show the number of images for each sensor, where the sites reported them. (Where the use of a sensor was reported without a number of images, an ‘x’ appears.) The figures in this table give an idea of relative volume of data. However, a word of caution when reading these figures. Clearly, the area of one image in km² varies widely from sensor to sensor. Also, large numbers should not be interpreted as necessarily more important than small numbers; sometimes a few images can bring immense benefit to a research team.

The JECAM sites are looking at a common range of monitoring needs over a very diverse range of landscape conditions and cropping systems, including:

- Crop identification and acreage estimation
- Yield prediction
- Near Real Time Crop condition
- Land management
- Soil moisture.

Many of the JECAM sites reported having produced numerous papers (peer reviewed and other), presentations and other documents with the research results.

Table 1 Types of EO Data Used at Each JECAM Test Site

JECAM Site	Low/ Moderate Optical							Moderate SAR				Fine/ Very Fine Optical					
	Terra/Aqua	Landsat	Sentinel-2	Hyperion	HJ-1	UK-DMC-ii	Deimos	Proba-V	RADARSAT-2	TerraSAR-X	Sentinel-1	ALOS-2	SPOT	Pléiades	Formosat-2	GF-1	Chris
Argentina								x	x								
Brazil – São Paulo		19					3										
Burkina Faso		3							9		10		9	6			
Canada CFIA – Ottawa		5							17				9				1
China/ Jiangsu									13								
China/ Shandong	46				21				x				17			16	
France		23	5				3			14	28	32	38				
Italy Apulian Tavoliere		2									2						
Madagascar		11											26	9			
Morocco	x	x									x		53				
Russia/ Tula	x	x		3													
Senegal		12								5			2	4			
South Africa		500											450				
Spain		14															
Taiwan		67							28		x		28		x		
Tunisia		27	x							4	x		32				
Ukraine		9						9			15		8				

JECAM will continue to be responsive to GEOGLAM “R&D towards monitoring enhancements”, and the GEOGLAM needs will define the JECAM community activities. To this end, JECAM intends to support enhanced collaboration between sites. The collaboration will support the development of standards and practices that inform the GEOGLAM “system of systems” for agricultural monitoring. JECAM sites will also participate in the validation of new sensors as opportunities arise.

An important JECAM Science Meeting was held in Brussels, Belgium in November 2015. The group reviewed the guidelines (proposed in 2014) for minimum data sets (MDS) for all JECAM sites to use for collection of both EO and ground in-situ data. The objective of the JECAM

minimum data set requirements is to build a common data set of satellite and in situ observations to support research and methods benchmarking activities across JECAM sites. Results of a number of cross-site experiments using various optical sensors were presented. A cross-site experiment using synthetic aperture radar (SAR) was initiated. The JECAM network facilitates data sharing and collaborative research among its partners to develop crop assessment and agricultural monitoring methods for a large variety of agriculture systems. The enhanced coordination will facilitate a high level of bi-lateral and multi-lateral collaboration.

Multi-user licences are being pursued with a number of EO data suppliers (space agencies and commercial data suppliers), to allow sharing of EO data. The JECAM network is working to develop a “cloud” prototype to enhance data sharing and provide mechanisms for enforcement of the multi-user licences.

This is a rich set of scientific results, produced by expert teams around the world, in a wide variety of geographic settings and cropping systems, available for sharing and definition of ‘best practices’. It provides clear indication of the impact of CEOS support.

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1. Introduction

This report shows the progress that GEO JECAM (Joint Experiment for Crop Assessment and Monitoring) test sites have made since JECAM started in 2011, with the focus on progress made in 2015. The amount and types of Earth Observation (EO) data received are also reported, along with in situ data, analytical results, and future plans. JECAM is the foundation of the Research & Development (R&D) portion of the GEOGLAM (GEO Global Agricultural Monitoring) initiative, and so the R&D results are important for the development and sharing of 'best practices' in agricultural monitoring.

2. Background

In November 2009, the first JECAM meeting was held at the SAR for Agricultural Monitoring Workshop, in Kananaskis, Alberta, Canada. In December 2009, at the request of the GEO Agricultural Community of Practice, Canada took on JECAM coordination. In January 2010, a call was issued to the international community to provide standardized documentation of research sites. In September 2010, a JECAM meeting was held in Hong Kong to focus on Asian sites and data sharing issues. In-situ data sharing protocols were developed. In October 2010, a meeting took place in Brussels, concentrating Europe and Africa. In May 2011, a meeting in Brazil focused on South America.

In order for JECAM to succeed, collaboration with CEOS (Committee on Earth Observation Satellites) is needed to ensure access to and sharing of EO data of the test sites around the world. Without coordinated acquisition of EO data of the test sites, JECAM will be unable to develop the agricultural monitoring system of systems. The world's space agencies have collaborated for the benefit of the international community before; examples of coordinated acquisition of data to support scientific efforts include (but are not limited to) the International Polar Year (2007 – 2009), the GEO Global Forest Observation Initiative (GFOI) and the Polar Space Task Group (PSTG).

An international meeting of the JECAM secretariat was held with the space agencies and commercial data providers in Ottawa, Canada in June 2011 to discuss this question. Several data providers once again agreed to marshal their resources to provide coordinated EO data for this task which can be instrumental in addressing food security.

The benefits for CEOS and the space agencies are visible demonstrations of support to the international community on a matter of such high priority as food security. These demonstrations have the potential to translate into public support for CEOS programs. In the examples of the International Polar Year and the GEO GFOI, these benefits have been realized.

Further benefits include validation of the usefulness of the data from each EO sensor for agricultural monitoring, and dissemination of the research results.

The overarching purpose of JECAM is to compare data and methods for crop area, condition monitoring and yield estimation, with the aim of establishing 'best practices' for different agricultural systems. The goal of the JECAM experiments is to facilitate the inter-comparison of monitoring and modeling methods, product accuracy assessments, data fusion, and product integration for agricultural monitoring. These international shared experiments are being undertaken at a series of sites which represent the world's main cropping systems and agricultural practices. The approach is to collect and share i) time-series datasets from a variety of Earth observing satellites useful for agricultural monitoring and ii) in-situ crop and meteorological measurements for each site.

Synthesis of the results from JECAM will enable the following outcomes:

- (i) Development of international standards for agricultural monitoring and reporting protocols;
- (ii) A convergence of the approaches to define best monitoring practices for different agricultural systems;
- (iii) Identification of requirements for future EO systems for agricultural monitoring.

The JECAM sites are looking at a common range of monitoring needs over a very diverse range of landscape conditions and cropping systems, including:

- Crop identification and acreage estimation
- Yield prediction
- Near Real Time Crop condition / Crop stress
- Land management
- Soil moisture.

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Results of a number of cross-site experiments using various optical sensors were presented. A cross-site experiment using synthetic aperture radar (SAR) was initiated. The JECAM network facilitates data sharing and collaborative research among its partners to develop crop assessment and agricultural monitoring methods for a large variety of agriculture systems. The enhanced coordination will facilitate a high level of bi-lateral and multi-lateral collaboration.

Multi-user licences are being pursued with a number of EO data suppliers (space agencies and commercial data suppliers), to allow sharing of EO data. The JECAM network is working to develop a “cloud” prototype to enhance data sharing and provide mechanisms for enforcement of the multi-user licences.

There are currently thirty-five JECAM sites in the following countries:

- Argentina
- Belgium
- Brazil (2)
- Burkina Faso
- Canada (3)
- China (6)
- France
- Italy Apulian Tavoliere
- Kenya
- Madagascar
- Mali
- Mexico
- Morocco
- Paraguay
- Russia (2)
- Saudi Arabia
- Senegal
- South Africa
- Spain
- Taiwan
- Tunisia
- Ukraine
- Uruguay
- USA (3).

JECAM collaborates with the Asia-RiCE (Asian Rice Crop Estimation & Monitoring) activity led by Japan, with a number of Asian countries participating. Asia-RiCE is directed by an ad hoc team of stakeholders with an interest in the development of Asia-RiCE as a component of the GEOGLAM initiative. It is a regional cooperative framework for monitoring of the rice crop, which is the staple food for more than half of humanity, with 90% of the world crop grown and consumed in Asia. The objectives of Asia-RiCE are:

- To ensure that Asian countries receive the full potential benefits of GEOGLAM, and that they are suitably engaged and prepared to do so;
- To ensure that rice crop monitoring issues are given suitable priority and attention within the scope of the full GEOGLAM initiative, including in the development of the observing requirements; and
- To establish a framework for the coordination necessary to engage, manage and support the various stakeholders.

The NASA CEOS Systems Engineering Office (SEO) provides technical support to implement a secure portal with cloud-based hosting services for this JECAM initiative and Asia-RiCE team activity. The actual portal will be provided by another organization TBD. It is expected that the portal will receive shared EO data (among them, RADARSAT-2). Approved users will have controlled (via login and password) access to datasets, analysis applications and processing tools.

The following sections provide a progress report for the JECAM test sites up to February 2016, with the emphasis on their progress in the previous twelve months.

We wish to thank the JECAM site teams for their impressive contributions to this work.

3. Argentina

Team Leader and Members: Diego de Abelleira, Santiago Verón

Project Objectives

The original objectives for the site have changed.

- Crop identification. We are testing several classification methods using optical images, RADAR images, and combinations. During the 2015-2016 campaign, we continued obtaining data from a minimum dataset area of 20x20 Km. This area matches RADARSAT-2 acquisitions during this campaign. We developed an intercomparison of methodologies for cropland identification with other JECAM/SIGMA sites (China, Russia, Ukraine, Brazil, France). We are moving from local to regional estimation of crop land and crop type.
- Crop Rotations. Crop rotations in the last 5 campaigns are described and analyzed. A manuscript is being written.
- Soil moisture. Analysis of the effects on radar signals.
- Yield Prediction and Forecasting. During 2015, we started an intercomparison study for yield estimation with SIGMA/JECAM Partners from Russia, China, Ukraine and Africa led by Alterra (Wageningen, The Netherlands).

Site Description

- Location: San Antonio de Areco, Buenos Aires, Argentina

Centroid	Latitude: 34° 7'18.69"S
	Longitude: 59°35'53.05"W

- Topography: gentle slopes less than 3%
- Soils: Mostly Mollisols. Silt loam / Silty clay loam textured.
- Drainage class/irrigation: Well drained soils / Mostly rain fed fields
- Crop calendar: Main grain crops are soybean, maize and wheat. Early wheat is planted in June/July while late wheat is planted at the end of July and August. Wheat heading occurs in mid October and its harvest takes place at the beginning of December. After a wheat crop, a late soybean crop is commonly planted in December, and is harvested in April. Also, a late maize crop can be planted after a winter crop. Soybean and maize are mostly planted as one season crop. In these cases, soybean is planted in November and harvested in March/April and maize is planted in October and harvested in March.

- Field size: Typical field size is 20 ha but there is high variability in plot size.
- Climate and weather: The climatic type is humid temperate with an isohydro precipitation regime, with annual mean of about 1000mm.
- Agricultural methods used: Mostly no till agriculture. Main rotation (three years): Maize, Soybean, Wheat/Soybean.

EO Data Received

RADARSAT-2

- Supplier: CSA
- SAR
- Number of scenes:
- Range of dates: September 2015 – January 2016
- Beam modes/ incidence angles/ spatial resolutions:

Fine Quad Pol mode: FQ21

Wide mode: W3
- Processing level: Single Look Complex

Proba-V

- Space agency or supplier: VITO
- Optical
- Beam modes/ incidence angles/ spatial resolutions:

100 m product
- Number of scenes: all available from March 2014

In addition free available images were obtained: LANDSAT-8, MODIS, and SENTINEL 1.

Collaboration

We developed an intercomparison study of cropland classification methods among several JECAM partners, and a manuscript was sent to a scientific journal. In addition, a yield intercomparison study is being carried out. We also joined the Radarsat-2 MURF project for cropland and crop type classification. Since 2015, an intensive data collection area was defined in accordance with the JECAM MDS and RADARSAT-2 MURF approaches. See Figure 1. The red polygon is the JECAM SIGMA wide area. The JECAM MDS area is in yellow. The RADARSAT-2 FQ21 scene footprint is in orange. The surveyed fields are in blue.

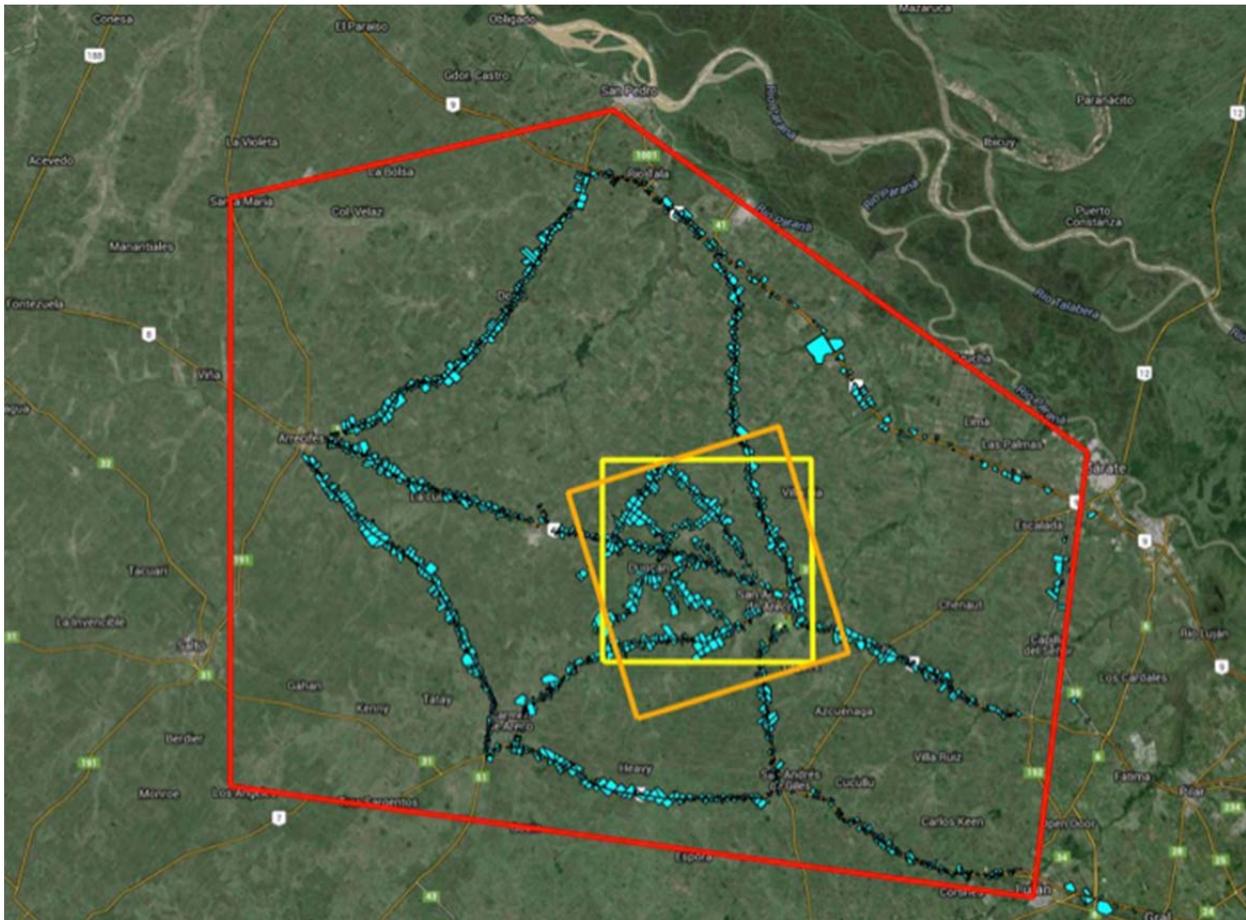


Figure 1 JECAM Study Area - San Antonio de Areco

Results

Crop type maps were generated during the last 5 campaigns (2010 to 2015) using different sources of high resolution optical data (Figure 2). Field surveys for training and validation of classifications were performed during these campaigns and 5 classes were defined: Early soybean, Wheat-soybean (double crop), Early and Late Maize and Forages (pastures and grasslands). In situ data increased since 2010 particularly during the last campaign, in part

because of the incorporation of the JECAM MDS area (Figure 3). Overall accuracies of single year classifications ranged from 0.87 to 0.96. It allowed us to perform crop rotation maps and to analyze spatial patterns. We are preparing a manuscript on this topic.

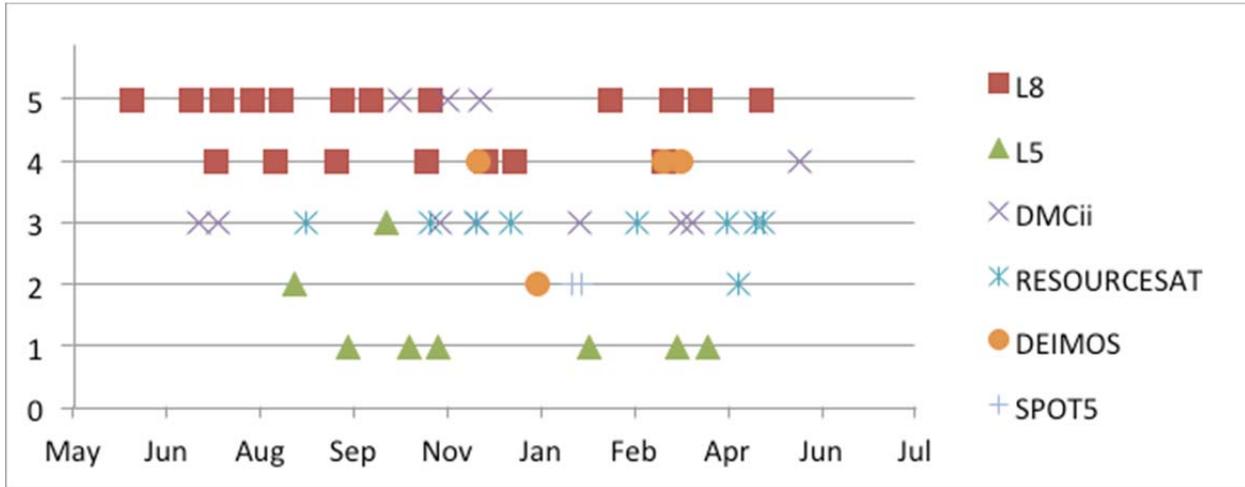


Figure 2 Optical Hi Res Images Acquired over the Study Area for the Five Campaigns 2010 - 2015

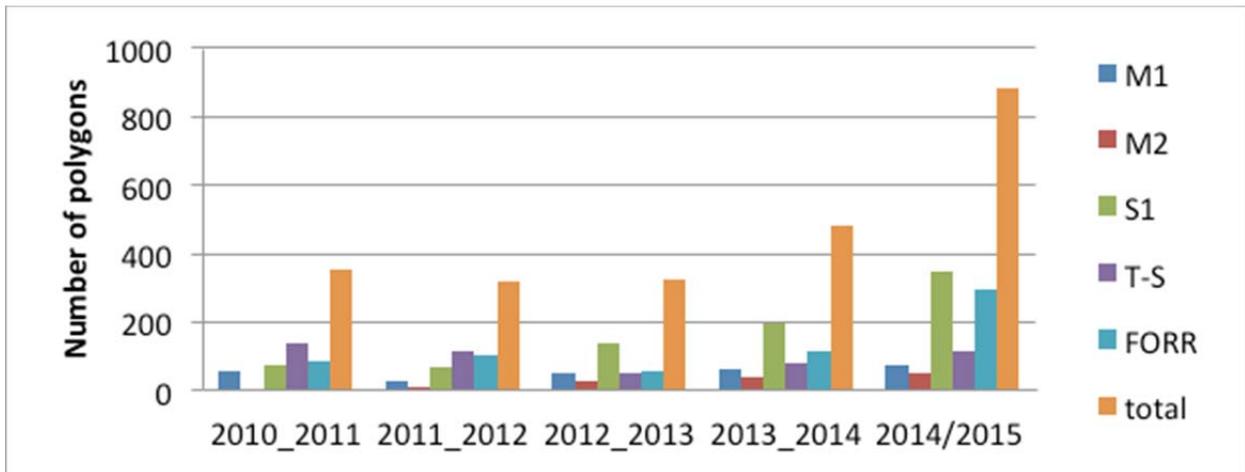


Figure 3 Number of Fields Surveyed per Class for each Campaign

Plans for Next Growing Season

In the next year, we anticipate ordering the same type and quantity of EO data. We plan to generate a manuscript of yield estimation intercomparison, as well as a second paper of cropland intercomparison, using different data sources as an alternative of in situ data (i.e. visual identification of fields).

Publications since last year's report

Verón SR, de Aballeyra D, Lobell DL. 2015. Impacts of recent precipitation and temperature changes on crop yields in the Pampas. *Climatic Change*, 130: 235-245.

Bontemps S, M Arias, C Cara, G Dedieu, E Guzzonato, O Hagolle, J Inglada, N Matton, D Morin, R Popescu, T Rabaute, M Savinaud, G Sepulcre Canto, S Valero, I Ahmad Bhutta, A Begué, B Wu, D de Aballeyra, A Diarra, S Dupuis, A French, I Hassan Akhtar, Kussul, V Lebourgeois, M Lepage, T Newby, I Savin, S R Verón, B Koetz, P Defourny. 2015. Building a Sentinel-2 like data set specifically dedicated to agriculture monitoring over 12 sites globally distributed. *Remote Sensing*, 7(12), 16062-16090; doi:10.3390/rs71215815

Waldner F, Diego De Abeyllera, Dmitry Plotnikov, Gueric Le Maire, Sergey Bartalev, Stéphane Dupuy, Santiago R. Verón, Mykola Lavreniuk, Ian Jarvis, Pierre Defourny, Miao Zhang, Sergii Skakun, Nataliia Kussul. 2016. Cropland mapping in five contrasted agrosystems dominated by large sized fields (sent).

Presentations:

De Aballeyra D, Verón SR, 2015. JECAM Argentina. JECAM/GEOGLAM Science Meeting Brussels, Belgium, 16-17 November, 2015.

4. Belgium

No report was received this year.

5. Brazil

5.1 São Paulo

Team Leader and Members: Guerric le Maire, CIRAD; Yann Nouvellon, CIRAD; Jean-Paul Laclau, CIRAD; José-Luiz Stape, IPEF and UNESP; Stéphane Dupuy, CIRAD.

Project Objectives

The project objectives for the site are:

- Crop identification and Crop Area Estimation.

Site Description

- Location: Latitude -22.9677, Longitude -48.7274.
- Topography: slope <5% in centroid area.
- Soils: Ferralsols, 20% Clay (in centroid area).
- Drainage class/irrigation: Moderately to well drained, high water consumption for Eucalyptus stands, cropland sometimes irrigated.
- Crop calendar: Eucalyptus: 6 year rotations; Other crops and sugarcane: monitoring started in December 2014, but mainly sugarcane monoculture and orange tree orchards.
- Field size: 40 ha for Eucalyptus field, large fields for other crop classes.
- Climate and weather: Humid Tropical (Aw Koppen), weather stations.



Figure 4 Sugarcane



Figure 5 Soybean Fields



Figure 6 Young Eucalyptus



Figure 7 Orange Tree Orchards

EO Data Received/Used

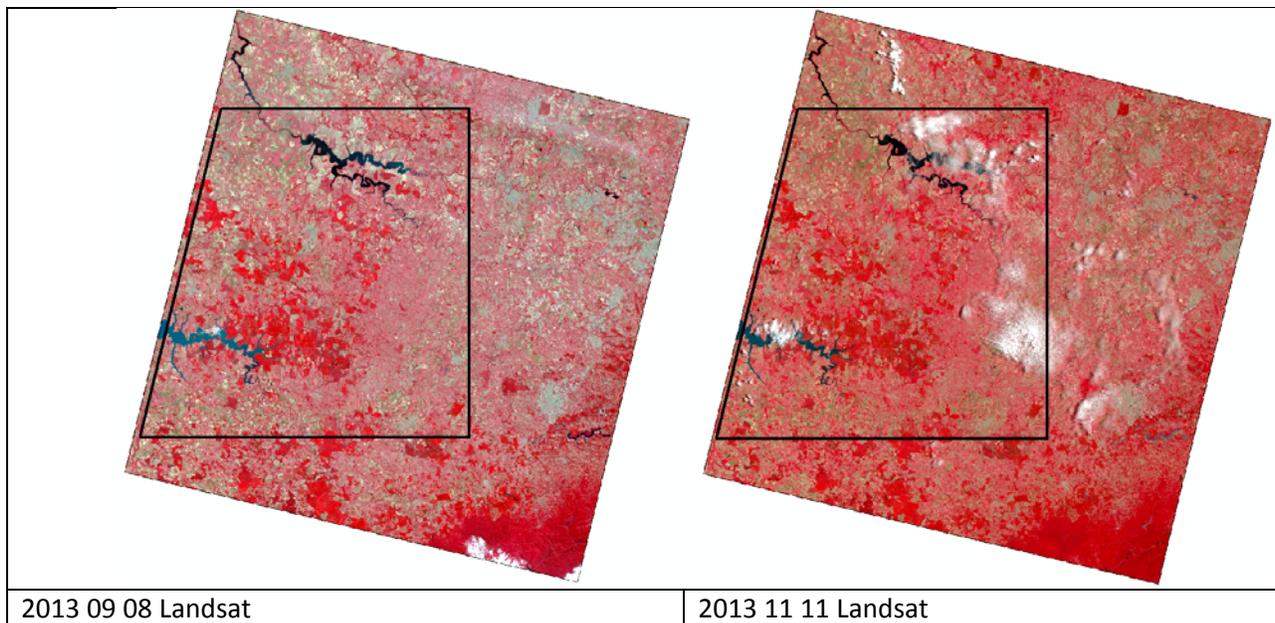
Mission/sensor: Landsat-8

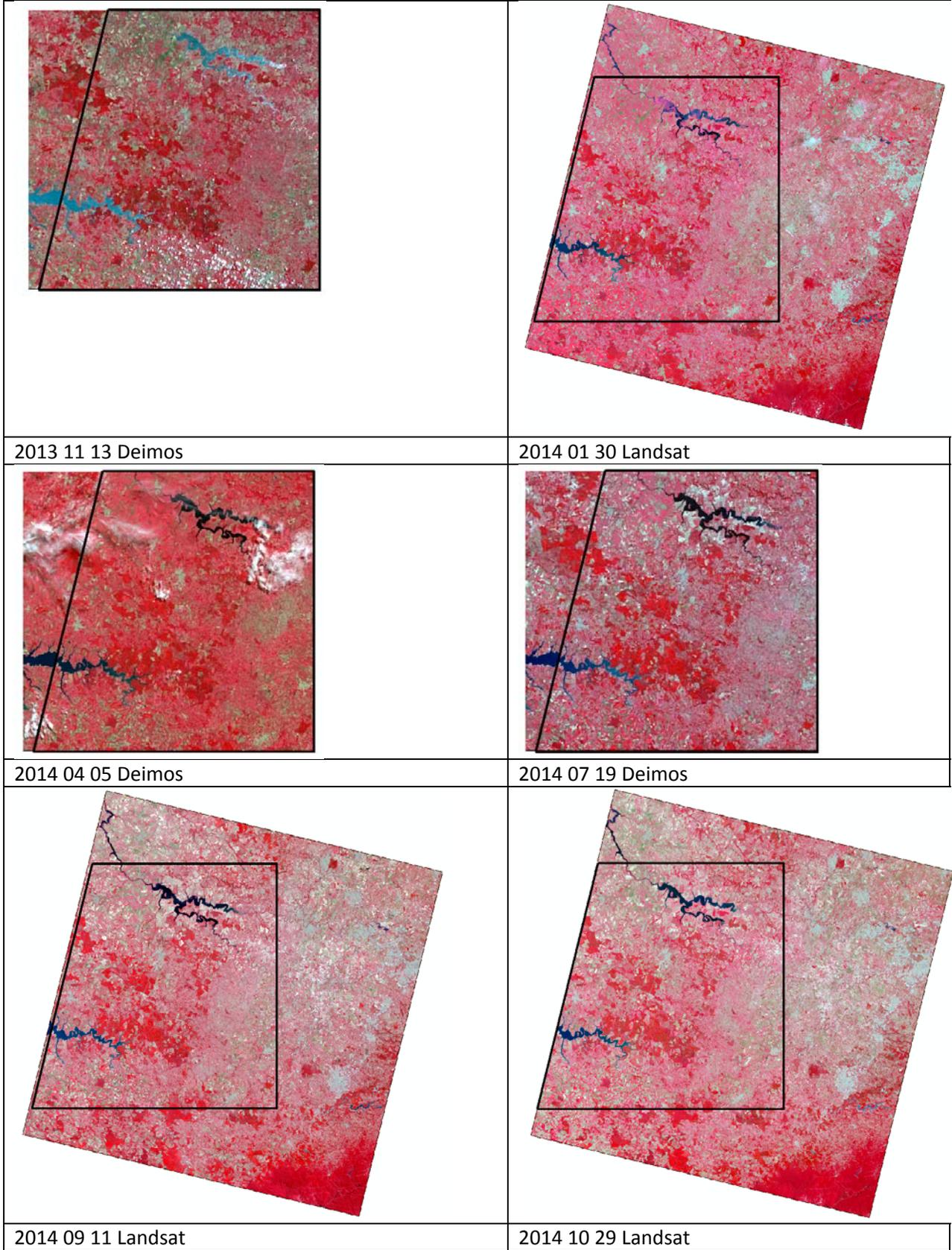
- Space agency or Supplier: NASA
- Optical
- Number of scenes: 19
- Range of dates: 08/09/2013 – 05/02/2016
- Beam modes/ incidence angles/ spatial resolutions: , 30 m MS + 15 m PAN
- Processing level: TOA reflectance

Mission/sensor: DEIMOS

- Space agency or Supplier: Deimos Imaging
- Optical
- Number of scenes: 3
- Range of dates: 13/11/2013 – 14/10/2015
- Beam modes/ incidence angles/ spatial resolutions: 20 m
- Processing level: TOA reflectance

Figure 8 DEIMOS and Landsat Images of São Paulo Site





In situ Data

We collected 847 GPS point in the field in December 2014, following the JECAM protocol and updated nomenclature for our site specificities. GPS points were chosen along roads to cover most parts of the JECAM area (see Figure 9). GPS points were afterwards converted to polygons based on the images.

During the 2015 year, measurements field visits were done every 3 months (March, May, August, November) for a subset of 265 sites located in the “annual crop” area of the image (i.e. South West). The most precise nomenclature was used (species), and other attributes such as irrigation or not, height of the crop, etc. were also recorded.

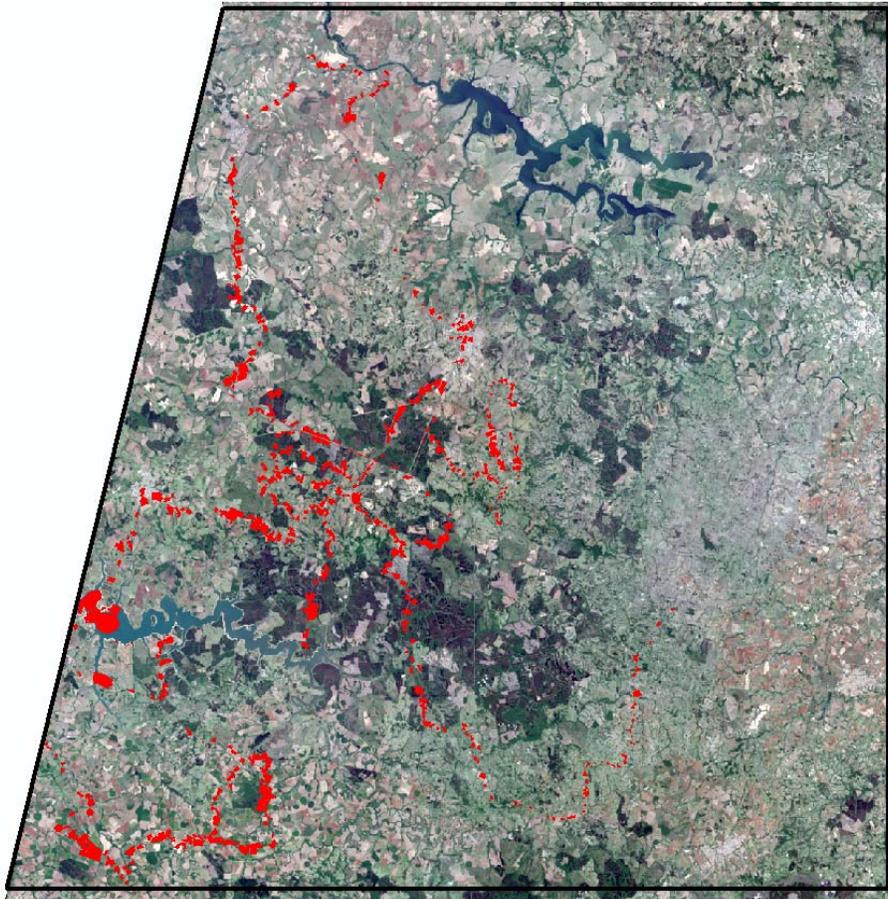


Figure 9 Illustration of the 847 Polygons of the Classified Area

In February 2016, all the 847 GPS points measured in December 2014 were visited, including the 265 sites located above. Most of the other 582 sites (847-265) were located in areas with a majority of perennial crops i.e. an annual visit is mostly sufficient. These sites are mostly

Eucalyptus plantations, sugarcane, pastures, coffee plantations, citrus plantations, pines plantations). Land used changes occurred in a few of these sites, and they were discarded in some of the treatments.

In 2014, the number of polygons for each class was as shown in Table 2 for the 847 polygons.

Table 2 Number of Polygons for each Class

Class	# polygons
Banana plantation	3
Built-up	53
Coffee plantation	14
Corn	30
Eucalypts plantation	160
Fallow	7
Forest	36
Orange tree plantation	63
Other	30
Pasture	127
Pines plantation	47
Rocks	11
Soybean	91
Sugarcane	154
Water	21

During 2015, of the 265 sites visited regularly, 96 sites were annual culture fields, and the others were mainly pasture and sugarcane. These sites presented a large variety of crop cycles, listed in Table 3 below. There is a very large number of combinations of land cover classes through the year. To see a bit more clearly, we have added different colours for soya, corn and “winter cereal”. We can see that many fields alternate between soya and corn, or soya and winter crop, with the soya being planted during the wet season and the corn/winter crop during the dry winter months. For the corn, the scheme is a bit different, because it could be planted at any time throughout the year. For the sugarcane, not presented in the figure, the date of harvest could be almost any time in the year. Some fields have a succession of 3 different cultures during the year.

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n	Dec2014	Mar2015	May2015	Aug2015	Nov2015
7	soya	corn	corn	corn	soya
7	soya	bare_soil	wheat	wheat	soya
6	soya	soya	wheat	wheat	soya
3	soya	corn	corn	bare_soil	soya
3	soya	soya	bare_soil	wheat	soya
3	soya	bare_soil	millet	bean	bean
2	corn	corn	bare_soil	wheat	soya
2	soya	corn	bare_soil	bean	bean
2	soya	corn	wheat	wheat	soya
2	soya	soya	wheat	wheat	corn
2	soya	bare_soil	potato	bare_soil	soya
2	soya	bare_soil	corn	bare_soil	soya
2	bare_soil	sugarcane	sugarcane	sugarcane	sugarcane
2	bare_soil	pasture	pasture	pasture	pasture
2	bare_soil	soya	wheat	wheat	soya
1	potato	soya	wheat	wheat	soya
1	sugarcane	corn	oat	oat	bare_soil
1	sugarcane	bare_soil	bean	bare_soil	corn
1	corn	bean	bare_soil	oat	soya
1	corn	corn	bare_soil	bean	soya
1	corn	corn	bare_soil	bare_soil	millet
1	corn	corn	wheat	wheat	soya
1	corn	bare_soil	millet	bare_soil	potato
1	corn	bare_soil	millet	bare_soil	corn
1	corn	bare_soil	millet	bare_soil	soya
1	corn	bare_soil	bare_soil	wheat	soya
1	soya	cotton	bare_soil	bare_soil	soya
1	soya	rice	bare_soil	bean	bean
1	soya	sugarcane	sugarcane	sugarcane	sugarcane
1	soya	corn	millet	bean	bare_soil
1	soya	corn	corn	oat	soya
1	soya	corn	corn	bare_soil	bean
1	soya	corn	bare_soil	bean	bare_soil
1	soya	corn	bare_soil	wheat	soya
1	soya	corn	sorghum	bare_soil	soya
1	soya	soya	avocado	avocado	avocado
1	soya	soya	oat	bare_soil	soya
1	soya	soya	millet	millet	soya
1	soya	soya	corn	corn	millet
1	soya	soya	corn	corn	soya
1	soya	soya	corn	bare_soil	soya
1	soya	soya	pasture	pasture	pasture
1	soya	soya	bare_soil	bean	bean
1	soya	soya	bare_soil	bean	soya
1	soya	soya	bare_soil	bare_soil	bean
1	soya	soya	wheat	bare_soil	soya
1	soya	bare_soil	oat	oat	soya
1	soya	bare_soil	millet	bean	soya
1	soya	bare_soil	millet	bean	bare_soil
1	soya	bare_soil	bare_soil	oat	soya
1	soya	bare_soil	bare_soil	wheat	bare_soil
1	soya	bare_soil	wheat	bare_soil	bean
1	soya	bare_soil	wheat	bare_soil	corn
1	soya	bare_soil	wheat	wheat	pasture
1	soya	bare_soil	wheat	wheat	bare_soil
1	soya	bare_soil	wheat	wheat	bare_soil
1	bare_soil	corn	corn	bare_soil	bare_soil
1	bare_soil	corn	bare_soil	pasture	pasture
1	bare_soil	soya	millet	bean	bare_soil
1	bare_soil	soya	bare_soil	pasture	pasture
1	bare_soil	soya	bare_soil	bare_soil	bare_soil
1	bare_soil	soya	wheat	wheat	bare_soil

Table 3 Land Cover Classes throughout the Year

Collaboration

Our work is part of the SIGMA - JECAM experiment on medium to large field size agrosystems.

The main objective of this project is to test and compare classification methods for cropland area estimations based on MODIS data, and applied in different contrasted sites. These sites were selected within JECAM for their large field size agrosystems. The nature of the collaboration for the Brazil-SP site relies on data preparation and share, field expertise, review of the results obtained in this experiment, complementary measurements, reviewing the paper, etc. A paper was written and submitted on this work.

Another work at a larger scale is ongoing.

Results

We have seen from the December 2014 results that it is possible to classify the perennial crops and forests with a good precision, with a single class “annual crop”. We will again improve this first level classification by using new field data measured in February 2016, and by using 2015 images including higher resolution SPOT 5 images acquired in March 2015.

Once the “annual crop” mask generated in the first step, we will improve its sub-classification in a second step. There is a big challenge for the classification of the cropland areas in the level of species, as we have seen last year: the lowest accuracies were for the annual crop species. One option is to perform a classification with a reduced number of species, by grouping species types (eg. winter cereal). Another option is to classify the entire annual rotation, with a reduced number of rotations obtained from the table with a merged similar type of rotations. This second option has the advantage of overcoming the issue of bare ground between different cultures. The last option is to perform a date-by-date classification at the species scale; however, some species will have few training points. We will test these different options.

Another main question is which remote sensing data could be used. Indeed, during the wet season, very few images are available. Therefore, we are developing a new classification program which could use all the available data, including Landsat 7 data or images only partly covering the area. This is a challenge mainly for the issue of the “no data” values within the time series (clouds, area covered by the satellite, Landsat 7 SLC issue, etc.). For this, we will test two options: 1) filling the “no-data” with an advanced gap filling algorithm, based on the available data at that period and the surrounding data 2) training different classification models as a function of the available data. Again, these two options will be tested and compared. In the

end, as for last year's map, we will produce a classification stability based on the class membership.

We do not have new results for the moment, since the year 2015 was mostly dedicated to field data surveys.

The objectives have been met for the moment. With the new data acquired in 2015, we will continue to improve the map mainly for the annual crop assessment. The method seems well adapted for the main perennial class, and will be improved with the new data for the annual crop class.

Can this approach be called 'best practice'? The method seems reliable enough, and the new classification tests will give interesting results for improving the classification on annual crops.

Plans for Next Growing Season

We will maintain the current approach, by doing field inventories every 2.5-3 months on the south-western part of the JECAM area (265 sites), mainly covered by croplands.

We anticipate ordering the same type/quantity of EO data next year, including DEIMOS data if possible, and we will use also Sentinel 2 data. Indeed, this site is part of the program "THEIA-S2" which will give access to pre-processed datasets by CNES. This will greatly increase the number of available images during 2016 (and also the end of 2015). We will also test the complementary use of Sentinel 1 data.

Publications

One submitted paper:

Waldner, F., Veron, S., Abeyllera, D.D., Zhang, M., Wu, B., Plotnikov, D., Bartalev, S., Lavreniuk, M., Skakun, S., Kussul, N., le Maire, G., Dupuy, S., Jarvis, I., & Defourny, P. (submitted). Cropland mapping in five contrasted agrosystems dominated by large sized fields. International Journal of Remote Sensing

5.2 Brazil - Tapajos

No report received.

6. Burkina Faso

Team Leader: Raffaele Gaetano, Maison de la Télédétection

Team Members: Patrice SANOU, ISESTEL Ouagadougou; Jacques IMBERNON, Montpellier; Mamy SOUMARE, IER, Bamako; Eric VALL, CIRDES, Bobodioulasso; Audrey JOLIVOT, CIRAD, Montpellier; Agnès BÉGUÉ, CIRAD, Montpellier

Project Objectives

The original project objectives have not changed. They are:

- Crop identification and crop area estimation
- Yield prediction and forecasting.

Site Description

The county of Koumbia is located in the southwest of Burkina Faso in the province of Tuy, in the Hauts-Basins.

Site Extent	Centroid: lat: 11°10.596 / long: -3°39.830
Top left: lat: 11°24.54 / long: -3°53.089	Bottom Right: lat: 11°4.301 / long: -3°26.086

- Soils: Mostly sandy
- Drainage class/irrigation: No
- Crop calendar: June to November
- Field size: ≤ 3ha (Cotton and Maize/Sorghum)
- Climate and weather: Tropical dry.

EO Data Received/Used

The EO images received in 2014 are shown in Figure 10. The red dots correspond to the Pleiades images. The crop calendar is highlighted. The images received in 2015 are shown in Figure 11, again with the crop calendar highlighted.

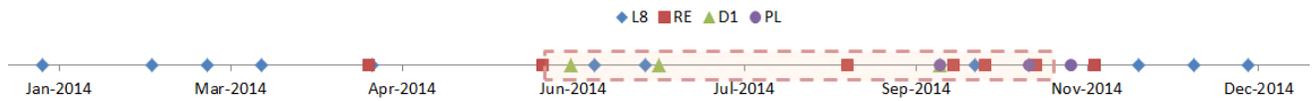


Figure 10 EO Images Received in 2014

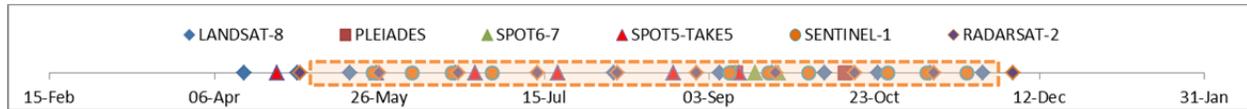


Figure 11 EO Images Received in 2015

Pléiades

- Space agency or Supplier : Airbus Defence and Space
- Optical
- Number of scenes: 6
- Range of dates: 2015/09/11 – 2014/10/21 – 2015/10/14
- Beam modes/ incidence angles/ spatial resolutions: pan-sharpened B/G/R/NIR bands at 15m spatial resolution
- Processing level: L1 ortho

The 2015 Pléiades mosaic is shown in Figure 12.

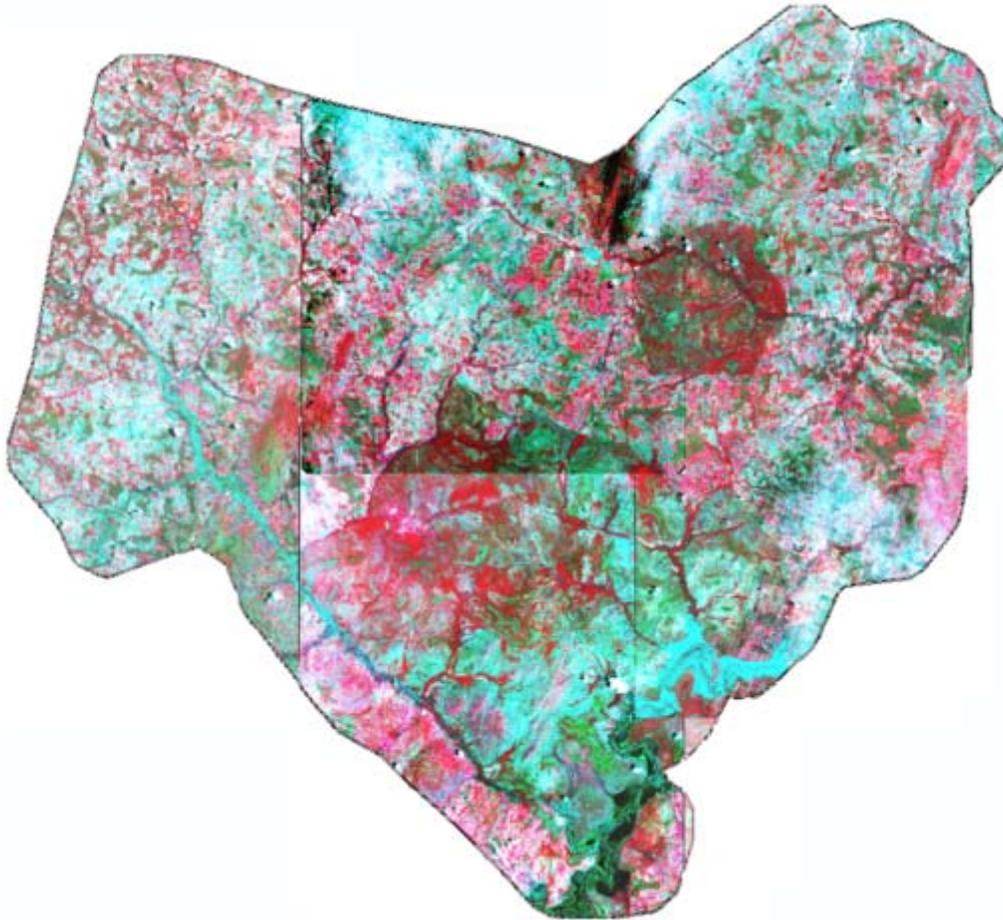


Figure 12 Pleiades Mosaic for 2015

SPOT 6/7

- Space agency or Supplier : Airbus Defence and Space
- Optical
- Number of scenes : 3
- Range of dates : 2015/09/11 – 2015/09/24
- Beam modes/ incidence angles/ spatial resolutions : pan-sharpened B/G/R/NIR bands at 1.5m spatial resolution
- Processing level : L1 ortho

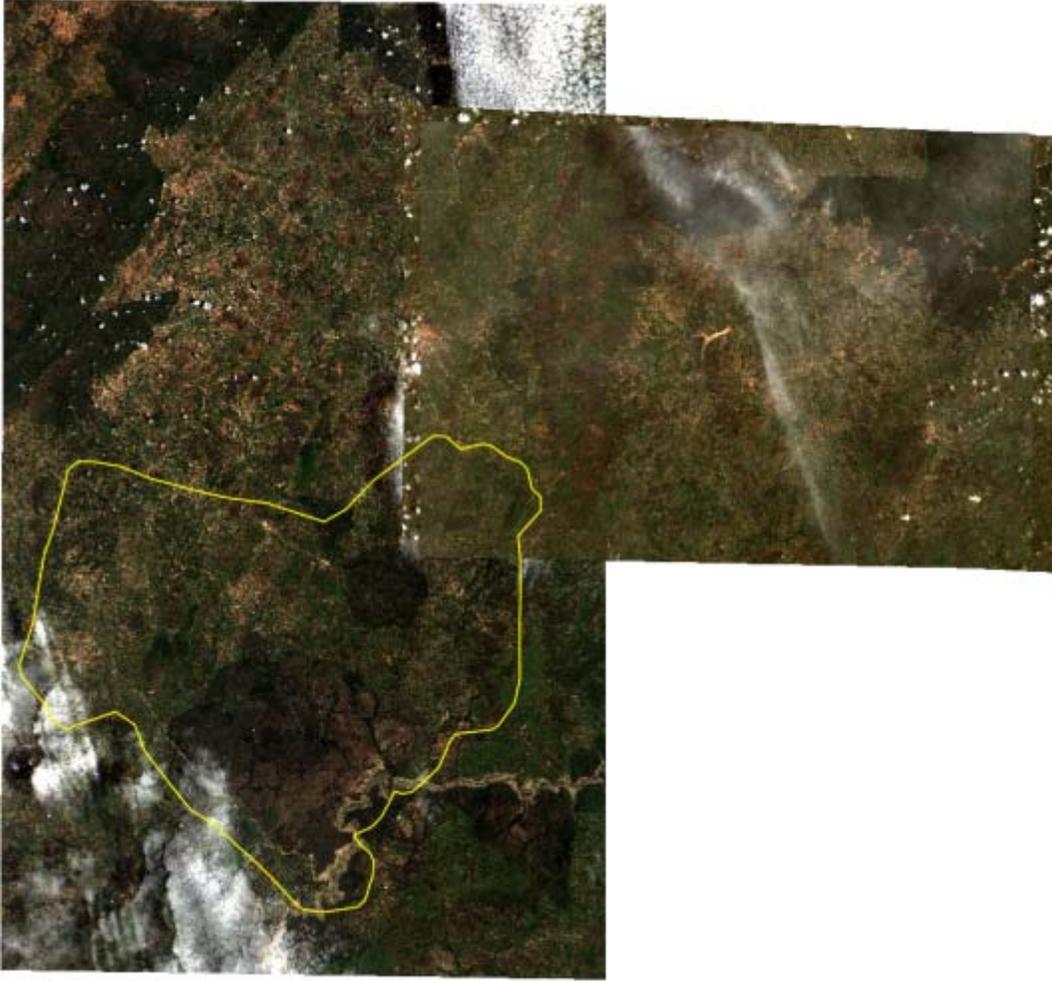


Figure 13 Samples of the SPOT 6/7 Images

Landsat-8

- Space agency or Supplier : USGS
- Optical
- Number of scenes: 3
- Range of dates : 2015/04/15 – 2015/11/25
- Beam modes/ incidence angles/ spatial resolutions: pan-sharpened (blue to SWIR2 bands) at 15m spatial resolution
- Processing level: L1 ortho

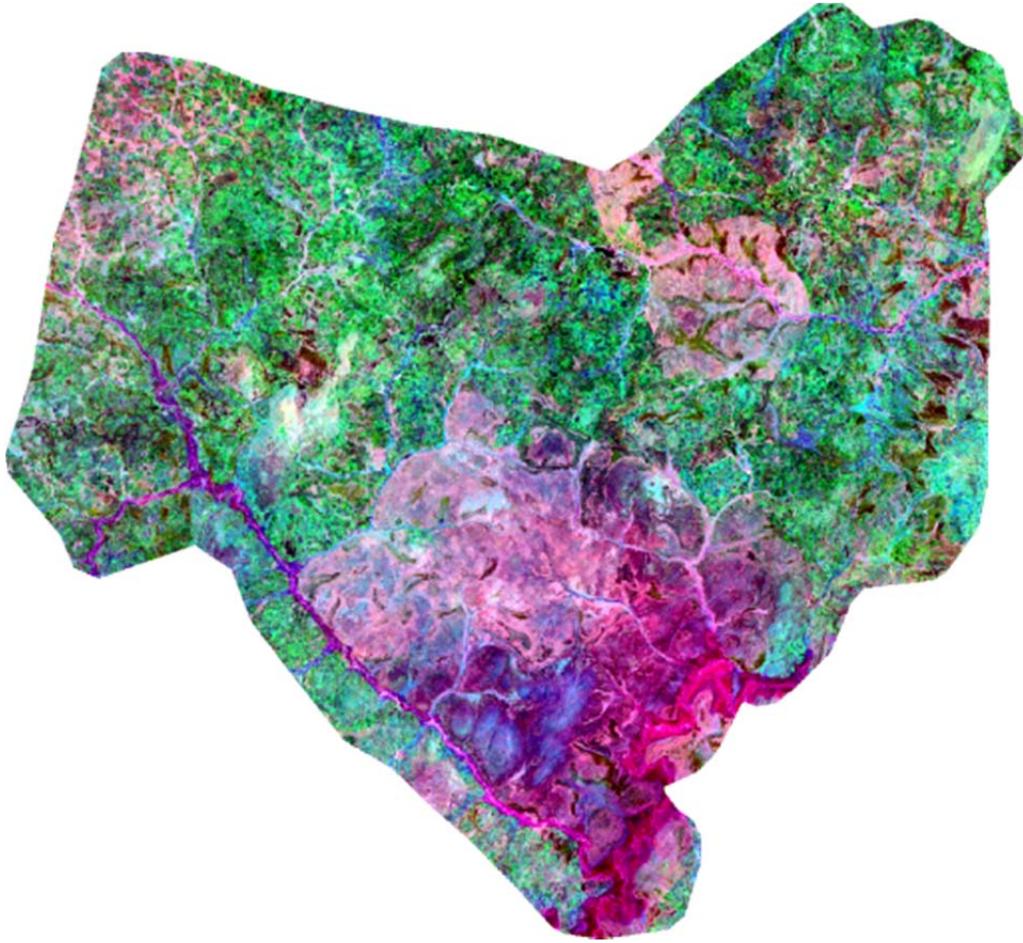


Figure 14 LANDSAT-8 June-October-November NDVI Composite for 2015

SPOT5-TAKE5

- Space agency or Supplier: Sentinel-2 for Agriculture
- Optical
- Number of scenes: 6
- Range of dates: 2015/04/25 – 2015/09/12
- Beam modes/ incidence angles/ spatial resolutions: G/R/NIR/SWIR bands at 10m spatial resolution
- Processing level: L3A (monthly cloud-free composite)

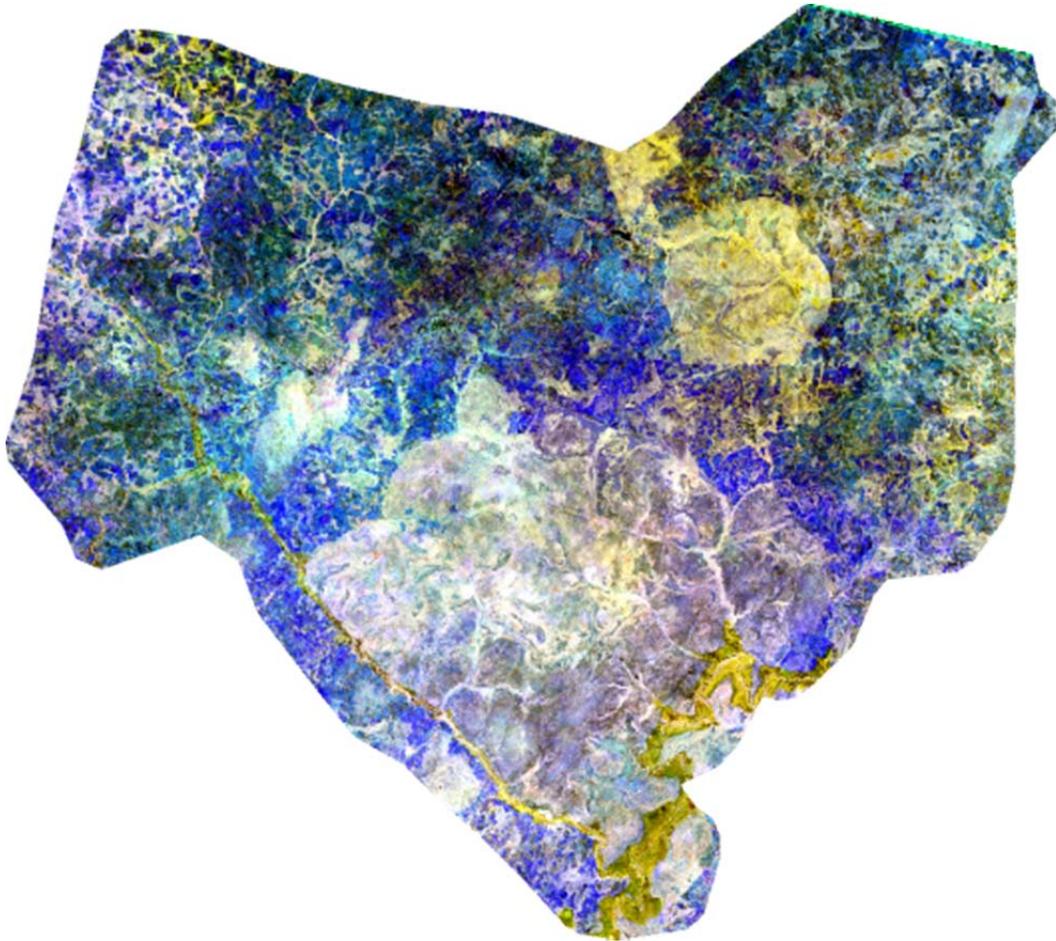


Figure 15 SPOT5-TAKE5 July-August-September NDVI Composite for 2015

SENTINEL-1

- Space agency or Supplier : European Space Agency
- Radar
- Number of scenes : 10
- Range of dates : 2015/05/24 – 2015/11/20
- Beam modes/ incidence angles/ spatial resolutions : Dual (VH/VV) polarization at 10m resolution
- Processing level : Level1 SLC + GRD

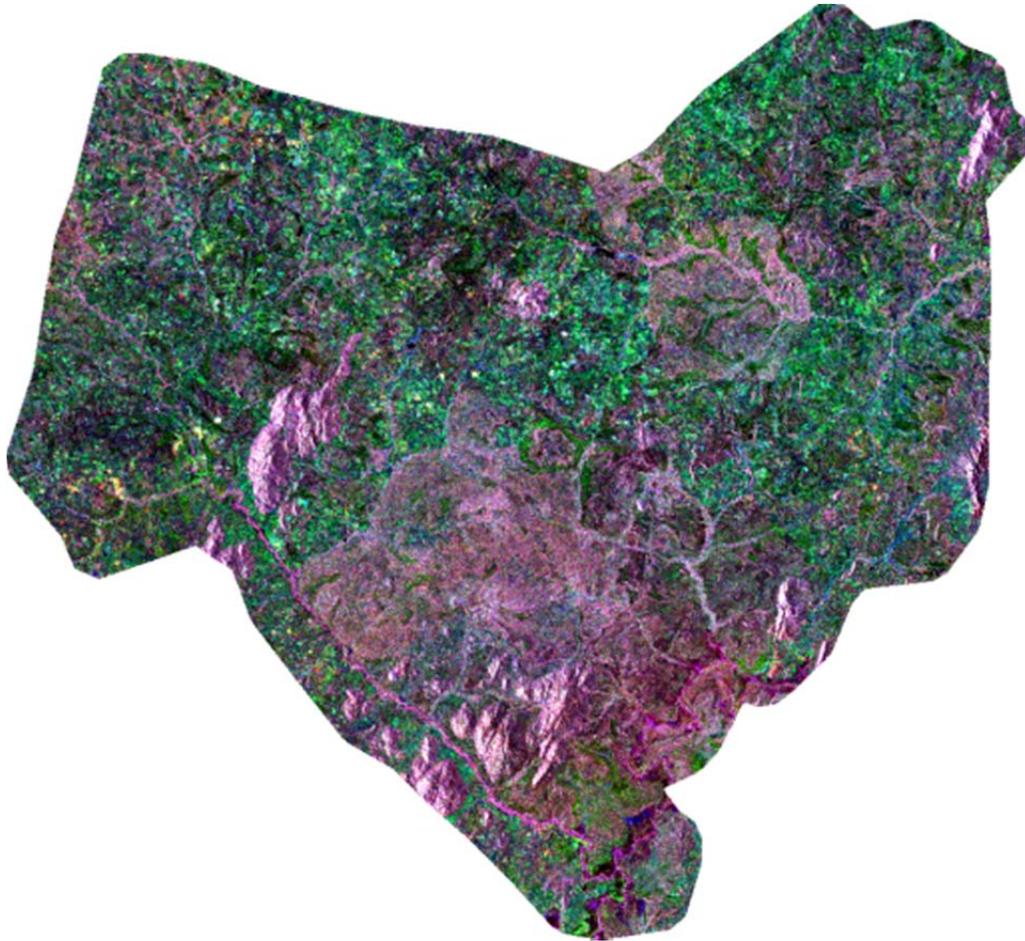


Figure 16 SENTINEL-1 June-September-November Composite (Pre-processed VV Intensities) for 2015

RADARSAT-2

- Space agency or Supplier: Agriculture and Agri-Food Canada
- Radar
- Number of scenes: 9 (Ascending - FQ5) 10 (Descending – FQ9)
- Range of dates: 2015/05/02 – 2015/12/04
- Beam modes/ incidence angles/ spatial resolutions : Quad-Pol at 11.5m resolution
- Processing level: SLC
- Acquired data only partly cover the study site.



Figure 17 RADARSAT-2 June-Sept-Dec Composite (Pre-processed VV Intensities) for 2015

In situ Data

The points in red in Figure 18 are plots selected for yield prediction and forecasting. Parcels in yellow are field surveys conducted in October 2015.

Field surveys were conducted on agricultural plots in October 2015. Approximately 900 GPS waypoints were collected to identify crop types following the recommendations of the “*JECAM Guidelines for Field Data Collection_v1 0*”. Parcels for cropland/crop types identification (in yellow) were manually digitized into polygons (surface data) using the VHSR Pleiades mosaic. Points for yield prediction (in red) will also concur to the validation of the classification products. With few exceptions, almost all points were identified transecting along roads and tracks at the end of the rainy season and using a GPS tablet with Pleiades/SPOT7 base maps.

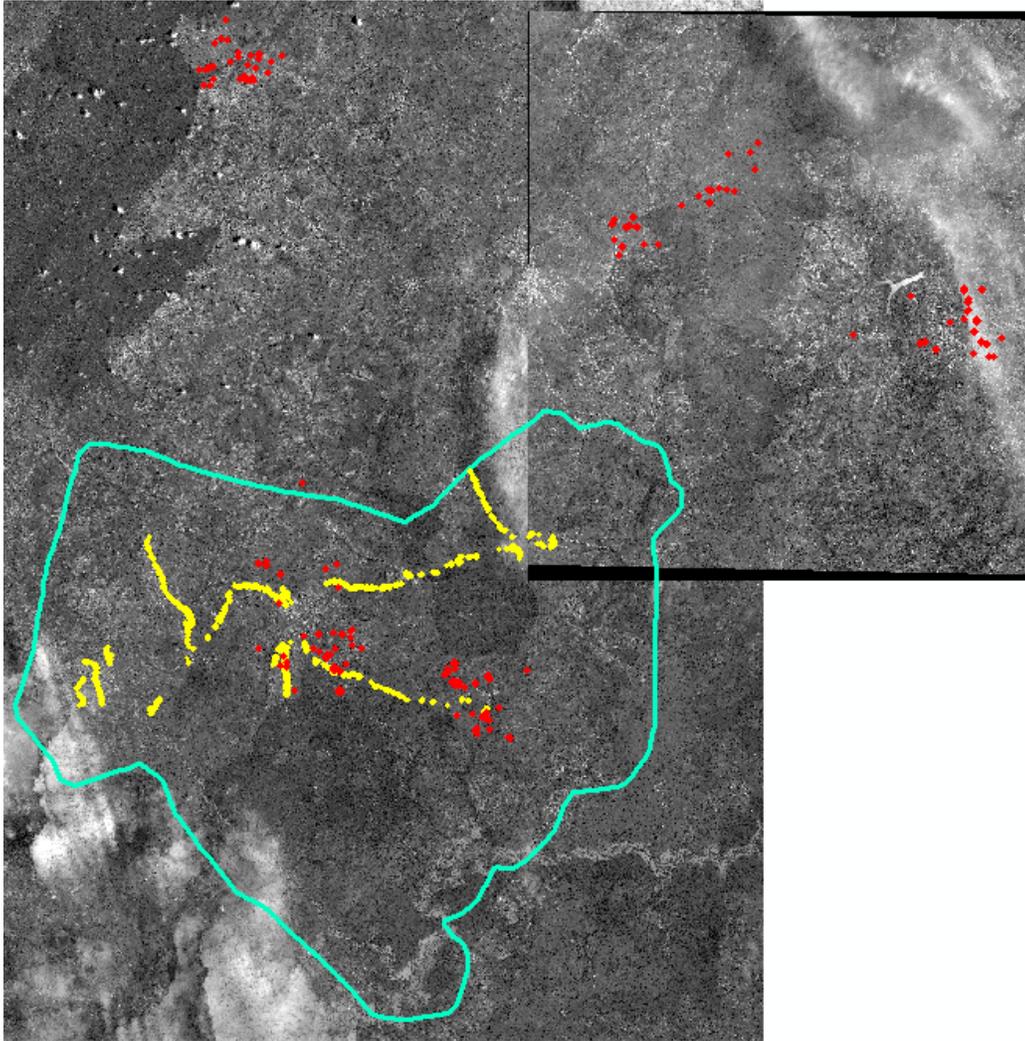


Figure 18 Plots selected for Yield Prediction and Forecasting, and Field Surveys



Sesame



Cotton and Maize



Groundnuts



Herbaceous Savannah



Maize



Sorghum

Figure 19 Photos Taken in 2015 during Field Surveys



Cow Peas



Young Fallow

Results

Cropland/Crop Type identification

Challenges:

- (1) Build a cropland/crop type identification map at the highest possible spatial resolution (0.5m) provided by the available EO data for the 2014 agricultural season (data acquired in 2015 that will be processed in 2016), for the different levels of the JECAM nomenclature (see Table 4).
- (2) Develop a novel methodology for classification leveraging the data-fusion approach and limiting the use of site-specific prior information, in order to devise a processing chain which can work at a global scale.

Methods: Our data-fusion approach relies on the OBIA (Object Based Image Analysis) paradigm:

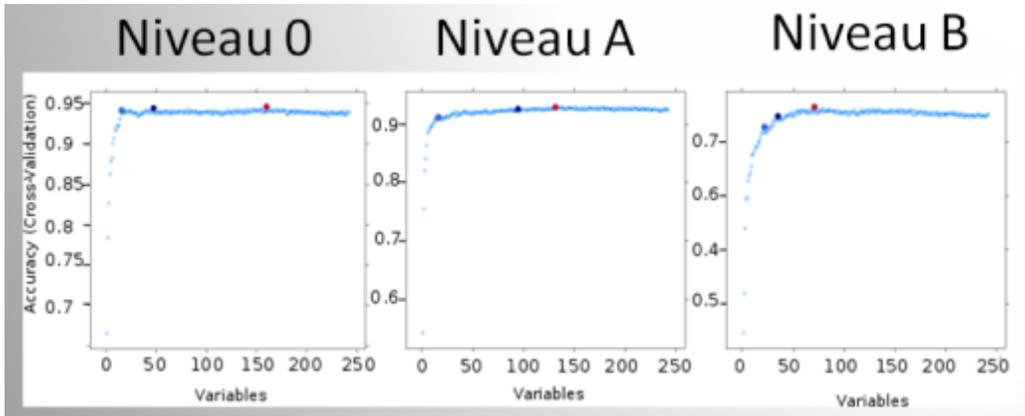
- an object layer is generated by segmenting the VHSR image, and a large set of radiometric/multi-temporal indices from HR imagery are projected at the object scale and joined to VHSR textural indices;
- a Random Forest (RF) classifier is used to carry out object-based classification, as well as to perform importance analysis over selected variables and to assess classification performances;
- several classification strategies have been tested to match the different levels of the JECAM nomenclature with an additional Level 0 for crop vs. non-crop identification (see Table 4), namely a traditional single level approach, and two (top-down and bottom-up) hierarchical approaches;
- a more robust validation is also performed using external validation segments not included in the training set, obtained by photo-interpretation based on additional in-situ data.

•	Level 0	Level A	Level B	Level C	Level D
CLASS	Non-crop	Water bodies	Water bodies	Water bodies	Water bodies
		Built-up surface	Built-up surface	Built-up surface	Built-up surface
		Natural spaces	Rocks	Rocks	Rocks
			Grassland	Herbaceous savannah	Herbaceous savannah
			Natural forest	Natural forest	Natural forest
			Shrub land	Savannah with shrubs	Savannah with shrubs
		Fallow	Young fallow	Young fallow	Young fallow
			Old fallow	Old fallow	Old fallow
	Crop	Ligneous crop	Other Cash woody crops	Other Cash woody crops	Other Cash woody crops
		Annual crop and	Oilseed	Groundnuts	Groundnuts
				Other	Sesame
				Soja bean	Soja bean
			Leguminous	Cowpeas	Cowpeas
			Cash crop	Fibre crop	Cotton
			Cereals	Maize	Maize
				Millet	Millet
				Rice	Rice
Sorghum	Sorghum				

Table 4 Modified JECAM Nomenclature including Level 0 (Crop vs Non Crop)

Variable Importance Analysis

To limit the complexity of the overall methodology, we performed a first set of Random Forest classifications to assess the number of important variables to retain. The figure and table below (Figure 20) show the overall accuracies as a function of the number of important variables used for levels 0, A and B. These experiments confirm that a number of variables around 20 (one tenth of the total) is enough to achieve a satisfactory accuracy (above 95% of the maximum achievable accuracy).



		Number of important variables used			
		15	40	159	242
Level 0	Overall accuracy	94.2 %	94.5%	94.5%	93.9%
		15	87	131	242
		91.1%	92.6%	92.6%	92.4%
		17	36	71	242
Level A	Overall accuracy	70.2%	74.7%	76.5%	75.2%
		15	87	131	242
		91.1%	92.6%	92.6%	92.4%
		17	36	71	242
Level B	Overall accuracy	70.2%	74.7%	76.5%	75.2%
		15	87	131	242
		91.1%	92.6%	92.6%	92.4%
		17	36	71	242

Figure 20 Overall Accuracies Obtained Varying the Number of Important Variables Used

Classification assessment using internal Random Forest validation

A first assessment of classification accuracies has been carried out using the internal Random Forest validation strategy (mean of the accuracies on randomly chosen validation samples over different trees). **Encouraging results have been obtained, especially for the Levels 0 and A**, as reported in Figure 21. Scores for the most detailed levels C and D are very promising, but further inspection is necessary to confirm these outcomes.

Classification assessment using external validation segments

A further set of manually segmented areas (mainly obtained by photo-interpretation) has also been used as an additional test set to assess classifications. Accuracies obtained using this test set are less interesting, especially starting from level B, as shown in Table 5. However, the reliability of the external validation set has to be further inspected.

We could also test the different classification strategies, and verify that the hierarchical approach starting from the level-0 map gives the best accuracies at finer scales.

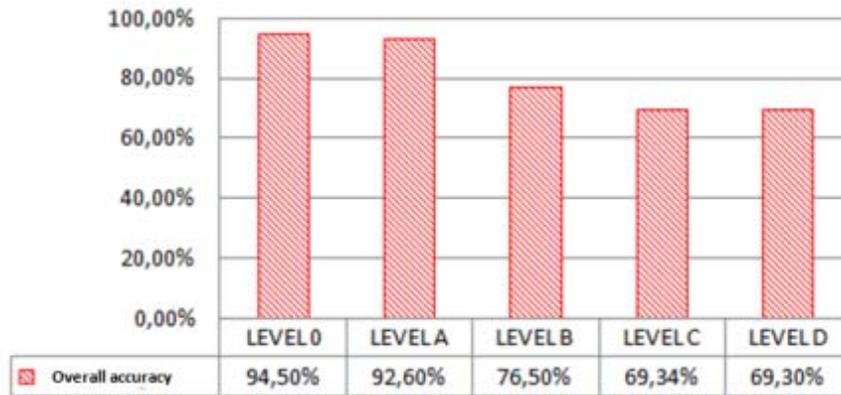


Figure 21 Overall Accuracies for Single Level Classification using Internal RF Validation

	Level 0	Level A	Level B
Level-specific	87.4 %	87.4 %	50.5 %
Hierarchical	-	90.5 %	54.1 %
By grouping	85.4	84 %	37.1 %

Table 5 Overall Accuracies for Different Classification Strategies using External Validation Data

In the next Figures, some samples of the cropland/crop-type maps generated for the 2014 agricultural season are shown.

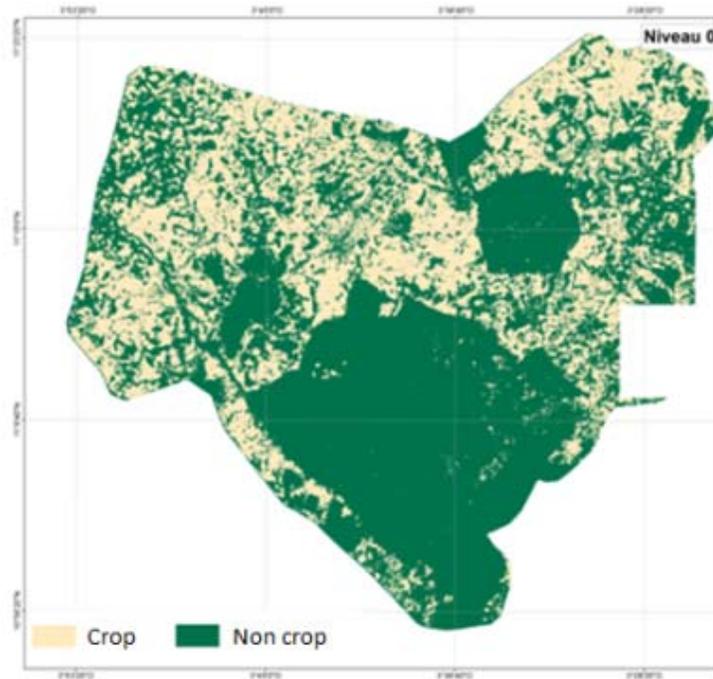


Figure 22 Level 0 Map (Crop vs Non Crop) for Koumbia Village

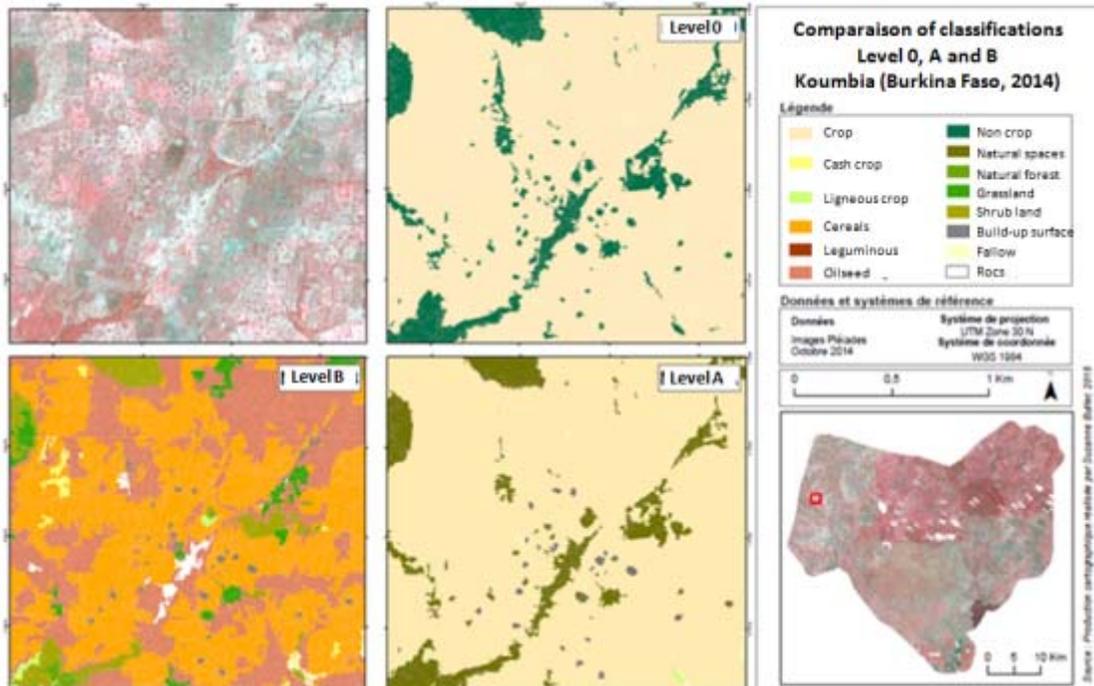


Figure 23 Details of Classifications at Levels 0, A and B

Yield Prediction and Forecasting

Challenges:

- (1) Describe and evaluate the main crop systems of the site: crop varieties, crop rotation, use of inputs, tillage, fallow, use of plough or tractors and
- (2) quantify the yield variability obtained by farmers and evaluate the link with the climate variability.

Methods: Six villages have been selected according to their spatial distribution, their accessibility, the studies already carried out, and the remote sensing image footprints. In agreement with the farmers and peasant organizations, thirty plots have been chosen in each village, to carry out two types of survey:

- A survey with the farmer, concerning the plot monitored: Preceding crops for the three last years, crop management techniques, area cultivated, production obtained, crop residues.
- Concerning the crop monitoring on the plot for the season 2014:
 - Ten days of crop monitoring
 - The weighing of grains and biomass for three quadrants by plot.
 - The daily measurement of rainfall, with three rain gauges put in each village (a total of eighteen rain gauges).

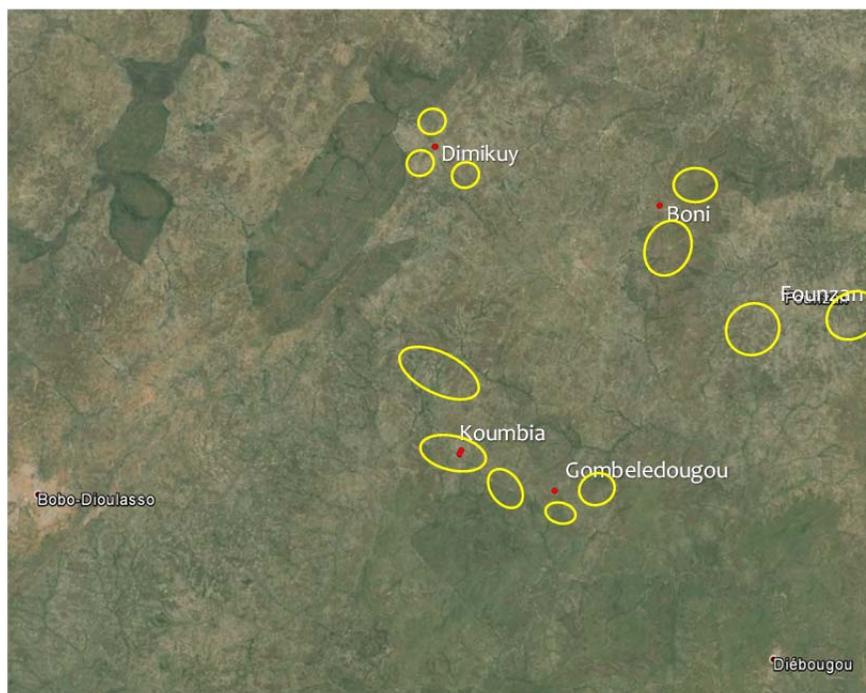


Figure 24 Site with Villages and Monitored Plots

Figure 25 shows the cotton yields for each village in recent years, and Figure 26 shows the crop rotation with maize.

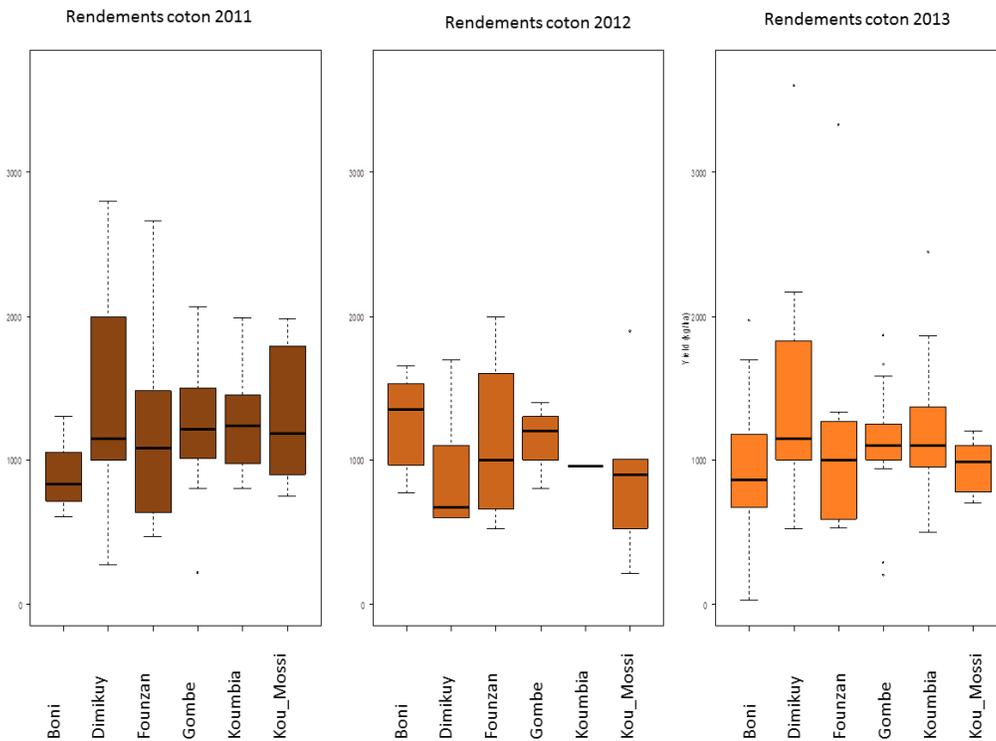


Figure 25 Cotton Yields for each Village, 2011 - 2013

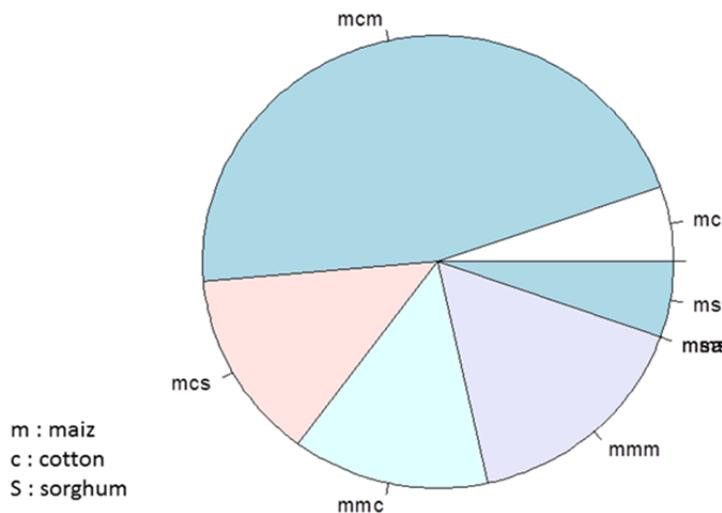


Figure 26 Crop Rotation with Maize 2009-2011

Figure 27 shows the rainfall at the rain gauges in Boni village, and Figure 28 shows the sowing related to rainfall in Gombeledougou.

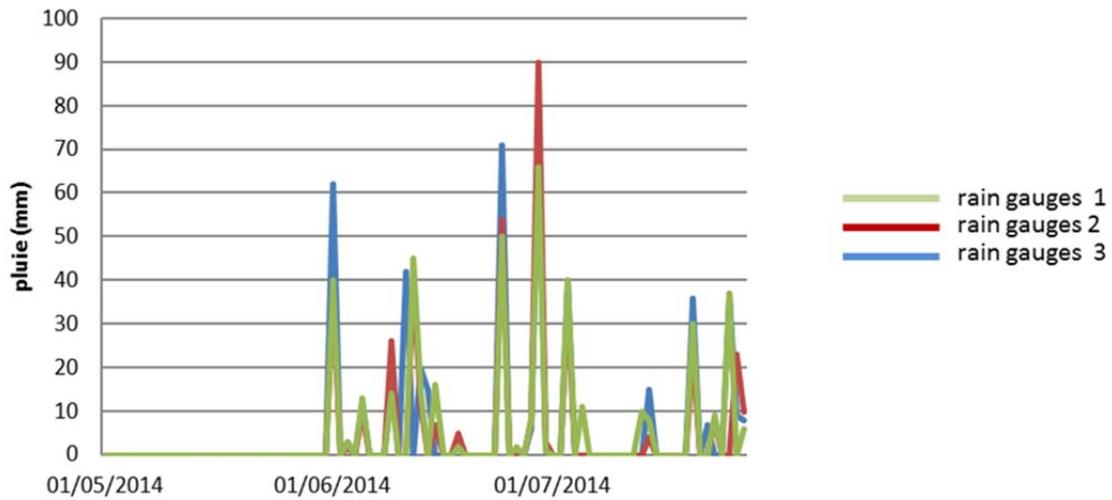


Figure 27 Rainfall at the 3 rain gauges in Boni Village, 2014

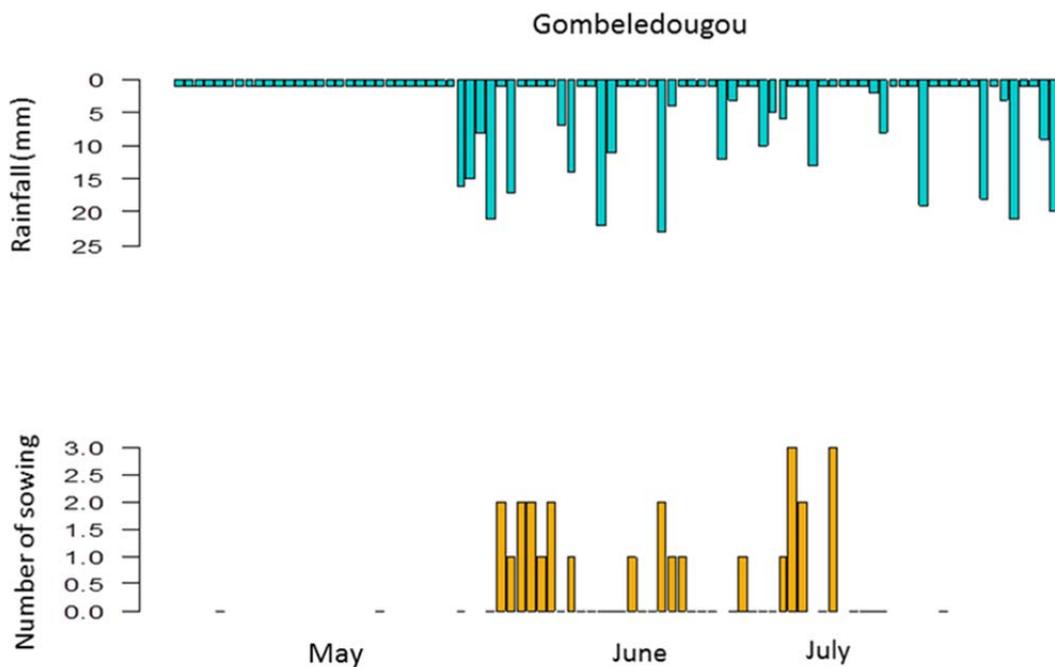


Figure 28 Sowing Related to Recorded Rainfall in Gombeledougou, 2014

Data analysis for 2015 growing season is still ongoing. The number of monitored plots has been raised to 160, 85 cultivated with maize, 33 with cotton and 42 with sorghum.

Collaboration

The workflow for crop type identification carried out for the Koumbia site has been conceived and applied in collaboration with the Brazil (Sao Paulo) and Madagascar (Antsirabe) study teams. We confirm the value of this approach with respect to the geographical and agricultural specificities of the different sites.

Conclusions

An appropriate general workflow based on the fusion of heterogeneous data has been successfully carried out for the identification of crop types. Current classification scores, although to be further validated, stand unprecedented for the Burkina Faso site and confirm that the proposed approach is promising. However, further development has to be carried out in order to :

- select more appropriate variables at different scales;
- refine methodology with respect to object-layer generation and object-based classification strategies;
- collect and process data from other sensors (radar) and/or sources,
- identify a more reliable external validation strategy.

We followed the recommendations of the “JECAM guides” for the acquisition of field data. However, we have adapted to the nomenclature cultures present on our site.

We modified the project objectives in the sense that we added the study of Yield Prediction and Forecasting.

Plans for Next Growing Season

Next growing season, we will maintain basically the same approach; however, the approach will be further investigated.

The EO data to be acquired will change as follows:

- We will continue programming Pleiades images on the area. The vesting period will be the same.
- We plan to renew the order for SPOT 6-7 data (one image in the dry season and one at the end of the rainy season).

- We hope that this site will be selected for the acquisition of images from the VENUS mission (spatial resolution : 5m / temporal repetitiveness 2 days)
- We will rely again on Landsat-8 images, and add Sentinel-2 multi-spectral images to the dataset in 2016 (including L3A products from the “Sentinel-2 for Agriculture” platform).
- We expect to obtain further improvement through the use of SAR data for the generation of 2015 crop type maps. We will renew the acquisition of radar data.

We also hope to renew field surveys: this will depend on the security conditions for the organization of the missions.

Publications

No publications yet; two papers are currently being prepared for submissions in the coming months.

7. Canada

7.1 CFIA (Canadian Food Inspection Agency)

Team Leader and Members: Drs. E. Pattey & G. Jégo

Co-App.: A. Vanderzaag, J. Liu, B.Qian, W. Smith, X. Geng

Coll.: F. Baret, M. Weiss, N. Beaudoin, R. Desjardins, R. Fernandes, I. Jarvis, T Huffman, R. Lacaze, J. Sheng, H. McNairn, et al.

Project Objectives

The original objectives of the project have not changed. They are:

- Crop identification and Crop Area Estimation
- **Crop Condition/Stress**
- Soil Moisture
- **Yield Prediction** and Forecasting
- Crop Residue, Tillage and Crop Cover Mapping
- **Soil properties.**

Project title: "From fields to regions: Improving crop model predictions, using remote sensing-derived biophysical descriptors and climate data, to evaluate the impact of climate variations on crop production and environmental performance."

Objectives:

- Validation of LAI and fAPAR from Sentinel computation chain
- Assimilation techniques (re-initialization, forcing)
- Yield Prediction
- LAI, evapotranspiration, RUE, N₂O fluxes
- Crop Condition/Stress
- The project needs Crop Cover Mapping and site can serve for training/validation.

Site Description

- Location: The centroid is at latitude 45° 18' 00"N, longitude 75° 46' 00"W. CFIA Ottawa Laboratory 3851 Fallowfield Road, Ottawa, Ontario, Canada.
- Topography: flat < 0.5% Gradient.
- Soils: Modified marine sediments with a fine texture and neutral composition. Layers of silty sediments interspersed in the upper 2 meters. Clay loam is the dominant texture.

- Drainage class/irrigation: Tile Drainage and Precipitation Fed Field.
- Crop calendar: spring crops: corn soybean, wheat canola.
- Field size: 15-75 ha fields.
- Climate and weather: Average of 732 mm of rain yr⁻¹ and 236 mm of snow yr⁻¹ and temperature averages from 13.4 °C- 20.9 °C from May-August (Environment Canada, Government of Canada 2014).
- Agricultural methods used: Tillage, synthetic fertilizer, seeding, harvest when grains are dry enough.



Figure 29 CFIA-Ottawa Field Equipment

As shown in Figure 29, CO₂, H₂O and sensible heat flux is measured in two fields using 3 eddy covariance towers. Nitrous oxide fluxes are measured using 2 flux gradient towers. Destructive biomass, LAI, soil sampling, and yield mapping and non-destructive PAI, IChl (Dualox, SPAD), crop cover (nadir photos) soil moisture & T, intercepted PAR are performed. Other data are obtained from the weather station.

EO Data Received/Used

The EO data used in 2015 are shown in Table 6. Figure 30 provides examples.

Table 6 EO Data Collected for CFIA in 2015

Data	Supplier	Sensor	# scenes	Dates	Mode/ resolution	Processing level	Challenges
Landsat-8	USGS	Optical	5	May 20, May 29, Jul 16, Aug 17, Sep 18	30-m	Radiance	Cloud/long revising cycle
SPOT-5	ESA	Optical	17 (9 good)	Apr 30, May 5, May 20, Jun 4, Jun 19, Jun 24, Jul 4, Jul 24, Sep 7	10-m	Reflectance	Cloud
CHRIS	ESA	Optical	1	May 13	MOD 3 17-m	Radiance	Cloud, spontaneous acquisition
Radarsat-2	CSA	SAR	17	Apr 17-Nov 19	FQ various angles	Quad-pol	Ordering conflict

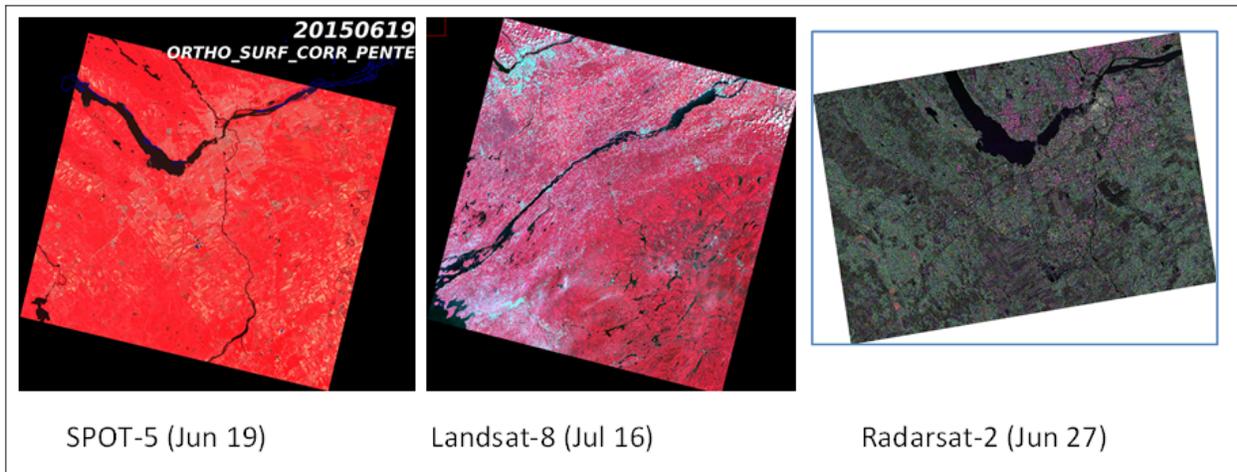


Figure 30 Example Images of CFIA Site

In situ Data

The following in situ data was collected:

- Eddy covariance fluxes (ET, sensible heat & CO₂ fluxes)
- Soil respiration (discrete & automated chambers)
- Crop cover (photography)
- PAI (DH photography, PASTIS-57 sensors)
- APAR (using 1-m long integrated PAR bars and PASTIS-PAR)
- Soil moisture (continuous soil profiles & soil sampling)
- Soil fertility sampling (analytical chemistry)
- Destructive biomass & LAI, and yield mapping
- Non-destructive Leaf chlorophyll (Duallex)

- Meteorological stations (rain gauge, net radiometers, PAR, anemometers, soil T& moisture profiles)
- Flux gradient N₂O fluxes (using tunable diode lasers).



Figure 31 Flux Towers in the Canola Field in 2015 at the CFIA Experimental Site

Figure 32 shows an ultrasonic anemometer installed on the eddy covariance flux tower for measuring CO₂, latent and sensible heat fluxes.

Figure 33 shows an automated soil respiration chamber to measure CO₂ efflux from the field surface (LI-COR, Lincoln, NE).



Figure 32 Ultrasonic Anemometer



Figure 33 Automated Soil Respiration Chamber

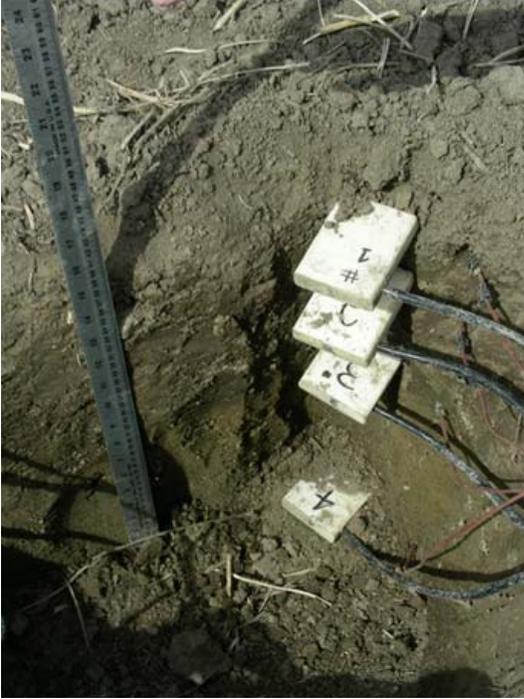


Figure 34 CS616 Soil Moisture Probes Installed at 4 Depths



Figure 35 Digital Photo for Determining Green Plant Area Index and Cover Fraction



Figure 36 Leaf Chlorophyll Content Determination (Dualex, France)

Collaboration

We are collaborating with the following colleagues through the IMAGINES program:

- Roselyne Lacaze, Hygeos and Fred Baret, INRA
- Ferdinand Camacho (EOLAB) with flux data, FAPAR, LAI
- Fred Baret/Marie Weiss (INRA) (provided Pastis 57 sensors for deployment on the site).

Results

Four crops were monitored: canola (F14), spring wheat (F14N), soybean, and corn. Corn was the dominant crop planted by the private producers at CFIA (Figure 37). Fields for instrumentation and sampling were selected to cover a range of soil conditions. Monitoring took place in fields 14 (canola), 14N (wheat), 5, 9, 15N, 16 (soybean), and 2, 6, 11, 15S, 23E/W, 25N/S (corn). The locations of PASTiS (triangles), APAR (squares), and biomass sites (circles) are indicated. Image dated 18 June 2015.

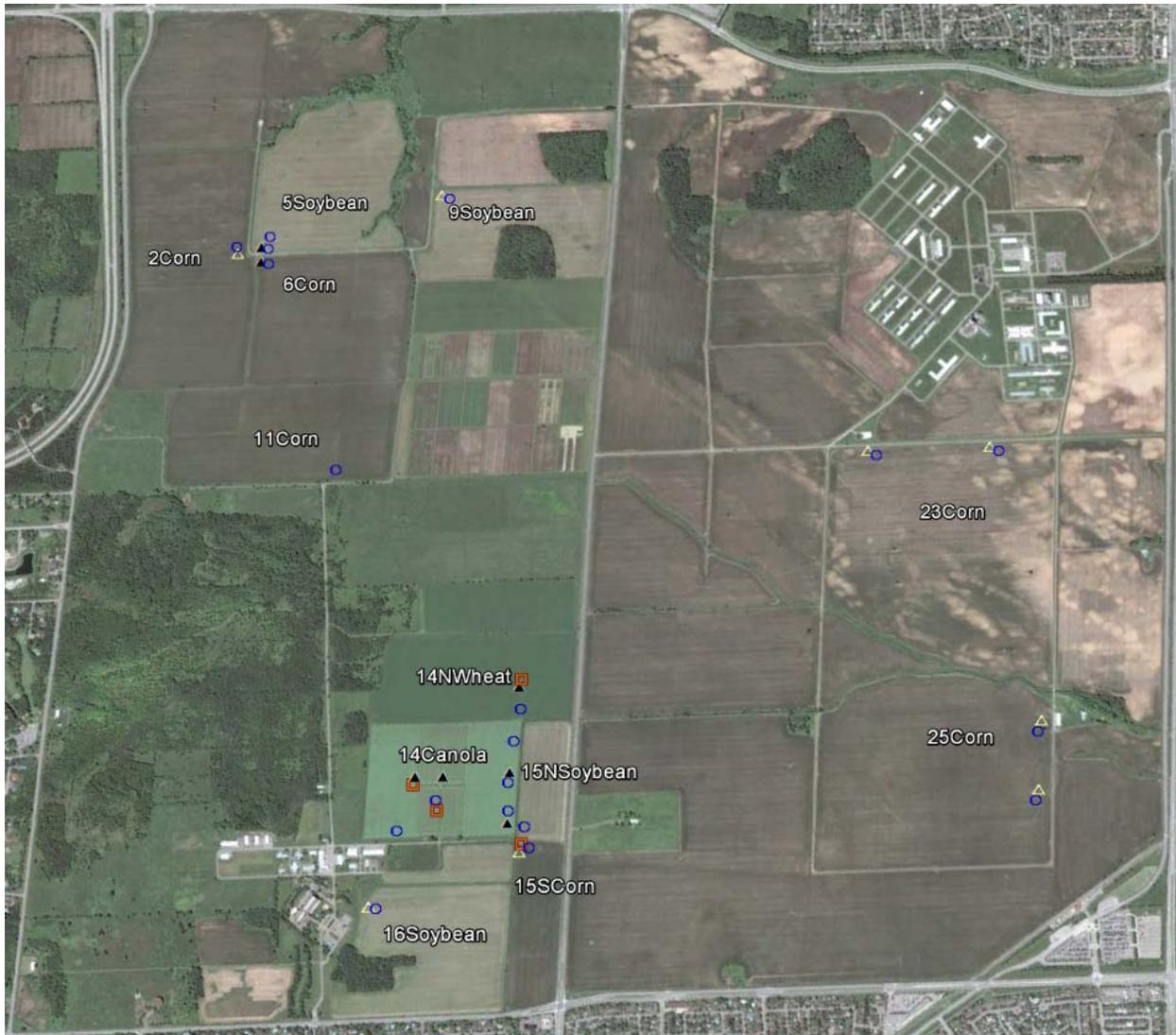


Figure 37 Layout of Crops Planted in 2015 at CFIA-Ottawa

Figure 38 shows the daily precipitation measured at the field site (April 1 to November 30) or at the nearby airport site (before April 1 and after November 30). Greater than normal rainfall in June helped to make up for lower than normal rainfall amounts in the spring and July.

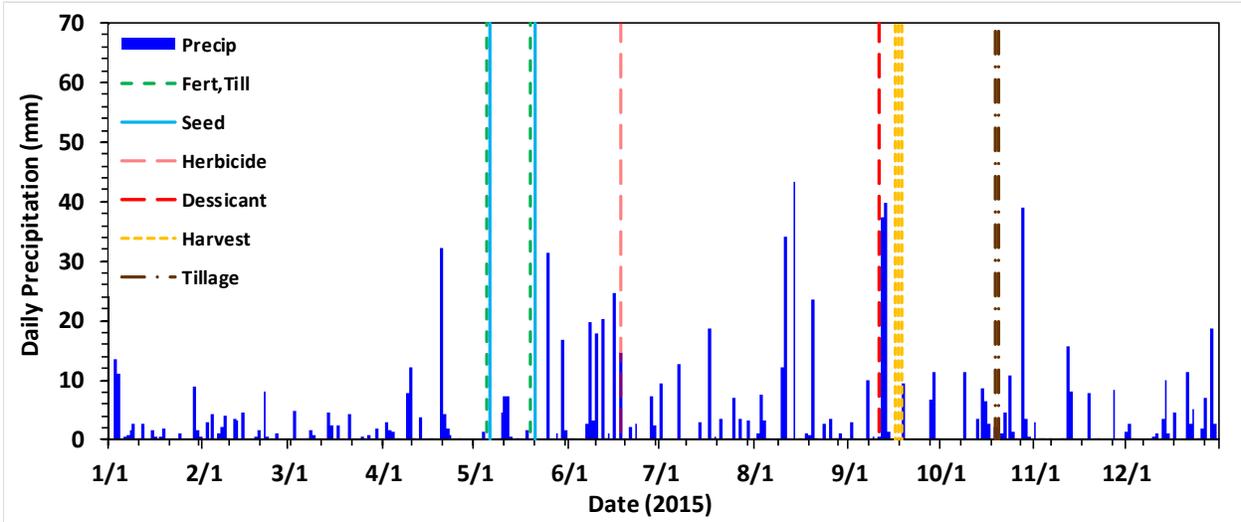


Figure 38 Daily Precipitation

The delay in seeding was seen in the biomass sampling data in field 14 (see Figure 39 and Figure 40).

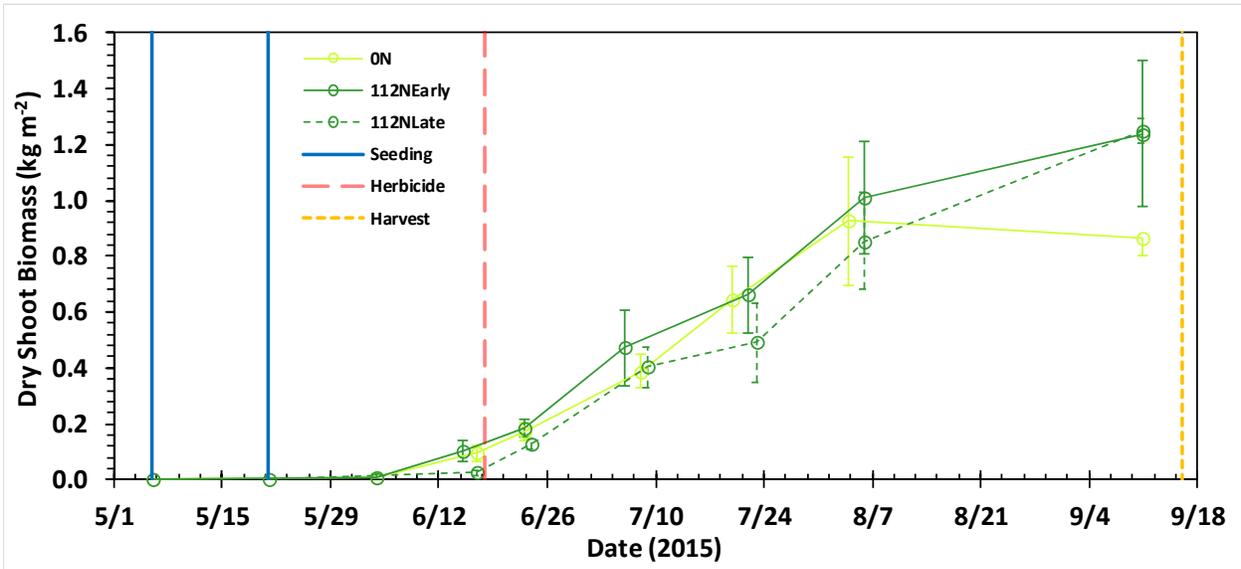


Figure 39 Dry Shoot Biomass of Canola in 2015

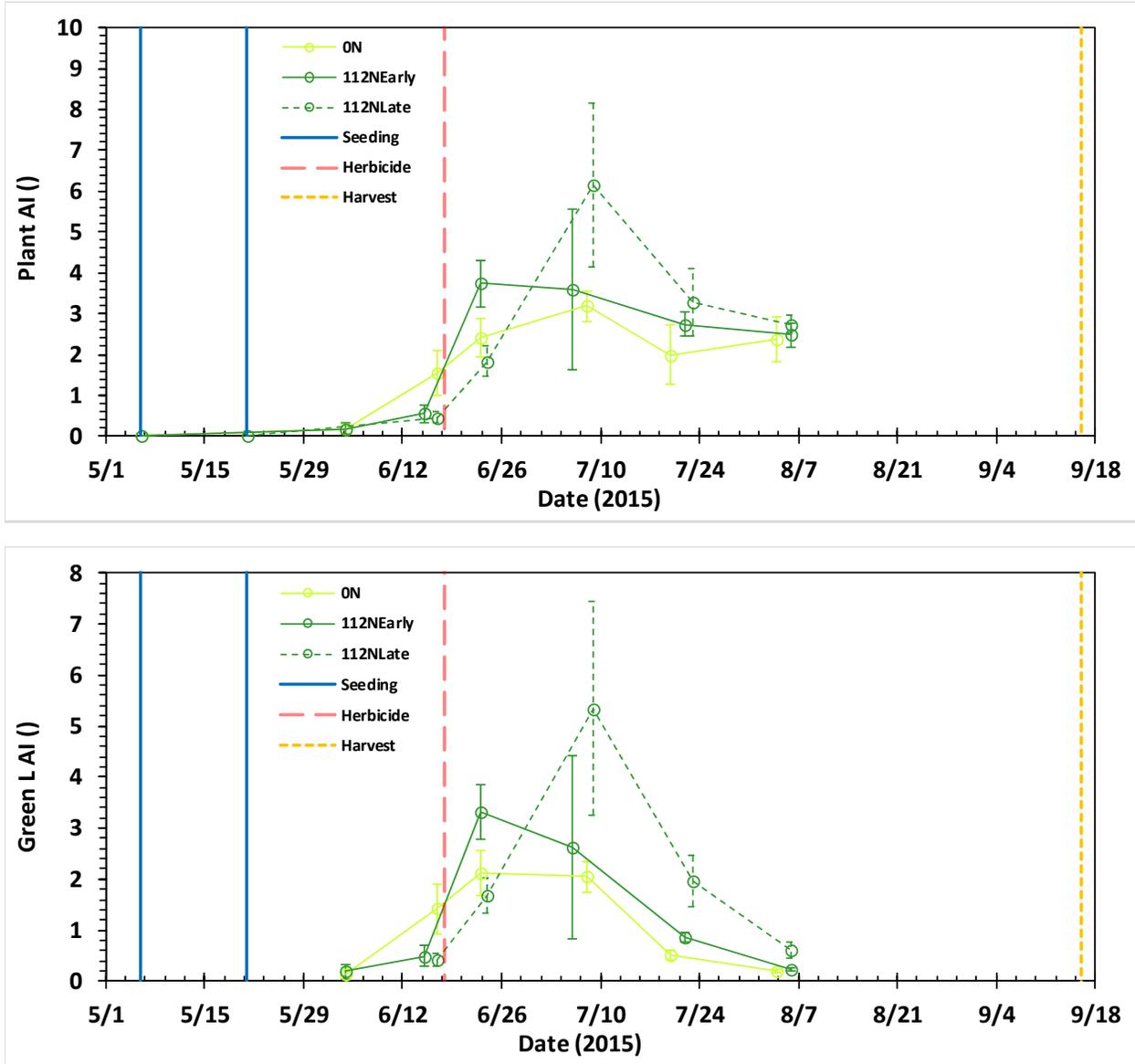


Figure 40 Plant Area Index and Green LAI of Canola in 2015

Fraction of absorbed PAR was measured using longbars in early and late seeded canola as well as wheat and corn (Figure 41). PASTiS-PAR and PASTiS-57 measurements were also made but processing has not been completed.

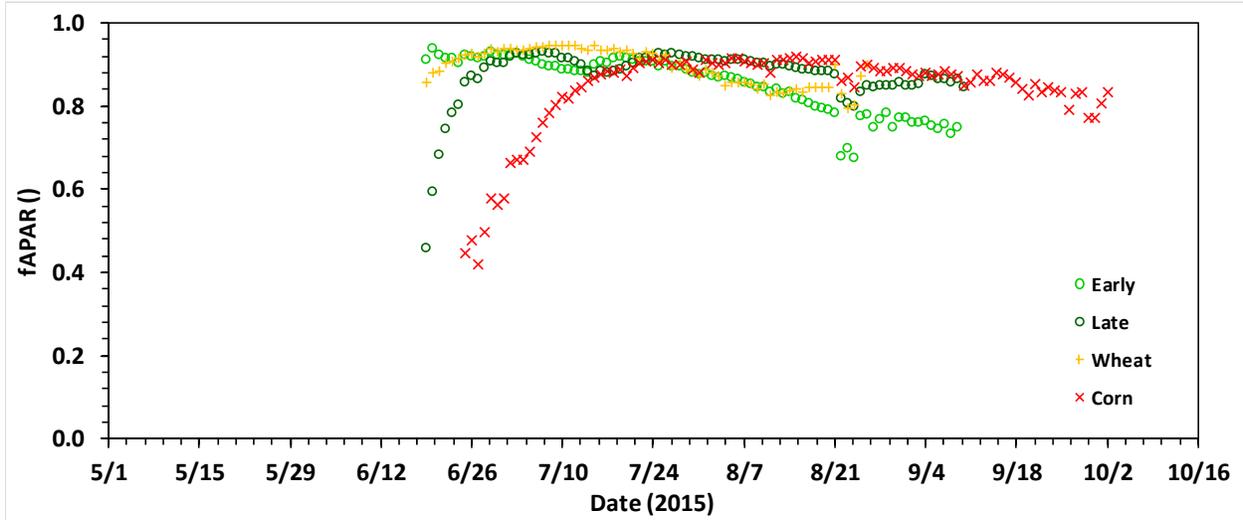


Figure 41 Fraction of Absorbed PAR from Longbar Measurements

The delay in seeding was also seen in the leaf chlorophyll measurements obtained with the Dualex (see Figure 42.) Dualex units approximate $\mu\text{g m}^{-2}$ leaf chlorophyll.

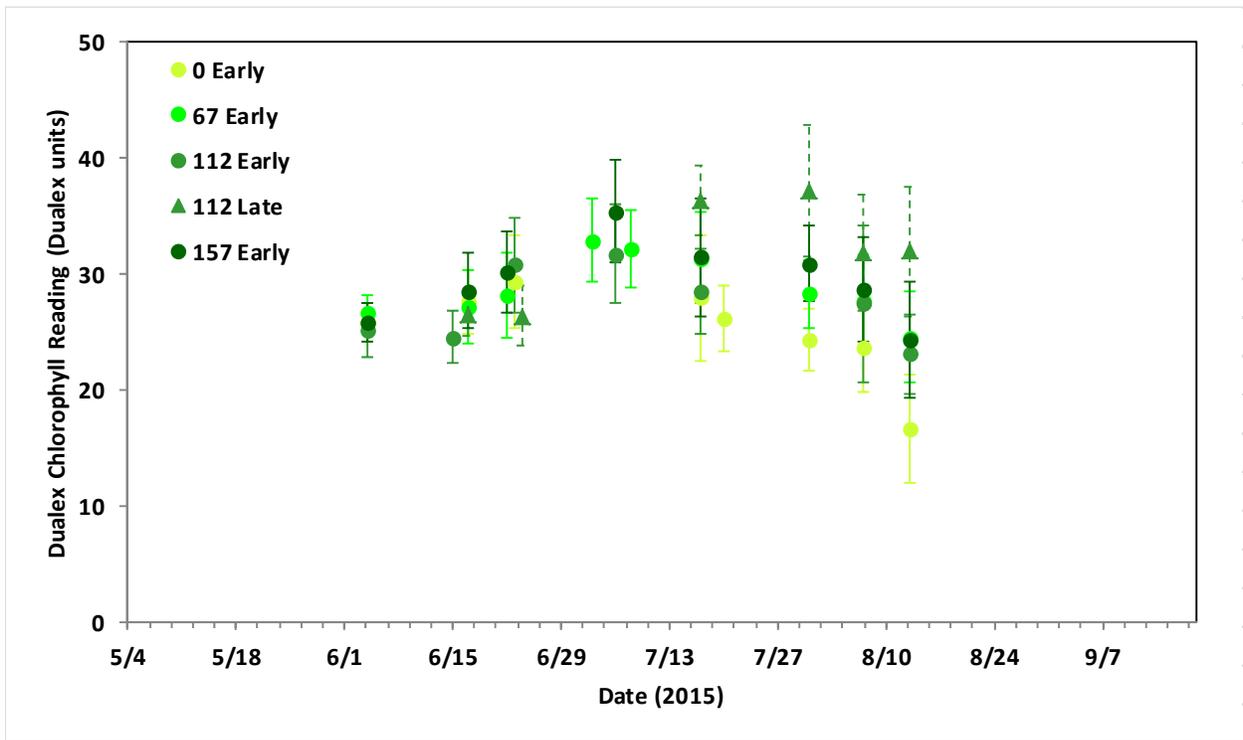


Figure 42 Dualex Leaf Chlorophyll Readings for the Top Leaves of Canola

Canola yield measurements showed similar values across the field (Table 7), except for the unfertilized sector.

Zone	Count	Average	Standard Deviation
ON	769	0.226	0.025
112NEarly	18308	0.241	0.032
112NLate	8445	0.246	0.043

Table 7 Yield Statistics for Canola Harvest in km m^{-2} from Yield Mapping

Yield from the wheat field has not been finalized. Yield data from the corn and soybean fields have not been received from the private producers.

Eddy covariance measuring systems were recording fluxes during all the growing season. The cumulative evapotranspiration associated with the late seeded canola was consistently lower (~300 mm) than the early seeded canola (~350 mm) during the whole growing season.

The cumulative dry biomass extracted from the CO₂ flux data indicated that the late seeded canola cached up the dry biomass of the early seeded canola in September. This trend was confirmed by the destructive biomass samples and by the yield mapping results.

The approach developed in the previous study for LAI estimation from optical remote sensing data was applied to Landsat-8 and SPOT-5 data, and provided satisfactory results.

Landsat-8 and RapidEye data collected in 2013 and 2014 were processed by partners in CNES, to retrieve LAI, fCover, fAPAR using their Neural Network Inversion approach. Satisfactory results were achieved with a preliminary assessment, and a more rigorous assessment is underway.

The data assimilation into the STICS model is delayed because a significant proportion of the images were discarded due to cloud interferences. An alternate source of images is needed to be processed to better populate the EO time series.

Plans for Next Growing Season

Next growing season, we will use the same approach. The main experimental site will be planted in soybean, and the second instrumented field will be planted in corn. We do not anticipate destructive sampling of other fields because there is no more funding to support this activity. However, we will deploy the PASTIS PAR sensors in addition to PASTIS 57.5 sensors and longbar fAPAR sites in representative fields.

We anticipate ordering the same type/quantity of EO data next year. We hope to get Sentinel-2 data and finally Chris-Proba data, as we missed opportunities to get hyperspectral image time series.

Publications

Jégo, G., Pattey, E., Mesbah, M., Liu, J., Duchesne, I. 2015. Impact of the spatial resolution of climatic data and soil physical properties on regional corn yield predictions using the STICS crop model. *Int. J. Appl. Earth. Obs. Geoinf.* 41: 11-22.

Shang, J., Liu, J., Huffman, T., Qian, B., Pattey, E., Wang, J., Zhao, T., Geng, X., Kroetsch, D., Dong, T., Lantz, N. 2014. Estimating plant area index for monitoring crop growth dynamics using Landsat-8 and RapidEye images. *J. Appl. Remote Sens.* 8(1): 085196

Pattey, E., Jégo, G., Liu, J., . Smith, W.N., VanderZaag, A.C., Desjardins, R.L., Tremblay, N., Geng, X., Qiu, B., Shang, J., McNairn, H., Jarvis, I. (2015). "Field-scale research to quantify the impact of climate variations on crop production and to enhance the environmental performance.", ECORC/ACGEO Agri-Environmental Science Day. Invited Presentation, Ottawa, ON, Canada, February 10, 2015. (Presentation)

Pattey, E., Jégo, G., Mesbah, S.M., Liu, J., and Duchesne, I. (2015). "Impact of spatial resolution of soil and climatic data on regional corn yield predictions using OptimiSTICS package.", STICS workshop 2015, Rennes, France, March 24-26, 2015, pp. 2 pages.

Mesbah, S.M., Pattey, E., Jégo, G., Liu, J., Hagolle, O., Dedieu, G., Buis, S., and Lecharpentier, P. (2015). "Assimilation of Earth Observation biophysical descriptors into the STICS crop model using a formal Markov Chain Monte Carlo algorithm.", American Geophysical Union Annual Meeting, Montreal, QC, Canada, May 3-7, 2015. (Poster)

Camacho, F., Lacaze, R., Latorre, C., Baret, F., De la Cruz, F., Pattey, E., and others (2015). "Collection of Ground Biophysical Measurements in support of Copernicus Global Land Product Validation: The ImagineS database.", 2015 EGU General Assembly, Vienna, Austria, April 2015, Oral presentations; *Geophysical Research Abstracts* Vol. 17, EGU2015-2209-1.

7.2 South Nation Watershed

Team Leader and members: Dr. Heather McNairn, Dr. David Lapen, Dr. Angela Kross

Project Objectives

The original project objectives have not changed. This JECAM site is being used as a test bed for the use of SAR sensors for crop identification and crop area estimation. As well, optical and SAR data are being collected to determine if these sensors are capable of measuring crop condition and crop stress in response to controlled tile drainage (CTD) practices. Research on soil moisture using SAR is conducted in an area within the South Nation Watershed, that is adjacent to the area used for intense biophysical measurements in the Little Castor sub-watershed.

Site Description

Locations

South Nation Watershed

Site Extent	Centroid:	45.332, -75.050
Top left: 45.416, -75.214	Bottom Right:	45.249, -74.886

WEBs Sub-Watershed

Site Extent	Centroid:	45.265, -75.176
Top left: 45.268, -75.214	Bottom Right:	45.248, -75.142

The overall extent of the South Nation watershed is approximately 3,900 km², with a centroid at coordinates 45° 11' 53.4"N, 75° 15' 39.6"W. Nestled within the greater watershed are two smaller study basins of focused study and research, namely WEBs (centroid of 45° 15' 49.1"N, 75° 10' 41.9"W, approximately) and Casselman.

Drainage:

The WEBs (Watershed evaluation of Beneficial Management Practices) study basin comprises a sub-'tiled' (tile drained watershed, see area in orange in Figure 43) area of approximately 950 hectares. Mean field sizes within the WEBs basin are 4.75 hectares, with the largest reaching over 24 hectares.

Crop Calendar and Agriculture Methods:

Livestock and cash crops in the watershed consist of corn, soybean, wheat (*Triticum* spp.) and forages. Field crop rotations can vary. For cropland without hay planting, crop rotations follow a three year sequence: cereals-corn-soybean. Cropland with hay has a six year cycle: cereals-corn-soybean, and the following three years in hay. However, rotations can be heavily impacted by market conditions, and repetitive sequences of crops have been observed (for example corn).

Farms located within the WEBs basin are generally dedicated to dairy production. Manure spreading is normally done in either late summer or early fall. Conventional tillage, which is the dominant tillage practice in the study area, typically consists of spring cultivation and fall ploughing.

Just less than 50% of the WEBs study area receives liquid or solid bovine manure as a fertilizer amendment in spring and/or fall. Chemical fertilizer application rate varies according to the type of crop grown.

Climate and Weather:

Situated in a cool temperate humid continental climate in eastern Ontario Canada, mean yearly air temperatures are approximately 6.2°C, total yearly precipitation is approximately 963 mm, and total yearly rainfalls are approximately 771.

Soils:

Dominant soils at the WEBs site are Bainsville silt loams, characterized by layered silt and fine sand, overlying clayey deposits, with poor natural drainage. The lower hydraulic conductivity clayey soils lie beneath top soils at approximately 1.0–1.5m depth.

Topography:

Local slope of the study area is generally <1%.

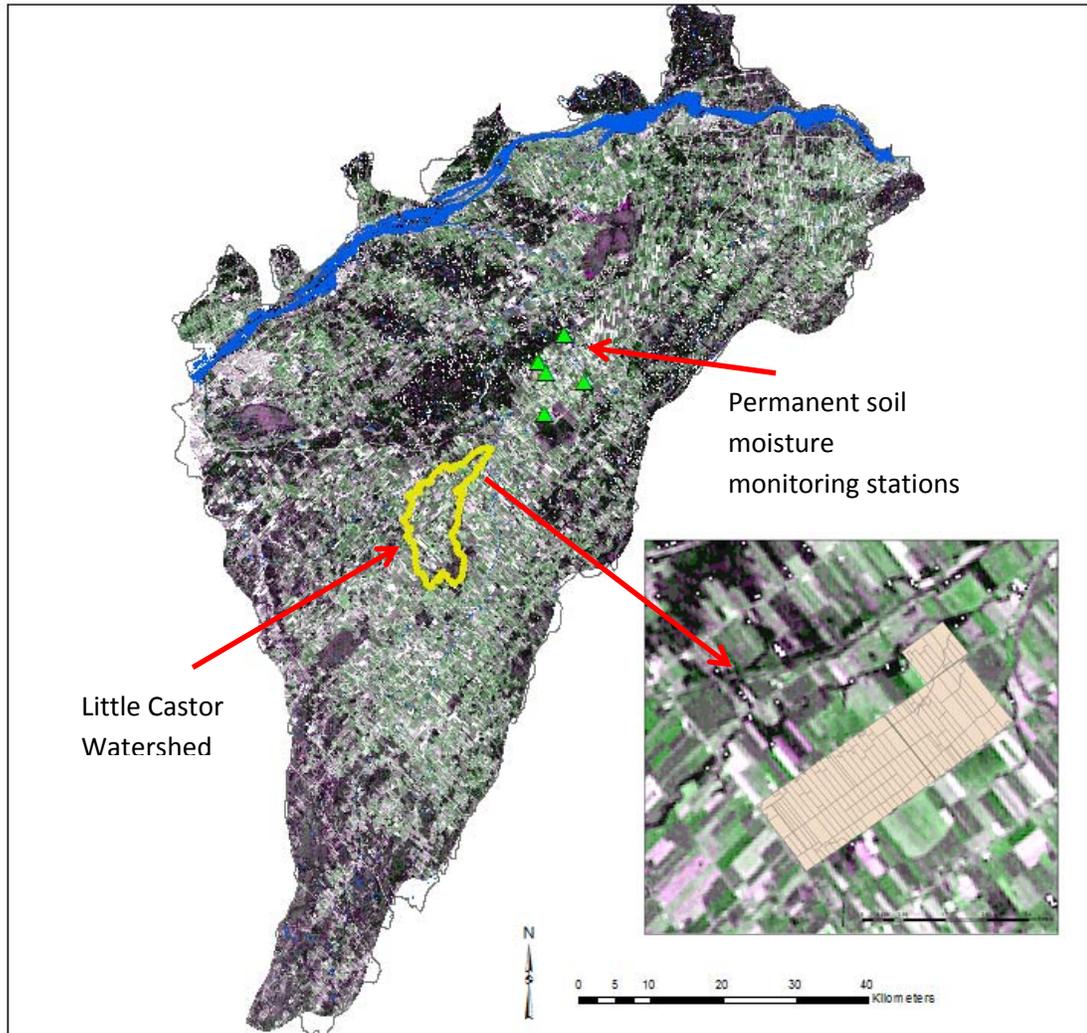


Figure 43 South Nation Watershed JECAM Site

EO Data Received/Used

None in 2015.

Results

This site was quiet this year.

Plans for Next Growing Season

2016 will be more active with our SMAPVEX16 experiment starting in June, and with the SAR-cross site work on LAI/biomass.

7.3 Red River Watershed

Team Leader and Members: Ian Jarvis, Andrew Davidson, Heather McNairn, Jarrett Powers, Bahram Daneshfar, Catherine Champagne, Jiali Shang.

Project Objectives

The original project objectives of the site have not changed. They are:

- Crop Mapping at 30m pixel resolution
 - 2014 growing season crop inventory maps were created (30m resolution) covering all Manitoba as a part of the Agriculture and Agri-Food Canada annual EO-based national crop inventory program.
 - Developing spatial data and very accurate EO-based crop identification at 5m pixel resolution: Testing various EO-statistically-based methods and developing methodologies for highly accurate classification of target crops in different parts within the Manitoba pilot area with various levels of landform homogeneity. A journal paper is submitted for publication related to this component.
 - Testing the application of multivariate statistical methods to improve classification of pasture and forage crops from some of the annual target crops within the Manitoba pilot site. Results submitted for publication as a journal paper.
 - Testing, developing and applying geostatistical methodologies for re-allocation of target variables to the Terrestrial Monitoring sampling framework points within the prairie province based on the results of the pilot sites.
 - Developing spatial databases based on the above methods to estimate value:
 1. As discrete data for the location of the samples of the Terrestrial Monitoring Framework, and depending on the variable
 2. As continuous spatial data.
 - Methods to accurately estimate the area of target major crops based on the stratification of the pilot sites by farming systems are being tested and developed.
- Crop Condition/Stress
 - Collected crop phenology, leaf area index, and biomass over selected fields in 2014 (Figure 47).
- Soil Moisture
 - With the addition of 3 new stations in 2014, this site currently has twelve automated in situ monitoring stations set up to capture larger scale variation in soil moisture to support calibration and validation of remotely sensed and modeled soil moisture data products. The data from these stations is collected

every 15 minutes and transmitted to a central server, where it undergoes a quality control filtering before it is released for distribution.

- Soil moisture measurements were taken at 5-cm depth weekly over two spring wheat fields, two corn fields, two canola fields and two soybean fields throughout the growing season using a Theta probe.
- Crop Residue, Tillage and Crop Cover Mapping
 - Nothing for 2014.

Site Description

- Location: Red River and Assiniboine River Basins, Manitoba (MB), Canada (see Figure 44).
- Topography: The majority of the soils in the study area are derived from lacustrine-based depositions and are very flat. The northern edge of the study area is more influenced by glacial-till deposition and has a lower relief ridge and swale topography.
- Soils: The majority of soils have a clay surface texture as a result of lacustrine deposits. Soils in the southwest region of the study area have sandier surface textures (sands-loamy sands) overlaying heavier clay deposits. Soils in the northern region are generally finer textured loams-clay loams with the occurrence of stones as a result of glacial-till deposits.
- Drainage class/irrigation: The majority of the soils are imperfect to poorly drained. A large network of surface drains is in place to allow the production of annual crops. A limited amount of irrigation exists in the area near Portage la Prairie and Carmen on lands devoted to the production of potatoes and high-value horticultural crops. Tile drainage is installed on a small percentage of land around Carmen on imperfectly drained soils that are used for high value crop production.
- Crop calendar: Early May – early June (seeding), August – early October (harvest).
- Field size: Quarter Section - 64 hectares (160 acres).

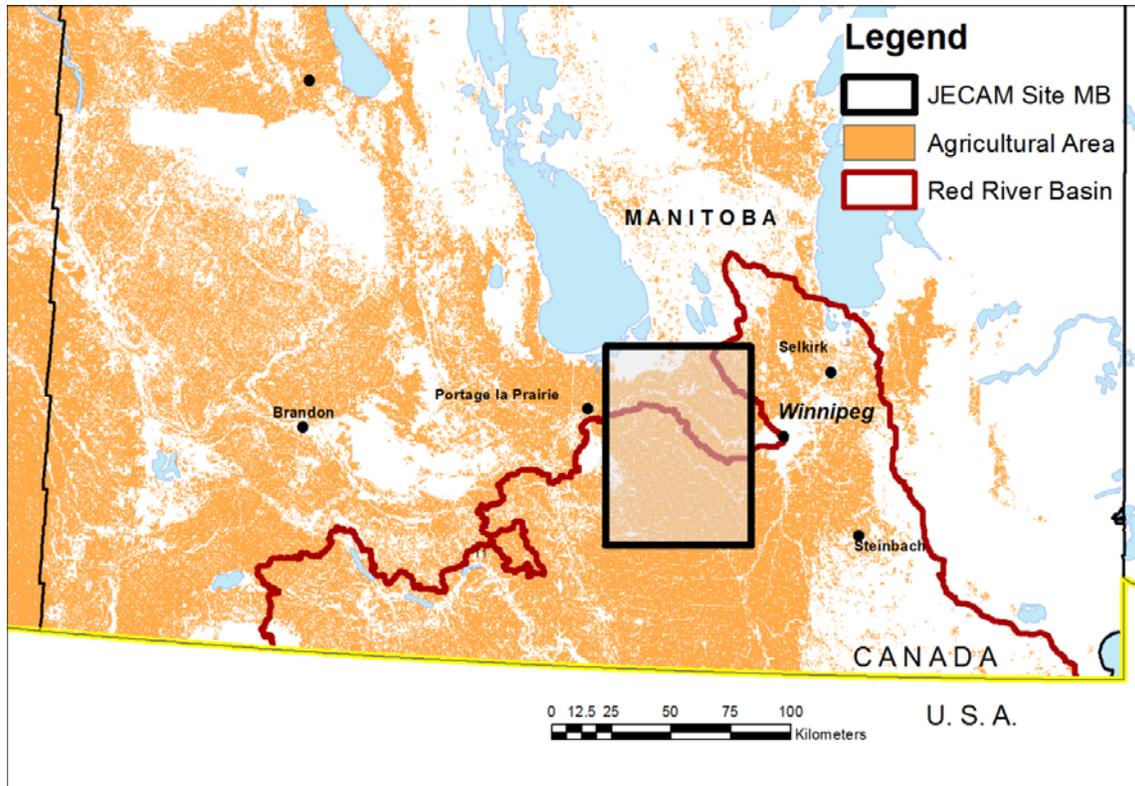


Figure 44 Location of the JECAM Monitoring Site in Southern Manitoba, Canada

- Climate and weather: The study area falls into the Humid Continental climate zone with cold winters and warm summers. Precipitation is distributed throughout the year with the majority of precipitation falling in the spring and summer months.
- Agricultural Crops used: Land is primarily used for the production of annual crops. Primary crops include: wheat, oats, canola, soybeans, corn. Potato production and other horticultural crops are produced near Carmen and Portage la Prairie. Conventional and minimum tillage systems are used for most annual crop production. The more marginal land in the northern areas is used for forage and pasture production.



Figure 45 Example of the General Morphology and Landscape of the JECAM Monitoring Site in Manitoba, Canada

EO Data Received/Used

None in 2015.

In situ Data

Presently there are 12 in situ soil moisture monitoring stations in the Red River basin site as indicated in Figure 46. Intensive crop biophysical parameters were measured weekly throughout the growing season in 2014 for spring wheat, corn, soybean, and canola.

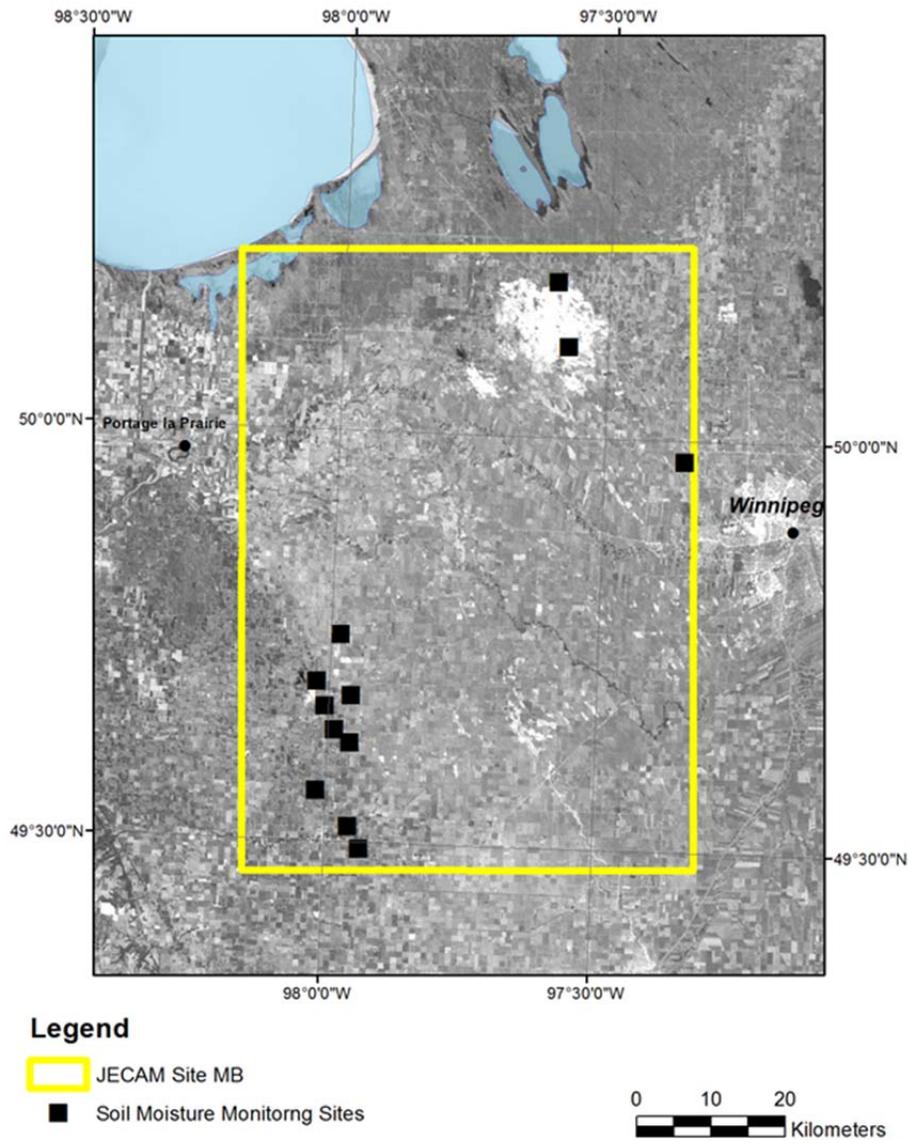
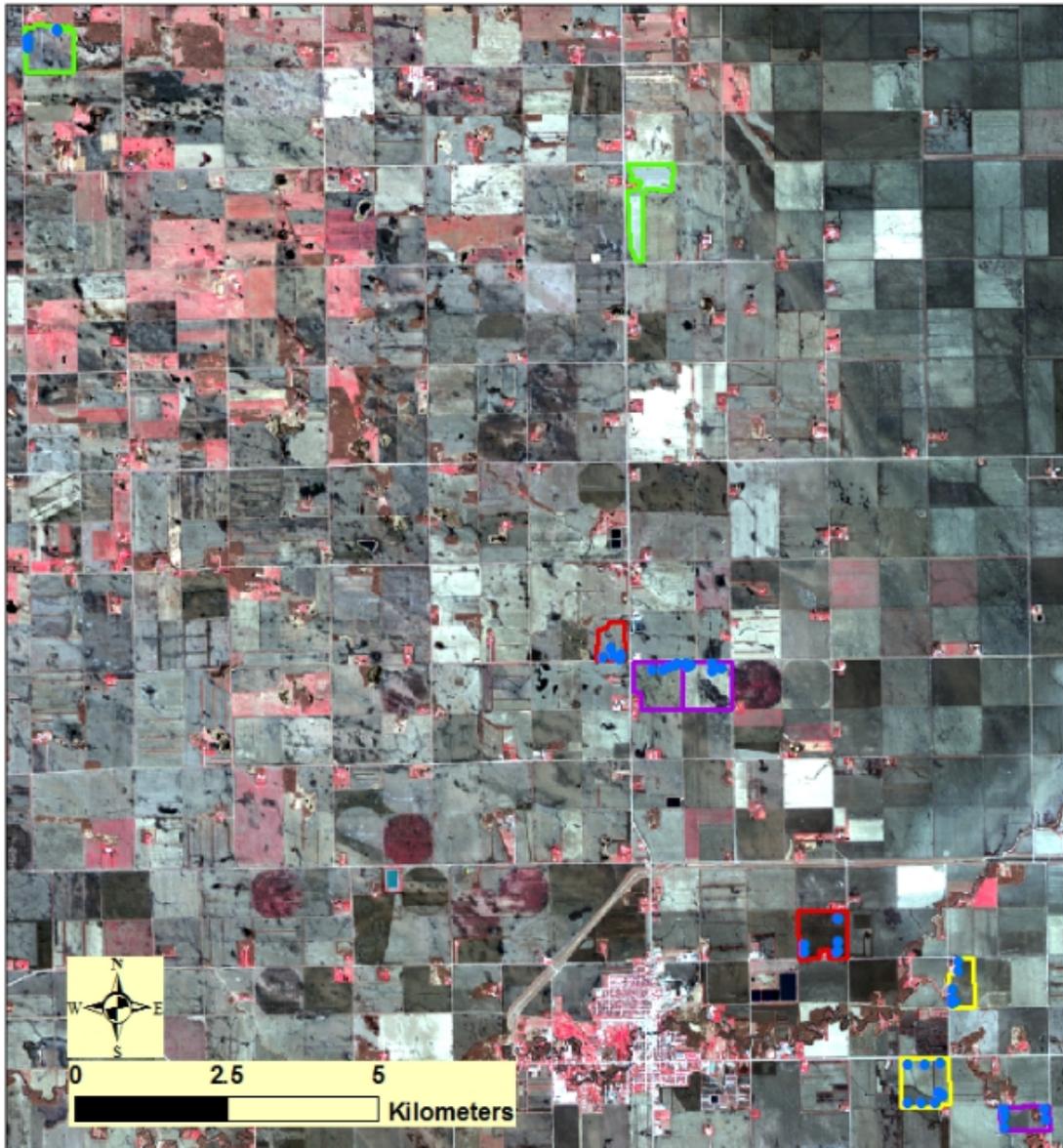


Figure 46 Location of the 12 In situ Soil Moisture Monitoring Stations within the JECAM Monitoring Site in Southern Manitoba, Canada

Manitoba 2014 Field Locations and Sample points



Legend

- 2014_MB_SamplePoints
- Canola
- Corn
- Soybean
- Wheat

RGB Composite: 5-3-2
Image: RapideEye
Date: May09, 2014

Figure 47 Intensive Field Sampling Distribution of the JECAM Monitoring Site in Manitoba, Canada

Results

This site was quiet this year.

Plans for Next Growing Season

2016 will be more active with our SMAPVEX16 experiment starting in June, and with the SAR-cross site work on LAI/biomass.

8. China

8.1 Anhui

No report was received this year.

8.2 Guangdong

No report was received this year.

8.3 Heilongjiang

No report was received this year.

8.4 Jiangsu

Team Leader: Yun Shao

Members: Kun Li, Brian Brisco, Fengli Zhang, Long Liu, Zhi Yang

Project Objectives

The original objectives of the site have not changed. They are:

- Crop identification and Crop Area Estimation

Identify rice fields with polarimetric responses and scattering mechanisms, and estimate the rice acreage accurately.

- Crop Condition/Stress

Rice phenological stage retrieval, providing timely and accurate information about rice growth condition, in order to plan cultivation practices (irrigation, fertilization, etc.).

- Yield Prediction and Forecasting

A quantitative relationship between polarization variables and rice key parameters (biomass, LAI) will be established. Then a crop model, taking into account the variation of the time - domain and environmental stress, will be employed for rice yield prediction.

Site Description

The test site is located in Jinhua (33°15'22.33"N - 32°58'35.00"N, 118°49'39.97"E - 119°6'51.67"E), Jiangsu Province, east of China (Figure 48). The terrain is flat, with the average altitude mostly less than 10m. The area belongs to the transition region between the subtropical and the temperate climatic zones, with four distinct seasons. The annual average temperature of the test site is about 13 to 16°C. The average precipitation is about 800 to 1200 mm every year, and more than half of the precipitation occurs from June to September. The sunshine hours can be up to 2400 every year. The soil type of this region is mostly yellow brown clay, which is favourable for rice plant development. The main paddy varieties in this area are hybrid rice and japonica rice. There is one rice crop a year, with the growth cycle about 150 days, from early June to late October or early November.

There are two rice planting methods in the test site, transplanting and direct-seedling, which will produce two different rice field structures (Figure 49) and have a certain impact on rice yields. The size of rice field parcels is 1700 m² or so. In this study, forty-two sample plots were selected in the test site, covering twenty-nine transplanting fields and thirteen direct-seedling fields. The distribution of these sample plots is shown in Figure 48. The cloud and sun symbols mean Transplant and Direct-planting Rice Fields respectively. Apart from agricultural land, the five other land cover types at the test site were forest, bare land (B-L), urban, crab ponds (C-P), and water.

Figure 48 Location of Jiangsu Test Site and the Distribution of the Sample Plots

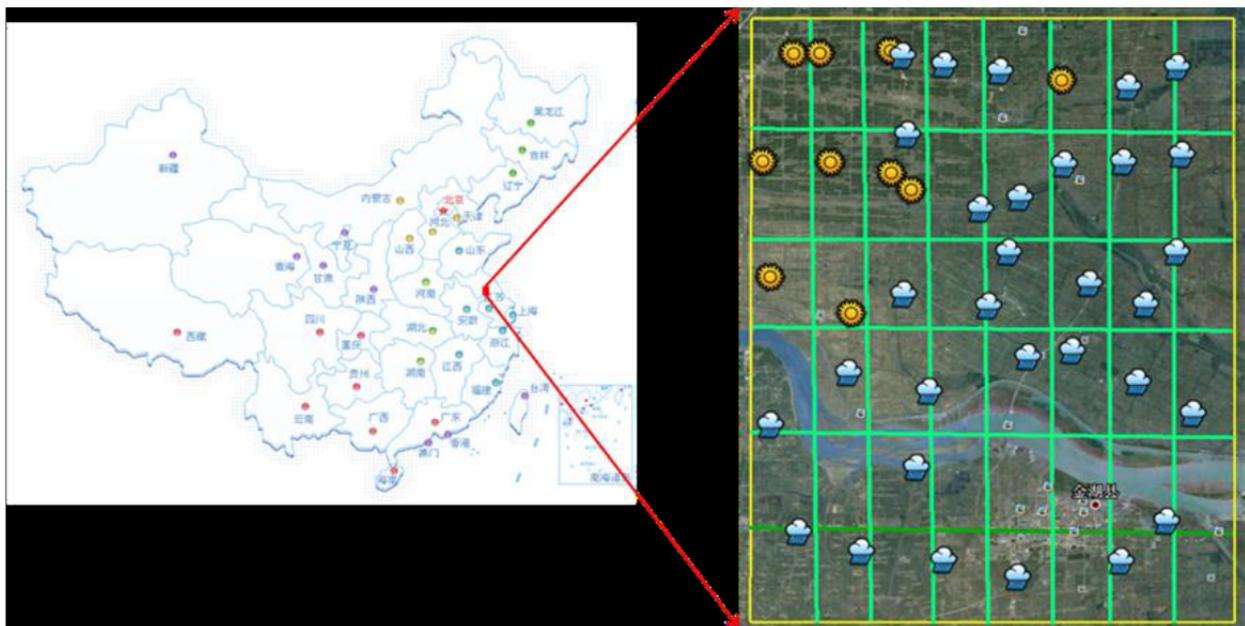


Figure 49 Rice Fields in the Jiangsu Test Site



(a) Transplanting

(b) Direct-seedling

EO Data Received/Used

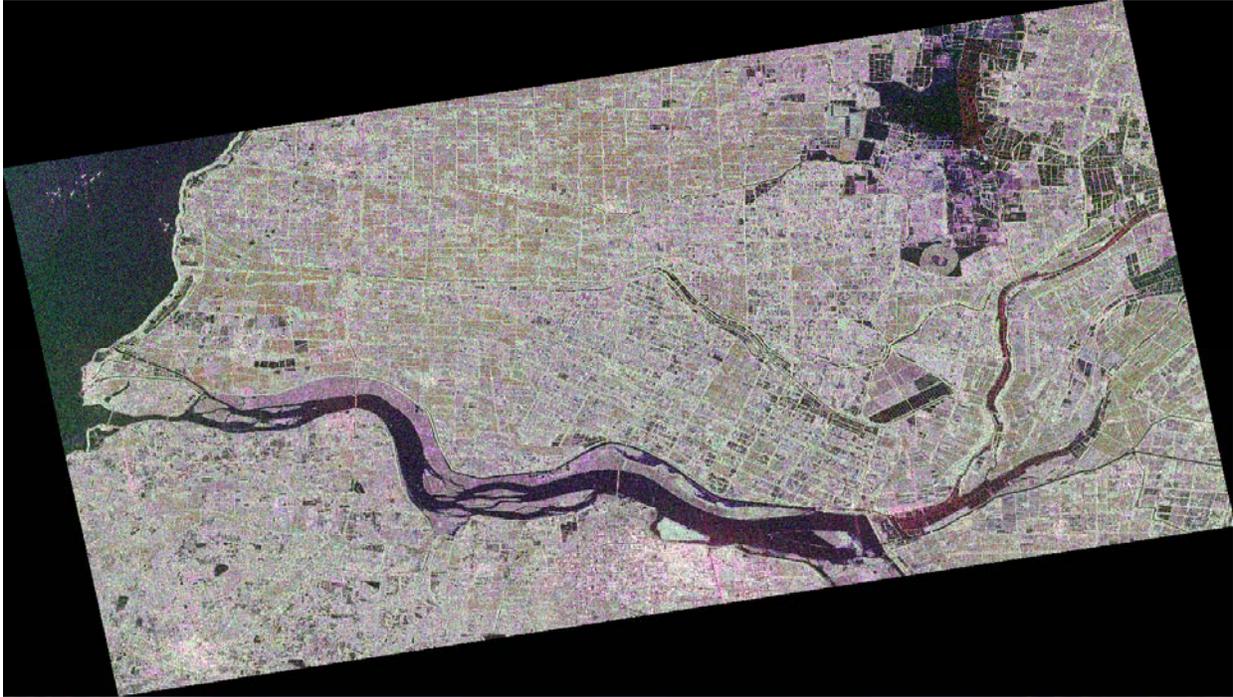
During rice growing season of 2015, thirteen scenes of RADARSAT-2 images were received, including seven Quad-pol images and six Ultra-Fine images. The details of the SAR data is displayed in Table 8.

Data preprocessing, such as radiometric calibration, terrain correction, speckle filtering, mosaicing etc., have been done to all the images. Figure 50 shows RADARSAT-2 Quad-pol and Ultra-Fine images after data preprocessing.

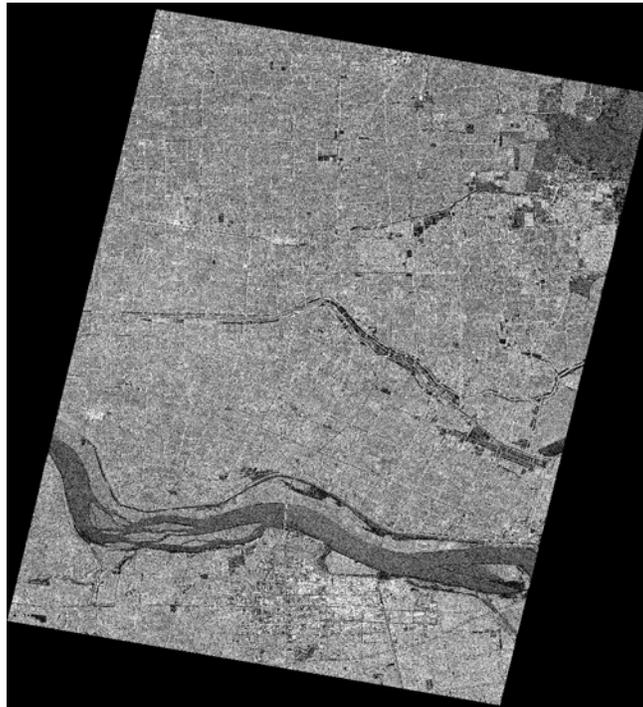
Table 8 EO Data Received in 2015 for the Jiangsu Site

Space agency or Supplier/ Mission	Optical/SAR	Number of scenes	Range of dates	Beam modes	Incidence angles (Degree)	Spatial resolutions (Rng x Az, m)	Processing level
MDA/ RADARSAT-2	SAR	7	June 12-Nov 27,2015	FQ20W	38.6-41.3	5.2x 7.6	SLC
		2	June 9, 2015	UF76	26.0-27.5	1.6x 2.8	SLC
		2	June 13, 2015	UF25	47.4-48.3	1.6 x 2.8	SLC
		2	June 19, 2015	UF6	34.0-35.3	1.6 x 2.8	SLC

Figure 50 RADARSAT-2 Quad-pol and Ultra-Fine Images after Data Preprocessing



(a) Fine Quad-pol image acquired on June 12, 2015 (R=HH G=HV B=VV)



(b) Mosaic image of RADARSAT-2 Ultra Fine images acquired on June 09, 2015 (HH)

In situ Data

During the rice growing season of 2015, seven ground campaigns were conducted (see Figure 51). Forty-two sample plots were selected; most of them coincided with the sample plots of 2012. Several sample plots were different from that of 2012, as they changed into tree nurseries or herbal plant fields.

Rice variety, crop calendar, phenological stage, plantation geometry, leaf area index were collected at each sample plot. Three representative rice plants were selected in each sample plot for rice plant parameter measurement. Rice plant height, number of leaves, leaf length and width, number of stems and ears, plant biomass (dry and wet weight) were acquired. In addition, soil and meteorological data in the test region were collected.



Figure 51 Field Work - Jiangsu

Collaboration

We have not been approached to participate in a collaborative project with other sites.

Results

Data preprocessing was just finished for the SAR dataset of 2015. So the results below were based on the data of 2012.

In 2014, we developed a method of rice phenological stage retrieval using SAR data and found that the rice canopy is heterogeneous in the horizontal direction and the heterogeneity will change with rice phenological stage. So in 2015 we modified the traditional water cloud model, considering the heterogeneity of rice canopy and its phenological variation. The configuration of the modified water cloud model and the scattering mechanisms is presented in Figure 52. The yellow, green and red dots consist of ear, leaf and stem layers respectively. D, V and S denote the double-bounce, volume and surface scattering, respectively. The acronyms e, f, t, and g represent the ear, leaf, stem and ground layers, respectively. The acronyms r and s denote rice and space, respectively.

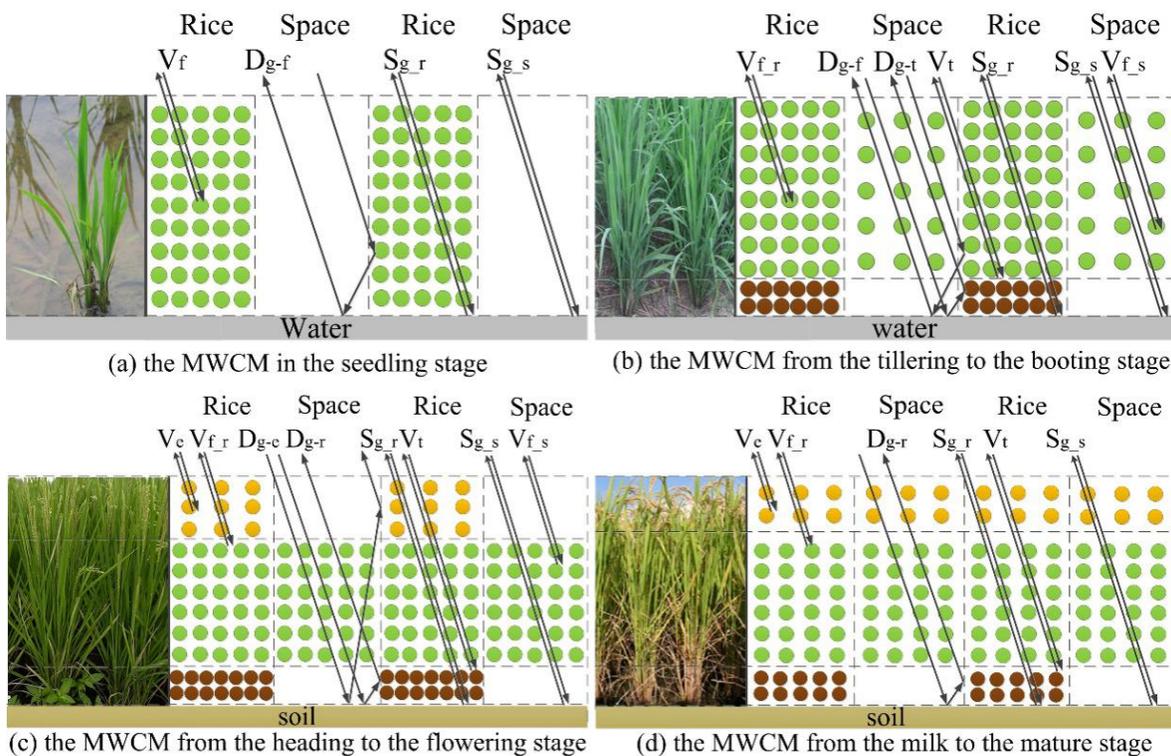


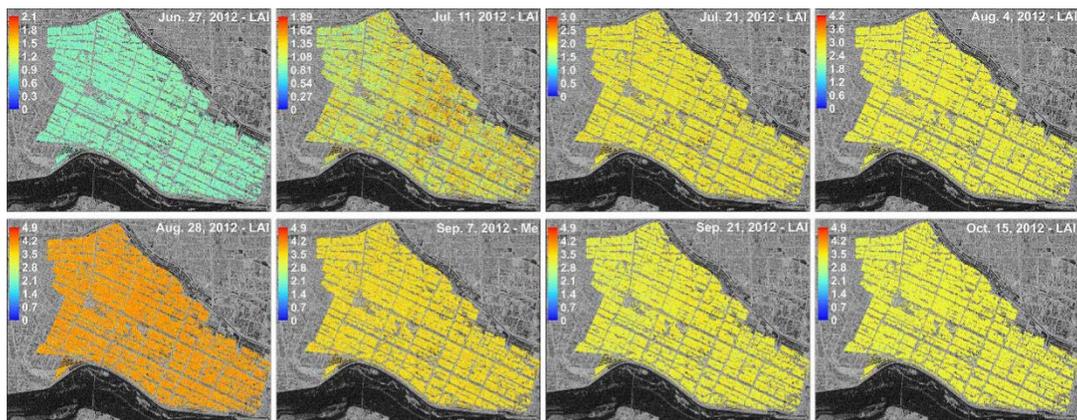
Figure 52 The Configuration of the Modified Water Cloud Model and Rice Scattering Mechanisms with Rice Phenological Stage

In addition, scattering components of an improved polarimetric decomposition (Sato et al., 2012; Xu & Jin, 2005; Antropov, Rauste, & Hame, 2011) were introduced to the modified water cloud model for rice parameter estimation. The relationship between the scattering components and the rice parameters can be built as follows:

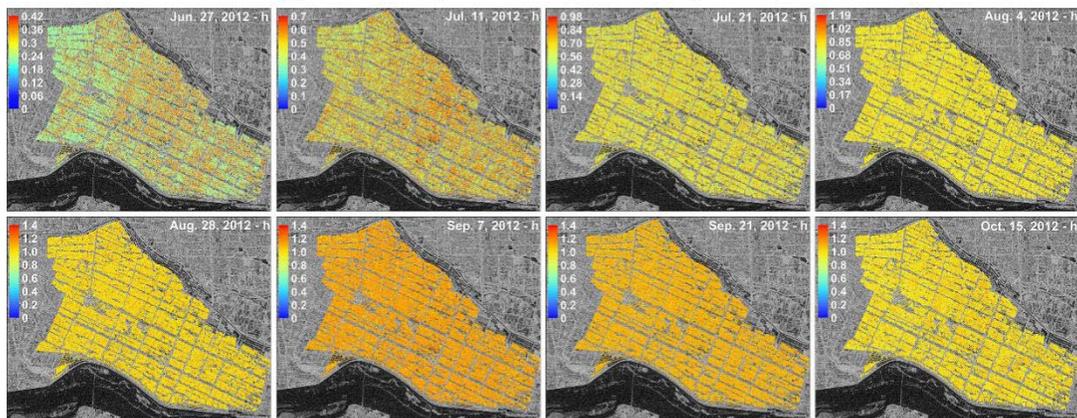
$$\left. \begin{aligned} P_v &= V_e + V_{f_r} + V_{f_s} + V_t \\ P_d &= D_{g-e} + D_{g-t} + D_{g-f} \\ P_s &= S_{g-r} + S_{g-s} \end{aligned} \right\}$$

Ps is the surface scattering, Pd is the double-bounce scattering and Pv is the volume scattering.

Two rice biophysical variables, LAI and plant height were estimated with the Genetic Algorithm. Figure 53 shows rice LAI and plant height estimated using the model during the growing season of 2012. Ground measurements were used for validation (Figure 54). The values of R^2 were both higher than 0.85, implying that the estimated rice variables were in agreement with ground truth data quite well.



(a) Thematic images for LAI in the whole rice growth cycle



(b) Thematic images for h in the whole rice growth cycle

Figure 53 Temporal Behaviour of LAI and h in the Rice Fields

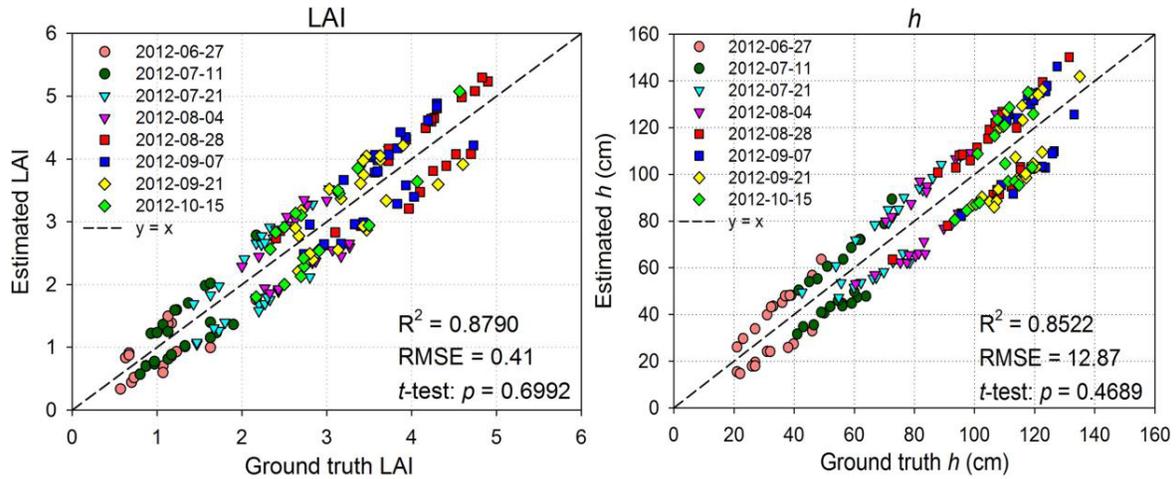


Figure 54 Validation of Rice Variable Estimation

Rice mapping and rice area estimation with polarimetric SAR data has now been completed. A method for retrieval of rice phenological stage using a decision tree was developed. An inversion model for rice variables (biomass, plant height) considering the heterogeneity of the rice canopy and its phenological variation using polarimetric SAR data has been proposed. However, the methods need further validation and improvement. Moreover, we have not considered the influence of environmental stress on rice yields. We will introduce environmental stress into our model in 2016.

Plans for Next Growing Season

We will improve the method of rice phenological stages retrieval methods, by using the SVM and SFS algorithms. In addition, we will further validate our models of rice mapping, rice phenological stage retrieval, and rice variable estimation with the new data acquired in 2015.

We plan to order RADARSAT-2 polarimetric SAR data in 2016-2017. We also plan to acquire ALOS polarimetric data and apply for compact polarimetric data.

Publications

Long Liu*, Kun Li, Shao Yun, Pinel Nicolas, Zhi Yang, Gong Huaze, and Wang Longfei. 2015. Extension of the Monte Carlo Coherent Microwave Scattering Model to Full Stage of Rice. IEEE Geoscience and Remote Sensing Letters, Vol.12, No.5, pp. 988-992.

8.5 Shandong

Team Leader: Bingfang Wu

Team members: Miao Zhang, Hongwei Zeng, Sheng Chang, Nana Yan, Yang Zheng, Mingzhao Yu, Xin Zhang, Mingyong Li

Project Objectives

The original objectives of the site have not changed. They are:

- Crop identification and Crop Area Estimation
 - Multi-temporal optical data
 - Decision Tree classification based on time series
- Estimation of Biophysical Variables
 - fAPAR, LAI-Radiation transfer model
 - fAPAR & above ground biomass (AGB) retrieval

Site Description

- Location
 - Top-Left
Latitude: 37.331°N Longitude: 116.319°E
 - Bottom-Right
Latitude: 36.331°N Longitude: 116.819°E
- Topography
 - Plain
- Soils
 - Soils in the study site are mainly alluvial soil.
- Drainage class/irrigation
 - Almost all the farmlands are irrigated in the site. Irrigation water is mainly from the river or underground water.
- Crop calendar
 - Typical crop rotation is winter wheat and corn.
 - The crop calendar for winter wheat is from mid-October to early June of the next year, and for corn is from mid-June to end of September.
- Field size
 - Typical field size is 2000 - 8000 m².
- Climate and weather

- The climatic zone is temperate, semi-arid, monsoon climate. The annual mean temperature is about 13.1°C. The annual mean precipitation is about 582 mm, concentrated from late June to September.

EO Data Received/Used

China Environmental Satellite (HJ-1 CCD, GF-1 multi-spectral data):

- Supplier: China Centre for Resource Satellite Data and Applications (CRESDA)
- Optical
- 21 scenes of HJ-1 CCD images, 16 scenes of GF-1
- From late March to early October, 2015
- Level 1A Product
- We no difficulty in acquiring, processing and using HJ-1 & GF-1 data.
- Sample locations were the same as 2014.

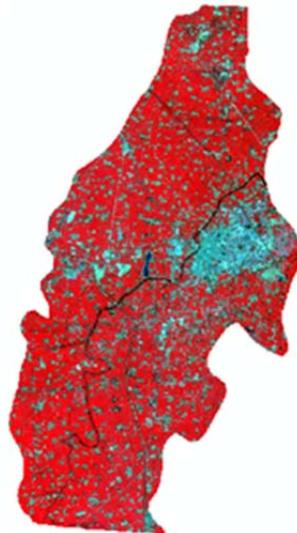


Figure 55 GF-1 Images of China Shandong JECAM Site (16m resolution)

MODIS:

- Supplier: NASA
- Optical
- 46 scenes
- From 10 October 2014 to 30 September 2015

- Beam modes/ spatial resolutions: H27V05, 250m/500m/1km
- Level 2
- We had no difficulty in acquiring MODIS data, nor in processing and using MODIS data. However, the resolution is too coarse for the study site.

RADARSAT-2

- MDA
- SAR
- Archived data from 2012 – 2014
- We have not started processing the data yet.

SPOT 5

- SPOT 5 TAKE-5 plan
- Optical
- 17 images
- 8 April – 15 September 2015
- The data was provided as level 2A products.

In situ Data

The main variables measured and instruments we are using are shown in Table 9. All the variables were measured once a month from April to September except for the following. Yield, harvest index and crop type mapping were measured once per growing season.

Table 9 In situ Variables and Instruments - Shandong

Main variables	Instruments or processing method
Above ground dry biomass	Oven dried and weight
Yield	Oven dried and weight
Harvest index	Calculated by yield and AGB
Density/canopy height	Tape measured
Crop type field boundary	GPS record using GIS system

The biggest challenge is weather condition during the field observations. It is sunny in the morning while cloudy at noon; this may influence measurements of field spectral and FAPAR.

The shift from growing cereals to cash crops makes the field observation at all the same fields as the previous year impossible. We had to slightly change the selected fields during the field campaign.

Collaboration

We collaborated with JECAM sites in Argentina, Ukraine, Russia, and France-Belgium to compare different methods for annual arable land mapping. The potential of different methods for large scale arable land mapping was also investigated. The joint experiment was supported by the Sentinel-2 Agri project.

Results

Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) Retrieval by Chlorophyll-related Vegetation Indices

Over the China Shandong JECAM site, chlorophyll-related vegetation indices (VIs) were selected and tested for their capability in crop FAPAR estimation using simulated Sentinel-2 data. These indices can be categorized into four classes:

- ratio indices,
- normalized difference indices,
- triangular area based indices, and
- integrated indices.

Two crops with distinctive canopy and leaf structure, wheat and corn, were studied. Regression analysis was conducted between measured FAPAR and different vegetation indices derived from Sentinel-2 reflectance simulated from field spectral measurements. At the same time, the effects of the red-edge reflectance on crop FAPAR estimation and the impact of different crop types on FAPAR estimation were explored. It is found that VIs using the near-infrared and red-edge reflectance, including the modified Simple Ratio2 (mSR2), the red-edge Simple Ratio (SR705), the Red-edge Normalized Difference Vegetation Index (ND705), MERIS terrestrial chlorophyll index (MTCI), and the Revised Optimized Soil-Adjusted Vegetation Index (OSAVI[705, 750]), were strongly correlated with FAPAR, especially in the high biomass range. Among all the indices, RDVI705 and mSR2 were more linearly correlated with FAPAR, whereas the other indices deviated slightly from a linear correlation.

When the red-edge reflectance was used, the ratio indices (e.g., mSR2 and SR705) had a stronger correlation with crop FAPAR than the normalized difference indices (e.g., ND705). Sensitivity analysis showed that mSR2 had the strongest linear correlation with FAPAR for the two crops across the growing season. Further analysis indicated that indices using the red-edge

reflectance might be useful for FAPAR retrieval. Indices using the red-edge reflectance are independent of crop types. This suggests the potential for high resolution and high quality mapping of FPAR for precision farming using Sentinel-2 data.

The same approach was also applied to investigate the relationship between above ground biomass and various vegetation indices.

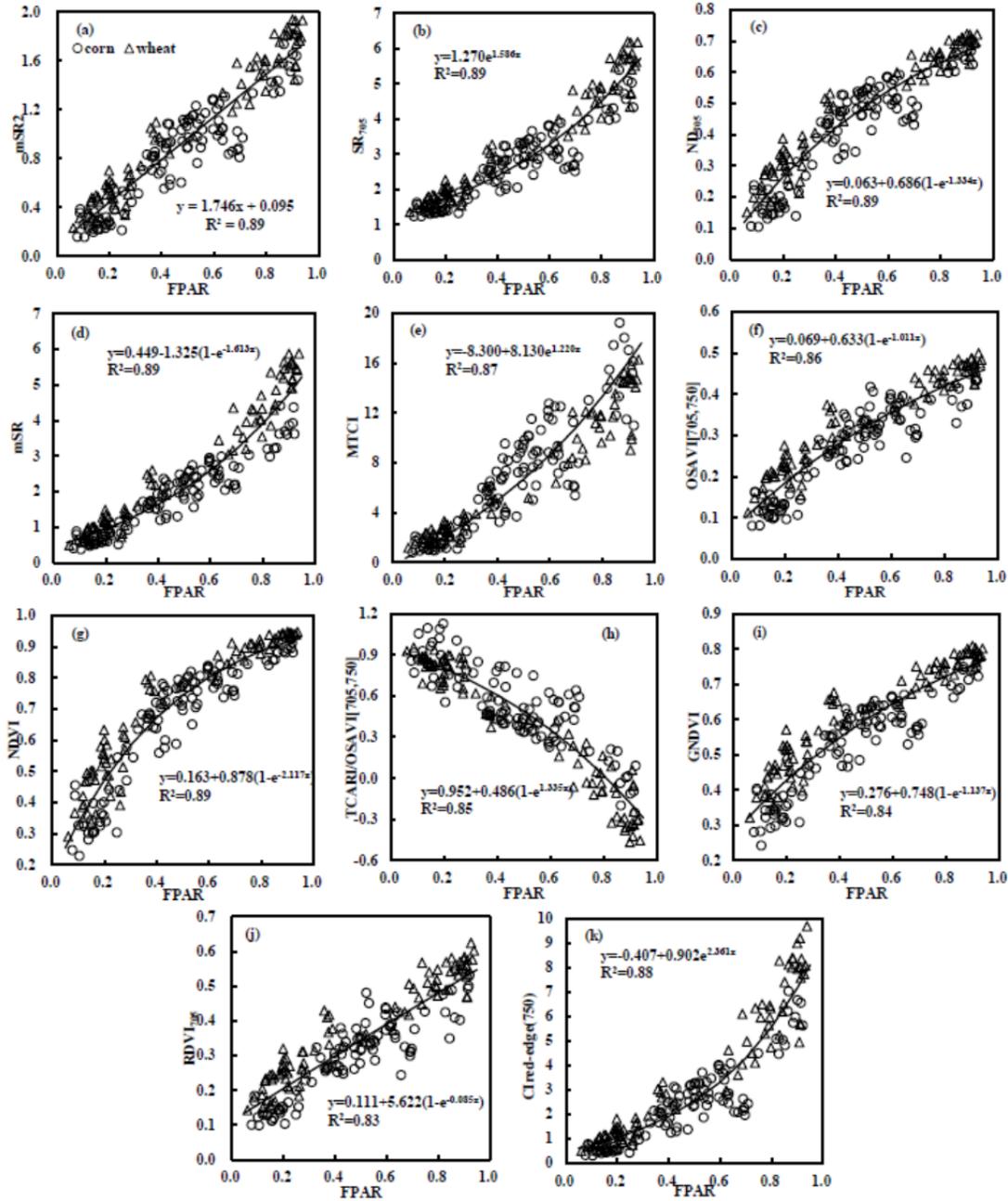


Figure 56 Relationships between FAPAR and Vegetation Indices with a Linear Coefficient of Determination greater than 0.83

Annual Cropland Mapping

Together with other four JECAM sites, we applied five different existing methodologies over five JECAM sites using same dataset (7-day 250m resolution MODIS NDVI time series). Confusion matrices and derived accuracy indicators were produced with and without equalizing class proportions of validation samples and correcting for the spatial resolution bias. A decision tree was used as the general method from China JECAM site.

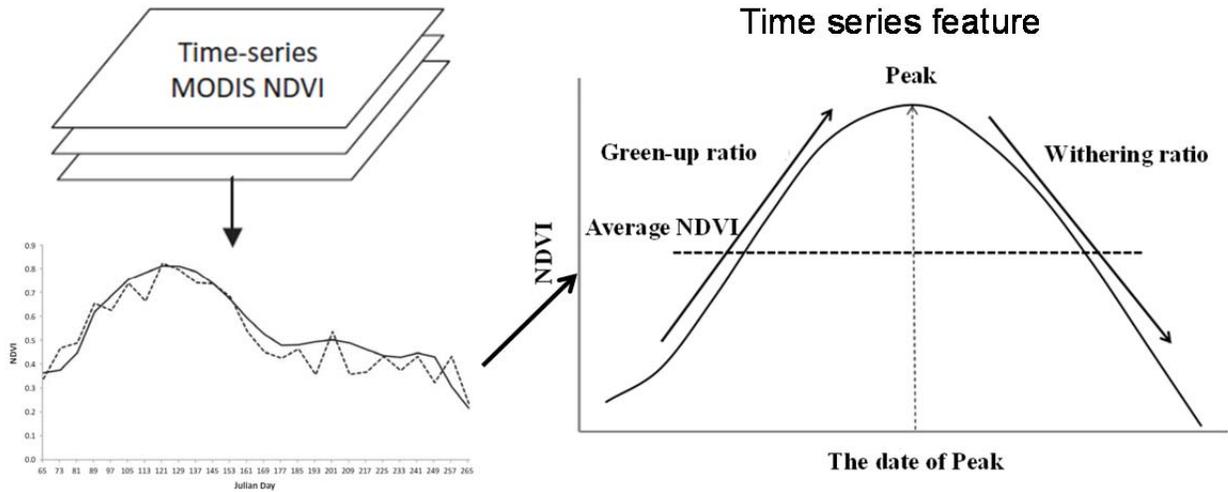


Figure 57 Features Extracted from Smoothed Time Series NDVI Data

The MODIS time-series were not directly inputs for the classification as it was reported that when a high number of input data are used for classification, some make negligible or even negative contributions in terms of classification accuracy (Zhao et al., 2008; Zhang et al., 2012). In order to avoid such issues and to reduce the classification computing time, four temporal features were extracted from smoothed Normalized Difference Vegetation Index (NDVI) temporal profiles: the maximum vegetation index values observed at the date of the peak, the average vegetation index during the growing season as well as the green-up ratio and withering ratio. Cropping intensity derived from time-series NDVI data is also considered to identify cropland and non-cropland. For pixels with two growing seasons, four temporal features were only extracted from the first growing season. The smoothing was achieved by applying a Savitzky-Golay filter (Savitzky and Golay, 1964; Tsai and Philpot, 1998). Based on the extracted parameters and the training samples, a decision tree was generated using the Classification and Regression Tree (CART) algorithm and applied to the whole study area to produce a land cover map.

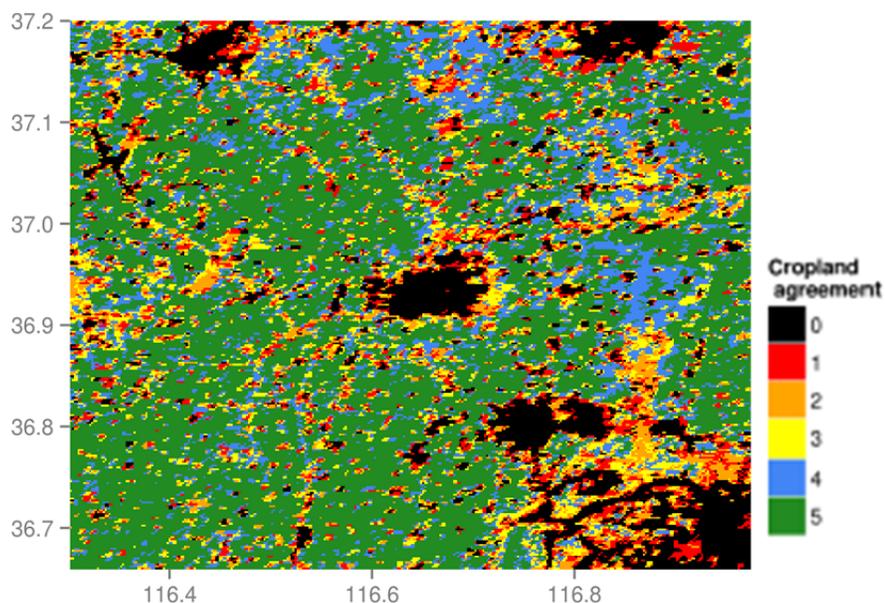


Figure 58 Cropland Agreement Map using 5 Different Methods

Results using five different methods were overlapped to evaluate the agreement of the five cropland maps. Overall accuracy (OA) using five different methods over China JECAM site all exceeded 0.9. OA using the decision tree method over five different JECAM sites also presented high accuracy (higher than 0.9) except for the Sao Paulo, Brazil site.

Plans for Next Growing Season

In 2016 and the future, we will measure the same variables as in 2015.

We already submitted the acquisition plan for newly launched GF-5 geostationary satellite images with 50m resolution at daily temporal resolution.

Publications

Dong T, Meng J, Shang J, et al. Evaluation of Chlorophyll-Related Vegetation Indices Using Simulated Sentinel-2 Data for Estimation of Crop Fraction of Absorbed Photosynthetically Active Radiation[J]. Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of, 2015, 8(8): 4049-4059.

Dong T, Meng J, Shang J, et al. Modified vegetation indices for estimating crop fraction of absorbed photosynthetically active radiation[J]. International Journal of Remote Sensing, 2015, 36(12): 3097-3113.

Meng J, Xu J, You X. Optimizing soybean harvest date using HJ-1 satellite imagery[J]. Precision Agriculture, 2015, 16(2): 164-179.

Zhang M, Wu BF, China Shandong JECAM site Progress Updates in 2015, Oral presentation at JECAM/GEOGLAM Science Meeting, Brussels, Belgium, 16-17 November, 2015.

Francois Waldner, Santiago Veron, Deigo de Abeyllera, Miao Zhang, Bingfang Wu, etc, Cropland mapping in five contrasted agrosystems dominated by large sized fields, submitted to International Journal of Remote Sensing.

9. France

Team Leader and members: **Eric Ceschia**, Aurore Brut, Olivier Hagolle, Frédéric Baup, Gérard Dedieu, Jean François Dejoux, Jordi Inglada, Valérie Demarez, Benoit Coudert, Vincent Rivalland, Silvia Valero, Claire Marais-Sicre, Valérie Le Dantec, Patrick Mordelet, Milena Planells, Vincent Bustillo, Tiphaine Tallec, Jérôme Cross, Mireille Huc, Nathalie Jarosz, Bartosz Zawilski, Hervé Gibrin, Amanda Veloso, Marjorie Battude

Project Objectives

The original project objectives have not changed. They are:

- Crop identification and Crop Area Estimation
- Crop Condition/Stress
- Soil Moisture
- Yield Prediction and Forecasting
- Crop Residue, Tillage and Crop Cover Mapping
- CO₂ and water fluxes/budgets.

Site Description

The JECAM Test Site Name is OSR (Observatoire Spatial Régional, or Regional Space Observatory).

- Location: South west of Toulouse, France (area of study is approx 50*50 km) including 2 experimental plots, Auradé and Lamasquère (which are Fluxnet/ICOS sites, installed in 2004).
- Topography: hilly for Auradé, in a valley for Lamasquère.
- Soils: clay at Auradé, clay loam at Lamasquère.
- Drainage class/irrigation: irrigation at Lamasquère when maize is grown.
- Crop calendar: depends on crops.
- Field size: around 30 ha at Auradé and 20 ha at Lamasquère.
- Climate and weather: mean annual temperature around 13 °C, mean annual precipitation around 650 mm.
- Agricultural methods used: crop rotations are winter wheat, sunflower, winter wheat, rapeseed at Auradé and maize for silage, winter wheat at Lamasquère. Auradé only receives mineral fertilizers whereas Lamasquère receives both mineral and organic fertilizers. Lamasquère is irrigated when maize is grown.

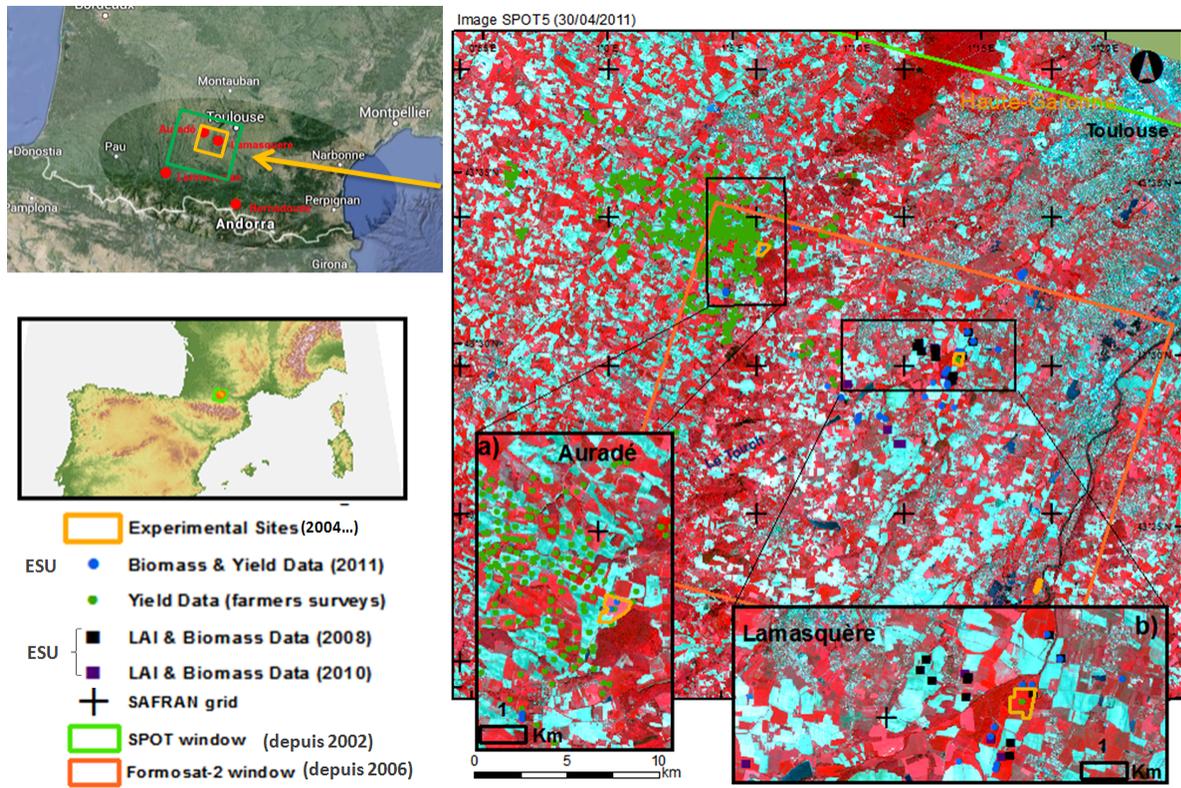


Figure 59 OSR including the Auradé and Lamasquère Fluxnet/ICOS Sites

Figure 60 Formosat-2 Image of the Area around the Auradé Site, 27 May 2006



EO Data Received/Used

Figure 61 shows a chronogram of the optical satellite data acquisitions (Sentinel 2 data not included). All images were obtained independently from the JECAM project.

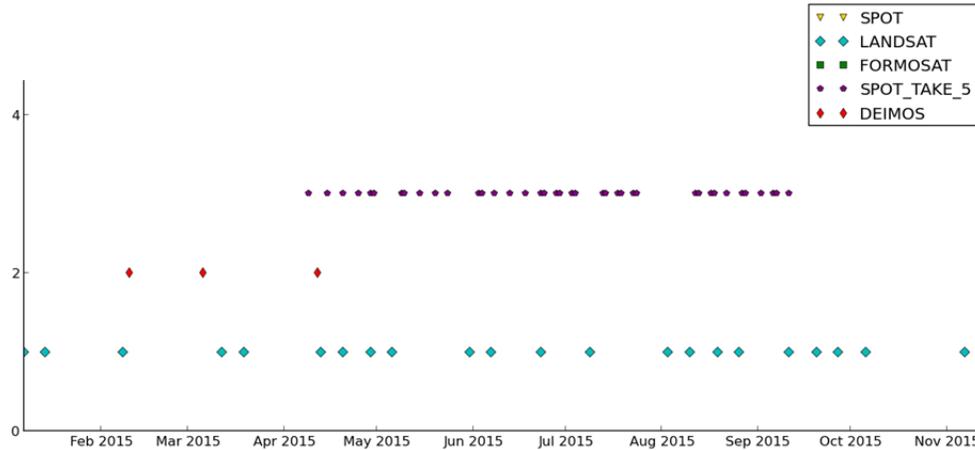


Figure 61 Chronogram of EO Images for France OSR Site

SPOT images were obtained from the CNES KALIDEOS program. Landsat Images were obtained from the French THEIA consortium (level 2A). Deimos data were obtained from specific_projects in which CESBIO is involved.

Image characteristics:

Spot5 (optical, 10m, 2500 km²): 38 images

Landsat 8 (optical,30m ,all over the OSR footprint): 23 images

Deimos 1 (optical, 22m, 10 000 km² on average enclosing the OSR area): 3 images

Concerning the SAR data:

- 14 TerrasarX (Kalideos) images were acquired in 2015 (April 28 and 29, May 10 and 21, June 01, 11, 12, 22 and 23, July 4, 14, 15 and 26, August 6).
- 32 ALOS 2 (Kalideos) images were acquired between January 19 and March 29.

Additionally, Sentinel 1 and 2 images were acquired over the OSR area in 2015: 28 images with orbit 110 for Sentinel 1 and 5 cloud-free images for Sentinel 2.

In situ Data

Both Auradé and Lamasquère sites are ICOS sites and therefore biomass, soil humidity, meteorological, and flux measurements are standardised according to the ICOS protocols. See <http://gaia.agraria.unitus.it/icos/working-groups>.

In total, 135 micro-meteorological variables are recorded every 30 minutes at each site. They include air temperature and humidity, air pressure, soil temperature and humidity at 0-5, 5, 10, 30, 100 cm depth, soil heat flux at 5 cm depth, global (shortwave and longwave) and PAR incident radiation, global (shortwave and longwave) and PAR reflected radiation, albedo, transmitted PAR, diffuse PAR and global shortwave radiation, NDVI, PRI, surface temperature, soil CO₂ and N₂O fluxes (automatic chambers), net CO₂, water, sensible heat fluxes by means of the eddy-covariance method.



Figure 62 The Lamasquère Site Around the Micrometeorological Station



Figure 63 The Auradé Site Around the Micrometeorological Station

Collaboration

The OSR site and its members are involved in the following collaborations:

- 1) the Sentinel 2 agriculture project :

see: <http://www.esa-sen2agri.org/SitePages/Home.aspx>

The Sentinel-2 for Agriculture (Sen2-Agri) project has recently been launched by ESA, as a major contribution to the R&D component of the GEOGLAM initiative and to the JECAM network activities. The project will demonstrate the benefit of the Sentinel-2 mission for the agriculture domain across a range of crops and agricultural practices. The intention is to provide the international user community with validated algorithms to derive Earth Observation products relevant for crop monitoring (in particular mapping of the crop fields).

Partners of the S2-Agri project:



[Canada](#)



[International Fund for Agricultural](#)



[ARVALIS \(Institut du vegetal\),](#)

[France](#)



[Alberta Terrestrial Imaging Centre,](#)

[Canada](#)



[Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, China](#)



[Centre de cooperation Internationale en Recherche Agronomique pour le Developpement](#)



[European Commission](#)



[Food and Agriculture Organization](#)



[Federation of Irrigation Associations, Portugal](#)

[Development](#)



[Instituto Nacional de Tecnología Agropecuaria, Argentina](#)



[Chouaïb Doukkali University & Réseau National des Sciences et Techniques de la Géo-Information, Morocco](#)



[Regional Center for Mapping of Resources for Development, Kenya](#)



[National Earth Observation and Space Secretariat \(NEOSS\), South Africa](#)



[Space Research Institute \(SRI\) of the National Academy of Science & State Space Agency, Ukraine](#)



[US Geological Survey \(USGS\) - Earth Resources Observation and Science \(EROS\)](#)



[The World Food Programme \(WFP\)](#)

- 2) The sites are involved in several collaborative projects such as CiCC (<http://www.sud-ouest.cerema.fr/projet-de-recherche-ademe-cultures-intermediaires-a875.html>) and CESEC financed by the French agency ADEME, MAISEO (<http://www.pole-eau.com/Les-Projets/Projets-finances/Maiseo>) and REGARD (<http://www.fondation-stae.net/fr/actions/projets-soutenus/?pg=2>).
- 3) The sites are also involved in several networks such as Fluxnet (<http://fluxnet.ornl.gov/>) and ICOS (<http://gaia.agraria.unitus.it/home>). The ICOS network will be running for the next 20 years.
- 4) OSR is part of the French THEIA initiative (<https://www.theia-land.fr/>). The Theia Land Data Centre is a French national inter-agency organization designed to foster the use of images issued from the space observation of land surfaces. Theia is offering scientific communities and public policy actors a broad range of images at different scales, methods and services. They partners are potentially involved in "thematic" and / or "regional" expertise centres. The Scientific Expertise Centres are laboratories or groups of national laboratories leading research and developing innovative processes to use space data for "land surfaces" issues. The OSR is involved in 12 of them (see <https://www.theia-land.fr/en/presentation/scientific-expertise-centres>). The Regional CES's objectives are 1) to unite and coordinate users (scientists and public stakeholders) at regional level, and 2) to participate in community training efforts, particularly concerning added-value products developed by the thematic CES's. The OSR is identified in THEIA as the Midi-Pyrénées CES.
- 5) A scientific and technical network on sunflower has been laid out from 2012 to 2017 in Toulouse (named "UMT Tournesol"). Remote sensing research and development is one of the major contributions of CESBIO to this UMT. A 3-year project began in 2014 on "sunflower yield and quality prevision" involving agricultural cooperatives. Several campaigns have been performed in 2014 by Cesbio, Cetiom and INRA (measurements of GAI, biomass and yield). In this framework, we tested different approaches to calibrate relationships between remotely sensed and in situ GAI (calibration of BVnet). Field data will be used to calibrate models like SAFYE or SUNFLO that simulated among other things biomass and yield.
- 6) SENSAGRI (Sentinels Synergy for Agriculture): jointly with Universitat de València (UVEG), Consiglio Nazionale delle Ricerche - Istituto di Studi sui Sistemi Intelligenti per l'Automazione (CNR-ISSIA), Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria (CREA), Instituto Tecnológico Agrario de Castilla y León (ITACyL), National Research Institute - Institute of Plant Protection (IPP), we answered a H2020 call (Leadership in Enabling and Industrial Technologies – Space) in response of the EO Work programme 'EO-3-2016: Evaluation of Copernicus Services'. The name of the project is SENSAGRI. It aims to exploit the unprecedented capacity of S1 and S2 to develop an innovative portfolio of prototypes agricultural monitoring services, three

prototype services capable of near real time operations: (1) surface soil moisture (SSM), (2) green and brown leaf area index (LAI) and (3) crop type mapping. These prototypes will provide a baseline for advanced services that can boost the competitiveness of the European agro-industrial sector. SENSAGRI proposes four advanced proof-of-concept services: (i) yield/biomass, (ii) tillage change, (iii) irrigation and (iv) advanced crop maps. The algorithms will be developed and validated in four European agricultural test areas in Spain, France, Italy and Poland, which are representative of the European crop diversity, and their usefulness demonstrated in at least two non-European countries.

Results

Within the frame of the CICC project, a first map of the crop cover was produced in 2015 over the OSR area. Because the cover crops are spatially very heterogeneous and because their dynamics of development are very heterogeneous too, it is difficult to distinguish the different sub-classes or the species of cover crops. Ground truths are therefore needed to classify them correctly. We are, as of 2015, currently collecting ground truth data and we are improving some methods to map those different covers. This is a critical issue for improving spatial estimates of cropland carbon and water budgets. Figure 64 shows the first crop cover map produced over the OSR area. On this map, white represents the plots with bare soils, blue the spontaneous regrowth, green late regrowth, purple late intermediate crops, pink early cover crops. The area in red represents the area of study, the green area represents the area in which soils have high clay content (growing cover crops is not mandatory), pink represents the area in which nitrate leaching is an issue and in which cover crops should be grown. Our results show that most of the farmers are reluctant to grow cover crops in nitrate leaching sensitive areas because they feel constrained by the regulations. Most of the plots in which cover crops are grown are in areas with no regulations.

In the S2-Agri project, a test phase to develop, tune and validate the generation of agricultural products was performed at 10 JECAM sites around the world, in preparation for operational expansion to the global level once Sentinel-2 data are systematically acquired. These experiments rely on the use of SPOT4-Take5 data, complemented by LANDSAT 8 as a proxy for Sentinel-2. The test sites cover a range of agricultural systems intended to be representative of the global diversity of agricultural landscapes and satellite conditions. The sites are distributed across the globe. The list of sites covered Europe (France, Belgium, Ukraine, Russia), Africa (Morocco, Madagascar, Burkina Faso, South Africa), Asia (China) and South America (Argentina). See Figure 65.

The standardized field data JECAM protocol has been used to collect field data for these test sites. It was composed of crop pixels (wheat, sunflower, maize, etc.) and no-crop pixels (urban areas, water surfaces, grassland, etc.).

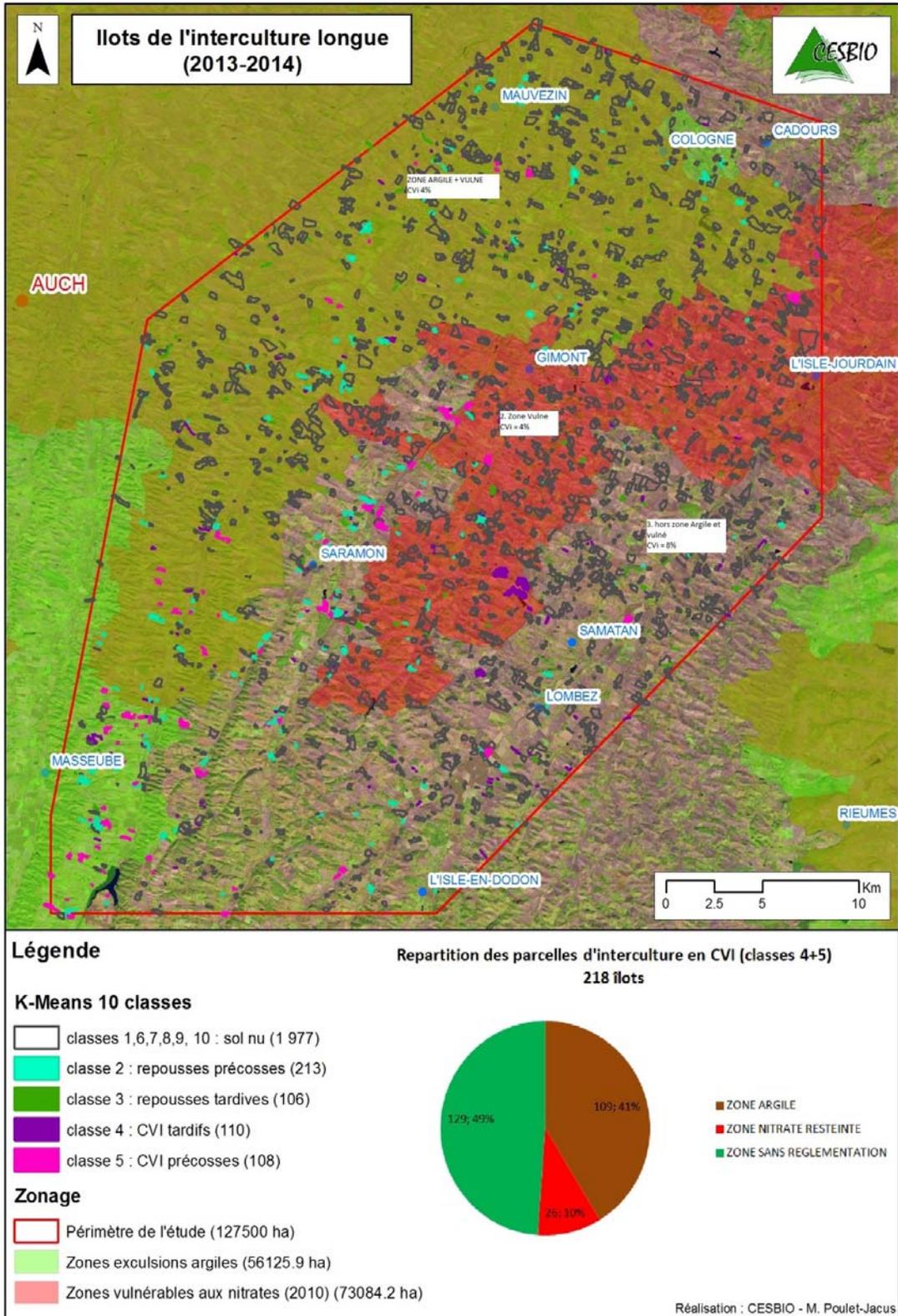


Figure 64 First Crop Cover Map of the OSR Area

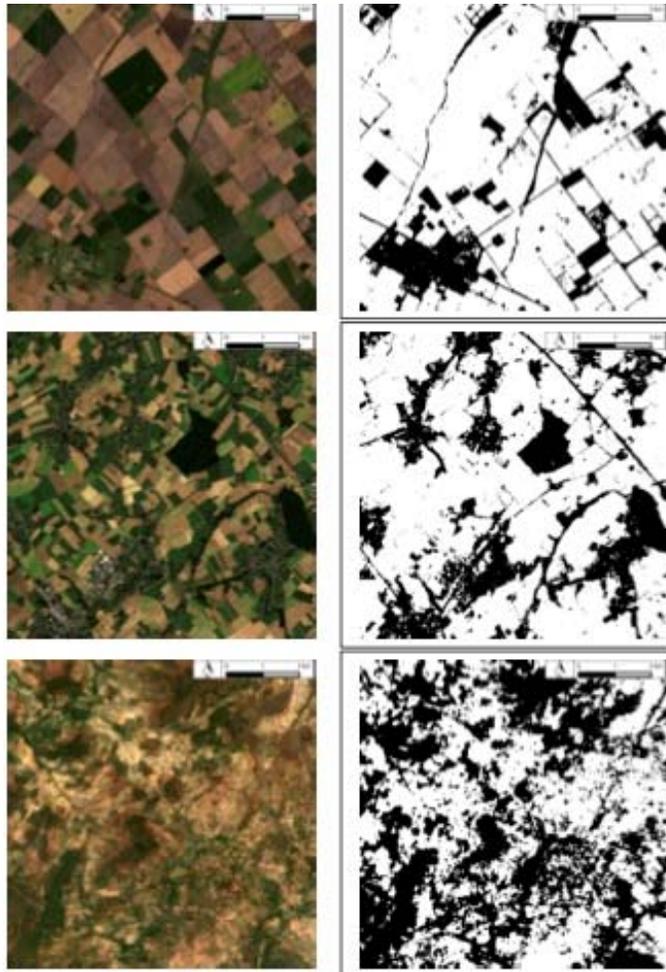


Figure 65 Cropland Mask Results Obtained after 12 Months at JECAM Test Sites in Argentina (top), Belgium, Burkina Faso (bottom)

So far for the different projects in which we are involved, the project objectives have been met.

The combination of HSTR (High Spatial and Temporal Remote sensing) data with a simple crop model and diverse ground data for validating different outputs of the model SAFYe-CO₂ (GAI based upon DHP, Biomass with intensive destructive campaigns, fluxes with eddy covariance data) has proven to be an efficient approach for estimating the main components of the carbon and water budgets for croplands.

Plans for Next Growing Season

In 2016, we will organise an intensive field campaign to validate the SAFYe-CO₂ model outputs, in particular yield. We plan to collect data through destructive sampling and yield monitors on a

range of crop plots and crop species. Those data will also be used to validate some of the biophysical products (GAI) produced within the framework of the S2-Agri project.

We anticipate ordering the same type/quantity of EO data next year.

Publications

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M. Campioli, S. Vicca, S. Luyssaert, J. Bilcke, E. Ceschia, F. Chapin III, P. Ciais, M. Fernández-Martínez, Y. Malhi, M. Obersteiner, D. Olefeldt, D. Papale, S. Piao, J. Penuelas, P. Sullivan, X. Wang, T. Zenone, and I. Janssens (2015) Biomass production efficiency controlled by

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M. Ferlicoq & E. Ceschia (2015). La gestion de l'albédo des surfaces cultivées représente un fort potentiel d'atténuation au réchauffement climatique dans Empreinte carbone : évaluer et agir par Bourges Bernard, Gourdon Thomas, Broc Jean-Sébastien 1, Paris : Presses des MINES, collection Développement durable, 2015. 386 pp. ISBN : 9782356712332

10. Italy Apulian Tavoliere

Team Leader and Members: Annamaria Castrignanò¹, Sergio Ruggieri¹, Domenico Ventrella¹, Pasquale Campi¹, Michele Rinaldi², Piero Toscano³, and Gabriele Buttafuoco⁴.

- 1- CRA-SCA Bari
- 2- CRA-CER Foggia
- 3- CNR-IBIMET Florence
- 4- CNR-ISAFOM Rende (Cosenza)

Project Objectives

The main objectives of the project were to collect soil and crop data in order to:

1. Use a validated simulation model of water balance and durum wheat growth;
1. test a multivariate geostatistical method of data fusion by which leaf area index (LAI), IPAR and crop height can be predicted from a set of ground-truth Li-COR measurements using Remote sensing multiband images as auxiliary variables;
1. explore the potential of recently ESA launched satellite Sentinel-1 for its use in agriculture.

The lack of granted projects obliged us to simplify the sampling strategy.

Site Description

The interest of our study is focused on “Capitanata area”, a plain of about 4000 km² located in the northern part of Apulia Region (south-eastern Italy). See Figure 66. This area is characterized by farms with average size up to 20 ha, and highly productive soils cultivated under intensive and irrigated regime. Winter durum wheat (*Triticum durum* L.) represents the main cereal crop often grown in rotations with irrigated horticultural species. Among these, processing tomato crop (*Lycopersicon esculentum* Mill.) is well represented. In particular, two-year rotation (tomato-wheat) and three-year rotation (tomato-wheat-wheat) are the typical farming rotations of this important productive area.



Figure 66 Aerial Photo of Study Area

The Capitanata plain is delimited by the Apennines Chain on the west side and by Gargano Promontory on the east, and is mostly constituted by continental and fluvial sediments and some terraced marine deposits of the Pliocene and Pleistocene ages. The climate of this zone is classified as “Accentuated Thermo-Mediterranean” (UNESCO-FAO), with winter seasons characterized by temperatures that sometimes descend below 0°C and hot summers with temperature that may exceed 40°C. Annual precipitation ranges between 400 and 800 mm, mostly concentrated in the winter months. The rainiest months are October and November, while the dry period is from May to September.

In general, the soils are deep and clay with vertical behaviour, characterized by large and deep cracks in summer season under rain fed conditions. A wide part of the area is served by an irrigation consortium that fulfils the water requirements of crops with spring-summer cycle (e.g. tomato). In other parts, the irrigation for spring crops is carried out by utilizing private wells. The water table is very deep (200-300 m).



Figure 67 Photo of Capitanata

EO Data Received/Used

We downloaded 2 Landsat-8 images (14 April, 2015, and 30 April, 2015) under clear sky conditions from the U.S. Geological Survey (USGS) website (<http://glovis.usgs.gov>, accessed on 2 February, 2015). The 2 images are SR (surface reflectance) Landsat-8 products with a 30 m spatial resolution corresponding to the period of field activities and experimental campaign.

We downloaded 2 Sentinel-1 images (19 March, 2015, and 24 April, 2015) from Sentinels Scientific Data Hub (ESA) website (<https://scihub.copernicus.eu/dhus/#/home>). The Interferometric Wide swath (IW) mode is the default acquisition mode over land. The ESA free software SNAP was used to process and calibrate the polarimetric SAR data. Calibrated values of the backscatter coefficient were calculated both for VV and VH polarizations (Amplitude bands).

The SAR images were registered to the DEM map of the site by Range Doppler Terrain Correction and filtered to reduce the effect of speckle (Speckle filtering, Lee filter with window size 7 by 7).

Map details: Projection UTM 33N WGS 84, DEM SRTM 1sec HGT, resolution 10m	
19/03/2015 image	Backscatter of σ^0_{VV} ranging from -18.6132 to $+15.7744$ dB and σ^0_{HV} from -26.1184 to $+5.2549$ dB
24/04/2015 image	Backscatter of σ^0_{VV} ranging from -18.8276 to $+10.1757$ dB and σ^0_{HV} from -24.11 to $+5.4484$ dB

Table 10 Sentinel-1 Data Details

AquaCrop Model Simulation

The objective of this task was to predict durum wheat yield by using the AquaCrop Model which was calibrated and validated previously. Six locations within the study area of Capitanata area were used for the model simulation.

The model inputs were:

- Meteorological data: Daily values of maximum and minimum air temperature, rainfall, and reference evapotranspiration. All the climatic parameters were collected from the standard agro-meteorological station of the experimental farm of CREA-SCA located in Capitanata;
- Physiological parameters: sowing date of 1st December, 2014, was considered. The Leaf Area Index (LAI) measurements are required for calculating the canopy ground cover parameter. The LAI data used were the measurements carried out with an area meter (LAI-2000 Plant Canopy Analyzer, Li-Cor USA) at two phenological stages (jointing and heading) of durum wheat. The canopy ground cover (CC) was derived using the Ritchie model (Belmans et al., 1983; Ritchie et al., 1985) from the following equation:

$$CC = 1 - \exp(-K \cdot LAI)$$

where K is the extinction coefficient, which was assumed to be equal to 0.65 for wheat (Heng et al., 2009);

For root depth, a value of 1.2 m was used.

- Soil characteristics observed in the experimental fields of CREA-SCA farm located in Capitanata were used. These parameters are reported in Table 11.

Water content at the field saturation (% in volume)	50
Water content at the field capacity (% in volume)	39
Water content at the wilting point (% in volume)	23

Table 11 Main Soil Characteristics Observed at the Capitanata Fields

APPLICATION OF LANDSAT-8 SATELLITE-DATA FOR UPSCALING LAI MEASUREMENTS TO THE STUDY AREA

In this report, we used the methodology described in the previous report to derive reference LAI maps from ground-based measurements over the study area cropped with durum wheat within the JECAM site of Capitanata. The up-scaling of point-based LAI measurements is based on multivariate geostatistics and makes use of ancillary information as Landsat-8 imagery. The

fields, within the study area cropped differently than durum wheat, were masked in displaying the maps of predicted LAI.

In situ Data

LAND USE

In the 2015 measurement campaign, two surveys were carried out in the 3 x 3 km area (Figure 68) to evaluate the diffusion and extent of different field crops, and mainly to identify and locate wheat cropped areas. The two periods were: 17-20 March 2015 and 23-24 April 2015.

All the fields of the area were monitored and each different crop was shown on a map. The results showed a large prevalence of wheat (70% of the area), other crops (chickpea and field bean 10%), other cereal crops (barley, oat and emmer 5%); moreover, several fields were tilled (bare soils) or with spontaneous weeds before the cultivation of the following processing tomato (15%). In the second survey on April, the only modification in land use we observed was the change of bare soil that was replaced by processing tomato crop.

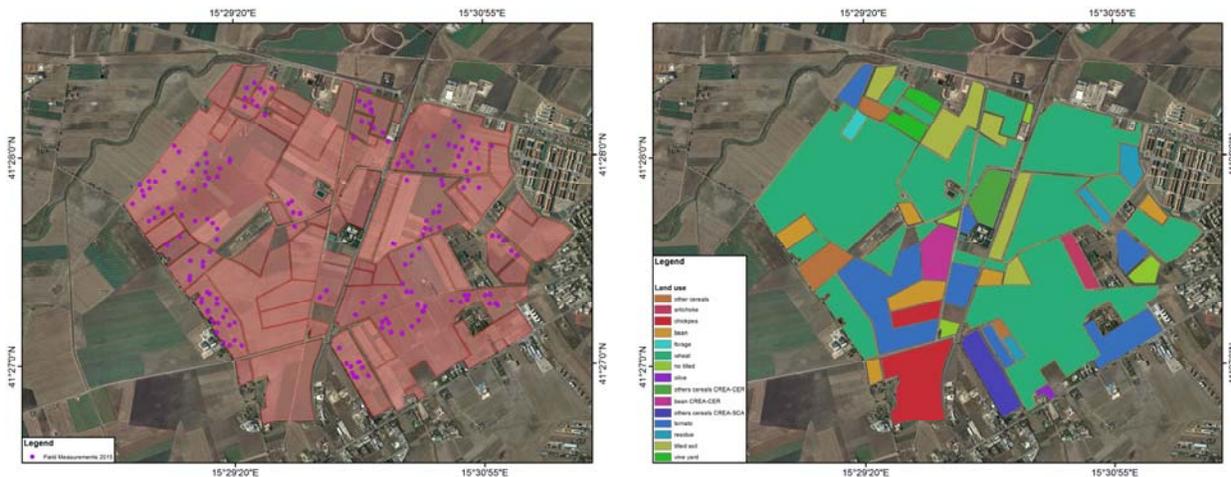


Figure 68 Left: Location of LAI Measurements within the 3km x 3km Area (pink polygon) Right: Land Use Map of the Study Area

LAI MEASUREMENTS

LAI was measured on 19-20 March 2015, in 35 experimental sampling units (ESU) of 10m by 10m size within the polygon of about 3 km by 3 km size (Figure 68); on 23-24 April an intensive measurement in the 3 x 3 km area was carried out with 93 ESUs.

The two LAI surveys were carried out when the durum wheat was at stem elongation phase (19-20 March 2015) and when it was at flowering - beginning of heading phase (23-24 April

2015) (Figure 69). Pictures of chickpeas and field beans at two different stages are also shown in Figure 70 and Figure 71.



(a)



(b)

Figure 69 Durum Wheat in (a) March and (b) April 2015



(a)



(b)

Figure 70 Chickpeas in (a) March and (b) April 2015



(a)



(b)

Figure 71 Field Beans in (a) March and (b) April 2015

Collaboration

We continued the collaboration with Dr. Consuelo Latorre from EOLAB to support the validation work of Copernicus Global Land products based on SPOT5 by using the ground data collected in the Italian site of JECAM. On-the-ground measurements of LAI were carried out from spring 2014 to 2015, as described in the previous and present reports. Unfortunately, the SPOT5 images were not made available by EOLAB, therefore we decided to download the free images of LANDSAT-8, though at a coarser scale. Therefore, the size of ESU (10 m) was not suitable for LANDSAT-8 because it was planned for SPOT5 imaging.

We accepted the invitation of Dr. Fabio Vescovi of the GHP14011 – EducEO project to work voluntarily in the Pilot1 Project aimed to combine data collected by the farmers with products derived from Sentinel-1 imagery. In the longer term, this activity will lead to the routine use of Sentinel-1 products to monitor the crops, help forecast the yields and provide a long term validation of Sentinel-1 products. We are going to jointly analyze Sentinel-1 images with ground-truth LAI data and yield maps.

Results

AquaCrop model simulations

The function of canopy ground cover (CC), previously calibrated and validated in the 2014 season, has been adapted to the values of CC obtained during the 2015 season ([Figure 72](#)). Subsequently, the simulation of the final biomass and yield of durum wheat at each ground-truth data point was performed.

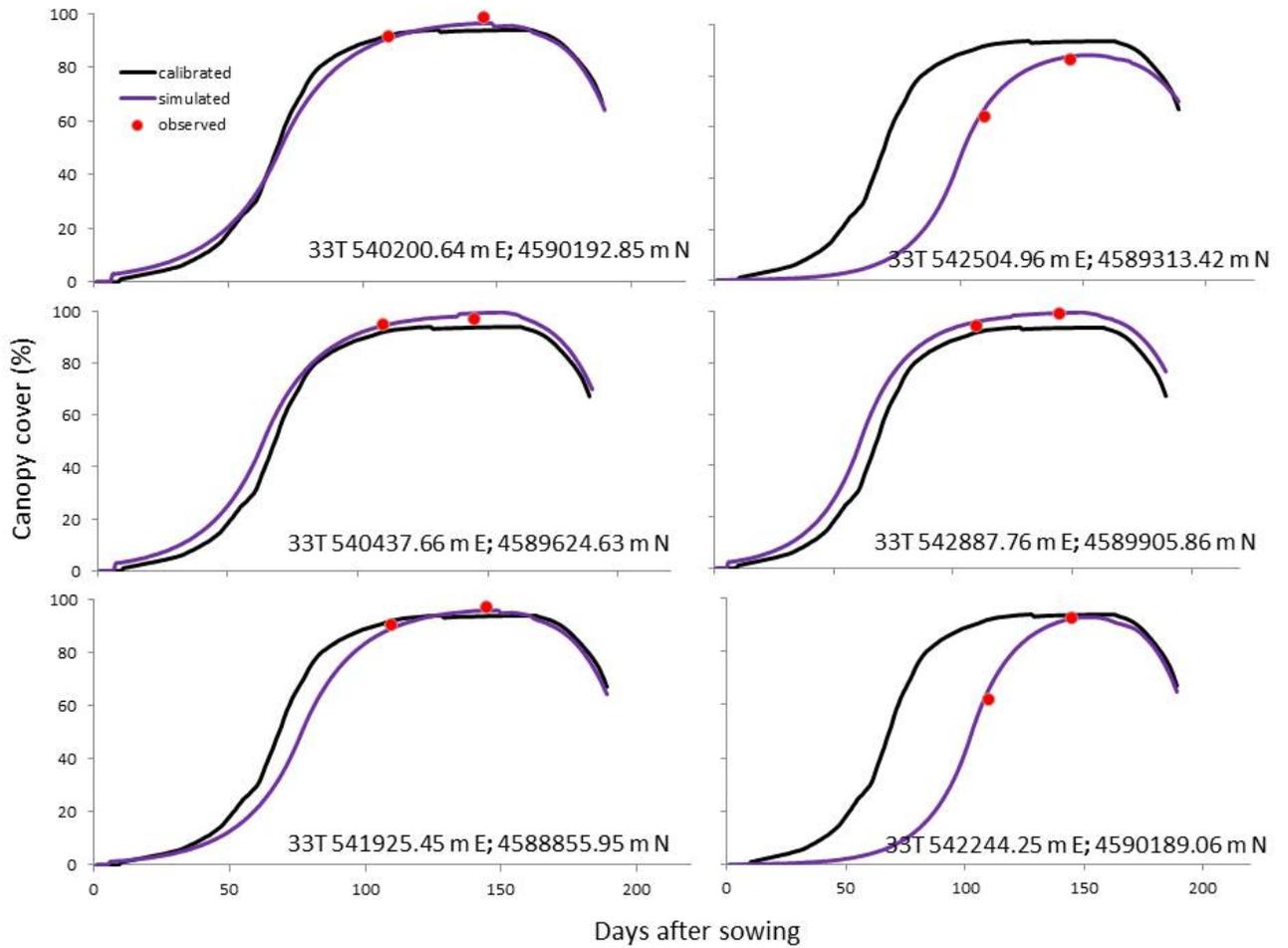


Figure 72 Trend of CC Calibrated during the 2014 Season and Simulated during the 2015 Season, with Observed Values

Table 12 and **Figure 73** show that biomass and yield widely vary over the Capitanata study area. In particular, the lower values occurred where the growth of durum wheat was reduced (low values of LAI). In **Table 12**, biomass and yield of durum wheat were simulated by the AquaCrop model.

GPS - UTM (m)	LAI Jointing	LAI Heading	CC Jointing (%)	CC Heading (%)	Biomass ripening (t ha ⁻¹)	Yield ripening (t ha ⁻¹)
33T 540200.64 m E; 4590192.85 m N	3.8	6.3	91	98	15.1	3.84
33T 540437.66 m E; 4589624.63 m N	4.6	5.3	95	97	15.8	3.85
33T 541925.45 m E; 4588855.95 m N	3.6	5.3	90	97	14.4	3.49
33T 542504.96 m E; 4589313.42 m N	1.6	3.1	64	86	11.5	2.68
33T 542887.76 m E; 4589905.86 m N	4.4	7.1	94	99	16.0	3.90
33T 542244.25 m E; 4590189.06 m N	1.5	4.1	62	93	11.4	2.81

Table 12 Observed LAI and Calculated CC in Jointing and Heading Phenological Stages

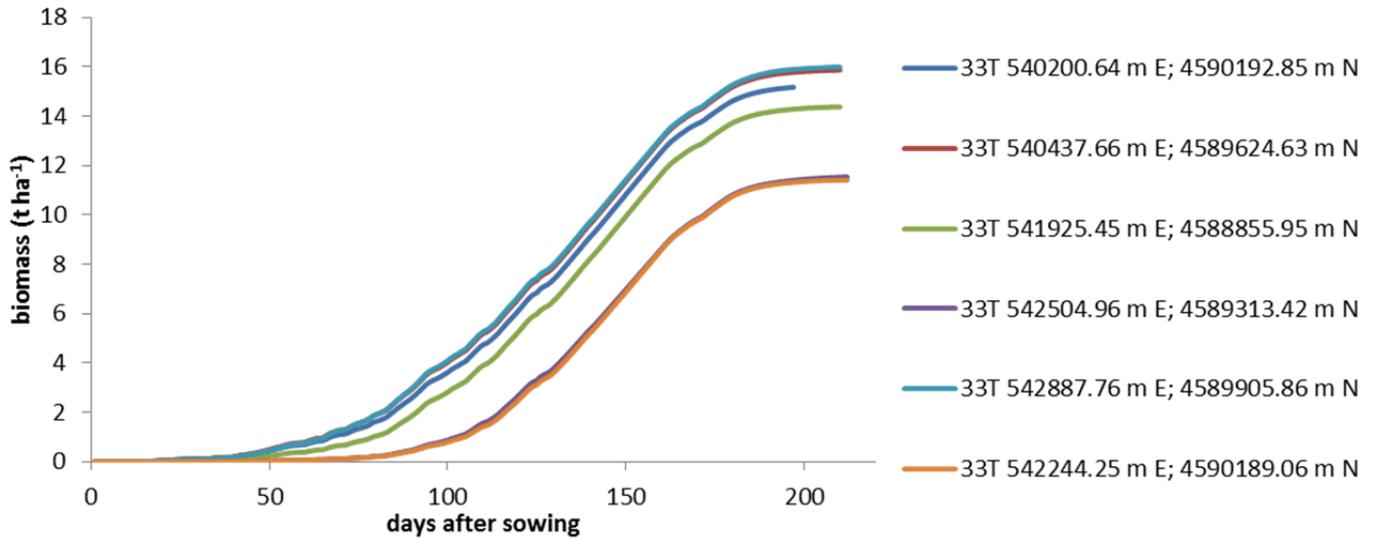


Figure 73 Trends of Wheat Biomass Simulated at Each Point of Capitanata Area

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Upscaled LAI maps

Table 13 and **Figure 74** show the basic statistics and the box-plot distributions of the two data sets of LICOR LAI-2000 measurements at the two dates (March and April 2015).

VARIABLE	Count	Minimum	Maximum	Mean	Std. Dev	CV	Skewness	Kurtosis
LAI_March	89	0.15	6.92	2.21	1.73	0.60	0.99	4.05
iPAR_March	89	3.55	351.21	140.55	110.10	0.78	0.53	1.74
Height_March	89	8.00	44.00	29.28	8.39	0.28	-0.67	3.11
LAI_April	93	1.48	8.86	4.64	1.76	0.38	0.13	2.04
iPAR_April	93	83.15	478.28	215.55	111.48	0.52	0.90	2.48
Height_April	93	25.00	110.00	63.87	16.70	0.26	0.19	2.99

Table 13 Descriptive Statistics of LAI, Intercepted PAR and Wheat Height Measured in March and April 2015

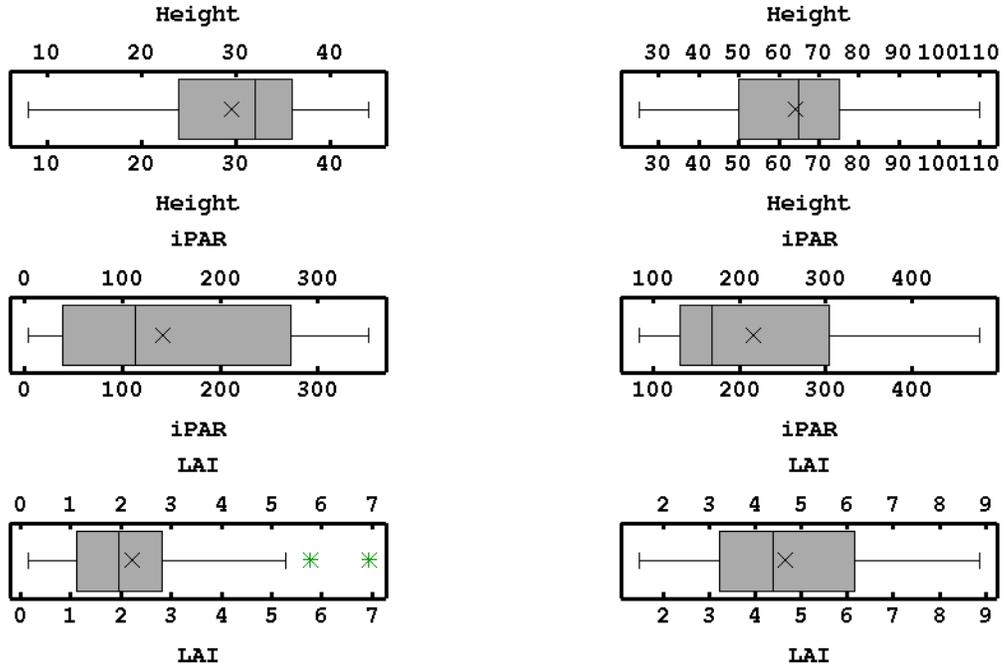


Figure 74 Box-Plots of Wheat Height, iPAR and LAI Measured in March (left) and April (right)

All the distributions of the three parameters were positively skewed with the exception of crop height, which was quite probably due to the occurrence of plants of limited growth. In particular, LAI in March was variable with two large outliers (LAI > 5.00). There was an expected increase of the mean values of the three parameters from March to April and a general decrease of variation. The observed departures from normal distribution (especially for LAI and iPAR) may be due to the large variability observed in the crop growth and development ascribable to differences in cultivar, sowing date and management.

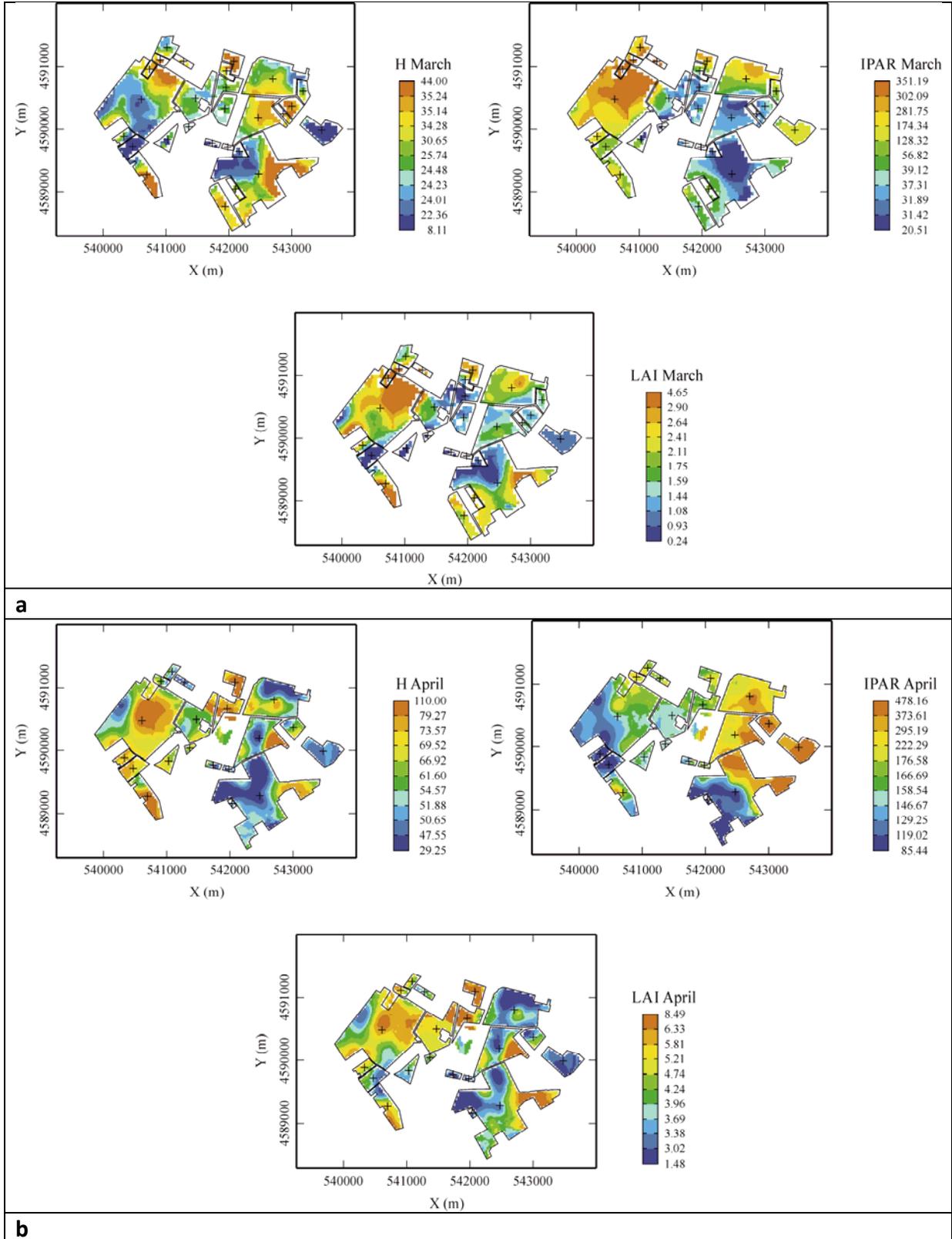


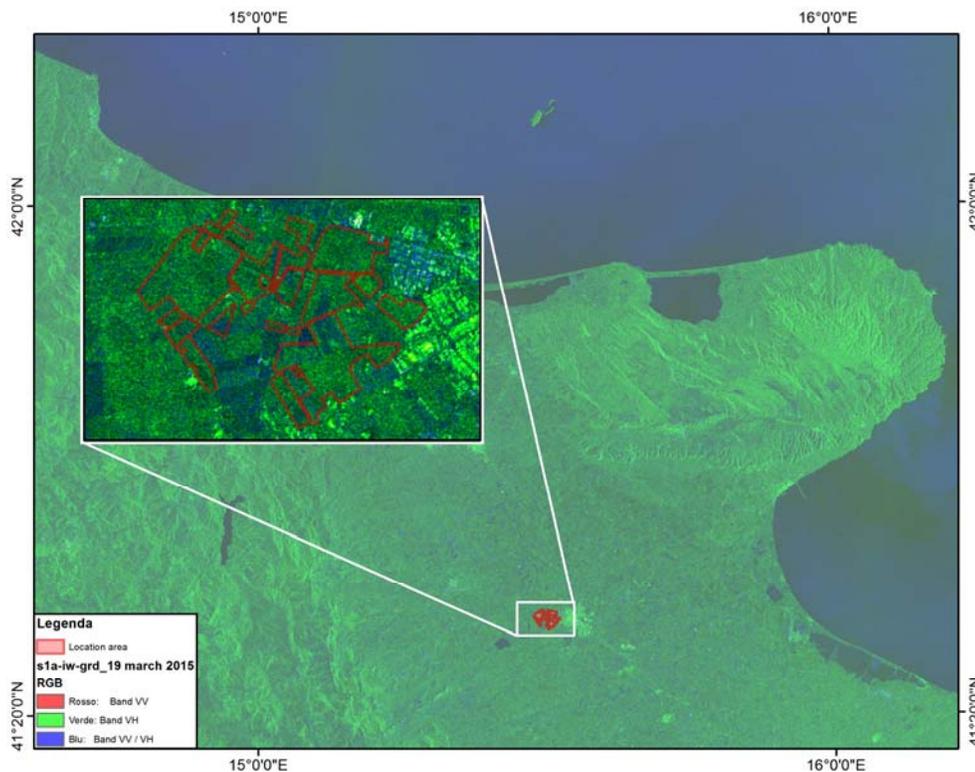
Figure 75 Cokriged Maps of Wheat Height, iPAR and LAI Estimated in (a) March and (b) April, Overlapped with Shapefiles of the Cereal Class of Land Use

The estimated maps of wheat height, iPAR and LAI at the two dates of observation show the potential of the proposed approach to use RS imaging for upscaling the point measurements of Li-COR sensor. The maps confirm the large variability observed in the plant observations which appeared to have greater vigour on the west side of the study area. A clearer distinction among the fields was observed in the later survey. The accuracy of the prediction could be improved by using RS images at a finer spatial scale than the one of LANDSAT-8, such as the recently launched ESA satellite Sentinel-2. However, these data will be available early in 2016.

In order to analyze the spatial and temporal relationship between Sentinel-1 data and wheat attributes/yield and improve precision of prediction, we are working to define some algorithms of data fusion based on multivariate geostatistical techniques.

The following figures show Sentinel-1 images of VV, VH, VV/VH recorded at the two dates of on-the-ground measurements overlapped with the shapefile of the wheat class of land use. At a visual inspection, it is difficult to establish a clear relationship between RS imaging and land use classification and/or durum wheat vigour. The potential of Sentinel-1 for agriculture can be evaluated only after an effective data fusion of data of different types. **Figure 76** shows the location of the site in southern Italy; The Level-1 GRD image of 19 March 2015 is in RGB, with VV in red, VH in green and VV/VH in blue.

Figure 76 Sentinel-1 Image of the Site in Southern Italy



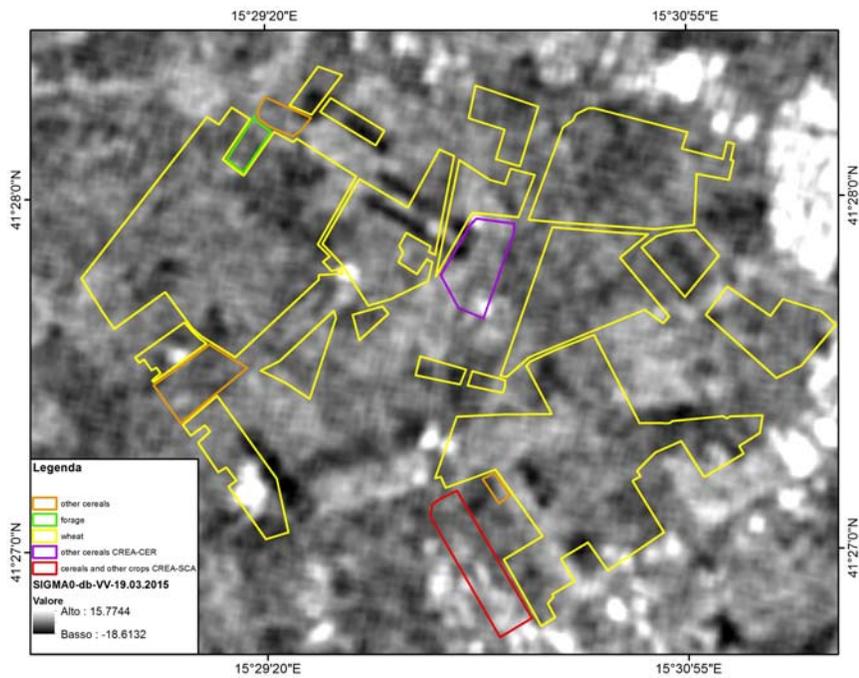


Figure 77 Sentinel-1 Image (19 March 2015) with Speckle Reduction Techniques and Filtering, Polarization VV

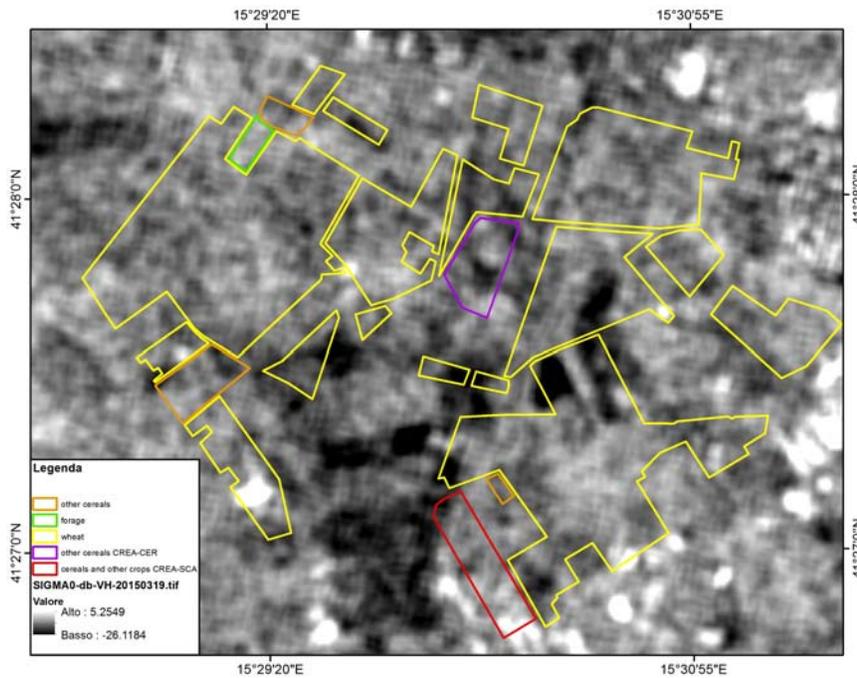


Figure 78 Sentinel-1 Image (19 March 2015) with Speckle Reduction Techniques and Filtering, Polarization VH

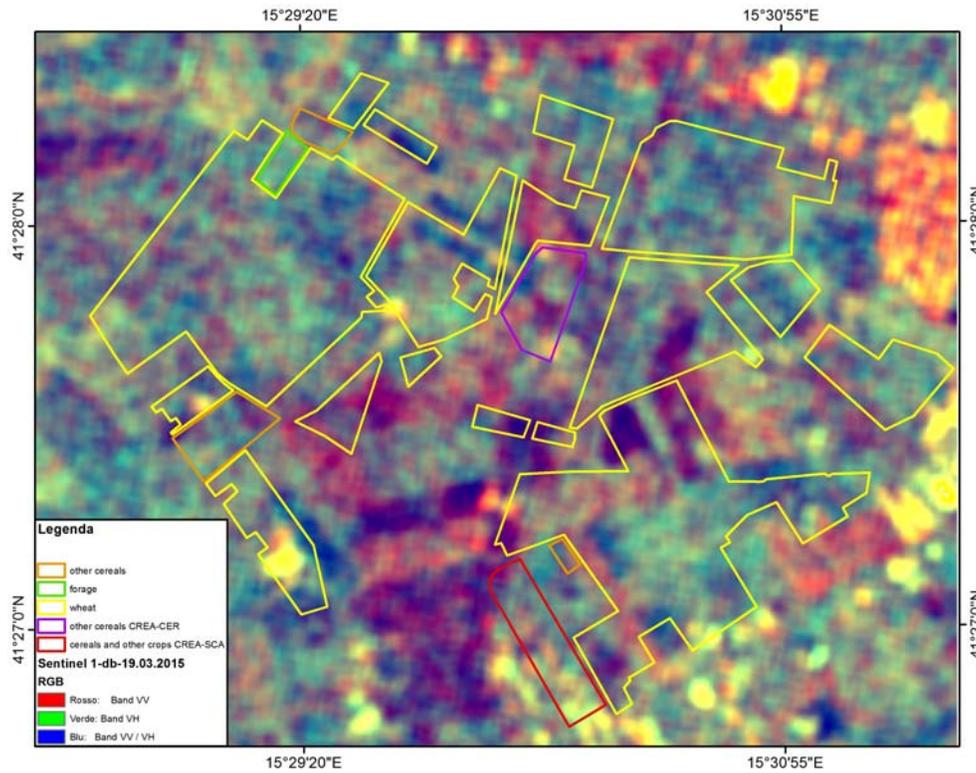


Figure 79 Sentinel-1 Image (19 March 2015) with Speckle Reduction Techniques and Filtering; Red: VV, Green: VH, Blue: VV/VH

Plans for Next Growing Season

Given the promising results at AquaCrop model validation, we are going to extend the application of the model to other sites, within the survey polygon, and predict soil water content and durum wheat yield at regional scale. We realize that, to improve LAI predictions, we need to increase the number of ESUs and the one of the replicated measurements (10-12) per each ESU. However, the realization of such plans of measurements, in support of validation activities, depends largely on funds for EO projects.

For the next durum wheat season (2015-2016) we are going to investigate the capabilities of the Sentinel-2 data of supplying valuable information on LAI, crop height and production potential. We will jointly analyze crop attributes, yield data and Sentinel-1/2 images with geostatistical data fusion techniques to assess the feasibility of generating yield forecasts.

Publications

S. M. Shaddad, S. Madrau, A. Castrignanò, A. M. Mouazen, 2015. Data fusion techniques for delineation of site-specific management zones in a field in UK. Precision Agric. DOI 10.1007/s11119-015-9417-6

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G. Buttafuoco, A. Castrignanò, G. Gucci, M. Rinaldi and S. Ruggieri, 2015. An approach to delineate Management Zones in a durum wheat field: validation using Remote sensing and yield mapping. Precision Agriculture '15, edited by J.V. Stafford, published by Wageningen Academic Publishers, Wageningen (NLD), pages 241-247.

11. Kenya

No report was received.

12. Madagascar

Team Leaders: Valentine Lebourgeois, Agnès Bégué and Stéphane Dupuy (Cirad UMR TETIS)

Team Members: Jacqueline Rakotoarisoa, Bodovololona Rabary (FOFIFA - National Center of Applied Research for Rural Development, Madagascar), Mathilde Sester (Cirad UR AIDA), Paulo Salgado (Cirad UMR SELMET)

Project Objectives

The original project objectives have not changed. They are:

- Crop identification and Crop Area Estimation
- Yield Prediction and Forecasting.

This work aims at testing the potential of the mission SENTINEL-2 to map croplands in a region of Madagascar characterized by small size fields, fragmented farmland and frequent cloud cover. The overall objective of this research is to provide new products from the future satellite mission, based on existing (SPOT, Landsat-8) or recent (PLEIADES) missions to support early warning systems for food security. This preparatory work is conducted in two steps: (i) mapping of different cropping systems from multisource data (SPOT time series, very high resolution PLEIADES images, DEM, ground data) and data mining methods (Random Forest) and (ii) estimation of agricultural production (phenological transition dates, yield).

Site Description

- Location: Antsirabe Region (60*60 km)
- Topography: The study site is located in a mid-altitude region characterized by presence of many hills.
- Soils: Clayey texture
- Drainage class/irrigation : Middle.
- Crop calendar: Main cropping season from October to April.
- Field size: Mean field size 0.03 ha.
- Climate and weather: Tropical climate of altitude.
- Agricultural methods used: Manual Tillage / Hoeing / Fertilization with manure more or less mixed with ashes (few NPK inputs due to availability and cost) / Irrigation on terraces or basins, rain fed crops on the hills.



Figure 80 Rice Fields in an Irrigated Basin



Figure 81 Irrigated Rice (bottom) and Rain Fed Corn Fields (top)



Figure 82 Rice Harvest



Figure 83 Irrigated (bottom) and Rain Fed (top) Fields

EO Data Received/Used

SPOT

- Space agency or Supplier: ASTRIUM - SPOT Image via SEAS-OI satellite receiving station.
- Optical
- Number of scenes: 26 images (60*60 km)
- Range of dates: October - June
- Beam modes/ incidence angles/ spatial resolution: Multispectral / incidence angles: between -31 and + 31 / 10 - 20 meters resolution
- Processing level:
 - SEAS-OI images: Delivered in level 1A then manually orthorectified and converted to top of atmosphere reflectance

Landsat-8

- Space agency or Supplier: USGS
- Optical/SAR: Optical
- Number of scenes: 11 images (subsets of 60*60 km)
- Range of dates: October - June
- Beam modes/ incidence angles/ spatial resolutions
Multispectral / incidence angles: variable / 15 meters pansharpenned.
- Processing level: Orthorectified and converted to top of atmosphere reflectance manually

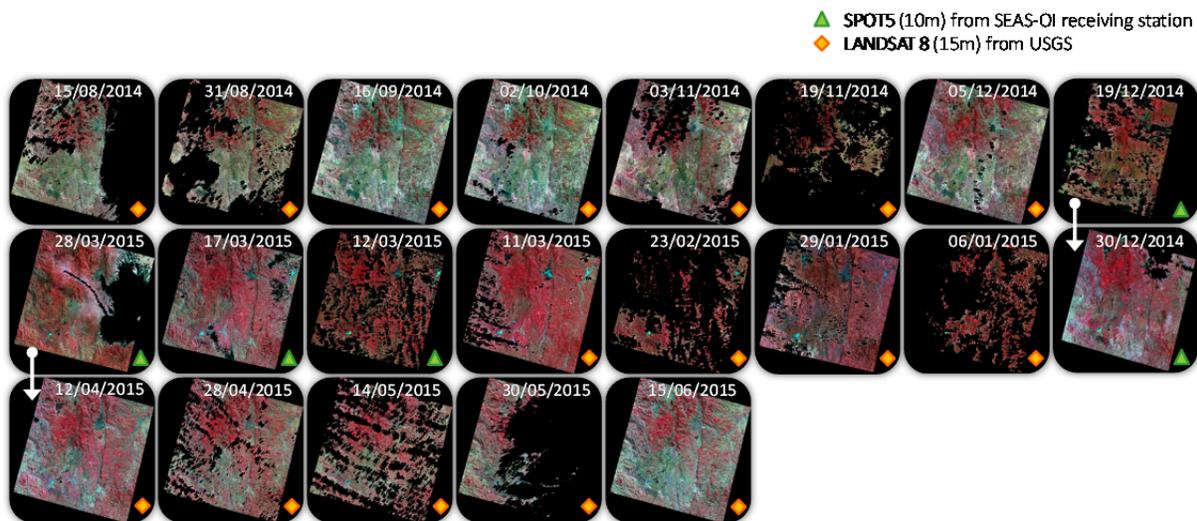


Figure 84 SPOT5 and Landsat-8 2014/2015 Time Series.

In Figure 84, clouds are masked and are black.

PLEIADES

- Space agency or Supplier: ASTRIUM - SPOT Image via CNES ISIS program
- Optical
- Number of scenes: 9 images covering 3 600 km²
- Range of dates: mid February – end of March (maximum of the growing season)
- Beam modes/ incidence angles/ spatial resolutions: Bundle (50 cm Pan + 2m 4-Band Colour) / standard incidence angle (30°)
- Processing level: Ortho.

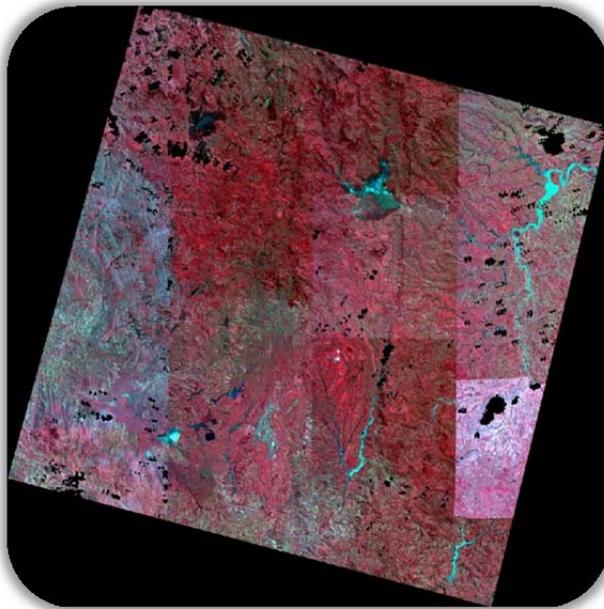


Figure 85 Mosaic of PLEIADES Scenes Acquired between February and March 2015

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In Figure 85, the black parts represent masked clouds.

In situ Data

Data Collected for Crop Characterization

Field surveys were conducted in the study zone during the growing peak (end of February) of the 2014-2015 cropping seasons in order to characterize the main cropping systems. A total of 1020 GPS waypoints were registered in the study area, chosen according to their accessibility and to be as well representative of the existing cropping systems as possible. The data gathered during the field surveys concerned farmers' practices (type of crop, use of fertilizers and

irrigation). GPS waypoints were also registered on different types of non-cropped classes (natural vegetation, urban areas, water bodies...) to obtain data on the non-crop class. 199 additionally points were added to the field database for non-crop class by photo interpretation of PLEAIDES very high resolution imagery, making a total of 1219 points finally usable (860 cropped and 359 non-cropped). The boundaries of the fields (for cropped classes) / objects (for non-cropped classes) were then digitized over PLEAIDES very high resolution imagery in order to obtain a polygon database.

Table 14 presents the number of polygons per type of class for the more detailed level (Sub Class) of the JECAM nomenclature. Green is cropped, and grey is non cropped. The map of the GPS waypoints acquired over the Antsirabe JECAM Site over 2014-2015 growing season is presented in Figure 86.

Table 14 Number of Polygons per Type of Class in the Field Database for Sub-class of JECAM Nomenclature

Sub Class (JECAM nomenclature)	Number
Maize	88
Oats	8
Rainfed rice	109
Irrigated rice	55
Beans	43
Peas	10
Groundnuts	27
Soya beans	33
Other crops	17
Grasses and other fodder crops	39
Casava	47
Potatoes	72
Sweet potatoes	92
Tomatoes	42

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Cabbages	22
Other leafy or stem vegetables	6
Carrots	43
Onions (incl. Shallots)	10
Taro	41
Fruit crops	56
Built up Surface	33
Old fallows	4
Young fallows	32
Bare soils	8
Pasture	18
Herbaceous savannah	66
Natural forest	59
Rocs	44
Savannah with shrubs	73
Water bodies	11
Wetland	11
Total	1219

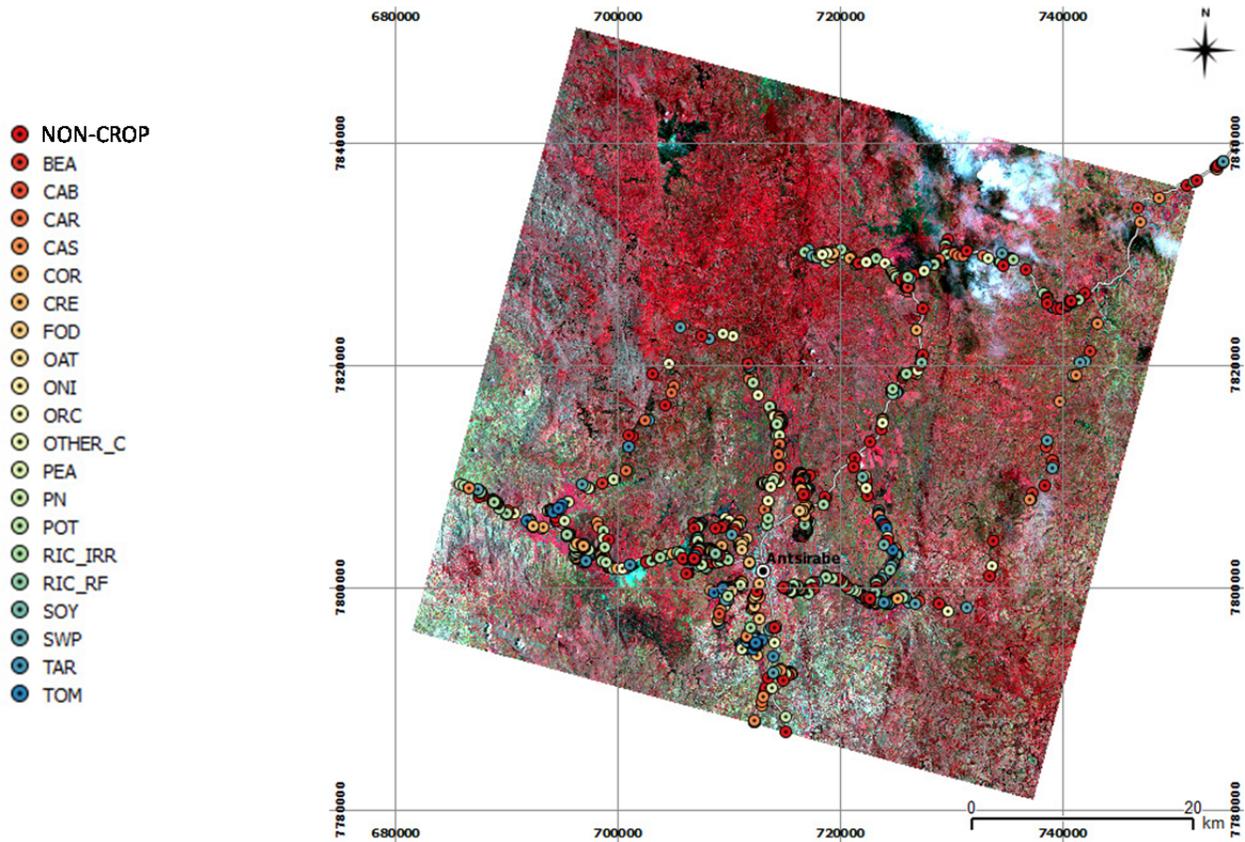


Figure 86 Map of the GPS Waypoints Acquired over the Antsirabe JECAM Site over 2014-2015 Growing Season

Data Collected for Estimate of Crop Production

During 2015 harvest season, 124 rice fields (88 irrigated, 36 rainfed) were sampled in order to obtain information on the farmers' practices (cultivar, planting date, irrigation, fertilization, harvest date) and the yield (total biomass, dry biomass, full and empty grain yield on two plots of 1m² inside the field). The map in Figure 87 presents the location of the 2015 yield surveys.

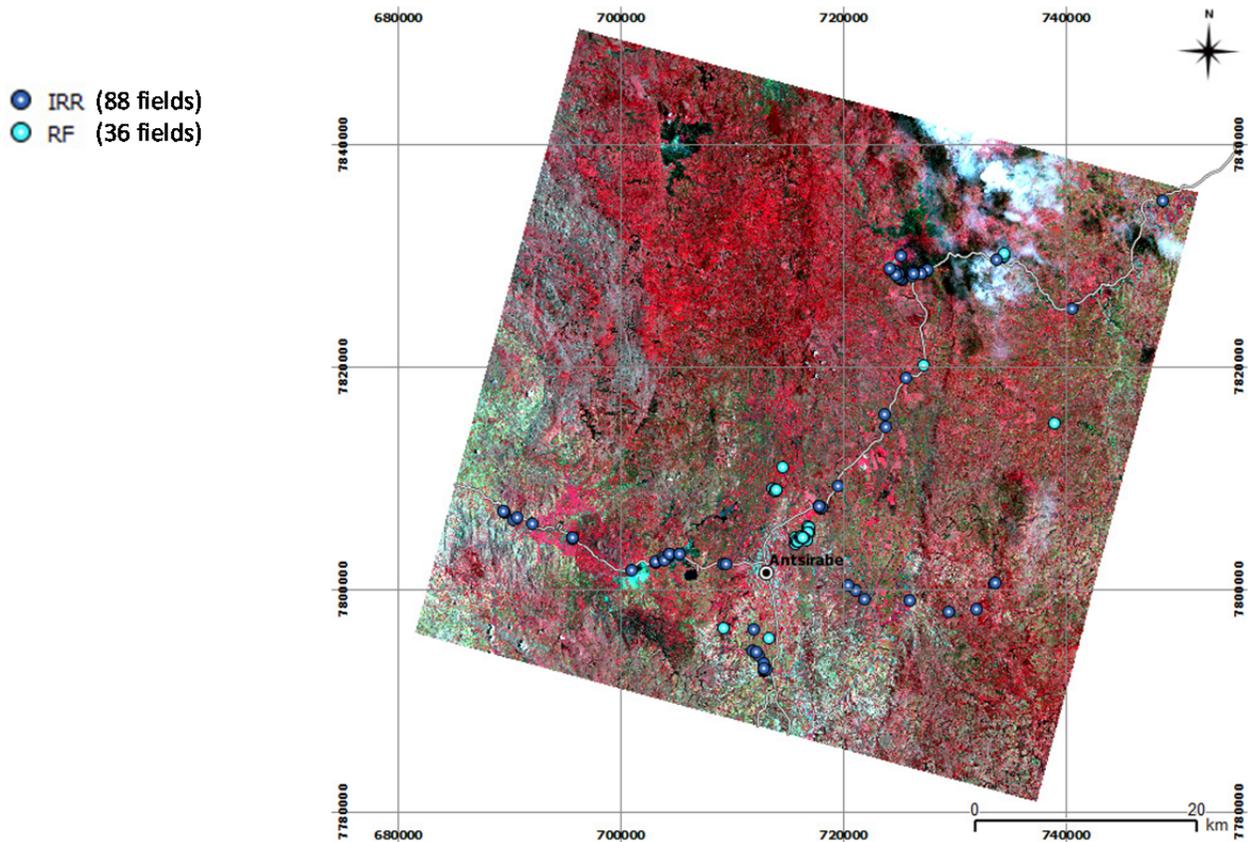


Figure 87 Locations of 2015 Field Surveys

Collaboration

We have been approached by the Burkina Faso (Koumbia) Cirad site for exchanges about methodology (image processing, data mining methods).

Results

The methodology for crop identification and crop area estimation is based on the combined use of object based image analysis and data mining. It involves 3 steps:

1. Preprocessing steps: (i) All images were transformed to top of atmosphere reflectance (top of canopy reflectance was tested but without satisfactory results because of the absence of reliable information on atmospheric composition), (ii) the boundaries of each field/object of the field database were digitized based on very high resolution PLEIADES imagery, (iii) SPOT DEM was processed to extract slopes.
2. Building a learning database: a learning database was built by extracting a set of 341 variables for each field/object of the field database including: 286 radiometric variables (spectral response, indices), 50 textural variables (only from PLEIADES imagery), and some topographic (altitude, slope) and geometric (object size) variables.

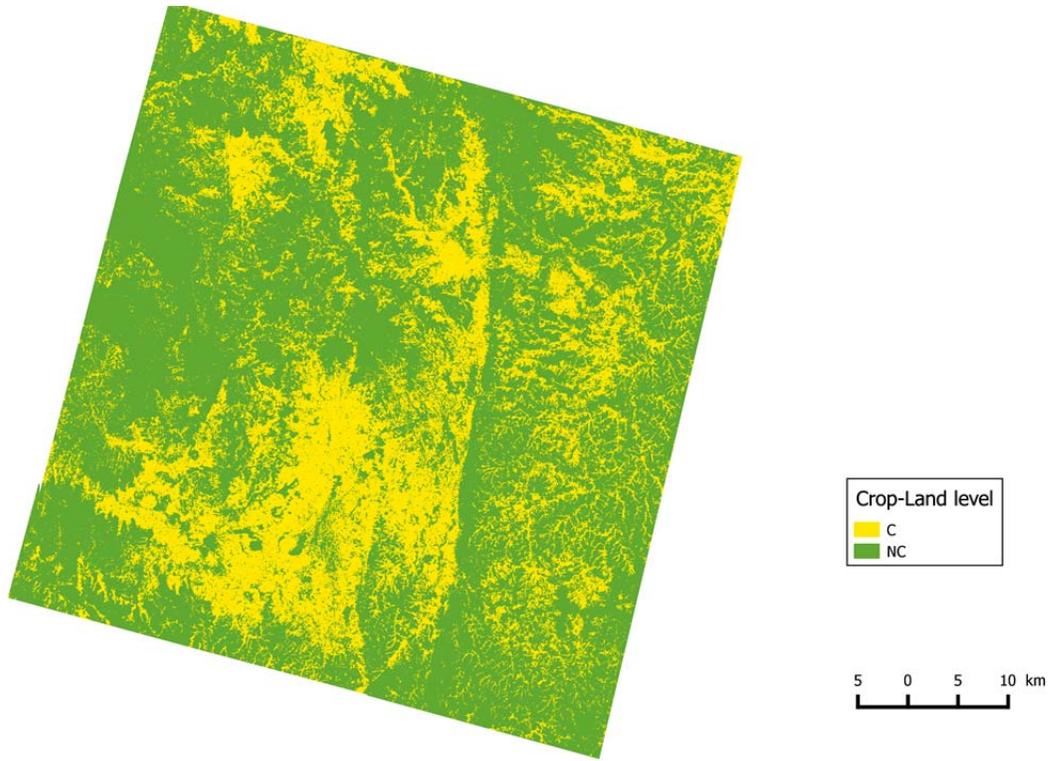


Figure 88 Crop-Non Crop Level

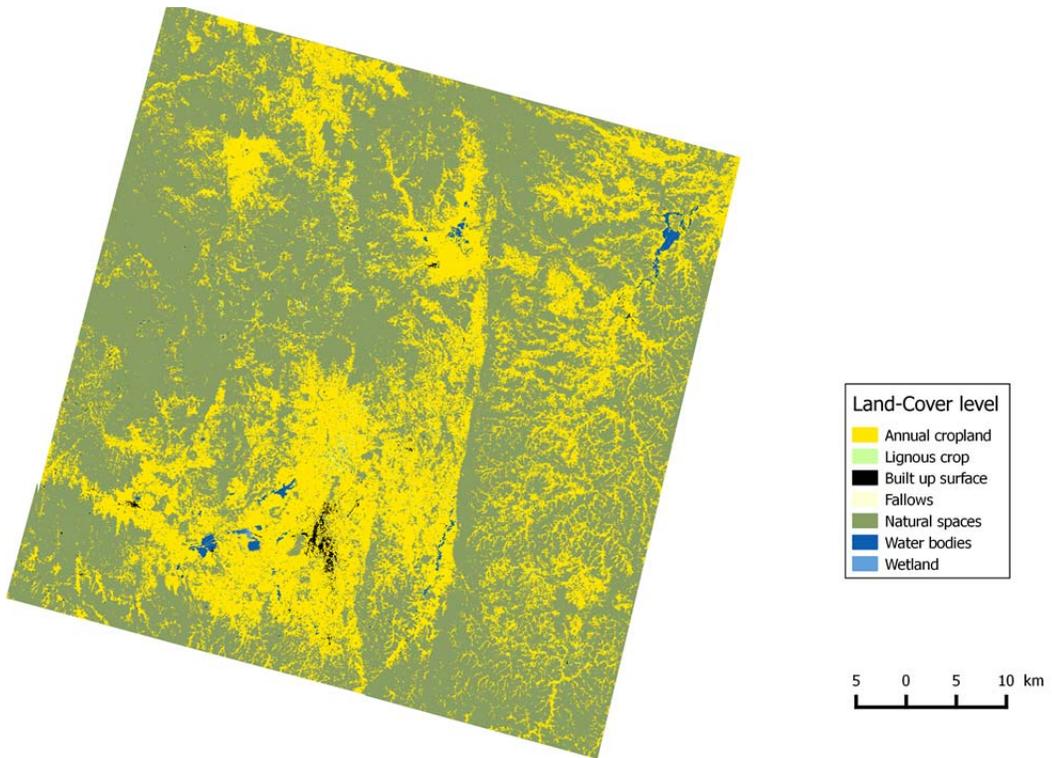


Figure 89 Land Cover Level

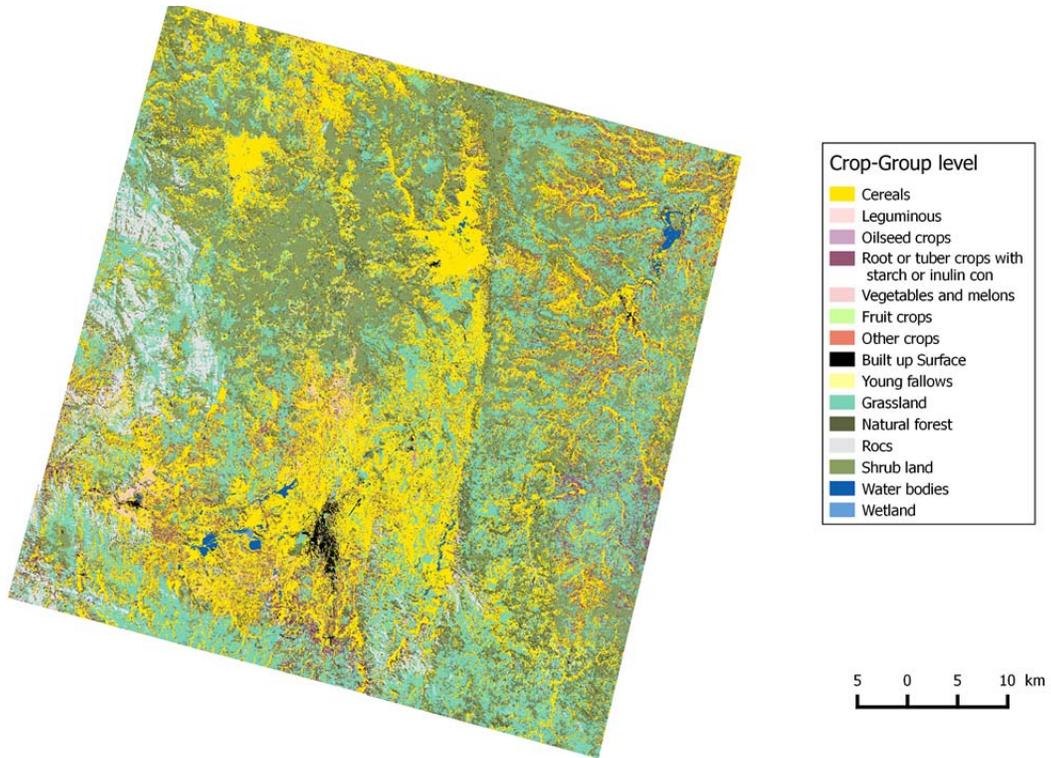


Figure 90 Crop Group Level

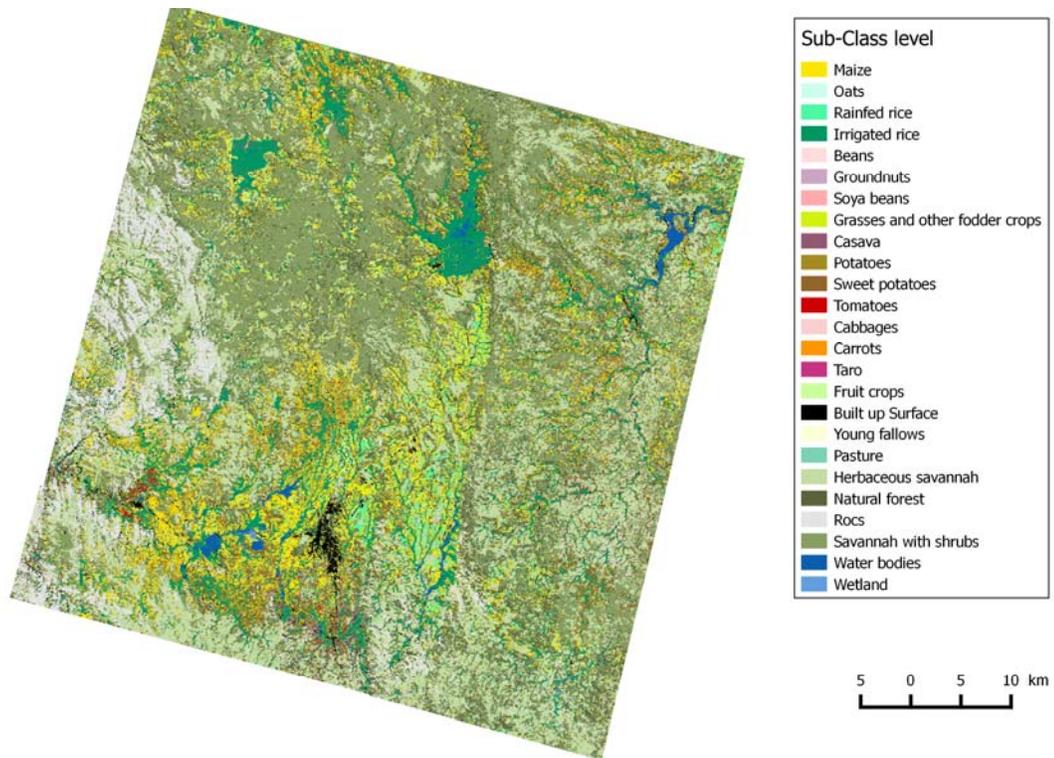


Figure 91 Sub-Class Level

Estimation of rice crop production

Work on estimation of rice crop production is in progress. Due to the small size of cultivated fields, compared to the spatial resolution of satellite images (10 – 20 m), temporal signal (NDVI from TOA reflectance in Red and PIR bands) extracted for each sampled plot was analyzed and smoothed using Stavitsky-Golay algorithm to eliminate noise linked to mixed pixels, but also to clouds, different sensors, and atmospheric effects. This allowed isolating only plots having a pure temporal signal (by comparing raw temporal signal and smoothed one). A set of twelve satellite variables was then extracted from the NDVI temporal profile of each plot: maximum NDVI of the growing season and integrals of the NDVI on different periods of the growing cycle. These satellite variables were compared to total biomass, dry biomass, full and empty grain yield to analyze the correlations. Results showed that the more the sorting was drastic (elimination of plots having a temporal NDVI profile with too much noise), the more the correlations between satellite and yield variables were good (but with less population). With a sorting leading to a resulting population of 14 irrigated rice plots (over the 88 plots initially available), the best correlations were obtained with the use of the integral of NDVI from the middle of the growing slope to the maximum of NDVI of the growing cycle (here referred to as integral.mid.max). Good and very significant ($p \leq 0.01$) linear correlations were obtained between this integral.mid.max and total biomass ($R^2 = 0.68$) and straw biomass ($R^2 = 0.61$). For grain yield, the correlation was less important ($R^2 = 0.58$) but significant ($p \leq 0.01$). Empty grain yield showed non-significant correlations with all satellite variables.

The estimation of rice crop production still needs to be analyzed further.

Plans for Next Growing Season

The same approach will be maintained for the next growing season but with time series of Sentinel-2 images (preprocessed by the CNES MUSCATE processing chain to obtain images in top of canopy reflectance and monthly synthesis free from clouds) and SPOT 6/7 images for the very high spatial resolution of the site during the peak of the growing season.

We anticipate ordering the same type/quantity of EO data next year.

Publications

Bontemps S., Arias M., Cara C., Dedieu G., Guzzonato E., Hagolle O., Inglada J., Matton N., Morin D., Popescu R., Rabaute T., Savinaud M., Sepulcre G., Valero S., Ahmad L., Bégué A., Bingfang W., de Aballeyra D., Diarra A., Dupuy S., French A., ul Hassan Akhtar I., Kussul N., Lebourgeois V., Le Page M., Newby T., Savin I., Verón S.R., Koetz B., Defourny P. 2015. Building a data set over 12 globally distributed sites to support the development of agriculture monitoring applications with sentinel-2. *Remote Sensing*, 7 (12) : p. 16062-16090.

13. Mali

No report received.

14. Mexico

No report received.

15. Morocco

Team Leaders: Lionel Jarlan (lionel.jarlan@cesbio.cnes.fr) and Saïd Khabba (khabba@uca.ac.ma)

Team Member: (JECAM correspondent) Vincent Simonneaux (simonneaux@ird.fr)

Project Objectives

The original project objectives have not changed. They are:

- Crop identification and Crop Area Estimation: Landcover maps at medium scale resolution from NDVI time series using either a thresholding algorithm, or an off-the-shelf algorithm for supervised classifications.
- Crop Condition/Stress: Methodological developments for the estimation and monitoring of surface states with multi-sensor, multi-spectral remote sensing of surfaces. Evapotranspiration from infrared thermal (energy budget approach) and visible data (FAO-56 coupled with NDVI time series).
- Soil Moisture: High resolution soil moisture, by disaggregation of SMOS satellite measurements based on thermal and visible data (Merlin et al., 2009, 2012, 2013) and Sentinel-1 radar data.
- Yield Prediction and Forecasting: A PhD thesis is working on the forecasting of wheat yield at the plot level using empirical relations linking yield with remote sensing data, or using efficiency models (Monteith like). ☐
- Others: The team has also as main objective the hydrological modeling of the whole Tensift watershed, including the mountainous part providing most of the water (with a significant fraction as snow) and the irrigated agricultural plain. In this framework, we are developing a modeling platform by satellite and ground observations to predict the evolution of resources under human pressure and climate changes. We especially compare various approaches of evapotranspiration estimate with contrasted level of

complexity and their application for irrigation management, and intend to assimilate various satellite products (VIS, SAR, TIR) to improve model functioning. Another objective is the production of bio-physical indicators at regional level using remote sensing data (drought, soil moisture, yield, etc.). This axis includes the study of inter-annual variability and the predictability of parameters.

Site Description

The watershed is located in the Tensift region of Marrakech in Morocco (Figure 92). Covering an area of about 20,000 km², it is composed of 3 hydrological parts. South of the basin, the northern slopes of the Atlas are well-watered and have snow (up to 600 mm / year). Peaking at over 4,000 m, these mountains are the water tower of the Haouz plain. In the center, a vast plain, characterized by a semi-arid climate (rainfall 250 mm / year), and where the water flows are predominantly vertical except for wadis and water infrastructures. The main irrigated areas are located in the central and eastern part (2000 km²) and rain fed cereals are grown on the rest of the plain. Wheat is the main crop with over 80% of acreage in wheat, followed by olive trees which occupy about 13% of the plain, and the remainder is occupied by citrus, apricot, market gardens, vineyards, fodder. These proportions change significantly in the irrigated area where tree crops dominate. In the north, the small chain of arid mountains "Jbilet" has, as far as we know, little influence on the hydrological cycle in the region.

Two test sites are considered for JECAM:

- The R3 sector is a 3000 ha area with flood irrigation on demand located 40 km east of Marrakech. The main crop is Winter Wheat. The other crops, representing less than 20% of the cultivated area, are sugar beets, olive trees, etc. The soil texture is mainly Clay Loam. The growing season of winter wheat is December-June, sugar beets from November to June, and olive groves are evergreen with latency during the summer. The whole site has been under study since 2002 and benefited from several remote sensing campaigns with optical (SPOT, Landsat, Formosat), thermal (Aster, Landsat), and SAR (ASAR) satellite time series.
- The Agafay plantation is a mandarin orchard located 20 km east of Marrakech which occupies 500 ha. The plantation benefits from drip irrigation. The soil texture is loam. Mandarin trees are evergreen with latency during the summer. The site has been monitored since 2006 with an eddy covariance system, soil temperature and humidity sensors, and flux meters. Sapflow measurements have been conducted for separation of evaporation and transpiration.

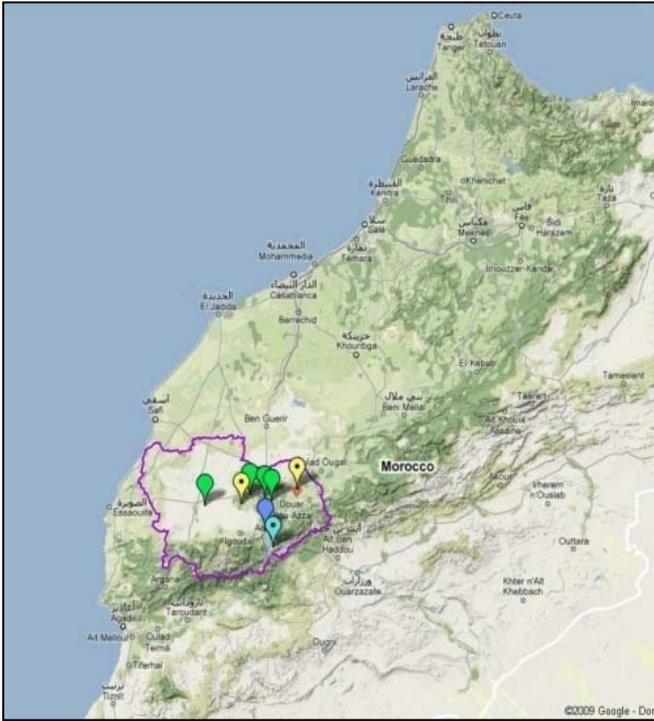


Figure 92 Location of the Tensift Watershed in Morocco

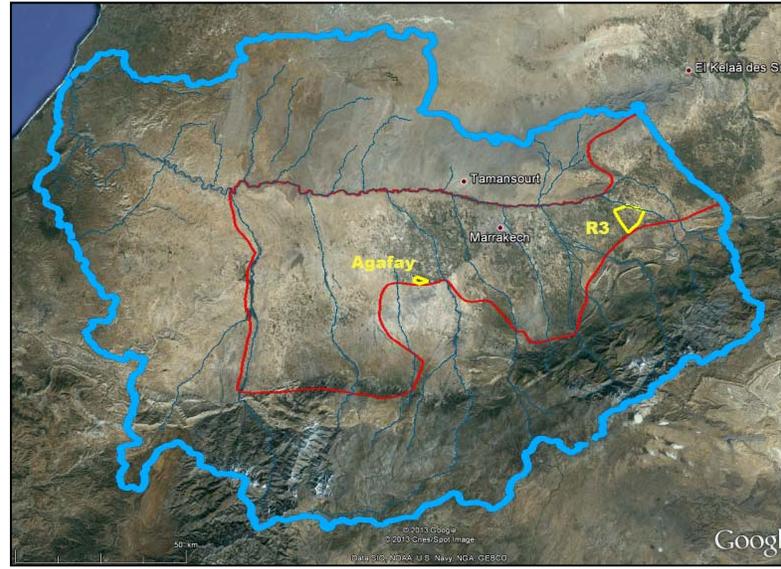


Figure 93 Location of the Haouz Plain (red) and two Sites (yellow) in the Tensift Watershed (blue)



Figure 94 A Wheat Field in the Haouz Plain of Marrakech, with the High Atlas Mountain in the Background

EO Data Received/Used

We have not received any EO through JECAM. The EO images used during 2015 are shown in Table 16.

	Supplier	Optical/SAR	Number of scenes	Range of dates	Processing level	Challenge ordering	Challenge Using
SMOS	CATDS	Passive Microwave (L-band)	>100	2002 onwards	L3	none	Spatial resolution
MODIS	LPDAAC	Optical	>100	2002 onwards	L2-L3	none	none
Sentinel-1	ESA	SAR	>100	2014 onwards	L1B	none	Soil moisture retrieval
Landsat-8	USGS	Optical (shortwave IR reflectance and TIR brightness temperature)	>100	Since launch	Surface reflectances and brightness temperatures	none	TIR data require atmospheric corrections (depending on application)
Landsat-7	USGS	Optical (shortwave IR reflectance and TIR brightness temperature)	>100	Since launch	Surface reflectances and brightness temperatures	none	TIR data require atmospheric corrections (depending on application)
SPOT 5-Take5	CNES	VIS-NIR	53	April – Sept 2015	TOC reflectance	Call for submission	Not yet

Table 16 EO Images Used during 2015

In situ Data

The team has installed an observatory running since 2002 (http://www.cesbio.ups-tlse.fr/fr/sudmed/sites_ateliers_maroc.html) which is collecting basically meteorological data (rainfall, wind speed, T, Rg) for about ten permanent stations, and additionally some flux experiments measuring especially ET using eddy correlation, soil moisture). These flux measurements are done each year on some annual crops (wheat) or during several years on permanent land cover (trees, rain fed wheat). For the 2015-2016 season, an experiment

comparing drip and traditional gravity irrigated wheat was installed including a lysimeter to monitor soil percolation.



Figure 95 Experiment on Winter Wheat with Eddy Correlation (top pictures) and Lysimeter (bottom pictures)

Collaboration

The International Joint Laboratory TREMA associates several partners from the research and academic sector (University Cady Ayad of Marrakech, Moroccan Center of Energy and Nuclear Sciences, Moroccan National Meteo Center, French Laboratory CESBIO) as well as decision makers (Basin Agency of the Tensift River, Regional Office of Agriculture). The LMI TREMA works in close collaboration with the “Merguellil team” in Tunisia, which is also a JECAM site (CESBIO and G-EAU labs, Tunisian Insitute of Agronomy). The Tensift site is part of the S2-AGRI project financed by the European Space Agency and will benefit from Sentinel-2 image surface reflectance processing.

We have also been approached to work on the neighbouring Tadla area (by the National Center for Remote Sensing) and in the Bahira plain (another lab from Marrakech University).

Results

Based on a lot of work done by the team since 2002 regarding crop hydrological functioning, the research in 2015 focused on the soil moisture retrieval (both surface and root zone) using microwave and thermal data, using disaggregation. This type of information may potentially be used directly by irrigation managers, and also to feed land surface models.

In addition, work is being done on the fractioning between vegetation transpiration and soil evaporation, as a key knowledge to assess crop water use efficiency and to suggest irrigation management improvement.

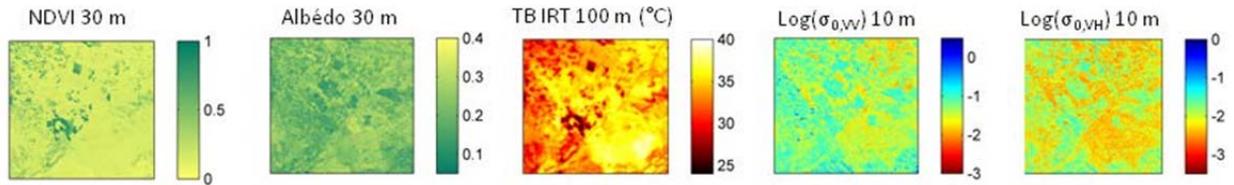
Also we are still working on yield assessment which is a key variable for decision makers.

Soil moisture retrieval

Currently, the soil moisture data sets available at global scale have a spatial resolution much coarser than the typical size (several ha) of fields. In particular, the soil moisture retrieved from passive microwave observations such as C-band AMSR-E (Advanced Microwave Scanning Radiometer-EOS; Njoku et al. 2003) and L-band SMOS (Soil Moisture and Ocean Salinity, Kerr et al., 2010) data have a spatial resolution of about 60 km and 40 km, respectively. The recent SMAP (Soil Moisture Active and Passive, Entekhabi et al. 2010) mission, launched in 2015, ensures continuity of L-band derived soil moisture products with similar resolutions. In this context, downscaling methodologies have been developed to improve the spatial resolution of readily available passive microwave-derived soil moisture data. DISPATCH (DISaggregation based on Physical And Theoretical scale CHange, Merlin et al. 2012b; 2013a) estimates the soil moisture variability within a 40 km resolution SMOS (or 10 km resolution SMAP) pixel at the target 1 km resolution using MODIS data and the target 100 m resolution using Landsat data (Merlin et al. 2005; 2006b; 2008a,b; 2009; 2010a). The DISPATCH method relies on a self-calibrated evaporation model.

In the microwave domain, active sensors (radars) achieve a spatial resolution much finer than that of radiometers. Successfully launched on 3 April 2014, Sentinel-1 (Torres et al., 2012) provides C-band SAR (Synthetic Aperture Radar) data at a spatial resolution of about 20 m with an unprecedented repeat cycle of 6 days by combining both ascending and descending overpasses (3 days by combining the two satellites available from 2016). Although backscatter data have potential to monitor surface soil moisture (e.g. Balenzano et al., 2011), there is currently no operational product at such fine resolution. This is due to the difficulty to model in time and over extended areas the impact of vegetation cover/structure and surface roughness on the backscatter signal (e.g. Satalino et al., 2014), and thus the need for site-specific calibration (e.g. Zribi et al. 2011).

Within the H2020 REC¹ framework (See Plans for Next Growing Season), we propose to combine Sentinel-1 SAR data with DISPATCH-disaggregated SMOS/SMAP soil moisture to derive a soil moisture product at both high-spatial and high-temporal resolutions. Figure 96 shows an investigation of synergy between Landsat-8 NDVI, surface albedo and TIR brightness temperature data and Sentinel-1 backscatter coefficients for soil moisture retrieval over an irrigated area near Marrakech.

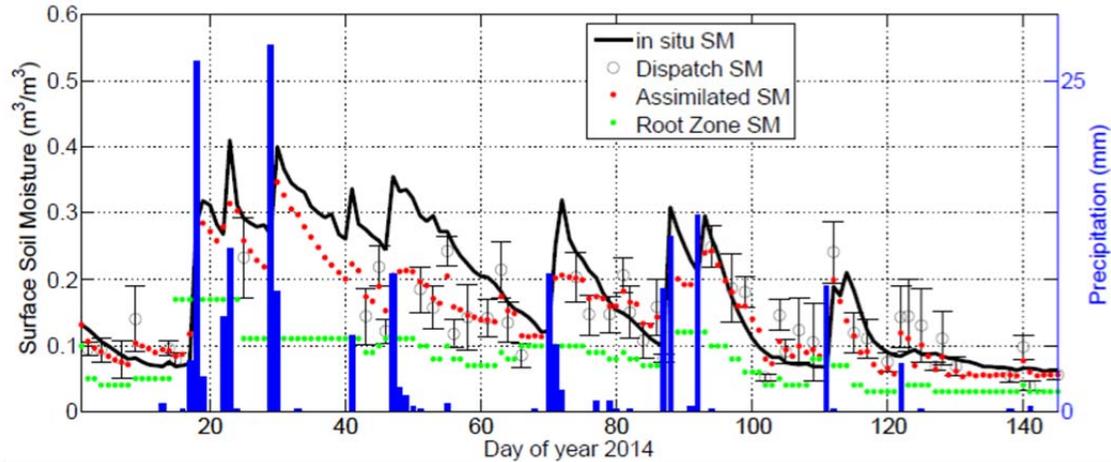


A. Amazirh PhD Thesis

Figure 96 Investigation of Synergy between Landsat-8 NDVI, Surface Albedo and TIR Brightness Temperature Data and Sentinel-1 Backscatter Coefficients for Soil Moisture Retrieval

As an original application of the above soil moisture products available over agricultural areas, we are investigating a remote sensing-based method to estimate irrigation. The proposed approach consists in combining the 1 km resolution DISPATCH data (disaggregated from SMOS and using MODIS data) and the modeling of the water budget in the soil surface (Malbêteau PhD thesis). In practice the remotely sensed soil moisture is assimilated into a force-restore type model that is forced by available meteorological including precipitation data. The approach has been tested already over a rain fed wheat area where no irrigation occurs (see **Figure 97**). As a step forward, we are extending it to an irrigated area in the Haouz plain where irrigation dates and volumes are precisely recorded using on-ground sensors for validation (see the REC campaign described in Plans for Next Growing Season).

¹ REC is a project funded by Europe. A summary can be found at: http://cordis.europa.eu/project/rcn/194344_en.html



(Y. Malbêteau PhD Thesis)

Figure 97 Assimilation of DISPATCH Soil Moisture Data into a Dynamic Model for Mapping Irrigated Areas and Retrieving Irrigation Dates

Among the considerable variety of existing approaches to estimate ET from remote sensing data, the most widely used approach is to force the FAO-56 method (Allen et al., 1998, 2005) with NDVI data (Bausch and Neale, 1989). However, the FAO-NDVI method is not sufficient to accurately estimate water consumption, especially when soil evaporation and stress under full vegetation cover conditions occur as highlighted by Er-Raki et al (2007). Within this context, Chirouze et al (2014) compared several approaches based on thermal imagery that should be better suited for evapotranspiration estimate under stressed conditions. Those approaches, either solving the surface energy budget at the pixel scale or assuming that complete stress conditions (from unstressed to fully stressed) are present in a remote sensing image, provide snapshot estimates of evapotranspiration at the time of the satellite overpass. This work highlights the good performance of the TSEB model for evapotranspiration estimates. TSEB has been further evaluated in different crop conditions by Bigeard et al (2015, submitted to HESS) and Diarra et al (2013). At the same time, a consistent and unifying interpretation of the image-based approaches in Moran et al (1994) and in Roerink et al (2000) was proposed. The monosource surface energy balance model (SEB-1S) estimates the evaporative fraction (defined as the ratio of evapotranspiration to the available energy) from satellite data composed of surface temperature, a vegetation index (e.g. NDVI) and surface albedo, resulting in accurate evapotranspiration estimates at 100 m resolution (Merlin 2013). Recently, Stefan et al 2015 have integrated a soil energy balance model in the image-based approach to improve the robustness of SEB-1S when applied to low resolution (MODIS like) data. As a further step, the SEB-1S approach was extended to a multi-source representation of agricultural fields (Merlin et al 2014). The main originality of SEB-4S (four source surface energy balance model) is to explicitly separate the energy and water fluxes of unstressed green (photosynthetically active)

vegetation, non- transpiring green vegetation, senescent vegetation and bare soil. SEB-4S has hence potential to better characterize the portion of evapotranspiration unusable for crop productivity (soil evaporation) and the crop water need (via the plant transpiration) from satellite images solely. Its modeling structure is also well adapted for integrating in the future the near-surface soil moisture retrieved from microwave data, as a further constraint on the evaporation/transpiration partitioning.

Partition between evaporation and transpiration

When estimating evapotranspiration, it is important to separate soil evaporation from plant transpiration. This would allow the assessment of irrigation efficiency, considering the objective is to minimize evaporation, and this is important in regions where water is scarce. In the project, the partition between T and E is measured on the ground using isotopic techniques or sap flux measurements. We also test models based on this criteria. The ISBA (Interactions Soil-Biosphere-Atmosphere) model was used for estimating ET and its partition over an olive orchard and a wheat field located near Marrakech City (Centre of Morocco). Two versions were evaluated: (1) a version which simulates a single energy balance for the soil and vegetation and (2) the recently developed multiple energy balance (MEB) version which solves a separate energy balance for each of the two sources. The test was done using previous eddy covariance measurements operated during years 2003-2004 for the Olive Orchard and during 2013 for wheat. The transpiration component was measured using a Sap flow system during summer over the wheat crop and stable isotope samples were gathered over wheat. The comparison between ET estimated by the ISBA model and that measured by the Eddy covariance system showed that the MEB version yielded a remarkable improvement compared to the standard version. The result also showed that the MEB version simulates more accurately the crop transpiration compared to the standard version.

SPOT5-TAKE5 experiment

A time series of 53 SPOT 5 images was acquired on our site from 9 April to 11 September 2015. The processing of this data has not been completed yet. The objectives are to use it to force a model for evapotranspiration estimates using the FAO56 method coupled with Kcb obtained from the NDVI from these images (SAMIR tool developed by the team).

Plans for Next Growing Season

The daily management of irrigation requires knowledge about the right amount of water that is needed by crops. The Spanish ASG (Aigües del Segarra Garrigues) and the Moroccan ORMVAH (l'Office Régional de Mise en Valeur Agricole du Haouz) have stressed the importance of

spatialized information on the soil water content in the root zone to optimize the use of irrigation water. The specifications mentioned by both ASG and ORMVAH regarding a potential soil moisture product are: spatial resolution finer than 100 m with temporal frequency of 1 per day. Note that the frequency of 1 per week remains, given the constraints imposed by the current water distribution systems. The scientific approach of the H2020 RISE REC (2015-2019) project aims to achieve those specifications by combining readily available multi-sensor remote sensing including Sentinel-1, Sentinel-2, Landsat-8, MODIS and SMOS data with adequate land surface modeling. REC partners are UPS-CESBIO, IRD-CESBIO, UCAM and two Spanish SMEs, isardSAT (PI) and LabFerrer, in collaboration with irrigation agencies. To meet the REC objectives, an original experiment is being conducted in two wheat crops located 40 km east of Marrakech. It combines advanced instrumentation (eddy covariance, tension controlled field lysimeters, sap flow and Photochemical Reflectance Index sensors) dedicated to a close monitoring of all the water fluxes in soil and at the surface-atmosphere interface. Moreover, the remote sensing variables (surface soil moisture, radiometric temperature, surface albedo, vegetation and water stress indices) are being measured continuously in both wheat crops, as well as in the surrounding area. Such data will allow the REC approaches to be tested for flood and drip irrigated wheat crops.

We anticipate ordering the same type and quantity of EO data next year.

Publications

Articles

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2. Ayyoub A., Khabba S., Er-Raki S., Merlin O., Bahlaoui A. 2016. Calibration and validation of the Penman-Monteith Model for estimating evapotranspiration of an orange orchard in semi-arid region. *Acta Horticulturae*, accepté. ☒
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 6. Stefan V., Merlin O., Er-Raki S., Escorihuela M.J., Khabba S. 2015. Consistency between in situ, model-derived and image-based soil temperature endmembers: towards a robust data-based model for multi-resolution monitoring of crop evapotranspiration. *Remote sensing*, 7(8): 10444-10479. doi:10.3390/rs70810444.
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 8. Malbêteau Y., O. Merlin, B. Molero, C. Rüdiger, S. Bacon (2016) DisPATCh as a tool to evaluate coarse-scale remotely sensed soil moisture using localized in situ measurements: Application to SMOS and AMSR-E data in Southeastern Australia. *International Journal of Applied Earth Observations and Geoinformation*, pp. 221-234. doi:10.1016/j.jag.2015.10.002 [DOI](#)
 9. Merlin O., V. G. Stefan, A. Amazirh, A. Chanzy, E. Ceschia, T. Tallec, J. Beringer, P. Gentine, S. Er-Raki, S. Bircher, and S. Khabba, Modeling soil evaporation efficiency in a range of soil and atmospheric conditions: A downward approach based on multi-site data, *Water Resources Research*, under review, 2015. [DOI](#)

16. Paraguay

No report received.

17. Russia

17.1 Stavropol

No report was received this year.

17.2 Tula

Team Leader: Igor Savin (V.V. Dokuchaev Soil Science Institute)

Team Members: Yuri Verniuk (ATI PFUR), David Sharychev (ATI PFUR), Irina Veretelnikova (V.V. Dokuchaev Soil Science Institute), Aidyn Bairamov (ATI PFUR)

Project Objectives

The original project objectives have not changed. We are working on the following:

1. Winter crop identification early in the season based on MODIS data
2. Monitoring of soil moisture in the rooting layer and in the ploughed horizon based on MODIS and Hyperion data
3. Winter crop phenological development based on MODIS and Landsat data.
4. Monitoring of soil erosion based on Landsat and Hyperion data.

Site Description

- Location: The site is located in the south of the Tula region of Russia (Plavsk district).
- Topography: The territory is characterized by slightly undulated plane, dissected by small river valleys.
- Soils: The dominant soil is chernozem with silty-clay texture and high humus content. The soil is eroded on the slopes.
- Drainage class/irrigation: The soil is moderately drained. Irrigation is absent.
- Crop calendar: Winter crops are sown in September. The flowering is at the end of May, and harvest is in July.
- Field size: Typical field size is near 100 hectares.
- Climate and weather: The climate is temperate with moderately cold winters (air temperature near -10°C) and warm summers (air temperature near $+25^{\circ}\text{C}$). The amount of precipitation is near 450 mm per year.

EO Data Received/Used

We used mainly MODIS and Landsat data, which were downloaded from the USGS Global Visualization web site (<http://glovis.usgs.gov/>). We use daily MODIS data for the year, and all available Landsat scenes. Additionally we have received a number of scenes of HYPERION. All scenes were acquired at dates close to the dates of field visits: 10 April 2015, 25 May, 30 June, 25 July and 25 August. Of these scenes only 3 were cloud-free (Figure 98).

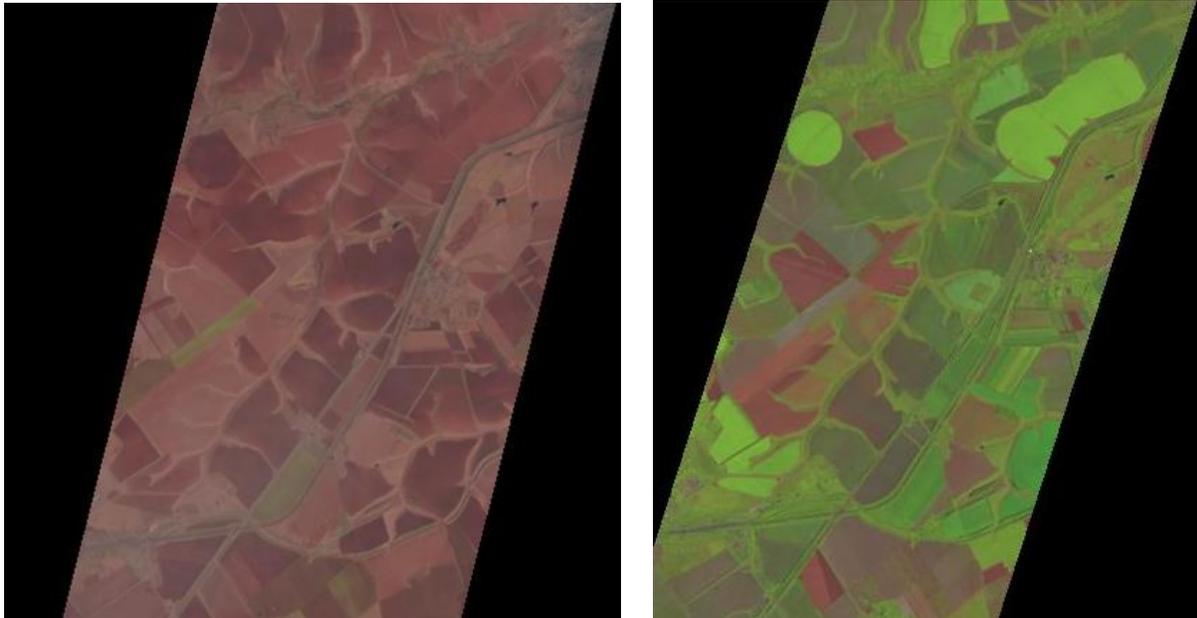


Figure 98 HYPERION Colour Composites (left) 10 April 2015 and (right) 25 July 2015

In situ Data

We made the following in situ observations:

- Crop type: Discrimination among crop types in georeferenced plots (60 plots). Frequency: once per crop season.
- Crop status was defined one time per month using hemispherical photo analysis by CanEye software. Used LAI and CF based on analysis of nadir photos of crop canopy.
- Soil moisture content: Measurements in selected georeferenced representative points. Frequency: before crop sowing, in the middle of the season, after crop harvesting (nearly 30 points).
- Crop phenology: Visual determination of phenological states. Frequency: each month during the growing season (nearly 30 plots).

- Soil erosion status (soil humus content): Samples were collected in selected georeferenced representative points and humus content was analyzed in the laboratory. Frequency: once in the year, after the harvest (nearly 30 samples).



Figure 99 Obtaining “Fish-eye” Photos over Winter Wheat



Figure 100 Soil Sampling



Figure 101 Soil Moisture Content Measurements

Collaboration

Our site has been included as a test site of the ESA Sen2-Agri Project (Project leader Pierre Defourny, UCL). We supplied the Project with field data on crop status, collected one time per month during crop growing season. The data have been used for the validation and calibration of the project approach.

Results

We have conducted field visits once per month from April 2015 to August 2015. See Figures 102 and 103. In Figure 103, the colour points indicate different crop types. The preliminary analysis of the collected data leads to the conclusion that soil moisture content in the ploughed soil layer can be detected by using Hyperion and Landsat data. MODIS data are not suitable for this purpose.

It has been found that weeds on many fields affect the NDVI and LAI, calculated based on Landsat and MODIS data. The effect of weeds differs from field to field due to crop type and crop development status.

To achieve more reliable conclusions we plan to collect more field data in 2016.

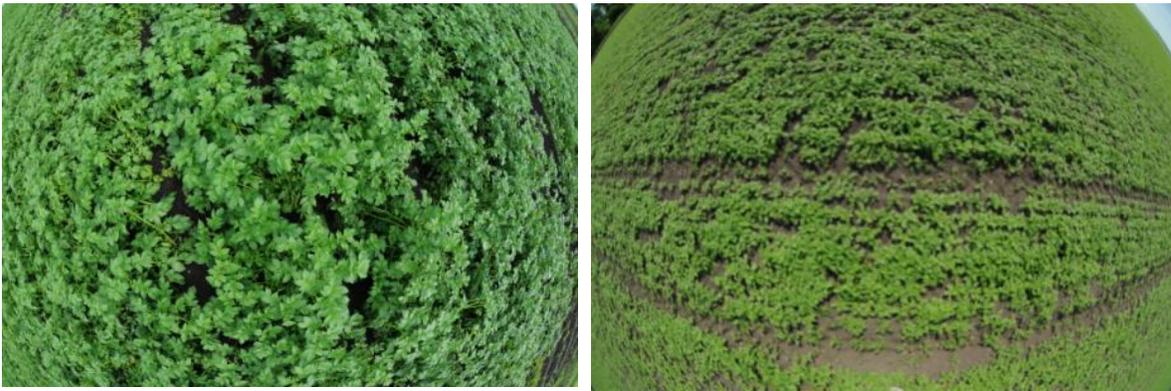


Figure 102 Examples of HSP

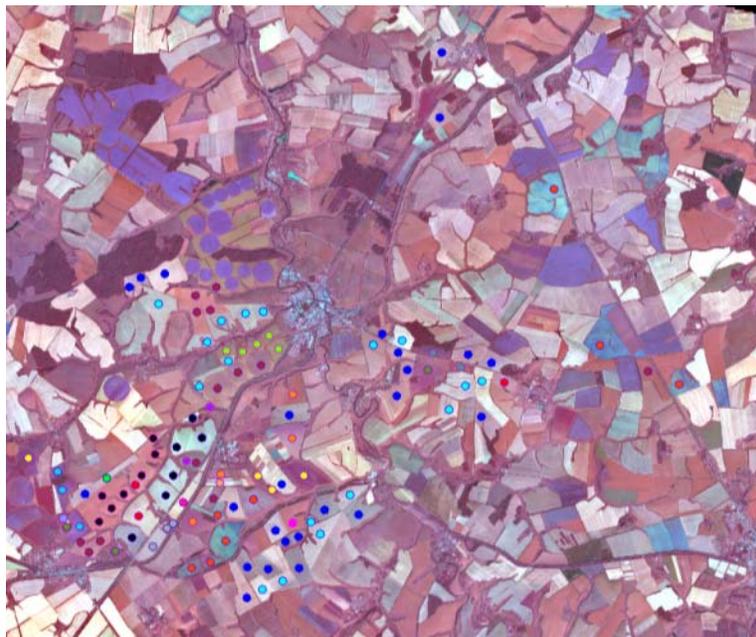


Figure 103 Field Crop Type Identification Results

Plans for Next Growing Season

In 2016, we plan to continue the same approaches.

We anticipate ordering the same type/quantity of EO data next year. In addition, we plan to test UAV (unmanned aerial vehicle) for crop status detection.

Publications

Bontemps S., Arias M., Cara C., Dedieu G., Guzzonato E., Hagolle O., Inglada J., Matton N., Morin D., Popescu R., Rabaute T., Savinaud M., Sepulcre G., Valero S., Ahmad I., Bégué A., Bingfang Wu., de Abelleira D., Diarra A., Dupuy S., French A., Ibrar H., Kussul N., Lebourgeois V., Le Page M., Newby T., Savin I., Veron S., Koetz B., Defourny P. BUILDING A DATA SET OVER 12 GLOBALLY DISTRIBUTED SITES TO SUPPORT THE DEVELOPMENT OF AGRICULTURE MONITORING APPLICATIONS WITH SENTINEL-2 // Remote Sensing. 2015. T. 7. № 12. C. 16062-16090.

18. Saudi Arabia

No report was received this year.

19. Senegal (Bambey)

Team Leader and Members: Valérie Soti (CIRAD), Séraphin Dorego (ISRA/CNRA), Bambey in Senegal; Ousman Bocoum (CSE Institute) of Dakar in Senegal

Project Objectives

The original objectives of our site have not changed. They are:

- Crop identification and crop acreage estimation: millet, groundnuts and maize
 - New sub-objectives: Crops and trees temporal evolution since 1968
- Crop Condition/Stress
- Soil moisture: Joor and Deck soils
- Other: Delineation and identification of trees and shrubby vegetation.

Site Description

- Location :

Top-Left

Latitude: 14.819407°
Longitude: -16.660269°

Top-Right

Latitude: 14.819419°
Longitude: -16.468938°

Bottom-Left

Latitude: 14.624525°
Longitude: -16.661012°

Bottom-Right

Latitude: 14.625431°
Longitude: -16.468897°

- Crop Types: Millet, Groundnuts and Maize
- Typical Crop Rotation: Millet and Groundnuts
- Topography: low slope, 30 m mean elevation
- Soils: Ferruginous tropical sandy soils (Joor and Deck soils)
- Drainage class/irrigation: Very poorly drained; no irrigation
- Irrigation Infrastructure: Wells and forages
- Crop calendar: July to the end of October
- Field size : around 200 m²
- Climate and weather: sub-Saharan climate with a wet season from September to November and a dry season from December to August.

- Agricultural methods used: low level mechanization dominated by draft animals and manual labour.

EO Data Used

1. CNES (ISIS Program)

- Optical: Pléiades satellite image
- 4 scenes (ISIS Program) since 2013
- 2013/01/16; 2013/12/31 and 2014/10/30, 2015/12/15
- Incidence angles : 7° (2013/01/16), 7.5° (2013/12/31), 7° (2014/10/30), 6° (2015/12/15)
- Spatial resolutions: 2 m in multispectral mode, and 0.5 m in panchromatic
- Spectral resolution: blue, green, red, near infrared
- Ortho level correction, UTM / WGS84 projection

2. TerraSAR-X (GeoSud program)

- Radar: TerraSAR-X Images
- 5 scenes during the 2014 rainy season
- Acquisition dates: 2014/07/24 ; 2014/08/15; 2014/09/06, 2014/09/28; 2014/10/20
- Polarisation : HH/VV (2014/07/24) ; HH/HV (2014/08/15); HH/HV (2014/09/06), HH/HV (2014/09/28); HH/VV (2014/10/20).
- Spatial resolution: 3 cm
- Spectral band: X
- Ortho level correction, UTM / WGS84 projection

3. Landat-8 (USGS portal)

- Optical : Landsat-8
- 12 scenes during the rainy season 2014
- Acquisition dates: from 2014/05/29 to 2014/11/21

- Spatial resolutions: 15 to 30 mm according to the band
- Spectral resolutions: 11 bands
- Ortho level correction, UTM / WGS84 projection

4. Spot 6/7 images (JECAM program)

- Optical : Spot 6 and 7 Images
- 2 scenes (one during the dry season, and one during the rainy season 2015-16)
- Acquisition dates: 2015/09/20; 2016/01/06
- Incidence angles: 5.5° (2015/09/20) and 3° (2016/01/06)
- Spatial resolution: 6 m in multispectral and 1.5 m in panchromatic mode
- Spectral resolution: blue, green, red, near infrared
- Ortho level correction, UTM / WGS84 projection

In situ Data

Vegetation field data collected in Bambey study area and used for satellite image processing was as follows.

Table 17 Vegetation Field Data Collected in Bambey Study Area

Missions	Number of fields	Number of trees
February 2013	397	427
February 2014	400	356
October 2014	458	758
Total	1255	1541

For each culture and trees, we collected geographic information with the GPS, the types, the species and the states of the culture or tree (Figure 104). Weekly rainfall data from 2013 to 2015 was collected by the ISRA/CNRA Bambey Institute.

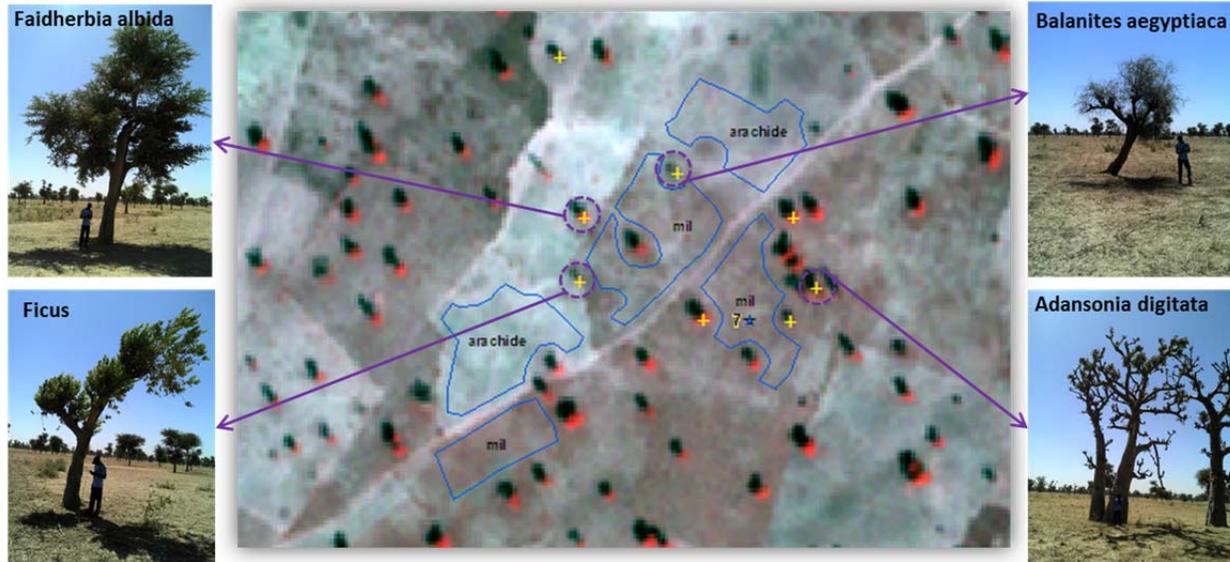


Figure 104 Pléiades Image Showing Different Tree Species in Bambeby Study Area

Collaboration

The first results and image acquisition have been initiated within the framework of TRECS (CNES funding), RECOR (WAPP funding) and SAFSE (Cirad funding) Projects which are ongoing. The partners in these projects are the CSE (Centre de Suivi Ecologique) of Dakar (Senegal) for field data collection and image processing, the ISRA Agronomic institute and the Biopass/IRD laboratory located in Dakar for insect field data collection and identification; the French IRSTEA research center of Montpellier (France) for developing radar image processing methods for cropping surveys; and the Cirad for spatial analysis and modelling to identify landscape management that enhances natural regulation of millet and groundnuts insect pests.

Results

Millet and Groundnuts Identification with Optical and Radar Sensors

Comparing the three maps that we created using Pleiades data alone (2013/01/16; 2013/12/31, 2014/10/30), results show that the millet and groundnuts crops are better classified during the dry season (2013/01/16; 2013/12/31), with respectively 81.4 and 82 % of good ranking. Indeed, contrary to all expectations, in the wet season (2014/10/30), the millet is only classified well in 47% and 30 % for the groundnut with the Pleiades image acquired in October 2014 used alone. On the other hand, the combination of the Pleiades image with the Landsat-8 time series in 2014 allowed to improve the classification (Random forest classification) with 80% of millet and groundnuts well classified and also to discriminate other crops which was technically impossible

during the dry season (Figure 105). Indeed, images acquired during the wet season allowed classifying the Niébé with 68.48%, the sorghum with 97.71%, the fallows with 89.83 % and the pastureland with 79.35% accuracies.

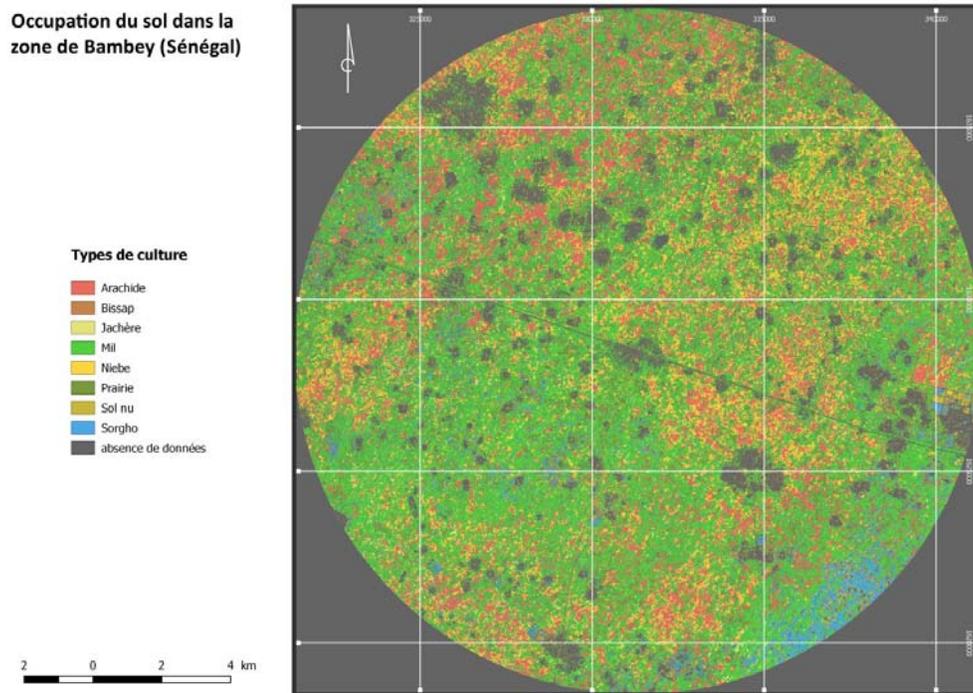


Figure 105 Land Use Map derived from the Combination of one Pleiades Image and Landsat-8 Time Series Acquired during the Wet Season 2014

Using the Normalized Difference Vegetation Index (NDVI) of the Landsat-8 image series, we also studied the phenological state of the main cultures (see **Figure 106** below). The NDVI allows one to follow the state of the cultures during the wet season. Most of them began to develop their leaves around August 15, and were mature with dense vegetation cover at the beginning of October 2014.

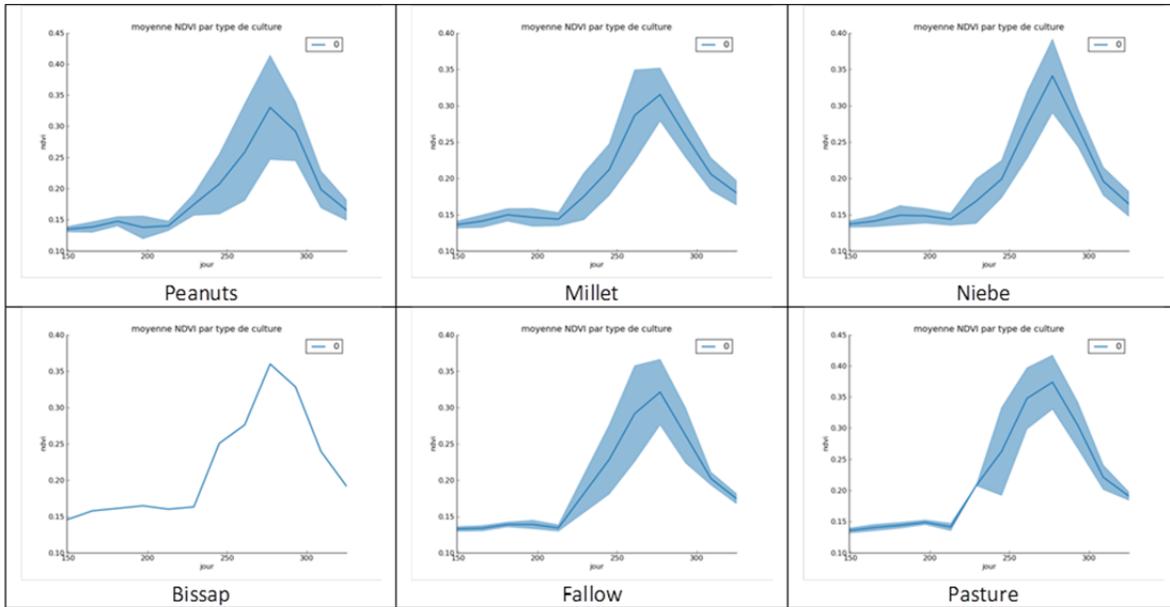


Figure 106 NDVI Temporal Profiles derived from Landsat-8 Time Series of the Main Cultures in the Bambeby Area during the Wet Season 2014

Millet and Groundnuts Conditions with a Radar Sensor during the Rainy Season 2014

We also tested a time series of TerraSAR-X radar images in Bambeby study area for crop discrimination and also to study the dynamics of their phenological states. After image calibration, different polarimetric parameters such as Shannon entropy and Pauli decomposition and methods as unsupervised classification based on H/A/α parameters and the SEaTH algorithm were performed. Unfortunately, these methods were not as effective in discriminating groundnuts from millets or in following their phenological states as the optical sensors tested (Figure 107).

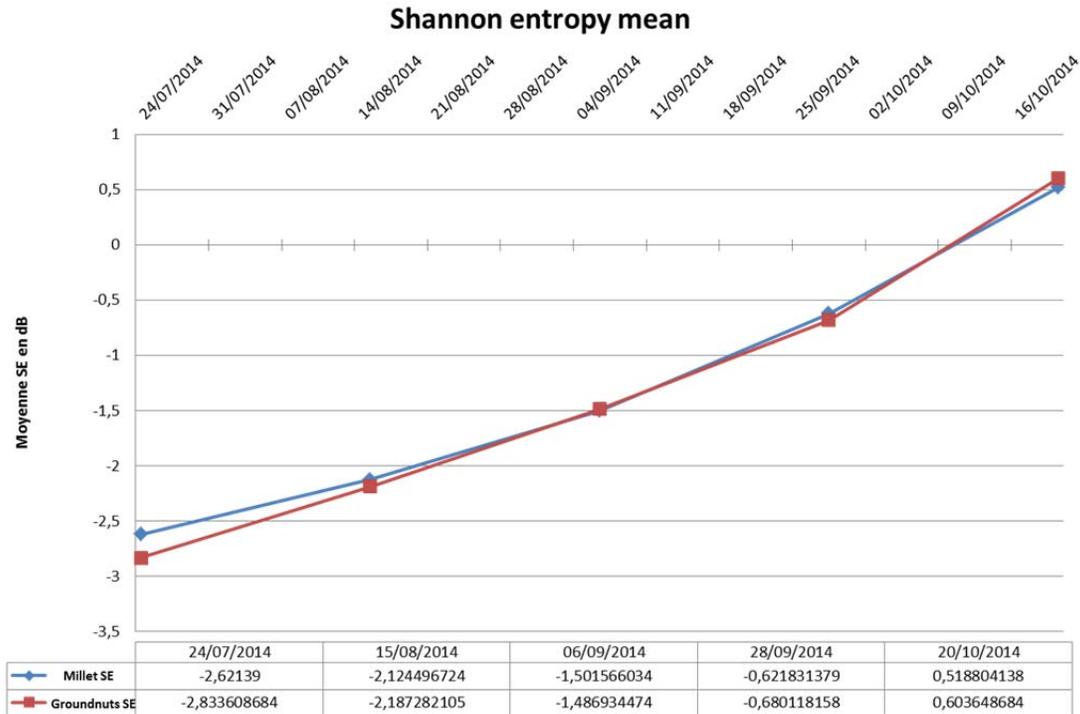


Figure 107 Millet and Groundnuts Temporal Profiles Showing the Shannon Entropy Mean derived from TerraSAR-X Time Series in Bambey Area during the Wet Season 2014

Evolution of the Crops and Trees since 1968

Our aim in this study is to follow the agricultural spatiotemporal dynamics in the Niakhar area close to Bambey village since 1968. We want to measure the evolution of the crop to the detriment of the natural vegetation and more especially the trees which are very important for soil fertilization, for biodiversity conservation and also for the people’s needs (firewood, medicine, fodder...). To achieve that, we acquired from the CSE Institute archived satellite photography from the Corona American mission in 1968, which had 2 m spatial resolution. We also acquired two Spot 6-7 satellite images within the framework of the JECAM Program. We recently performed the ortho-rectification of the images and now we plan to map trees (species if possible) and the groundnut and millet crops.

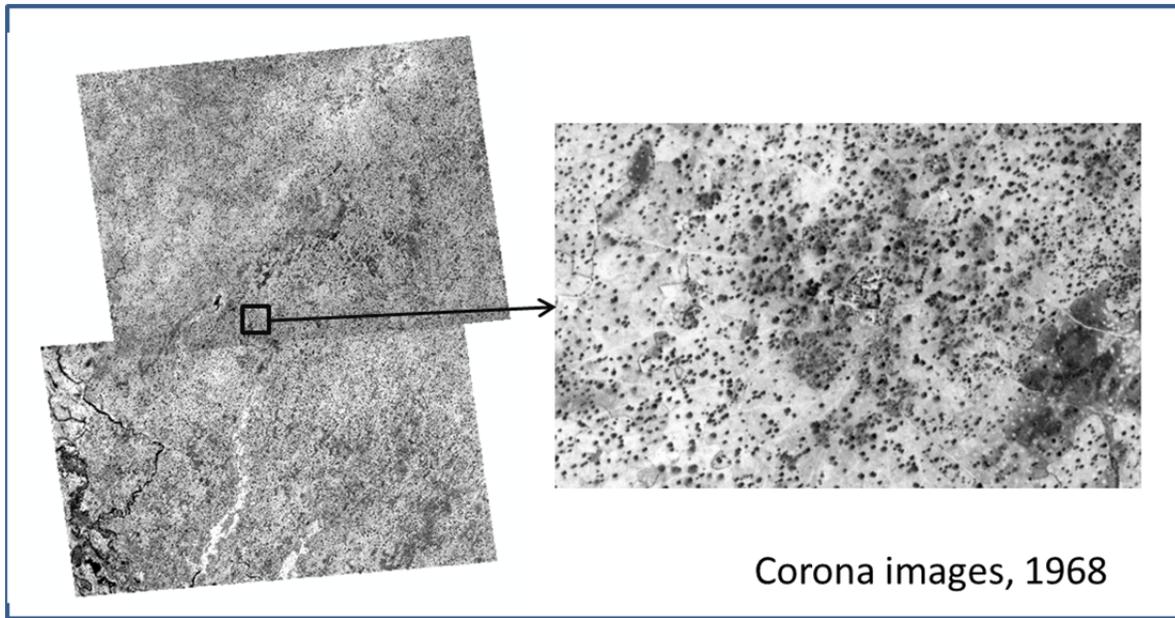


Figure 108 Corona Images, 1968

Plans for Next Growing Season

To build on these first results in the near future, and especially to improve identification of trees, we plan to use satellite images with a richness of bands and a high revisit time, such as the Sentinel-2 sensors which have 13 spectral bands during the dry season when trees are leafy.

Publications

Currently we have no publication within the framework of the JECAM program. The main reason is that the images became available very recently. However, we plan to publish a paper on the evolution of the rural area since 1968.

20. South Africa (Free State Province)

Team Leader and Members:

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Project Objectives

The original project objectives have not changed. They are:

- Crop identification and Crop Area Estimation
Operational crop area estimation for winter (Wheat, Barley) and summer (Maize, sunflower, sorghum, soya and dry beans) crops continue. This data is fed to the national Crop Estimations Committee. Operational systems are continually improved as technologies and systems become available. Satellite imagery is used to delineate and update the national cultivated field database as well as to selectively classify crop type.
- Crop condition/ stress
The Umlindi system, based on coarse resolution imagery (Proba V and Modis) and in situ (weather station data) continues to issue its monthly newsletter on drought monitoring, crop condition and other relevant information. The system is continually improved as new indices are incorporated.
- Soil moisture

The Umlindi system issues a monthly soil water product generated using the Topkapi model run by the University of KwaZulu-Natal. A number of soil water sensors have also been added to some of the automatic weather stations located in the JECAM site.

- Yield prediction and forecasting

Yield data for wheat and maize is also operationally collected and all this data is fed to the national Crop Estimations Committee for monthly national production estimates. Operational systems are continually improved as technologies and systems become available.

- Crop Residue, Tillage and Crop Cover Mapping

Not currently addressed due to resource constraints.

Site Description

See www.JECAM.org for the site description.

EO Data Received/Used

Landsat: South Africa is covered by approximately 74 Landsat frames.

- Space agency or Supplier: USGS
- Optical/SAR: Optical
- Number of scenes: Approximately 500 Scenes
- Range of dates: August 2014 up to May 2015
- Beam modes/ incidence angles/ spatial resolutions: 30m
- Processing level: Ortho-rectified
- Challenges, if any, in ordering and acquiring the data: none
- Challenges, if any, in processing and using the data: none

SPOT: South Africa is covered by approximately 450 Spot frames.

- Space agency or Supplier: SANSA
- Optical/SAR: Optical
- Number of scenes: 450 Single Date
- Range of dates: 1 April 2014 up to October 2014
- Beam modes/ incidence angles/ spatial resolutions: Panchromatic 2.5m & Colour 10m
- Processing level: Ortho-rectified
- Challenges, if any, in ordering and acquiring the data: None
- Challenges, if any, in processing and using the data: None

In situ Data

Climate Data

Forty-two weather stations within the JECAM site collect data daily. Parameters include rainfall, temperature, wind speed and direction, and soil water at a selected number of stations (5). The following graph shows data collected at one of the stations for rainfall and soil moisture.

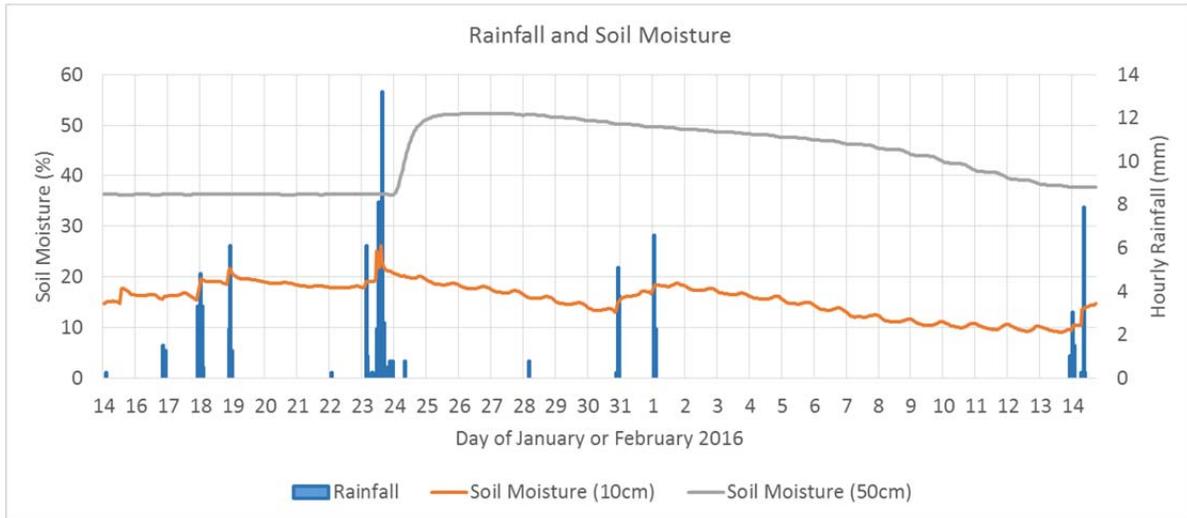


Figure 109 Hourly Rainfall (bars) and Soil Moisture (% at 10 cm and 50 cm) at Bethlehem for the Period 14 January to 14 February 2016

Crop Type Observations

The Producer Independent Crop Estimation System (PICES) collects around 4500 visual observations of crop type with in fields (and some ancillary data) from light aircraft for the winter and summer growing season. These points comprise observations of statistically selected sample points as well as opportunistic observations between sample points while traversing the agricultural area. This data is used to estimate crop type areas.

Yield Measurements

At around 670 points, yield measurements are collected in situ for wheat and maize. These are used to estimate average yield for the province for the two crops.

Figure 110 shows the crop condition on a scale of 1 (good) to 9 (total failure) on 18 February 2015. Drought ravaged some areas of the Free State.

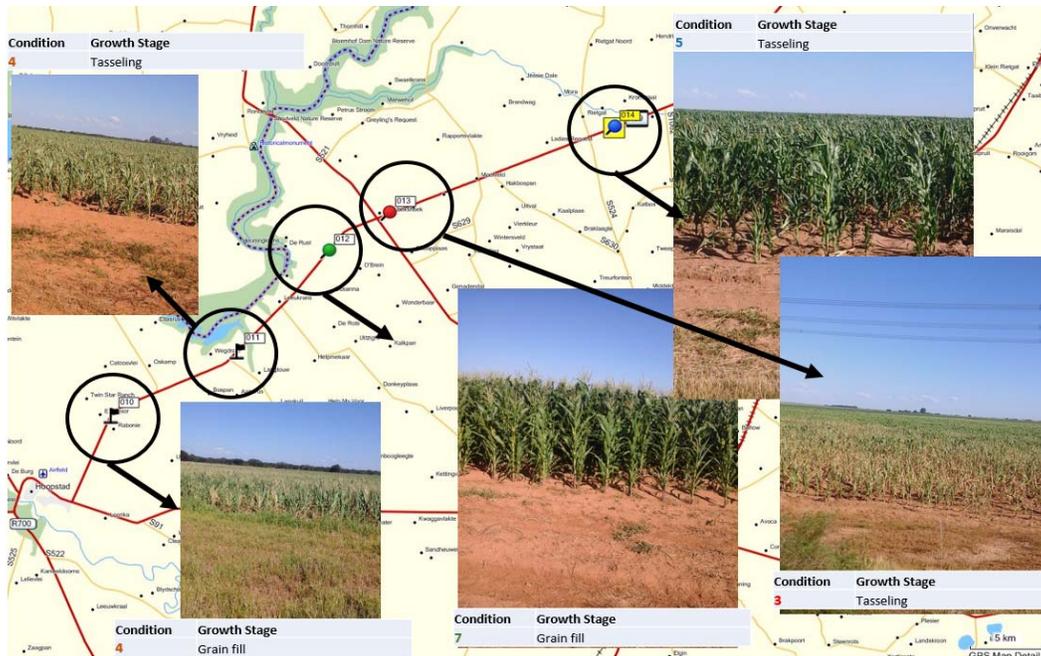


Figure 110 Crop Condition at 18 February 2105

Collaboration

Data from this JECAM site has been used by the **Sentinel-2 Agriculture project** of ESA for the development of the crop monitoring system.

Results

The crop monitoring and estimation system operational in this JECAM site provided data to the National Crop Estimation Committee. This committee issued the following official estimates for the Province:

Wheat (2015 season): 80,000Ha planted, 208,000 tons harvested (6th production forecast – 27 Jan 2016)

Total Maize (2014/2015 season): 1,220,000 Ha planted, 3,945,000 tons harvested (Final production forecast 29 Sept 2015)

Yellow Maize (2014/2015 season): 510,000 Ha planted, 1,708,500 tons harvested (Final production forecast 29 Sept 2015)

White Maize (2014/2015 season): 710,000 Ha planted, 2,236,500 tons harvested (Final production forecast 29 Sept 2015)

Sunflower: 285,000 Ha planted, 370,500 Tons harvested (Final production forecast 29 Sept 2015)

Sorghum: 36,000Ha planted, 45,000 tons harvested (Final production forecast 29 Sept 2015)

The operational system is working well and is being continually improved as research results are operationalized.

The current operational system, PICES, and the yield estimation system that supplies crop estimate information to the national Crop Estimates Committee are considered a best practice methodology.

This is confirmed by a recent quote from the Crop Estimates Liaison Committee representing the South African Agricultural grain crop industry. “The Crop Estimates Liaison Committee, as oversight body over the Crop Estimates Committee, congratulates and thanks the CEC for the sterling work they did over this past season. The 2015 season was exceptionally difficult since a serious drought and heat wave made crop estimates extremely difficult, but the CEC nevertheless were well within the 5% deviation target with their maize estimates right from the first estimate in February 2015. That is exceptional and needs to be recognized”, Dr John Purchase, Chairman of the CELC (and member of the GEOGLAM Steering Committee) said today (11 Feb 2016).

Plans for Next Growing Season

We plan to maintain the current approach next year. The EO data to be ordered next year will include Sentinel-2 data when available.

Publications

Yacob G. Beletse, Wiltrud Durand, Charles Nhemachena, Olivier Crespo, Weldemichael A. Tesfuhuney, Matthew R. Jones, Mogos Y. Teweldemedhin, Sunshine M. Gamedze, Pontsho M. Bonolo, Syanda Jonas, Sue Walker, Patrick Gwimbi, Thembeke N. Mpuisang, Davide Cammarano, Roberto O. Valdivia. 2015, *Chapter 4: Projected Impacts of Climate Change Scenarios on the Production of Maize in Southern Africa: An Integrated Assessment Case Study of the Bethlehem District, Central Free State, South Africa*. In Rosenzweig C, & D Hillel (2015) *The Agricultural Model Intercomparison and Improvement Project (AgMIP) Integrated Crop and Economic Assessments* — Joint Publication with American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America (In 2 Parts).

21. Spain (Barrax-Albacete)

Team Leader and Members: Fernando Camacho, Consuelo Latorre, Fernando de la Cruz

Project Objectives

The original objectives for your site have not changed? They are:

- Crop identification and Crop Area Estimation: Developing methods for crop identification and crop area estimation from HR. 2 maps/ year (winter/summer).
- Crop biophysical variables: Estimation of Biophysical variables (LAI, FAPAR, cover fraction). Seasonal monitoring of selected crops (continuous acquisitions). Intensive campaigns (multitemporal) and up-scaling with high resolution imagery.

Mapping biophysical variables from EO data, either from empirical relationship or physically-based methods.

Site Description

- Location:

The study area is located in the experimental farm of “Las Tiasas” in Barrax (Albacete, Spain), managed by ITAP (Instituto Técnico Agronómico Provincial, S.A.). The Barrax test site is situated within La Mancha, a plateau 700 m above sea level. The test site is located in the west of Albacete province, around 20 km far away from the capital town.

- Geographic Lat/Lon, WGS-84 (units=degrees). See **Table 18**.

Site Extent (25 km ²)			
Centroid	Latitude:	39.054371	Longitude: -2.100677
Top-Left	Latitude:	39.167	Top-Right Latitude: 39.167
	Longitude:	-2.244	Longitude: -1.954
Bottom-Left	Latitude:	38.942	Bottom-Right Latitude: 38.942
	Longitude:	-2.244	Longitude: -1.954

Table 18 Geographic Coordinates of Spain (Barrax) Site

- Topography: The area is characterized by a flat morphology and large uniform land-use units, surrounded by large areas of cereals. Differences in elevation range up to 2m. **Figure 111**

shows an aerial photo of the study area with 10x10 km and 25x25km footprints over Google Earth.

- Soils: Moderately well drained. The soil is classified as Petrocalcic Calcixerepts, with a silty-clayloam texture (13.4% sand, 48.9% silt, and 37.7% clay)
- Drainage class/irrigation: Irrigation Infrastructure: Sprinklers and pivots. Soil Drainage Class: Moderately well drained
- Crop calendar: Winter and summer crops
- Field size: Between 15 and 100 hectares
- Climate and weather: The climatic conditions are in line with the typical Mediterranean features: high precipitation in spring and autumn and the minimum in summer. The annual rainfall average is about 400 mm. The region has high thermal oscillations during all seasons. La Mancha represents one of the driest regions of Europe. The region consists of approximately 65% dry land and 35% irrigated land with different agricultural fields. **Figure 112** shows examples of landscapes taken in May 2015.



Figure 111 Aerial Photo of the Study Area

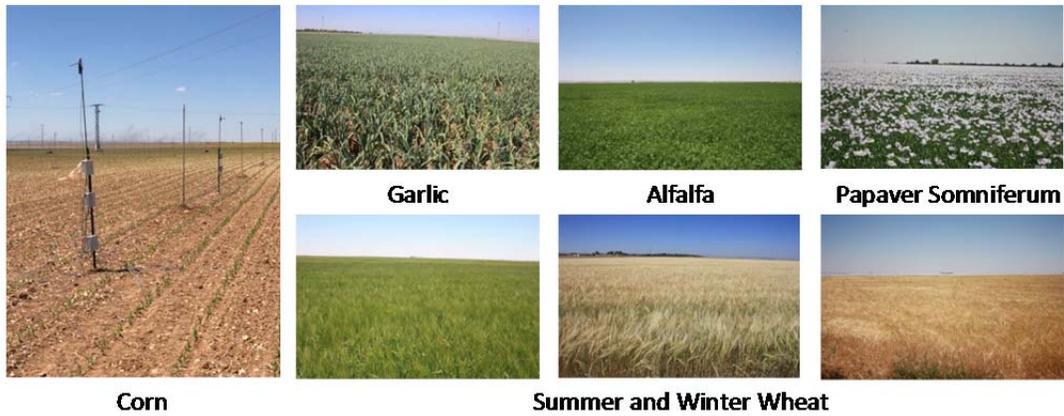


Figure 112 Examples of Landscapes Taken in May 2015

EO Data Used

Space agency or Supplier: through the USGS Global Visualization service.

Optical/SAR: Optical Landsat-8 HR imagery

Number of scenes: Two scenes downloaded (7 June and 16 July) were up-scaled with data from field campaigns carried out in these dates.

Several other images were downloaded in order to validate the data from PASTIS-PAR sensors installed from May to September. A total of 14 Landsat-8 cloud-free images. We have processed this dataset although we have not analyzed the results yet.

Range of dates: From May to September 2015

Beam modes/ incidence angles/ spatial resolutions: 127°/30m resolution

Processing level: TOA and TOC reflectances

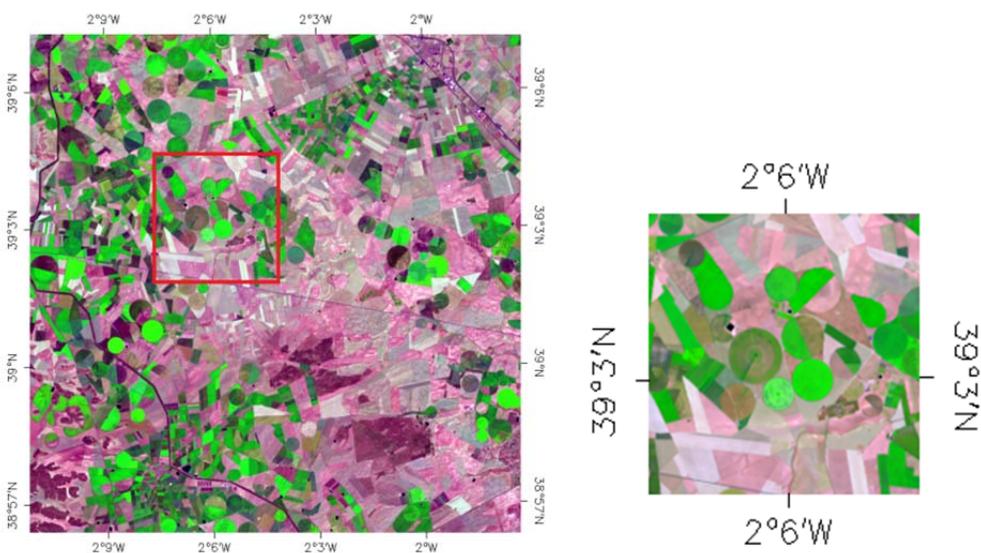


Figure 113 False Colour Composition (RGB: SWIR-NIR-RED) of TOC Reflectance Landsat-8 Images over Barrax 20 km² on 7 June (left) and 5 km² on 16 July 2015 (right)

Figure 113 shows Landsat-8 images taken on 7 June and 16 July 2015.

In situ Data

During 2015, two main activities were conducted funded by the IMAGINES project: (1) Two field campaigns on 27th May and 22nd July, 2015 for the spatial characterization of vegetation variables in the study area, conducted by EOLAB, and (2) set-up of PASTIS-PAR (PAI Autonomous System from Transmittance Sensors) systems for the continuous monitoring of FAPAR and Plant Area Index (PAI). The PASTIS-PAR sensors developed by INRA were installed from May to September.

Field Campaigns:

- First campaign: 26th – 28th of May 2015
- Second campaign: 22nd of July 2015

Several devices were used for estimating biophysical variables in the study area, including hemispherical digital photography (DHP), ceptometer (AccuPar LP-80) and LI-COR LAI 2200C plant canopy analyzer.

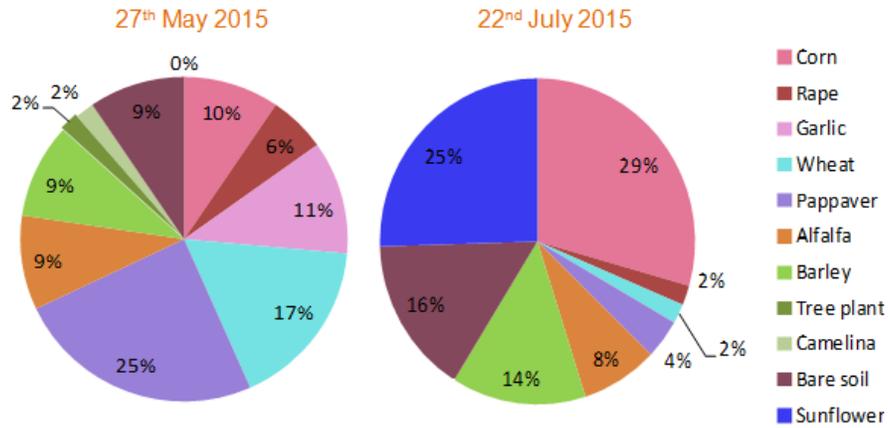


Figure 114 Distribution of Vegetation Types Sampled during the Field Campaigns

In **Figure 115**, the top left shows measurements with LAI2200C over a papaver somniferum field; the operator is Fernando Camacho. The top right shows measurements with ceptometer LP80 over a sunflower field, and operator María del Carmen Piñó. The bottom shows a field of corn where the PASTIS-PAR devices were installed on 27th May (left) and 22nd July (right), and operator Consuelo Latorre.



Figure 115 Team Involved in the Field Campaign of Las Tiesas Site in Barrax, Spain



Figure 116 Digital Hemispherical Photographs Acquired at Barrax Site during the Field Campaigns

Figure 116 shows digital hemispherical photographs acquired at the Las Tiasas-Barrax site during the field campaigns. The top shows the first campaign (27 May). The bottom shows the second campaign on 22 July.

Collaboration

In the context of validation of the Copernicus Land Service, field campaigns were supported by the FP7-SPACE-2012-1 IMAGINES project, under Grant Agreement N°311766. Many JECAM sites, such as Pshenichne (Ukraine), Ottawa (Canada), Guangdong-Xuwen (China), Tula(Russia), Capitanata(Italy) or Merguellil (Tunisia) have collaborated within the project. During 2015 the Space Research Institute NAS Ukraine, SSA and Integration-Plus provided us ground data collection over Pshenichne site for five field campaigns.

Results

Field works were deployed according the most demanding protocols. The activities were in accordance with other science developments, such as those included in [Guidelines for field campaigns, Issue I1.10](#)², showing the main elements and tasks to perform field campaigns, focused on ground data acquisitions. This approach is also in agreement with the methods proposed by the [CEOS Land Product Validation](#) group³, and the [VALERI project](#)⁴. The “best practice” is guaranteed as well by the experiences and good results of the working group developing by the FP7 ImagineS project.

Ground datasets, biophysical maps and technical reports are available at the Imagines website: <http://www.fp7-imagines.eu>

The dataset of ground data collected during two field campaigns on 27th of May and 22nd of July 2015 includes 31 and 37 elementary sampling units where digital hemispherical photographs were taken and processed with the CAN-EYE software to provide LAI, LAI_{eff}, FAPAR and FCOVER values. Additional measurements were collected with LAI2200 and LP80 devices over several ESUs. Several measures obtained during the field experiment have been used to control our maps on non-vegetated areas or non photo-synthetically active elements (senescent crops).

The sampling was evaluated based on the NDVI distribution and a quality flag map based on the convex-hull analysis performed. These maps also showed quite good quality (80% at 5x5 km² and 70% at 20x20 km²). In Figure 117, clear and dark blue correspond to the pixels belonging to the ‘strict’ and ‘large’ convex hulls. Red corresponds to the pixels for which the transfer function is extrapolated.

² http://fp7-imagines.eu/media/Documents/ImagineS_FieldCampaign_Guidelines_I1.10.zip

³ <http://lpvs.gsfc.nasa.gov>

⁴ <http://w3.avignon.inra.fr/valeri/>

High resolution ground-based maps of the biophysical variables have been produced over the site, derived using high resolution imagery (Landsat-8 TOC Reflectance) according to the CEOS LPV recommendations for validation of low resolution satellite sensors. See Figure 118 and Figure 119. Transfer functions have been derived by multiple robust regressions between ESU reflectance and the biophysical variables. Because the scene presents many senescent and harvested fields, we have selected the NDVI as input for the transfer function (an exponential relationship with LAI_{eff} and LAI, and a linear relationship with FAPAR and FCOVER). NDVI assures good consistency of the maps over the whole area. The biophysical variable maps are available in geographic (UTM 30 North projection WGS-84) coordinates at 30 m resolution.

The results of the PASTIS-PAR continuous data recorded are being analyzed and the results will be reported at the end of the Imagines project.

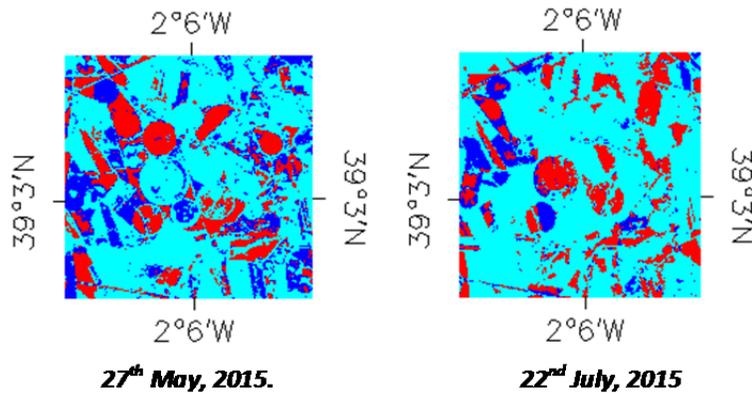


Figure 117 Convex Hull Test over 5x5 km² Areas

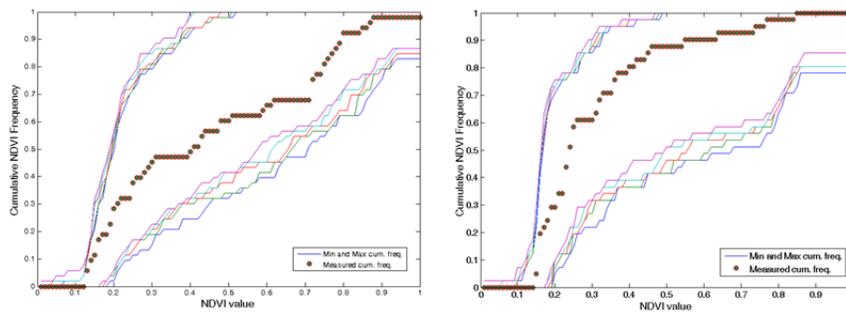


Figure 118 Comparison of NDVI TOC Distribution between ESUs (brown dots) and over the Whole Image (blue line)

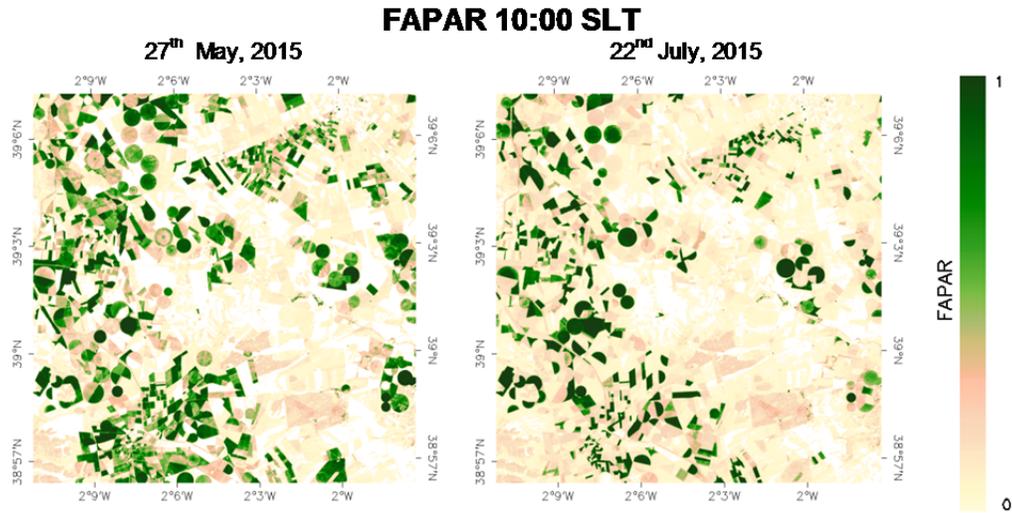


Figure 119 Ground-based Maps (20x20 km²) Retrieved at the Barrax Site

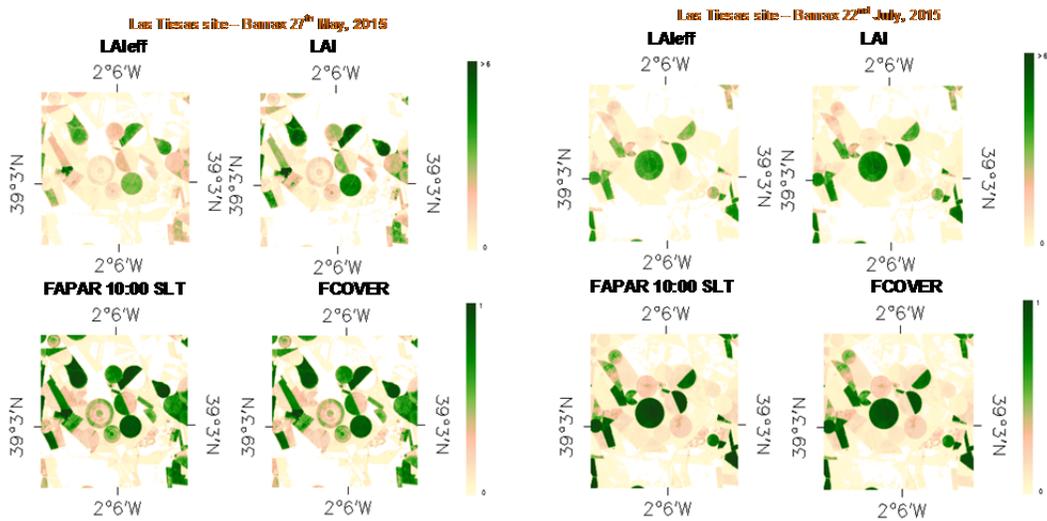


Figure 120 Ground-based Maps (5x5 km²) Retrieved at the Barrax Site

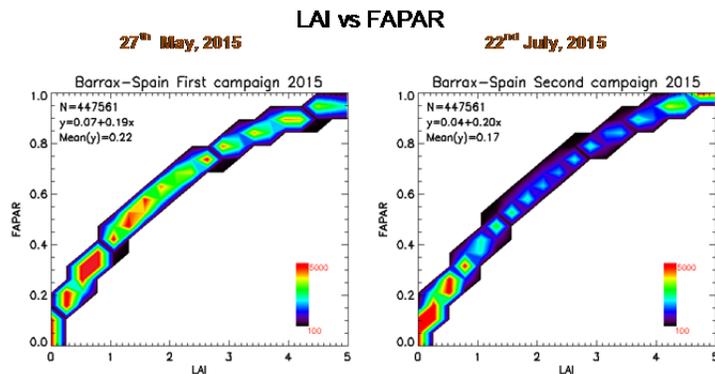


Figure 121 Scatter Plots LAI vs FAPAR for the Two Campaigns at the Barrax Site

Plans for Next Growing Season

We plan the following for next growing season:

- Crop mapping and classification of agricultural crops based on Satellite HR imagery.
- Field campaigns and ground based maps up-scaled using HR images with a robust regression algorithm.
- Use of UAV/drone for monitoring crops to retrieve biophysical maps.

Publications

ImagineS Technical report:

- C. Latorre, Camacho, F., Piñó, M.C, de la Cruz, F. (2015). **Vegetation Field Data and Production of Ground-Based Maps: Las Tiasas - Barrax site, Spain. May to July, 2015.** http://fp7-imagines.eu/media/Documents/ImagineS_RP7.5_FieldCampaign_Barrax2015_I1.00.pdf
- C. Latorre, Camacho, F., de la Cruz, F., Atienzar, F. (2014). **Vegetation Field Data and Production of Ground-Based Maps: Las Tiasas - Barrax site, Spain. 29th - 30th May, 2014.** http://fp7-imagines.eu/media/Documents/ImagineS_RP7.5_FieldCampaign_Barrax2014_I1.10.pdf

Presentations and Proceedings:

- C. Latorre, F. Camacho, F.de la Cruz, R. Lacaze, F. Baret, M. Weiss (2014). **Seasonal monitoring of FAPAR over the Barrax cropland site in Spain in support of the validation of PROBA-V products at 333 m.** 4th International Symposium on Recent Advances in Quantitative Remote Sensing, Torrent, Spain, 22-26 September 2014, (Publ. Univ. Valencia: Valencia), in press.
- F. Camacho, Lacaze, R., Latorre, C., Baret. F, De la Cruz, F., Demarez, V., Di Bella, C. et al (2015). **Collection of Ground Biophysical Measurements in support of Copernicus Global Land Product Validation: The ImagineS database.** 12 EGU2015-2209. EGU General Assembly, Vienna, Austria. 12-17 April, 2015
- F. Camacho, J. Sanchez, C. Latorre, R. Lacaze, M. Weiss, F. Baret, A. Verger, B. Smets (2016). **Collection of Ground Biophysical Measurements and Production of High Resolution Ground-based Maps in support of Copernicus Global Land Product Validation: The ImagineS database.** ESA living planet Symposium and PROBA-V Symposium.

22. Taiwan

Team Leader and Members: Chi-Farn Chen, Horng-Yuh Guo, Nguyen Thanh Son, Cheng-Ru Chen, Tsz Feng Lin, Chien-Hui Syu

Project Objectives

The original objectives for the site have not changed. They are:

- Crop identification and Crop Area Estimation: Use SAR imagery to support crop identification and crop area estimation;
- Yield Prediction and Forecasting: Collect minimum parameters corresponding to remote sensing data using standardized survey forms and procedures. The data will be inputted to adjust the DSSAT rice crop growth model in Taiwan.
- We are also working on the automatic data collection by sensor networks.

Site Description

- Location: Changhua and Yulin counties
- Topography: Plain
- Soils: Silt loam
- Drainage class/irrigation: Moderate – imperfect
- Major crop calendar: Rice (1st crop: February – early July/2nd crop: July – December)
- Field size: 0.5 – 1.1 ha
- Climate and weather: Subtropical monsoon / Typhoon/ Drought

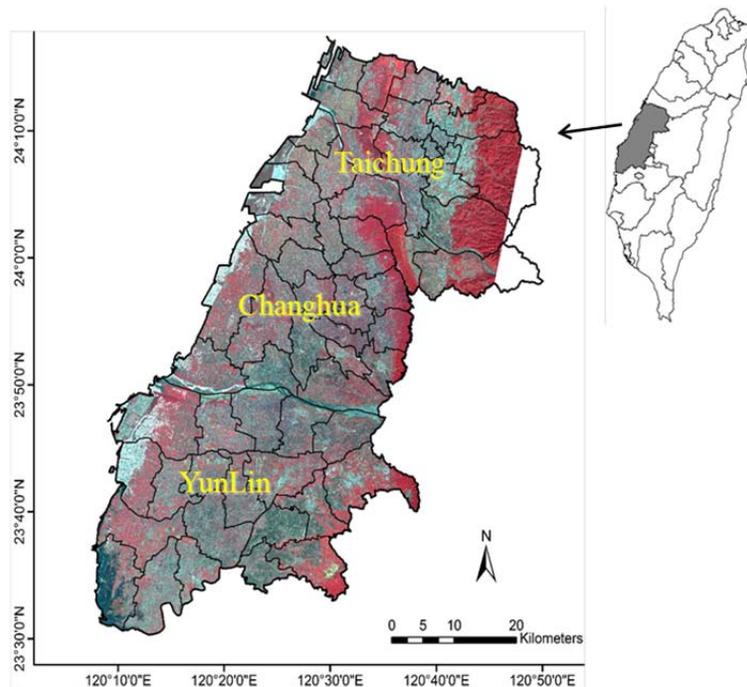


Figure 122 Map of Taiwan TARI Site

EO Data Received/Used

- RADARSAT-2
 - Supplier: CSA
 - SAR
 - Number of scenes: 28
 - Range of dates: January – August 2015
 - Beam modes/ incidence angles/ spatial resolutions: Fine wide mode.

- Sentinel-1
 - Supplier: ESA
 - SAR
 - Range of dates: May – August 2015
 - Beam modes/ incidence angles/ spatial resolutions: Fine wide mode.

- SPOT-5, SPOT-6, SPOT-7
 - Supplier: CNES
 - Optical
 - Number of scenes: 28
 - Range of dates: January – August 2015

- LandSat-8
 - Supplier: USGS
 - Optical
 - Number of scenes: 67
 - Range of dates: January – December 2015

- FORMOSAT-2
 - Supplier: NSPO
 - Range of dates: January – December 2015

In situ Data

(1) Surveys were performed during the crop growth stages by visual identification:

- Agricultural land use
- Soil type
- Crop type: Rice and cash crops
- Tillage system.



Figure 123 In situ Soil Data Investigation at the TARI Site

(2) Automatic Data Collection

Wireless sensor networks are used for monitoring various parameters in agriculture. For yield simulation using the DSSAT model, we designed and implemented a wireless sensor network to collect following parameters, including soil moisture, temperature, humidity, and crop growth condition. The Arduino architecture was selected for this prototype due to its easy and fast prototyping.



Figure 124 In situ Surveys at the TARI Site

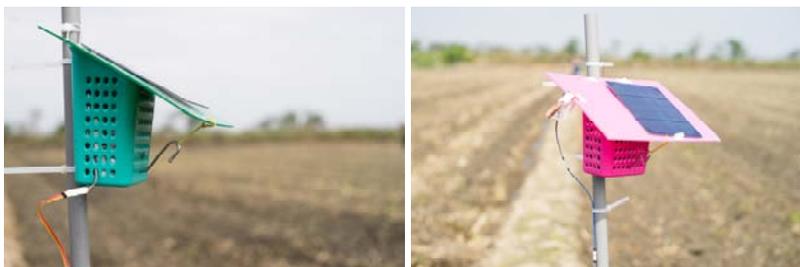


Figure 125 Wireless Sensor Data Collection

Collaboration

We have not been approached to participate in a collaborative project with other sites.

Results

The research for 2015 intended to map rice fields using RADARSAT-2 data at the Taiwan TARI site. The data were processed for the 2015 rice cropping season in four main steps:

1. data pre-processing, including radiometric and terrain corrections and speckle noise filtering of the backscattering coefficient of cross-polarization (VH) data,
2. Normalized Difference Sigma-0 Index (NDSI) calculation using 2 SAR images of sowing and heading dates selected based on the cropping calendar,
3. image classification using a threshold of NDSI, and
4. accuracy assessment of the mapping results.

The classification map compared with the government's rice crop map indicated an overall accuracy of 80% and kappa coefficient of 0.7, respectively. The rice areas derived from the RADARSAT-2 data classification were consistent with the government's rice area statistics. This study demonstrates the validity of the mapping approach for delineating rice fields at the TARI site using RADARSAT-2 data.

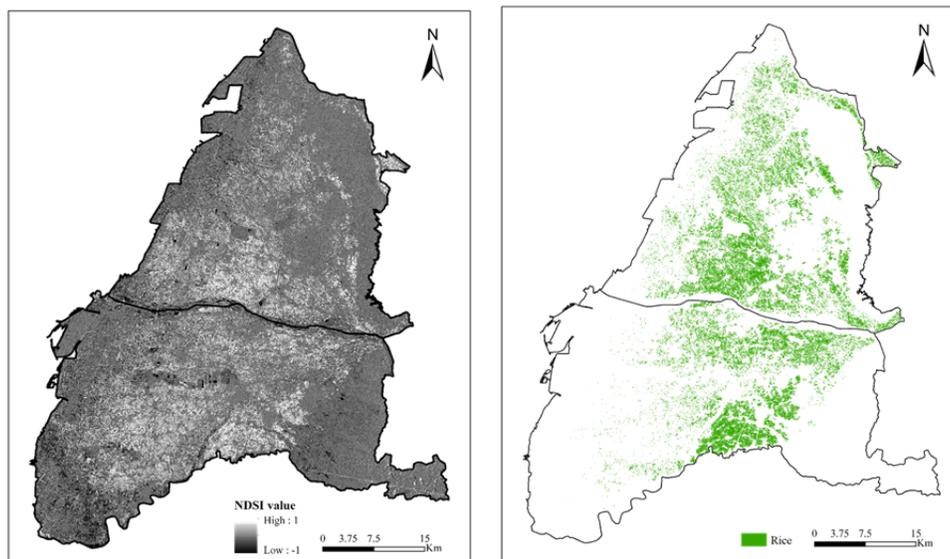


Figure 126 Sentinel-1 NDSI Map (left) and Rice Classification Map in 2015 (right)

Plans for Next Growing Season

For the next crop year (2015-2016), we will investigate the capability of RADARSAT-2 and Sentinel-1A data for crop identification and yield estimation. We will compare measurements

and yield data with requested satellite images acquired at different time steps across the growing season. Based on parameters corresponding to DSSAT crop yield model collected by sensor networks, we will estimate and forecast rice yield with different climate scenarios.

Publications

C.R. Chen, C.F. Chen, N.T. Son and K. V. Lau (2015) Statistical rice yield modelling using blended MODIS-Landsat based crop phenology metrics in Taiwan, Presented at 2015 Fall Meeting, AGU, San Francisco, Calif., 14-18 Dec.

23. Tanzania

No report received.



Figure 127 Tunisia Merguellil Site

The site is shown in Figure 127. The boundary of the upper watershed is in black, the boundary of the irrigated area is in red, and the boundary of the aquifer is in cyan.

- Topography: Alluvial plain.
- Soils: Variable texture, from fine sand to clay-loam.
- Drainage class/irrigation: Well drained soils.
- Crop calendar: See Table 19.
- Field size: Typically 1 to 4 ha.
- Climate and weather: Semi-arid mediterranean climate, rainfall around 250 mm/y, ETO around 1500 mm/year.
- Agricultural methods used: Dry cereals and olive cultivation; Irrigation for cereals, vegetables and some fruit trees (apple, peach, etc.).

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	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Melon early		Plough	Plant			Harvest						
Melon			Plough	Plant		Harvest	Harvest					
Watermelon					Plough	Plant				Harvest		
Tomato					Plough	Plant				Harvest		
Chili pepper						Plant			Harvest			
Tomato late								Plough	Plant		Harvest	
Chili pepper late								Plough	Plant		Harvest	
Broad bean	Harvest	Harvest	Harvest						Sow			
Olive trees	Prune									Harvest	Harvest	Prune
Almond trees						Harvest						
Oat					Harvest					Plough	Sow	
Barley (dry cultivation)					Harvest						Plough	Sow
Wheat (dry)	Sow					Harvest						Plough
Forage				Harvest								
Cattle pasture												

Table 19 Merguellil, Tunisia Crop Calendar



Figure 128 Flux Tower in Irrigated Barley (L); Flux Tower Installed in Dry Cultivated Olive Trees (R)



Figure 129 Orchard with Olives and Orange Trees (L); Irrigated Chili (R)



Figure 130 Field with Residues and Ploughing in Progress (L); Flow Measurements on a Pipe for Irrigation (R)

EO Data Received/Used

Although the project acquired images from various sensors (see below), only Landsat-7 and 8 images can be considered to have been acquired in the framework of JECAM. In addition, in 2015, we acquired:

- SPOT images from ASTRIUM-Geo (level 1A) with financial support of the CNES (ISIS action)
- TERRASAR images.

JECAM Progress Report 2016

Sensor	# Images	Optical /SAR	Supplier	Pixel Size	Proc. Level	Challenges Ordering	Challenges Processing
SPOT-5	3	Optical	SPOTIMAGE / CNES	10	1A	Specific offer for French Labs (ISIS Action)	Problem of getting atmospheric parameters. Global server (H2O, aerosols, ozone) are a significant advance but local photometer is better.
SPOT5-Take5	25		SPOTIMAGE / CNES	10	TOA ref	Specific set as simulator of Sentinel2	Processed using the MAACS chain prototype
SPOT 6-7	4	Optical	AIRBUS Defence and Space	5	1A	<i>Specific offer (French Data Center THEIA)</i>	Problem of getting atmospheric parameters. Global server (H2O, aerosols, ozone) are a significant advance but local photometer is better.
Landsat-7	12	Optical	JECAM / USGS	30	Radiance		Not yet processed
Landsat-8	15	Optical	JECAM / USGS	30	TOA ref		Processed using the MAACS chain prototype (designed for 2A level for THEIA)
TerraSAR	4	SAR	DLR (Germany)	2	dual polar.		
Sentinel-1	...	SAR	ESA	5-20		Free, high volume	First images
Sentinel-2		Optical	ESA/CNES/ THEIA	10-20			TOC processing in 2016

Table 20 Tunisia Site EO Data Ordered

In situ Data

- Crop identification ground campaigns for land cover classification training. Two campaigns: 80 plots in February, June and October. ☐
- Soil roughness observation on bare soil plots for SAR image processing validation. ☐
- Vegetation traits (LAI, fraction cover, biomass and yield on 15 fields) collected of wheat. ☐
- Three permanent meteorological stations (including temperature, humidity, wind speed, net radiation, rainfall).☐
- One Flux station on rain fed olive orchard (1/01 – 31/12/2015). ☐
- One X-LAS scintillometer transect (4 km) starting spring 2013 to June 2015 (area-averaged surface heat fluxes). ☐
- Soil moisture probes with automatic acquisition (8 sites on dry cultivation) + campaigns for soil surface moisture (20 sites).☐
- Surveys of monthly irrigation volumes at the perimeter scale + daily irrigation volumes at farm scale for about 30 private farms. ☐

Collaboration

The CESBIO Lab in Toulouse has two sites in north Africa (this site and the Marrakech site, also in JECAM) which are continuously communicating and are answering jointly to some calls. They are both involved in a joint project called AMETHYST funded by the French research agency (ANR). We also benefit from funding of student exchanges between Tunisia, Morocco, Algeria and France (PHC program). ☐

Results

Crop Water Budget Monitoring

Remote sensing has long been used for computing evapotranspiration estimates, which is an input for crop water balance monitoring. Up to now, only medium and low resolution data (e.g. MODIS) are available on regular basis to monitor cultivated areas. However, the increasing availability of high resolution highly repetitive VIS-NIR remote sensing, like the Sentinel-2 mission, offers unprecedented opportunity to improve this monitoring.

Methods for computing evapotranspiration (ET) using remote sensing belong basically to two broad families, either using thermal remote sensing used to solve the energy budget of the

surface, or using SVAT modeling forced by remotely sensed information of vegetation properties (e.g. fraction cover, leaf area index, crop coefficients...). The latter group includes the coupling of the dual crop coefficient method described in FAO paper 56 (Allen, 1998) with NDVI time series providing spatialized estimates of the fraction cover (f_c) and the basal crop coefficient (K_{cb}). We developed in previous work the SAMIR tool implementing this method using high resolution image time series (SPOT, Landsat, FORMOSAT and forthcoming Venus and Sentinel-2).

Instantaneous estimates of evapotranspiration

Thermal data (MODIS, ASTER, Landsat) have been used to derive actual evapotranspiration estimates (ETR). The methods have been improved by constraining ETR with potential values and using specific formalism for senescent vegetation. These algorithms have been validated for cereals (Boulet et al., 2015) and are under work for trees (rain fed and irrigated olive trees). Considering the importance of sparse coverages in the study area, a special focus has been put on the comparison of single versus dual source models (homogeneous crop or juxtaposition of bare soil and vegetation). Single source models show better results on simple crops like wheat.

Spatialized Estimates of Evapotranspiration

The objective of the work was to assess the operability of SAMIR and the accuracy of the modelled evapotranspiration (ET) at the scale of irrigated perimeters, in a context of high land cover complexity (i.e. trees, winter cereals, summer vegetables) and limited data available for parameterization.

Using the spatialized computation of the crop water budget presented in last year's JECAM report (published in *Remote Sensing*, Saadi et al. 2015), we achieved a validation of the ET using XLAS scintillometer measurements. The model was calibrated on the basis of local ET measurements from flux towers (eddy-correlation devices) installed on irrigated wheat and barley plots. For other crops for which no calibration data was available, parameters were taken from the literature. For validation, half hourly sensible heat flux measurements were obtained using a large aperture scintillometer (XLAS) over the study area along a path length of 4 km. The daily sensible heat flux (H) was used to compute daily latent heat flux (LE) using the energy budget conservation ($R_n + G = H + LE$). The daily net radiation (R_n) was computed using MODIS daily data at the time of satellite overpass (i.e. providing half hourly R_n estimates), and scaled at daily scale using a ground meteorological station. The soil flux (G) is supposed to be null at daily scale. For the R_n scaling, we used the ratio of radiation measure at the station and daily value, for both global radiation (R_g) or R_n computed using the FAO method. Both methods gave similar results. The comparison between modelled daily and measured ET are still being worked on.

Assessment of Irrigation Water Volumes at Farm Scale

The objective was to estimate the crop water consumption based on the FAO-56 method coupled with satellite estimates of crop coefficients and to compare it with pumped water volumes measured at farm scale using thermal devices (ibutton) providing times of pumping, transformed into distribution of volumes using the pump meter. The advantage of such data is that the number of crops in each farm is limited and we can better focus on discrepancies. To account for uncertainties in SAMIR parameterisation, we ran three irrigation scenarios (little irrigation, normal irrigation, high irrigation). Finally, the results gave more insights about farmers’ practices than model parameters, since for the three farms tested we see strong over-irrigation. This is consistent with the fact that some farms don’t pay for the water. In the figure below, over-irrigation shows clearly for one farm over two years.

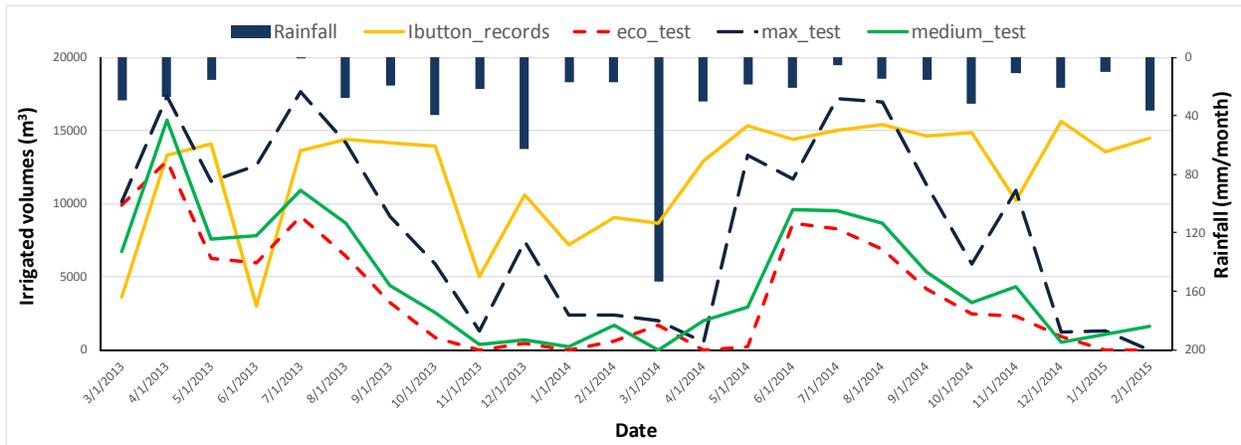


Figure 131 Comparison between Monthly Irrigation Volumes for Three Scenarios (min or eco, normal or medium, maximum or max)

Soil Water Content Monitoring and Soil Texture

Soil water monitoring using microwave data has been studied at various scales, from 1km to 2m. We present here the results on the JECAM site. A sensitivity analysis has been conducted on TerraSAR-X images regarding soil roughness and water content during three months in winter (Nov 2014-Jan 2015) and simultaneous ground observations on 15 bare soil plots. Relations have been established between the standard deviation of roughness maximum and a new SAR image parameter, Zg (Zribi, 2014a,b). Other backscattering schemes (IEM, Dubois, IEM-Baghdadi) have been validated on this data (Gorab et al., 2015).

The soil moisture is related to soil texture and clay content. A statistical approach was conducted with TerraSAR-X (Gorrab, 2015b), this method will be used with Sentinel-2 images. Another approach is to use a middle infrared index with Landsat TM data on dry bare soils to map clay content (Shabou, 2015).

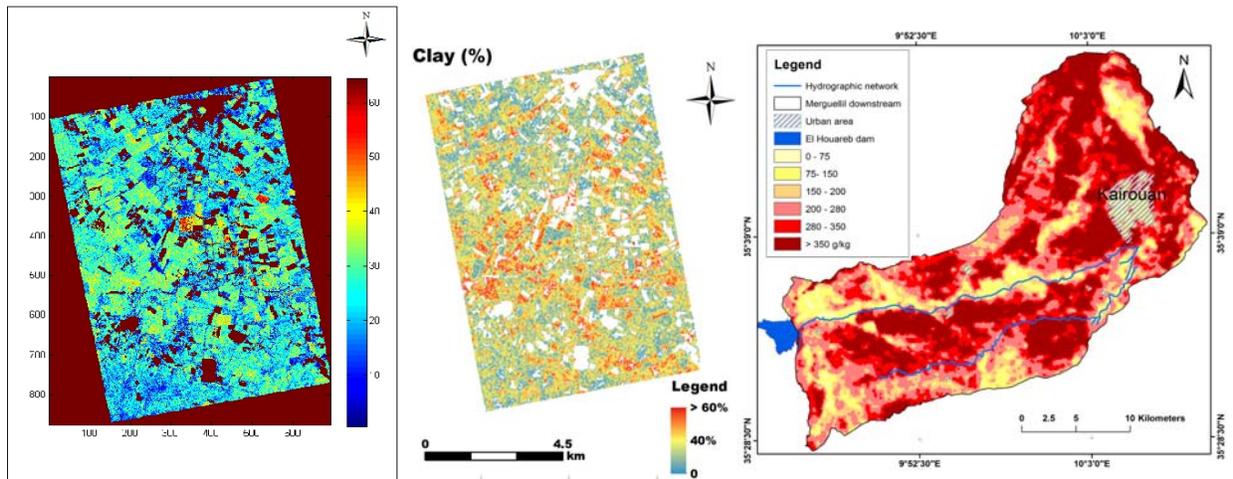


Figure 132 Soil Moisture Estimated with TerraSAR-X (L); Clay Content Estimated with Soil Moisture Mean TerraSAR (middle); Clay Map of Merguellil Plain: Co-kriging of Landsat MIR Index (R)

Yield Estimates

Wheat yields have been forecasted based on optical data (VIS-NIR) two months before harvest (Chahbi et al., 2014, 2015). This analysis is based on a three year database including satellite data and ground observations on a set of 30 wheat and barley plots. A second approach was successfully tested using the vegetation model SAFY (Simple Algorithm For Yield estimates, Duchemin et al., 2008), using as input remotely sensed LAI estimates (from VIS-NIR high resolution data) to calibrate an efficient model simulating biomass and yield.

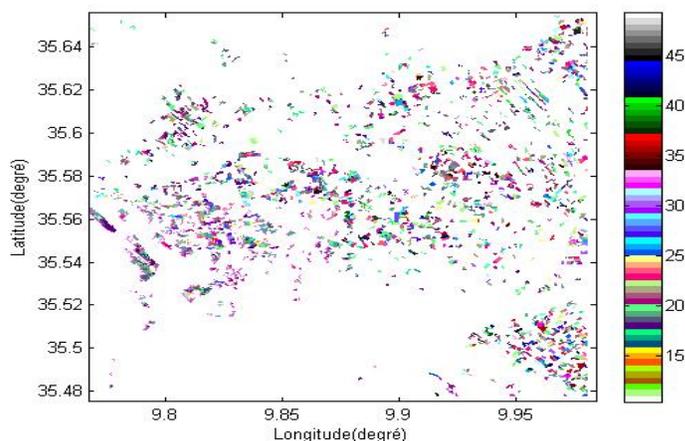


Figure 133 Yield Estimates with SAFY Model

Plans for Next Growing Season

A time series of SPOT6-7 images is currently being acquired to secure the availability of Sentinel-2 images in 2016. We will experiment with our tools such as SAMIR and these operational data to validate the model over large areas. We intend also to carry on the use of medium resolution time series (MODIS, MOD13Q1 products) with Thermal data (Landsat-8) and the new Sentinel-1 data to improve the soil water compartment control.

We anticipate ordering the same type/quantity of EO data next year.

Publications

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Saadi S., Simonneaux V., Boulet G., Raimbault B., Mougenot B., Fanise P., Ayari H. and Lili Chabaane, Z., 2015, Monitoring irrigation consumption using high resolution NDVI image time

series. Calibration and validation in the Kairouan plain (Tunisia), *Remote Sens.* 2015, 7(10), 13005-13028; doi:10.3390/rs71013005

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25. Ukraine

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Project Objectives

The original objectives have not changed.

- Crop identification and Crop Area Estimation
- Crop Condition/Stress.

Site Description

The main activities in 2015 were carried out for the JECAM test site in the Kyiv region.

- Location

The site consists of two parts:

- the whole Kyiv region (28,000 sq. km) intended for crop mapping and acreage estimation;
- intensive observation sub-site (25x15 sq. km) indented for crop biophysical parameters estimation. This sub-site consists of a research farm of the National

University of Life and Environmental Sciences of Ukraine where intensive in-situ measurements are being collected.

The latitude and longitude of the site and sub-site are given in Table 21. The map of the site is shown in Figure 134.

Table 21 Geographical Coordinates of the Ukraine Test Sites

Kyiv		
Centroid		Latitude: 50.355 Longitude: 30.715
Site Extent	Top left	Latitude: 51.54 Longitude: 29.26
	Bottom right	Latitude: 49.17 Longitude: 32.17
Sub-site for Intensive Observation (Pshenichne research farm of NULESU).		
Centroid		Latitude: 50.075 Longitude: 30.11
Site Extent	Top left	Latitude: 50.14 Longitude: 29.96
	Bottom right	Latitude: 50.01 Longitude: 30.26

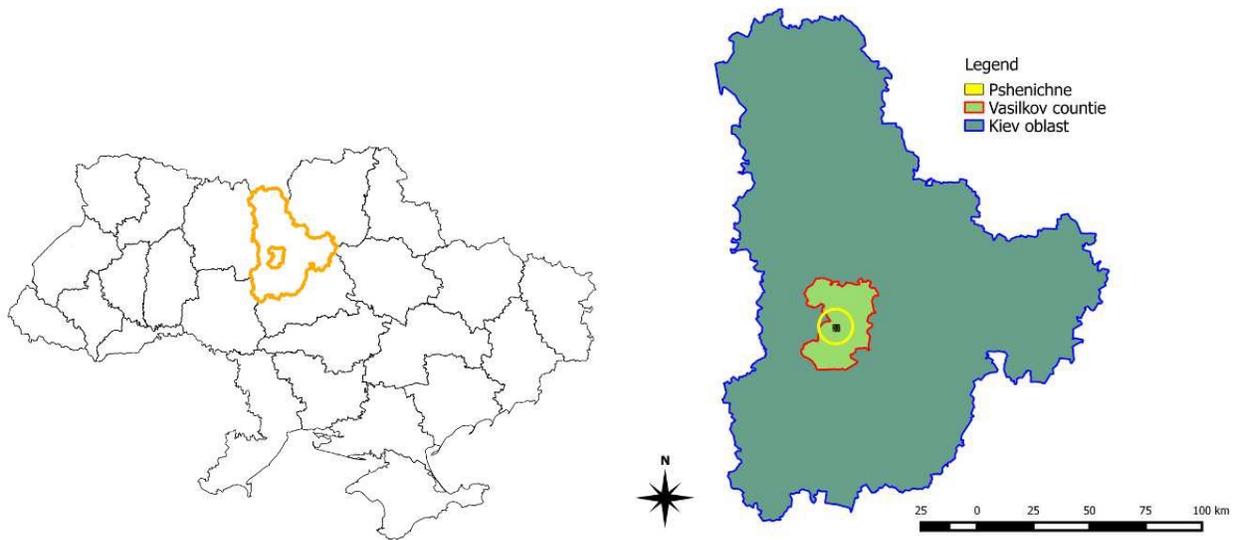


Figure 134 Location of JECAM Test Sites. Kyiv Region (L); Intensive Observation Sub-site, Vasilkov County (R)

- Topography: The landscape is mostly flat with slopes ranging from 0% to 2%. Close to 10% of the territory is hilly with slopes about 2-5%.
- Soils: The soils of the cultivated land are mainly different kinds of humus.
- Drainage class/irrigation: Soil drainage ranges from poor to well-drained. Irrigation infrastructure is limited. About 6% of the territory is drained (1700 km²). About 4% (1200 km²) of the territory is used for irrigated agriculture.
- Crop calendar: The crop calendar is September-July for winter crops, and April-October for spring and summer crops.
- Field size: Typical field size is 30-250 ha.
- Climate and weather: The climatic zone is humid continental.
- Agricultural methods used: Crop types include winter wheat, spring barley, maize, soy beans, sunflower, sugar beets and vegetables. Due to the relatively large number of major crops and other factors, there is no a typical simple crop rotation in this region. Most producers use different crop rotations depending on specialization.



Figure 135 Winter Wheat Field (September 2015)



Figure 136 Winter Rapeseed (30 April 2015)

EO Data Received/Used

Landsat-8

- Space agency or Supplier: USGS
- Optical
- Number of scenes: 9
- Range of dates: 13 April 2015, 22 April 2015, 29 April 2015, 24 May 2015, 31 May 2015, 9 June 2015, 25 June 2015 (Fig. 4), 18 July 2015, 28 August 2015
- Spatial resolution: 30 m
- Processing level: L1
- Challenges, if any, in ordering and acquiring the data: No challenges.
- Challenges, if any, in processing and using the data: No challenges.

Figure 137 shows a Landsat-8 image with band combination [5 4 3] – colour infrared.

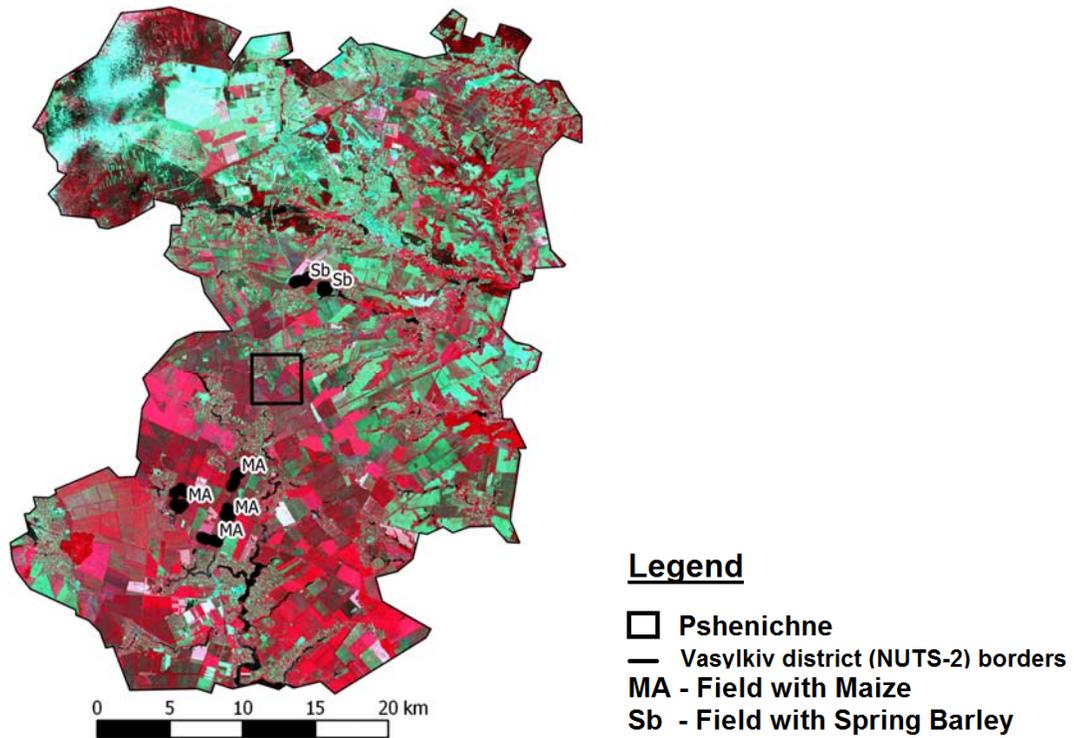


Figure 137 Landsat-8 Image Acquired on 25 June 2015

Proba-V

- Space agency or Supplier: VITO/ESA
- Optical
- Number of scenes: 9
- Range of dates: 16 March 2015, 25 March 2015, 08 April 2015, 12 April 2015, 23 May 2015 (Fig. 5), 10 June 2015, 15 June 2015, 24 June 2015, 08 August 2015
- Spatial resolution: 100 m
- Processing level: L1
- Challenges, if any, in ordering and acquiring the data: No challenges.
- Challenges, if any, in processing and using the data: No challenges.

Figure 138 shows a Proba-V image with band combination [3 2 1] – colour infrared.

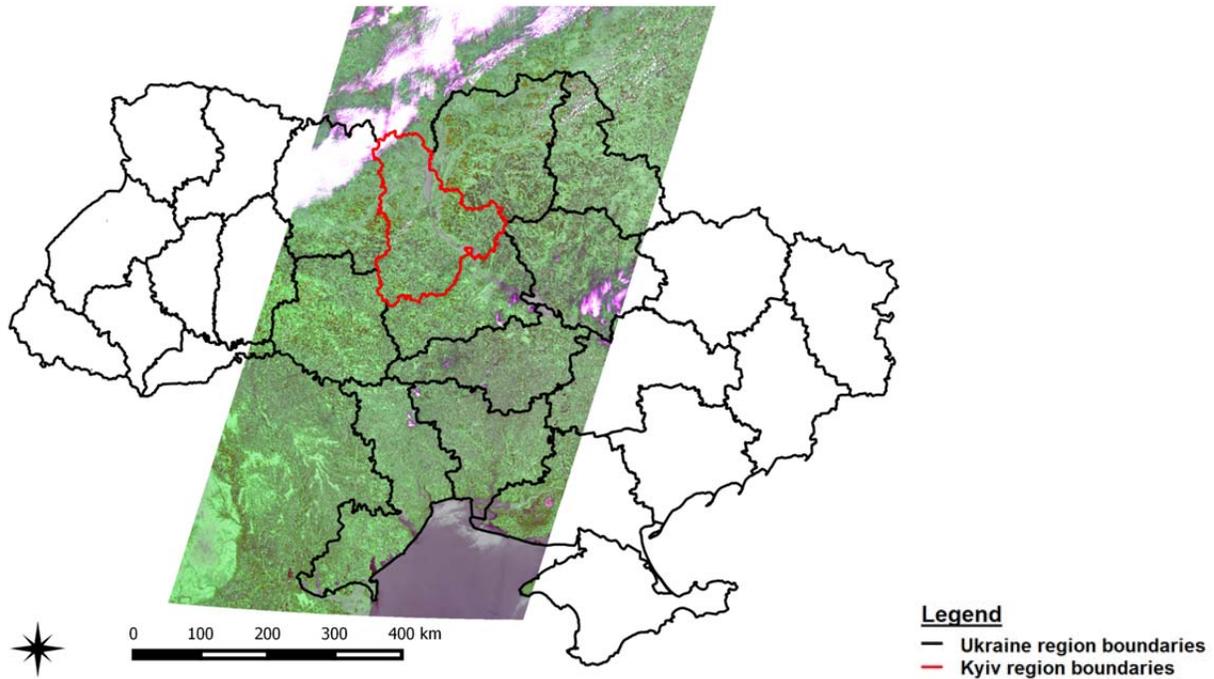


Figure 138 Proba-V Image Acquired on 23 May 2015

Sentinel-1A

- Space agency or Supplier: European Copernicus programme /ESA
- SAR
- Number of scenes: 15
- Range of dates: 1 March 2015, 13 March 2015, 25 March 2015, 6 April 2015, 18 April 2015, 30 April 2015, 12 May 2015, 24 May 2015 (Fig. 6), 05 June 2015, 17 June 2015, 29 June 2015, 11 July 2015, 23 July 2015, 16 August 2015, 28 August 2015
- Spatial resolutions: 30 m (resampled for compatibility with Landsat-8 data)
- Processing level: L1
- Challenges, if any, in ordering and acquiring the data: No challenges in ordering, acquiring the data
- Challenges, if any, in processing and using the data: No challenges in processing and using the data.

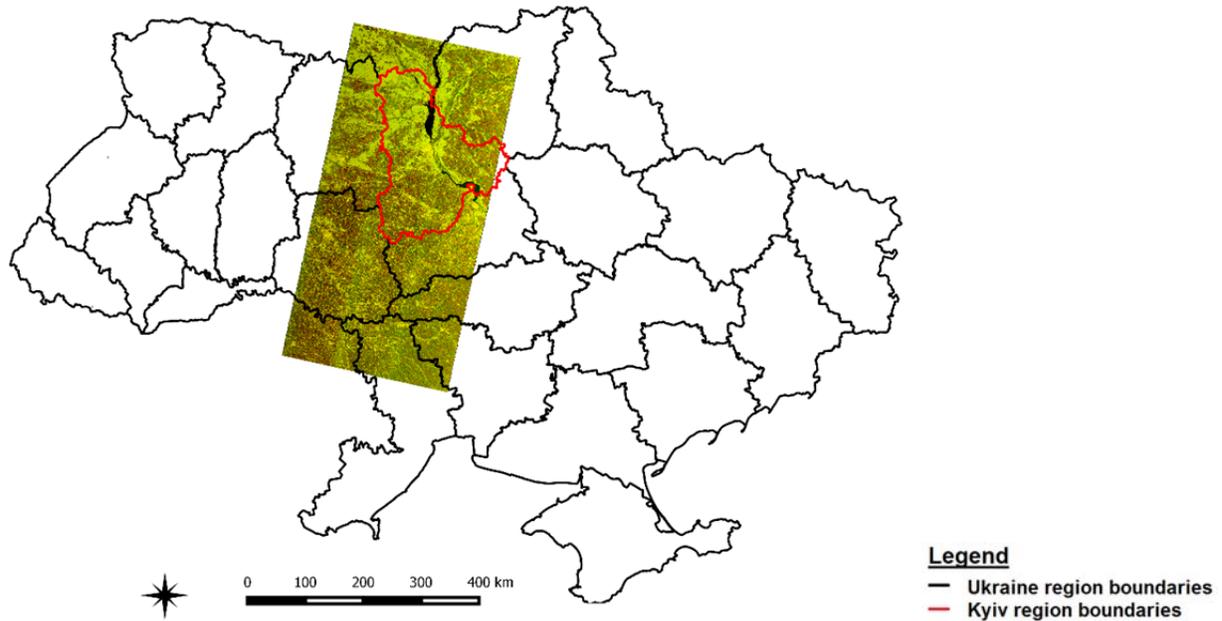


Figure 139 Sentinel-1 Images (VV & VH) Acquired on 24 May 2015

SPOT5

- Space agency or Supplier: European Copernicus programme /ESA
- Optical
- Number of scenes: 8
- Range of dates: 25 April 2015, 25 May 2015, 4 June 2015, 14 June 2015, 24 June 2015 (Fig. 7), 9 July 2015, 19 July 2015, 24 July 2015
- Spatial resolutions: 10 m
- Processing level: L2A
- Challenges, if any, in ordering and acquiring the data: No challenges in ordering, acquiring the data
- Challenges, if any, in processing and using the data: No challenges in processing and using the data

Figure 140 shows a Spot-5 image with band combination [4 3 2] – colour infrared.

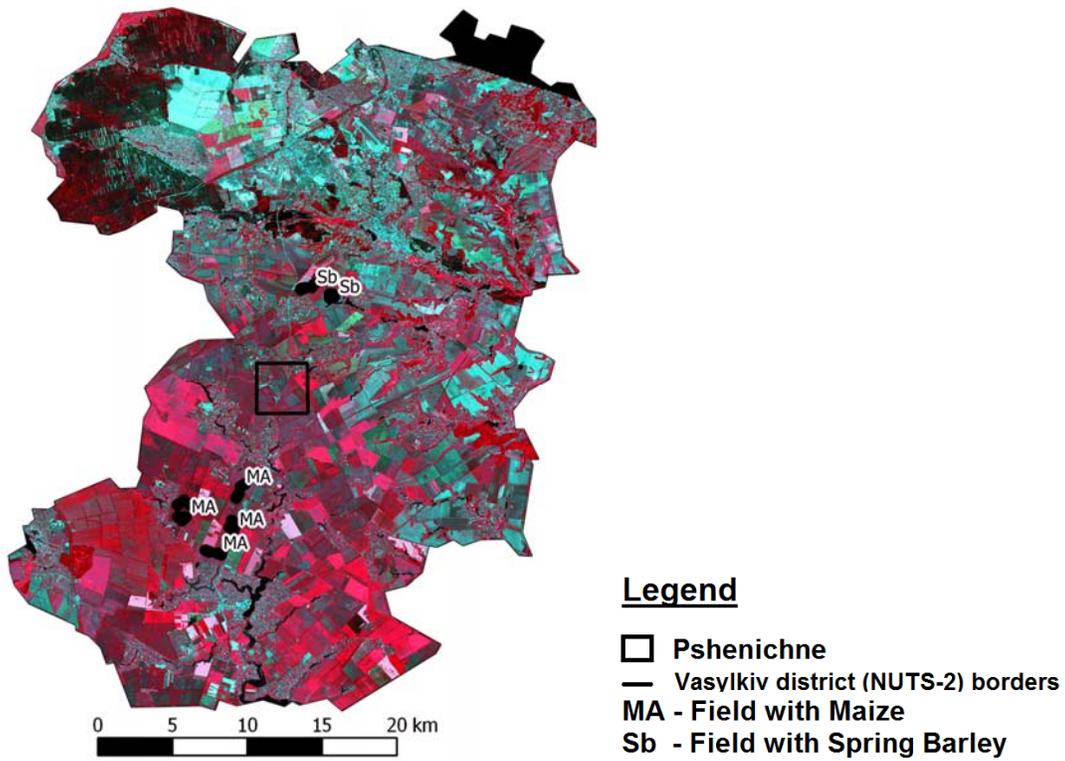


Figure 140 Spot-5 Image Acquired on 24 June 2015

In situ Data

Two types of ground data were collected:

- Along the roads to collect data on crop types
- Sample (point) observations on biophysical parameters using the VALERI protocol.

Along the roads

About 547 fields were observed with major crop classes (). Distribution of the crop classes is shown in Table 22.

Table 22 Crop Class Distribution in "Along the Roads" Dataset

	<i>Fields</i>	
No.	Description	Kiev
1	Winter wheat	102
2	Winter rapeseed	22
3	Spring crops	11
4	Maize	98
5	Sugar beet	8
6	Sunflower	53
7	Soy beans	87
8	Other crops	
9	Forest	49
10	Grassland	64
11	Bare land	10
12	Water	43
	Total	547

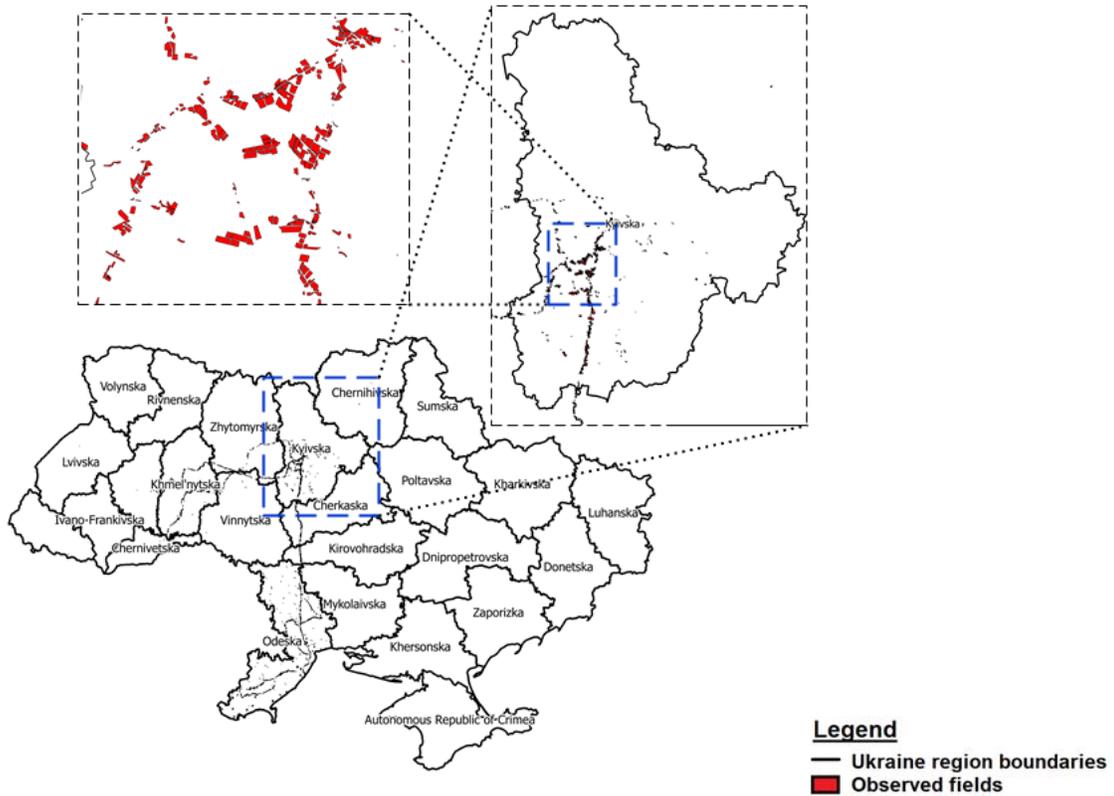


Figure 141 Fields Observed during the "Along the Roads" Surveys

Observations of biophysical parameters

Six field campaigns to characterize the vegetation biophysical parameters at the Pshenichne test site were carried out (see table below).

Table 23 Biophysical Parameter Measurements Collected during the Field Campaigns

Campaign No.	Data	Maize (ESU's)	Soy beans (ESU's)	Winter wheat (ESU's)	Other crops (ESU's)	Total
1	2015-04-15	0	0	15	0	15
2	2015-04-26	0	0	10	1	11
3	2015-05-01	0	0	14	4	18
4	2015-05-26	6	7	0	0	13
5	2015-06-16	6	8	0	0	14
6	2015-07-19	6	4	0	4	14
TOTAL		18	19	39	9	85

Digital Hemispheric Photographs (DHP) images were acquired with NIKON D70 and CANON 550D cameras. Hemispherical photos allow the calculation of LAI and FCOVER measuring gap fraction through an extreme wide-angle camera lens (i.e. 180°) (Weiss et al., 2004). The hemispherical images acquired during the field campaign are processed with the CAN-EYE software (http://www.avignon.inra.fr/can_eye) to derive LAI, FAPAR and FCOVER biophysical parameters.

The in situ biophysical values were used for producing LAI, FCOVER and FAPAR maps from optical satellite images, and provide cross-validation, and validation of global remote sensing products.

Collaboration

We participate in the following collaborative projects:

1. EU FP7 project “Stimulating Innovation for Global Monitoring of Agriculture and its Impact on the Environment in support of GEOGLAM” (SIGMA). Participation as project partner. Participation in large scale classification experiment.
2. EU FP7 project “Implementation of Multi-scale Agricultural Indicators Exploiting Sentinels” (ImagineS). Providing ground observations for validation of EO products.

3. ESA Spot5 Take5 experiment. Providing ground observations (crop biophysical parameters measurements and along the roads surveys), crop maps and biophysical parameters maps, made on Spot-5 data.
4. Sentinel-2 for Agriculture project (ESA). Participation as Champion User and Test Site.

Results

Crop Mapping

Crop mapping is performed using Sentinel-1 SAR data together with Landsat-8 and Proba-V optical imagery (Figure 142). Only four cloud-free Landsat-8 scenes were available for the Kyiv oblast during the crop season. The overall classification accuracy was 85.4%. In contrast, there were fifteen Sentinel-1 SAR images available during the period March–August 2015. Using only SAR imagery, 91.4% overall accuracy was achieved, higher than the Landsat-8 based classification by +6.0% over the same training and testing data sets. When integrating Sentinel-1 and Landsat-8 together, overall accuracy (OA) increased to 92.7%, higher by +7.3% and +1.3% for Landsat-8 and Sentinel-1 based classifications, respectively.

For the crop-wise accuracies, the following results were obtained.

Winter wheat. The best results were obtained for combination of Landsat-8 and Sentinel-1 data (User Accuracy or UA=95.3%, Producer Accuracy or PA=95.2%). With SAR images only, it was also possible to reliably map winter wheat (UA=95.5%, PA=93.0%). In general, this crop was reliably identified (with UA and PA more than 90%) in all cases.

Winter rapeseed. Performance of Landsat-8 and Sentinel-1 for this crop type was similar, and adding SAR images to optical ones did not increase accuracy substantially (UA=78.4%, PA=97.5%).

Spring crops. Discrimination of spring crops using available set of satellite imagery failed to produce reasonable performance for this type of crops, taking into account that it was impossible to discriminate winter crops from spring crops in the fields when collecting ground data. Therefore, all wheat samples were assigned to the winter wheat class and all barley samples were assigned to the spring crop class. Overall proportions of spring wheat and winter barley were small. The main confusion of this class was with winter wheat and other cereals. Confusion with other cereals can be explained by the similarity of the vegetation cycle of spring barley with other cereals produced in the region (rye and oats). Therefore, for 2015 other cereals were merged with spring crops to improve classification results. Addition of SAR data to optical data yielded gains of +43.3% and +10.7% for UA and PA, respectively.

Overall classification results are shown in Table 24.

Table 24 Comparison of UA, PA, OA and Kappa Coefficients for Sentinel-1 and Landsat-8 Classification Results for Kyiv Oblast in 2015

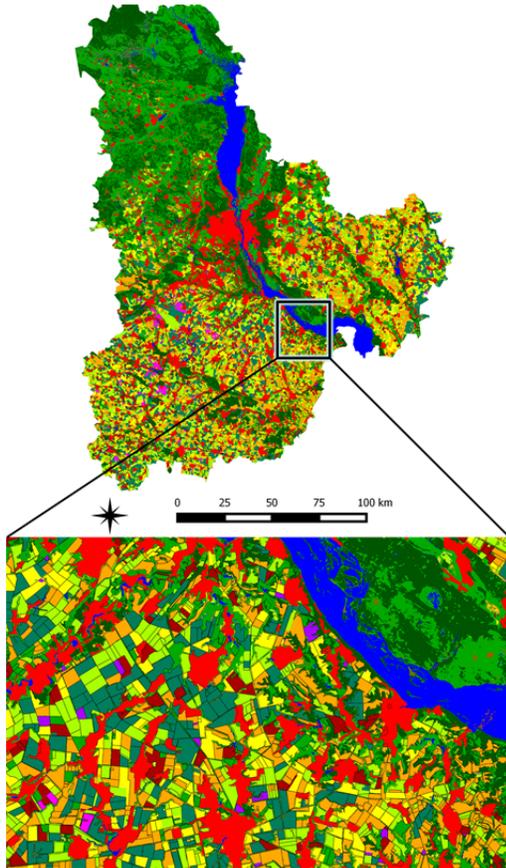
#	Class	Landsat-8		Sentinel-1		L8 and S1	
		UA,%	PA,%	UA,%	PA,%	UA,%	PA,%
2	Winter wheat	93.1	88.5	95.5	93.0	95.3	95.2
3	Winter rapeseed	78.0	96.4	78.3	97.6	78.4	97.5
4	Spring crops	54.4	39.9	71.5	49.8	96.7	50.6
5	Maize	87.2	81.4	89.7	89.3	90.8	90.6
6	Sugar beet	77.0	94.2	97.3	94.7	98.4	97.5
7	Sunflower	90.5	93.8	93.1	99.3	96.3	99.2
8	Soybeans	68.4	66.4	83.8	79.5	83.9	81.0
10	Forest	98.8	96.2	99.2	99.4	99.7	99.6
11	Grassland	77.8	88.5	85.9	92.3	91.6	94.5
12	Bare land	54.6	99.0	69.0	79.9	82.8	90.6
13	Water	97.3	99.5	99.9	98.7	99.9	99.8

Maize. This class was in general reliably classified using only SAR data and in combination with optical imagery. Adding SAR data to optical ones increased accuracy UA by +3.6% and PA by +9.2%.

Sugar beet. Radar data were very useful for mapping sugar beet. The use of SAR images alone yielded UA=97.3% and PA=94.7%, and combination of Landsat-8 and Sentinel-1 provided UA=98.4% and PA=97.5%.

Sunflower. This crop was reliably identified with UA and PA more than 90% for all combinations. Landsat-8 based classification yielded UA=90.5% and PA=93.8%. The gains of adding Sentinel-1 images to optical ones were +5.8% and +5.4% for UA and PA, respectively.

Soybeans. The gains of adding Sentinel-1 images were essential with gains of +15.5% and +14.6% for UA and PA, respectively. Classification results of using SAR only data and its combination with optical imagery provided almost the same performance. Unfortunately, even in this case reliable identification of soybeans was not achieved (with UA and PA less than 85%). The main confusion of the soybean class was with maize and sunflower.



Comparison of Overall Accuracy (OA) % and Kappa Coefficient

	2014		2015	
	OA, %	Kappa	OA, %	Kappa
Landsat-8 + Sentinel-1A	–	–	92.7	0.91
Proba-V + Sentinel-1A	–	–	92.3	0.91
Sentinel-1A	–	–	91.4	0.9
Landsat-8	90.7	0.89	85.4	0.83
Proba-V	91.7	0.9	84.6	0.82

Figure 142 Crop Map of Kyiv Region Performed by Classification of Proba-V Images with Classification Accuracy Table

Biophysical Parameter Retrieval

In our studies, quantitative assessment of features derived from remote satellite sensing images was performed to build regional empirical-based models for biophysical parameters retrieval. The approach was based on the Random Forest Algorithm that randomly permutes features to statistically estimate its influence on the resulting error, applied to the Landsat-8 and SPOT-5 imagery acquired for the JECAM test site in Ukraine. The results are shown in Table 25 and Table 26.

Table 25 LAI and FAPAR for Landsat-8: Linear and Exponential Relationships

LAI

Maize													
Year		Linear relationship						Exponential relationship					
		NDVI		NIR		NIR/RED		NDVI		NIR		NIR/RED	
		R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE
2013-2015	109	0.75	0.73	0.78	0.7	0.78	0.68	0.84	0.46	0.72	0.61	0.71	0.63
Wheat													
2013-2015	62	0.69	0.94	0.6	1.07	0.78	0.79	0.75	0.53	0.55	0.71	0.65	0.62
All data													
2013-2015	256	0.65	0.93	0.63	0.96	0.71	0.84	0.71	0.61	0.59	0.73	0.61	0.71

FAPAR

Maize													
Year		Linear relationship						Exponential relationship					
		NDVI		NIR		NIR/RED		NDVI		NIR		NIR/RED	
		R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE
2013-2015	109	0.86	0.1	0.79	0.12	0.8	0.12	0.81	0.32	0.66	0.43	0.65	0.43
Wheat													
2013-2015	62	0.89	0.08	0.58	0.15	0.74	0.12	0.75	0.26	0.51	0.36	0.56	0.34
All data													
2013-2015	256	0.74	0.13	0.66	0.15	0.69	0.15	0.6	0.47	0.48	0.54	0.47	0.54

Table 26 LAI and FAPAR for SPOT-5: Linear and Exponential Relationships

LAI

Maize													
Year		Linear relationship						Exponential relationship					
		NDVI		NIR		NIR/RED		NDVI		NIR		NIR/RED	
		R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE
2015	64	0.64	0.89	0.75	0.74	0.23	1.3	0.87	0.5	0.8	0.61	0.27	1.16
Soybeans													
2015	56	0.59	0.72	0.44	0.85	0.21	1	0.85	0.4	0.6	0.66	0.38	0.82
All data													
2015	134	0.56	0.91	0.56	0.91	0.22	1.21	0.82	0.51	0.68	0.68	0.3	1.02

FAPAR

Maize													
Year		Linear relationship						Exponential relationship					
		NDVI		NIR		NIR/RED		NDVI		NIR		NIR/RED	
		R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE	R ²	RMSE
2015	64	0.84	0.1	0.85	0.09	0.3	0.21	0.85	0.34	0.756	0.44	0.28	0.76
Soybeans													
2015	56	0.87	0.09	0.6	0.15	0.39	0.19	0.86	0.24	0.6	0.42	0.4	0.51

All data													
2015	134	0.83	0.1	0.7	0.14	0.31	0.21	0.82	0.33	0.65	0.46	0.29	0.65

We found that the most important features for estimation of biophysical parameters from satellite imagery include a NIR spectral band: NIR band itself, vegetation index NDVI and ratio between NIR and red bands. Other spectral bands such as blue, green, red and SWIR for Landsat-8, and green and SWIR for SPOT-5 were not important. In other words, these features provided little information (in terms of entropy) for estimation of biophysical parameters (LAI and FAPAR). These results suggest that including all spectral bands into the models to estimate biophysical parameters from satellite imagery will increase its complexity and likelihood of over fitting but will not lead to a decrease of estimation error.

These results were observed under varying input conditions, in particular:

–**LAI and FAPAR.** NIR, NDVI and NIR/red were equally important when estimating different biophysical parameters, namely LAI and FAPAR. This suggests that the same set of parameters can be used for extracting different biophysical parameters from satellite imagery.

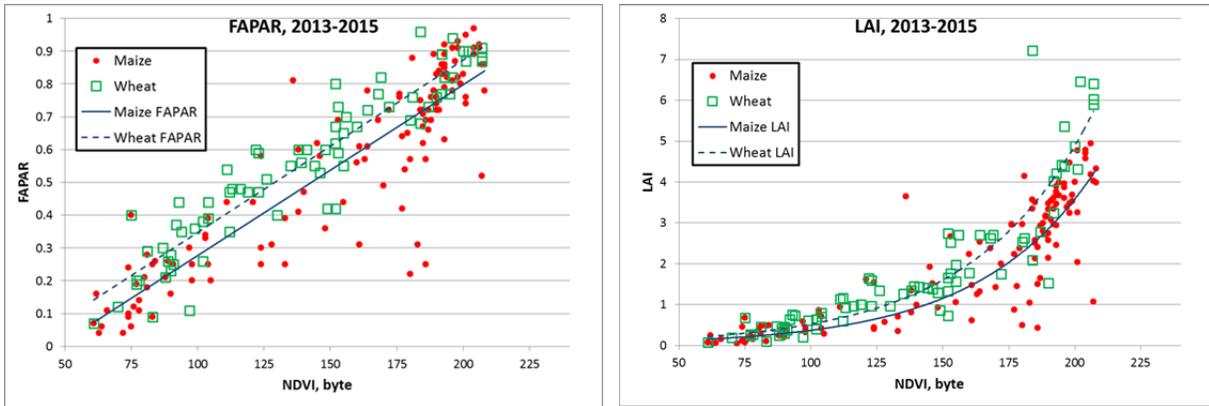
–**Different satellite sensors.** Features involving NIR spectral bands were the most important for different satellite remote sensing sensors, in particular Landsat-8 and SPOT-5. This suggests the possibility of inter-operable application of satellite imagery and also the possibility to build multi-mission models for extracting biophysical parameters.

–**Crop types.** There was no dependence of a set of the most important features on crop types. The same set was important when building models for different crops (maize, winter wheat and soybeans) and all crops together.

–**Number of input data.** The set of important features was the same when decreasing the number of samples for training the Random Forest Algorithm. This suggests the robustness of this approach in terms downscaling and little influence on the data size. However, since the feature importance metric is statistical in nature, a minimum number of samples should be used. We estimated empirically a minimum 10-12 samples with 7 features are necessary to reliably estimate feature importance.

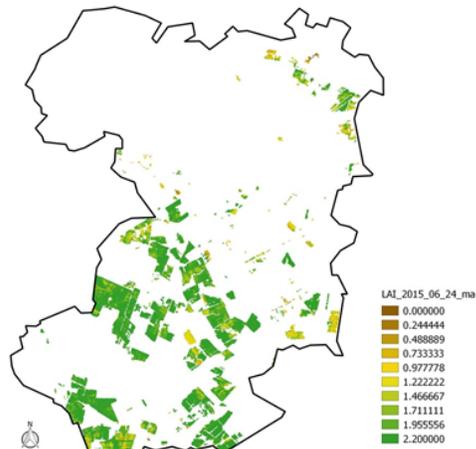
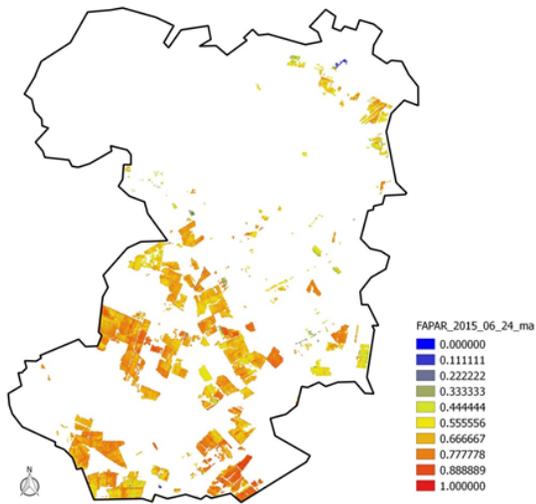
–**Intra-season variability.** Results obtained for different vegetation seasons (2013–2015) show that there is little variability in feature importance suggesting that the same set of features can be used for building models.

These results can be further exploited for building multi-mission (Landsat-8, Sentinel-2) multi-season models for extracting biophysical parameters from satellite imagery. Datasets and some mapping results for biophysical parameters are shown in Figure 143.



FAPAR dataset for JECAM test site

LAI dataset for JECAM test site



FAPAR for maize, 24 June 2015 (SPOT-5 data)

LAI for maize, 24 June 2015 (SPOT-5 data)

Figure 143 Datasets, FAPAR and LAI Maps for the JECAM Site (2015)

To what extent has the project objectives been met?

In 2015, all project objectives were met. Crop maps were produced based on Landsat-8, Proba-V and Sentinel-1 data. Proba-V provides very good performance in terms of coverage and spatial resolution for the Ukrainian landscape; Sentinel-1 is very efficient in cloudy periods (especially in 2015, with only 4 non-cloudy Landsat-8 images for the vegetation period). Also the combination of optical (Landsat-8) on SAR data (Sentinel-1) allows one to get up to 7% more accurate classification maps (compared to Landsat-8).

An updated set of features, namely biophysical parameters FAPAR and VHI was obtained. Feature selection for biophysical parameter mapping was performed with different data processing tools (Random Forest and regression).

We think that both approaches of crop and biophysical parameter mapping could be considered as 'best practices'. For more accurate results, the integration of SAR and optical data was performed. For dealing with missing data due to clouds and shadows in Proba-V images, we applied the same approach as for Landsat-8 images.

We have not modified the project objectives. Next growing season, we will maintain the current approach, and we anticipate ordering the same type and quantity of EO data as 2015. In addition, we are interested in RADARSAT-2 data and the continuation of the Take5 initiative.

Publications

1. **Efficiency Assessment of Multitemporal C-Band Radarsat-2 Intensity and Landsat-8 Surface Reflectance Satellite Imagery for Crop Classification in Ukraine** S.Skakun, N.Kussul, A.Y. Shelestov, M.Lavreniuk, O. Kussul *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*. - 2015. - DOI: 10.1109/JSTARS.2015.2454297.
2. **Regional scale crop mapping using multi-temporal satellite imagery** N. Kussul, S. Skakun, A. Shelestov, M. Lavreniuk, B. Yailymov, O. Kussul *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*. – 2015. - P. 45-52.
3. **Comparison of biophysical and satellite predictors for wheat yield forecasting in Ukraine** A. Kolotii, N. Kussul, A. Shelestov, S. Skakun, B. Yailymov, R. Basarab, M. Lavreniuk, T. Oliinyk, V. Ostapenko *International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences*. – 2015. - P. 39-44.
4. **Mapping of biophysical parameters based on high resolution EO imagery for JECAM test site in Ukraine** Andrii Shelestov, Andrii Kolotii, Fernando Camacho, Sergii Skakun, Olga Kussul, Mykola Lavreniuk, Oleksandr Kostetsky *Geoscience and Remote Sensing Symposium (IGARSS), 2015 IEEE International* - P. 1733-1736.
5. **Parcel based classification for agricultural mapping and monitoring using multi-temporal satellite image sequences** Nataliia Kussul, Guido Lemoine, Javier Gallego, Sergii Skakun, Mykola Lavreniuk. *Geoscience and Remote Sensing Symposium (IGARSS), 2015 IEEE International* - P. 165-158.

6. **Geospatial intelligence and data fusion techniques for sustainable development problems** N.Kussul, A.Shelestov, R.Basarab, S.Skakun, O.Kussul, M. Lavreniuk. *11th International Conference on ICT in Education, Research and Industrial Applications: Integration, Harmonization and Knowledge Transfer, ICTERI 2015 (14-16 May 2015, Lviv, Ukraine)*. - 2015. - Vol.1356. - P. 196-203.
7. **Building a Data Set over 12 Globally Distributed Sites to Support the Development of Agriculture Monitoring Applications with Sentinel-2.** Bontemps, Sophie; Arias, Marcela; Cara, Cosmin; Dedieu, Gerard; Guzzonato, Eric; Hagolle, Olivier; Inglada, Jordi; Matton, Nicolas; Morin, David; Popescu, Ramona; Rabaute, Thierry; Savinaud, Mickael; Sepulcre, Guadalupe; Valero, Silvia; Ahmad, Ijaz; Begue, Agnes; Bingfang, Wu; de Abelleira, Diego; Diarra, Alhousseine; Dupuy, Stephane; French, Andrew; ul Hassan Akhtar, Ibrar; Kussul, Nataliia; Lebourgeois, Valentine; Le Page, Michel; Newby, Terrence; Savin, Igor; Veron, Santiago R.; Koetz, Benjamin; Defourny, Pierre. *Remote Sens.* 2015, 7, 16062-16090.
8. **The use of satellite data for agriculture drought risk quantification in Ukraine** Sergii Skakun, Nataliia Kussul, Andrii Shelestov, Olga Kussul *Geomatics, Natural Hazards and Risk*. – 2015. – DOI: 10.1080/19475705.2015.1016555 – P. 1-18.

Presentations:

1. M. Lavreniuk, **“Regional scale crop mapping using multi-temporal satellite imagery”**, 36th International Symposium on Remote Sensing of Environment – ISRSE-36, 11-15 of May, 2015 in Berlin, Germany.
2. A. Shelestov, **“Comparison of biophysical and satellite predictors for wheat yield forecasting in Ukraine”**, 36th International Symposium on Remote Sensing of Environment – ISRSE-36, 11-15 of May, 2015 in Berlin, Germany.
3. N. Kussul, **“PARCEL BASED CLASSIFICATION FOR AGRICULTURAL MAPPING AND MONITORING USING MULTI-TEMPORAL SATELLITE IMAGE SEQUENCES”**, IGARSS 2015 IEEE International Geoscience and Remote Sensing Symposium was held on 26-31 of July 2015 in Milan, Italy.
4. A. Shelestov, **“Mapping of biophysical parameters based on high resolution EO imagery for JECAM test site in Ukraine”**, IGARSS 2015 IEEE International Geoscience and Remote Sensing Symposium was held on 26-31 of July 2015 in Milan, Italy.

5. *M. Lavreniuk*, “**Regional retrospective high resolution land cover for Ukraine: methodology and results**”, IGARSS 2015 IEEE International Geoscience and Remote Sensing Symposium was held on 26-31 of July 2015 in Milan, Italy.
6. *N. Kussul*, «**Satellite Based Crop Classification and Field Area Estimation in Ukraine**”, 8-th GEOSS Asia-Pacific Symposium, 9-11 of September 2015, People's Republic of China.
7. *A. Shelestov*, “**Geospatial Solutions for Data Sharing within WDS and JECAM**”, 8-th GEOSS Asia-Pacific Symposium, 9-11 of September 2015, People's Republic of China.
8. *N. Kussul*, “[Satellite monitoring products at national and regional levels](#)”, Joint Workshop on Information Needs in Crop Monitoring, 22-23 of October 2015, Kyiv, Ukraine.
9. *A. Shelestov*, “**Kyiv JECAM Site Progress (Ukraine)**”, Annual JECAM Meeting, 15-16 of November 2015, Brussels, Belgium.

25. Uruguay

No report received.

26. U.S.A.

26.1 Iowa

Team Leader and Members: Michael Cosh, USDA-ARS-HRSL, Joe Alfieri, USDA-ARS-HRSL, Martha Anderson, USDA-ARS-HRSL, Craig Daughtry, USDA-ARS-HRSL, Bill Kustas, USDA-ARS-HRSL, John Prueger, USDA-ARS-NLAE, Ali Sadeghi, USDA-ARS-HRSL, Mark Tomer, USDA-ARS-NLAE

Project Objectives

The original project objectives for our site have not changed.

- Crop identification and Crop Area Estimation

Crop area estimation was conducted via the USDA Farm Service Agency and National Agricultural Statistical Service programs for the South Fork. This is an operational product.

- Crop Condition/Stress

As part of a remote sensing project, the evaporative stress index (ESI) is being computed on a 10 km resolution for the continental U.S. This is available from <http://hrsl.arsusda.gov/drought/>. This is operational.

- Soil Moisture

Currently there are 20 stations collecting soil moisture and soil temperature data in the domain. <http://hrsl.arsusda.gov/southfork/>.

- Crop Residue, Tillage and Crop Cover Mapping

Assessments of crop residue amount are in the process of being analyzed for publication on methodologies for estimation.

Site Description

- Location: South Fork, Iowa (Hardin and Hamilton Counties, Iowa, USA). See Figure 144.
- Topography: Flat
- Soils: Clay Loam
- Drainage class/irrigation: Poorly drained, installed drainage tiles, limited irrigation.
- Crop calendar: April/May Planting, September/October Harvest
- Field size: 800 m by 800 m
- Climate and weather: Temperate/Humid
- Agricultural methods used: Corn and Soybean, no-till and tilled.

EO Data Received/Used

In situ Data

There are currently 20 in situ soil moisture stations collecting soil moisture, soil temperature and precipitation data in the South Fork Region, shown in Figure 144 and Figure 145. In addition, during the spring and fall, in situ crop residue studies were conducted to estimate residue amounts via field measures and roadside surveys. A collection of validation data points were collected during the summer of 2014 which will help to calibrate the in situ network for satellite comparisons.

Collaboration

Mr. Sujay Dutta of IRS has provided satellite data via the GEO collaboration

Soil moisture data is now actively being transferred to the NASA Soil Moisture Active Passive (SMAP) Mission for validation of the SMAP soil moisture product.

Results

The majority of the work in this domain is research in progress with no published conclusions. Data collection and infrastructure improvement are the primary tasks.

Analysis of the in situ soil moisture accuracy is complete and a manuscript is under development. Figure 146 contains a map of the network sites and the field sampled sites during the summer of 2014. Yellow circles indicate permanent stations and white squares are temporary sampling sites throughout the summer of 2014. Yellow, Green, and White boxes are the SMAP calibration/validation pixels for the 36, 9, and 3 km products, with respective names.

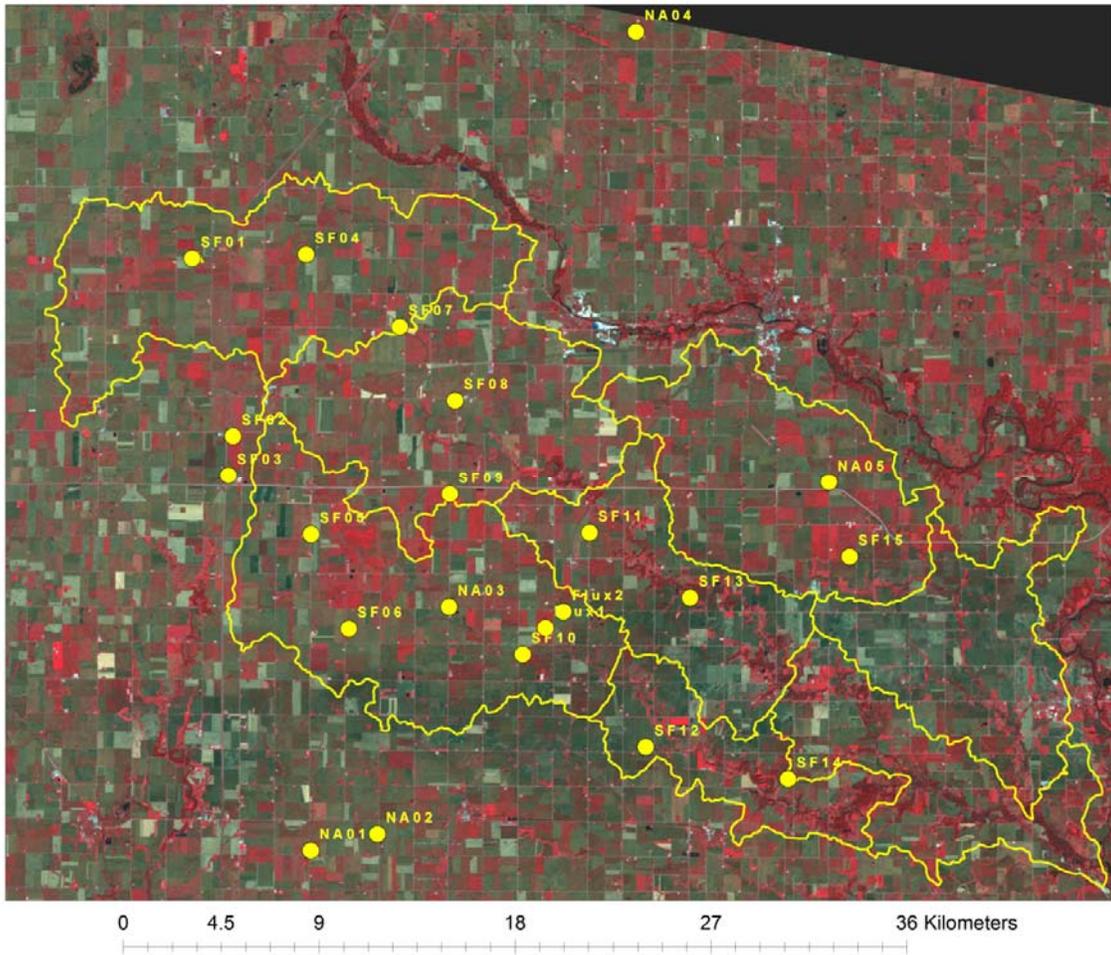


Figure 144 Plot of the Network at South Fork

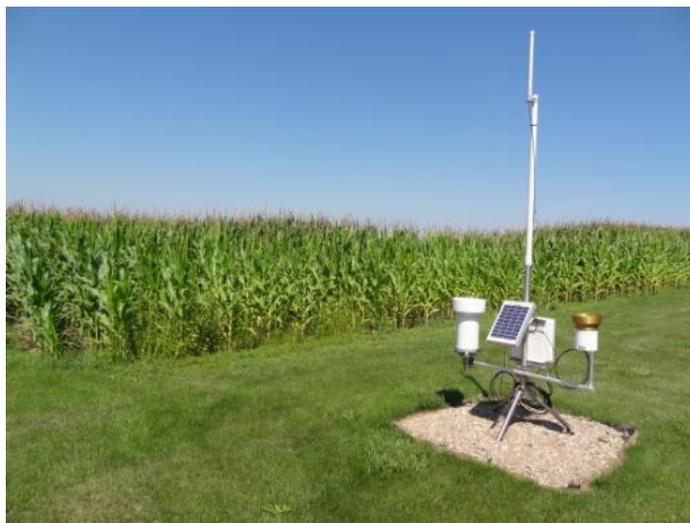


Figure 145 Example of a Network Site, Next to a Corn Field

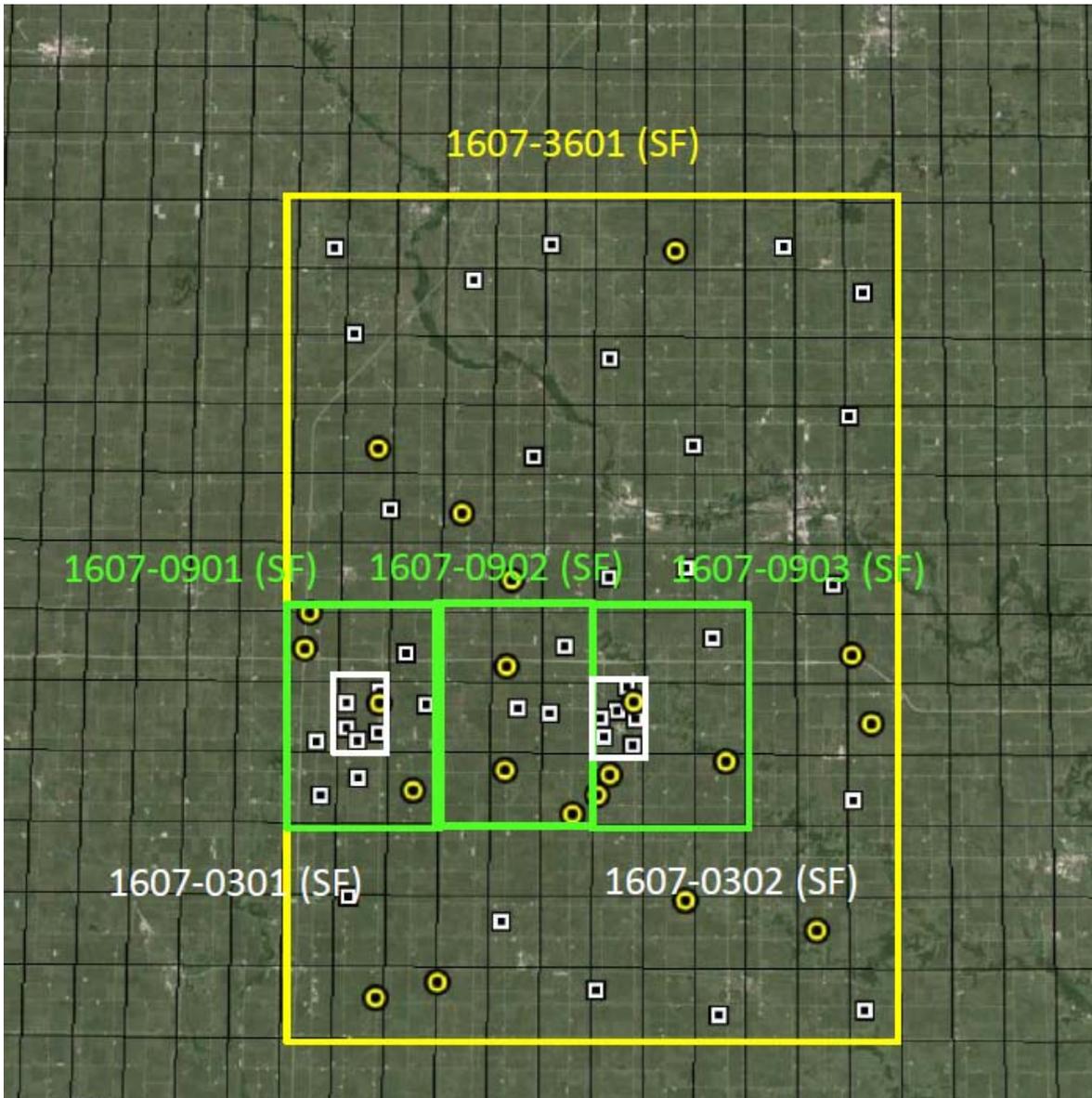


Figure 146 SMAP Pixel Domain of the South Fork Study Site

Figure 147 is a comparison plot of the network versus field sampled data. The red scaled data are calibrated and regressed comparisons to minimize errors. This regression is the basis for the scaling function used by SMAP. Table 27 contains the root mean square errors of the network versus actual field data. The scaling functions generated by this analysis are being incorporated into the SMAP cal/val program.

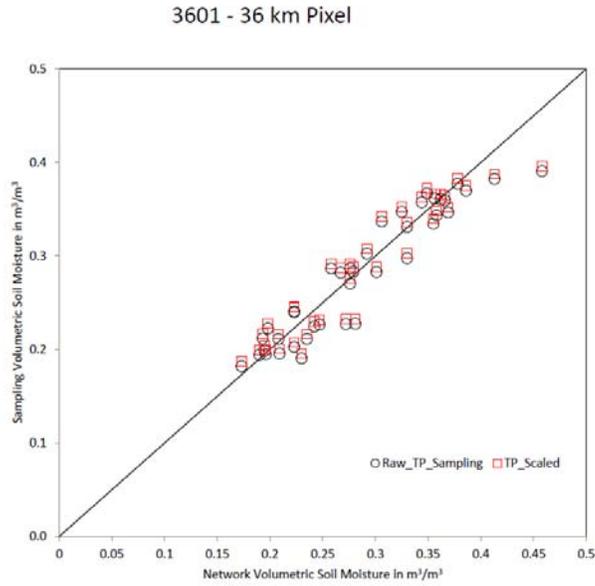


Figure 147 Sample Comparison of Field Sampled Data and Scaled Network Data versus the Network

RMSE	Raw TP in m ³ /m ³	Scaled TP in m ³ /m ³
3601	0.023	0.023
0901	0.052	0.037
0902	0.053	0.024
0903	0.035	0.027
0301	0.056	0.047
0302	0.067	0.035

Table 27 RMSE Values for Field Sampled Data and Regressed Field Sampled Data for each of the SMAP Cal/val Pixels

Plans for Next Growing Season

As part of the Soil Moisture Active Passive Mission’s calibration/validation program, a summer field experiment is planned on the South Fork as well as the Red River JECAM site in Canada which will include soil moisture mapping from aircraft and satellite platforms and field data collections. In situ resources will be expanded temporarily and planning is in process.

Publications

Rondinelli, W. J., Hornbuckle, B., Patton, J. C., Cosh, M.H., Walker, V. A., Carr, B. D., Logsdon, S. D. 2014. Different rates of soil drying after rainfall are observed by the SMOS satellite and the South Fork In Situ Soil Moisture Network, *Journal of Hydrometeorology*, 16, 2, 889-903.

Coopersmith, E., Cosh, M.H., Petersen, Walter, Prueger, J.H., Niemeier, James J. 2015. Soil moisture model calibration and validation: An ARS watershed on the South Fork Iowa River. *Journal of Hydrometeorology*, 16, 3, 1087-1101.

26.2 Michigan

No report received.

26.3 Oklahoma

No report received.