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

2017 Progress Report

April 2017
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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 2016. 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 2017 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 used in the last year, 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

<table>
<thead>
<tr>
<th>JECAM Site</th>
<th>Low/Moderate Optical</th>
<th>Moderate SAR</th>
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<tbody>
<tr>
<td></td>
<td>Terra/Aqua</td>
<td>Landsat</td>
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<tr>
<td></td>
<td>Sentinel-2</td>
<td>Hyperion</td>
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<td>Hyperion</td>
<td>HJ-1</td>
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<td>UK-DMC-ii</td>
<td>Deimos</td>
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<td></td>
<td>Proba-V</td>
<td>RADARSAT-2</td>
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<tr>
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<td>TerraSAR-X</td>
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<tr>
<td>Argentina</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Belgium</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Brazil – São Paulo</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Brazil - Tocantins</td>
<td>46</td>
<td>1</td>
</tr>
<tr>
<td>Canada CFIA – Ottawa</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Canada Southern Manitoba</td>
<td>3</td>
<td>x</td>
</tr>
<tr>
<td>China/ Jiangsu</td>
<td></td>
<td>21</td>
</tr>
<tr>
<td>China/ Shandong</td>
<td>46</td>
<td>21</td>
</tr>
<tr>
<td>France</td>
<td>147</td>
<td>230</td>
</tr>
<tr>
<td>Italy Apulian Tavoliere</td>
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<tr>
<td>Madagascar</td>
<td>10</td>
<td>10</td>
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<tr>
<td>Morocco</td>
<td>x</td>
<td>x</td>
</tr>
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<td>Russia/ Tula</td>
<td>x</td>
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<tr>
<td>Spain</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Taiwan</td>
<td>18</td>
<td>16</td>
</tr>
<tr>
<td>Tunisia</td>
<td>11</td>
<td>21</td>
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<tr>
<td>Ukraine</td>
<td>5</td>
<td>15</td>
</tr>
</tbody>
</table>

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 Kyiv, Ukraine in October 2016. Work has started to update the Data Requirements Document that was written early in JECAM. There
was discussion of procedures for formal approval of 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. Three working groups were established:

1. SAR inter-comparison
2. In situ sampling

These working groups may initiate collaborative inter-comparison projects. 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.

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 2016. 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 modelling 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 (NRT) Crop condition / Crop stress
- Land management
- Soil moisture.

We have instituted an annual report process to obtain information on JECAM research progress, EO data usage and collaboration activities. The JECAM web site, www.jecam.org, was launched in 2012. Content from the annual reports will be used to keep the site ‘fresh’, accurate and current.

An important JECAM Science Meeting was held in Kyiv, Ukraine in October 2016. Work has started to update the Data Requirements Document that was written early in JECAM. There was discussion of procedures for formal approval of 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. Three working groups were established:
1. SAR inter-comparison
2. In situ sampling

These working groups may initiate collaborative inter-comparison projects. 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.

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
- Bangladesh
- 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
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. 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 2017, 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 Abellelyra, 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 last campaign, we continued obtaining data from the original JECAM/SIGMA area as well as over a minimum dataset (MDS) area of 20x20 Km with higher density collection. This small area matches with RADARSAT-2 Fine Quad Pol acquisitions during this campaign that we are collecting for the SAR inter-comparison experiment. We developed an inter-comparison of methodologies for cropland identification together with other JECAM/SIGMA sites (China, Russia, Ukraine, Brazil and Belgium). We are moving from local to regional estimation of crop land and crop type. We are testing different sampling methodologies and different data sources together with other JECAM sites.
- Crop Rotations. Crop rotations in the last 6 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 are working on an inter-comparison study for yield estimation with SIGMA/JECAM Partners from Russia, China, Ukraine and Africa led by Alterra (Wageningen, The Netherlands). We are also working on the estimation of biophysical parameters at field level using optical and RADAR images.

Site Description

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

<table>
<thead>
<tr>
<th>Centroid</th>
<th>Latitude: 34° 7’18.69”S</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Longitude: 59°35’53.05”W</td>
</tr>
</tbody>
</table>

- 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 crops. In these cases, soybean is planted in November and harvested in March/April and maize is planted in October and harvested in March. Recently late maize crop is planted in December after a fallow.

- 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 isohygro 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: January/May 2016 – August/December 2016
- Beam modes/ incidence angles/ spatial resolutions:

  Fine Quad Pol mode: FQ21

  Wide mode: W3

- Processing level: Single Look Complex

In addition, the following freely available images were obtained: LANDSAT-8, MODIS, and SENTINEL 1 and 2.

**In situ Data**

On road surveys were performed at least twice a year to identify winter and summer crops as well as fallow, pastures and grasslands. Surveys are performed over the JECAM/SIGMA area (100x100 Km) and with a higher collection density over the MDS area (20x20 Km). Other in situ data sources are being collected in other areas of Argentina to expand the classification methodologies to other areas and get regional maps.
Collaboration

We are collaborating in 4 initiatives with other JECAM sites:

1. Inter-comparison of Methodologies for Cropland Classification: Evaluation of methodologies developed locally by several JECAM site partners over different JECAM sites (finished in 2016).
3. Inter-comparison of Calibration Data Sources for Cropland Classification: Evaluation of different data sources for training of cropland classifiers including in situ (on road surveys), crowdsourcing and information derived from reference maps (in process).
4. SAR inter-comparison experiment: Evaluation of the use of SAR for crop type classification and biophysical parameter estimation along different JECAM sites (starting during 2017).

Results

The main results are related to crop rotation map generation and analysis of spatial distribution over the JECAM area (manuscript in preparation) and the evaluation of different methodologies for Cropland Mapping that was published during 2016 (Waldner et al, 2016) that are described in detail below.

*Inter-comparison of Methodologies for Cropland Mapping (Waldner et al, 2016)*

Five methodologies developed for different JECAM sites (Argentina, Belgium, China, Russia and Ukraine) were tested over 5 locations (Argentina, Brazil, China, Russia and Ukraine). In situ (in field collected) data was collected by the JECAM site partners and used for training and validation of classifiers.

The results showed quite high overall accuracy for all methods (in general more than 90%). Higher variability was observed among sites than among methods. Russia and Ukraine showed the highest accuracy values, and Brazil the lowest. Some problems were observed in classifying no-cropland areas due to similarity with cropland fields and spatial distribution of land use.
A test was performed reducing the sample size for training up to 10%; it showed low reduction in overall accuracy when the reduction was higher than 40%.
Figure 7. Dependency of average OA for testing set on training size (expressed as percentage of full training size) for JECAM site in Ukraine. The full training data set is made of 4180 pixels. Methods reach their accuracy plateau with only 20–30% of the full calibration data set (830–1250 calibration pixels).

**Figure 1  Dependency of Average OA for Test Set on Training Size for Ukraine Site**

**Plans for Next Growing Season**

In the next year, we will modify our approach as follows:

1. We are moving from local (JECAM Area) to regional level (province / country) for crop area and yield estimations. We will test our classification methodology in different regions of Argentina during different agricultural campaigns.

2. Following the first inter-comparison study for cropland mapping finished this year, we are working this year in other two inter-comparison experiments: comparison of different sampling methods, and comparison of different data sources: in situ data, crowdsourcing and reference cropland maps.

3. We will participate in the two JECAM SAR experiments for crop type mapping and Biomass/LAI estimation.

4. Improve estimation of actual evapotranspiration (as a water stress index).

We anticipate ordering the same type/quantity of EO data next year.
Publications since last year’s report


4. Bangladesh

JECAM Test Site Name: CIMMYT Bangladesh (Alamdanga and Barisal)

Team Leader: Urs Schultess

Project Objectives

CIMMYT is a new member of JECAM. We are just starting with the collection of data during this winter growing season (Nov 2016 until April 2017).

The project objectives are:

- Crop identification and Crop Area Estimation
  - We are collecting crop type information from 2 sites in Bangladesh.
- Soil Moisture
  - Yes, coinciding with LAI measurements
- Others?
  - LAI for maize
    - 2 sites, 2-3 dates of observation

Site Description #1

- Location: Barisal, Bangladesh
- Topography: Flat
- Soils: Alluvial, heavy clay soils
- Drainage class/irrigation: Depends on crop type
- Crop calendar
  - Summer: rain-fed rice production
  - Winter (Dec – May): Winter crops
- Field size: 20 by 30 m
- Climate and weather
• Summer: hot and humid
• Winter: warm and dry

**Figure 2  Boro Rice Fields near Barisal, Bangladesh**

---

**Site Description #2**

- Location: Alamdanga (near Chuadanga), Bangladesh
- Topography: Flat
- Soils: Alluvial, heavy clay soils
- Drainage class/irrigation: Mostly irrigated in winter months
- Crop calendar
- Summer: rain-fed rice production
- Winter (Oct – May): Winter crops
- Field size: 30 by 50 m
- Climate and weather
  - Summer: hot and humid
  - Winter: warm and dry

**Figure 3  Various Winter Crops near Barisal, Bangladesh**

**EO Data Received/Used**

None so far

**In situ Data**

We are currently collecting ground truth data from the two sites:
JECAM Progress Report 2017

- LAI
- Crop types

Collaboration

We are collaborating with the team of UCL on data analysis. In particular, we are looking at the interplay between field and pixel size (or ground sampling distance).

Results

No description.

Plans for Next Growing Season

We ordered RADARSAT-2 images to complement our LAI readings.

Publications

None listed.

5. Belgium

Team Leader and Members: Pierre Defourny, Nicolas Bellemans, Guillaume Chomé, Cindy Delloye, François Waldner.

Project Objectives

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

- Crop Identification and Crop Area Estimation Cropped Land: developing a method to support crop area estimation on a field with resolution (minimum mapping unit) Nuts 3; Mapping Frequency: 2 maps / year; 1 for winter wheat mapping, 1 maize mapping.
- Crop Condition/Stress: improve estimation of biophysical variable retrieval for crop growth monitoring; methodology development for winter wheat Leaf Area Index (LAI) estimation from optical and SAR data in an operational perspective.

Site Description

- Location

Belgium
In the figure above, the background is a 10-m sen2agri L3A Cloud Free false-color Composite from September 2016 (Sentinel-2 and Landsat-8 -bands NIR, RED, GREEN).

- **Topography**

  The landscape topography is flatlands and hills.

- **Soils**

  The main soil texture is loam, with some sandy soils.

- **Drainage class/irrigation**

  Soil drainage class is moderately well-drained.

- **Crop calendar**

  Crop types are wheat, barley, potatoes, sugar beet, maize, alfalfa, etc. The crop calendar is:

  - **Wheat / barley**: Octobre - August;
• **Maize:** April - September.

• **Potato:** April - September.

• **Cover crop:** during winter – mixed species.

• **Field size**

Typical field size ranges from 2 to 15 ha. Average: 3 ha.

• **Climate and weather**

The climatic zone is temperate. The climate at site is moderately humid and cool, with annual rainfall of about 780 mm, which is relatively well distributed over the year. Yearly average temperature is approximately 11°C.

• **Agricultural methods used**

Mainly rain-fed, mechanized and intensive cropping systems, with typical field size ranges from 3 to 15 ha.

Irrigation infrastructure is not frequent.

---

*Figure 5*  Digital Hemispherical Pictures Acquired in Winter Wheat Field between March and July 2016 (BELCAM Project)
### EO Data Received/Used

<table>
<thead>
<tr>
<th>Data</th>
<th>Space agency or Supplier</th>
<th>Optical/SAR</th>
<th>No. of scenes</th>
<th>Range of dates</th>
<th>Beam modes/incidence angles/spatial resolutions</th>
<th>Processing level</th>
<th>Challenges, if any, in processing and using the data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radarsat-2</td>
<td>CSA SAR</td>
<td>53</td>
<td>2016-03 to 2017-03</td>
<td>FQ20 &amp; FQ22</td>
<td>SLC</td>
<td></td>
<td>Noise, interpretation</td>
</tr>
<tr>
<td>Sentinel-1</td>
<td>ESA SAR</td>
<td>-</td>
<td>2014 to inf</td>
<td>IW</td>
<td>SLC</td>
<td></td>
<td>Noise, interpretation</td>
</tr>
<tr>
<td>Sentinel-2</td>
<td>ESA Optical - Multi</td>
<td>-</td>
<td>2015 to inf</td>
<td>L2A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Landsat-8</td>
<td>ESA Optical - Multi</td>
<td>-</td>
<td>2016 to inf</td>
<td>L2A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spot-5</td>
<td>ESA-CNES Optical - Multi</td>
<td>-</td>
<td>2015</td>
<td>L2A</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6** Sentinel-2A Images Covering the JECAM Site (Level 2A) with Parcels of the BELCAM Project (White Dots)
In Figure 7, the revisit period of 12 days provides dense temporal information which can be used for agriculture monitoring.

**In situ Data**

**Tillage occurrence detection**

An intensive field data collection has been set up to retrieve information on 535 parcels, among which 107 are fully described in terms of practices occurrence for 2015. This detailed characterization of the practices occurrence has been achieved through farmers’ interviews. The condition of the parcels in February have been reported for the remaining 428 fields through field observations (bare soil, crop types, visible practices, previous crop from residues). All the fields have been manually delineated based on very high spatial resolution ortho-images. Hence, this dataset contains three main items: the polygon of the parcel, the occurrence date of the different practices (tillage, shallow ploughing...), the field condition on the 18th of February.

**Crop type**

An intensive field data collection has been carried out in July 2016 to collect crop type information of approximately 1800 fields spread over the Walloon region (southern part of Belgium).

**Digital Hemispherical Pictures (DHP)**

DHP have been acquired in 2015 and 2016 on three crops (winter wheat, maize and potatoes) throughout the growing season in a field sample spread over Belgium. Those DHP were acquired for validation purposes of the Biophysical Variables (BV) retrieved from satellite...
imagery (SPOT5 Take5 in 2015 and S2-A in 2016) with a radiative transfer model: fCover, fAPAR and LAI.

**Collaboration**

In the framework of the FP 7 and ESA funded projects, several collaborations have been established. The main research topics are crop mapping and retrieval of biophysical variables. A major goal of SIGMA (Stimulating Innovation for Global Monitoring of Agriculture and its Impact on the Environment) is to support GEOGLAM partly by coordinating JECAM activities. The consortium includes several JECAM site partners, including Stravopol (Russia), Kyiv (Ukraine), Shandong (China), San Antonio (Argentina) and Sao Paolo (Brazil). A standardized field data collection protocol for crop type classification has been provided to the sites. In addition, efforts have been made to gather and pre-process a minimum standardized data set for each site. Research activities focus on multi-sensor cropland and crop type mapping while encouraging cross-site experiments.

The ESA project Sen2Agri (Sentinel-2 for Agriculture) developed products relevant for agriculture monitoring in preparation for the future exploitation of the satellite Sentinel - 2. The goal is to promote to key agriculture monitoring stakeholders and facilitate ownership of the proposed solution based on Sentinel-2 and the open source tool box, through a specific relationship with the JECAM network. The representative user group includes the EU MARS project and the GEOGLAM partners. The Belgian JECAM site was selected as a voluntary site of the Demonstration phase of the Sen2Agri toolbox.

The BELCAM research project aims at developing a platform with useful information at the parcel level to help farmers to monitor their fields. To develop a product on the Nitrogen advice, radar images were required and collaboration was established on the Belgian JECAM site to detect the tillage.

**Results**

**Cropland and crop type mapping**

In the framework of the Sen2Agri ESA project, the JECAM site was selected as a site to demonstrate the Sen2Agri system in Near-Real-Time. The full growing season time series of Sentinel-2 and Landsat 8 images covering the JECAM site was automatically downloaded and processed to generate (1) a suite of Dynamic Cropland Mask and (2) Crop Type map.

The Dynamic Cropland Mask consists of a binary map separating annual cropland areas and other areas, thus corresponding to a mask over annually cultivated areas. The annual cropland is defined as a piece of land with a minimum area of 0.25 ha, planted and harvestable at least
once within the year following the sowing date. This binary map is produced throughout the agricultural season monthly, to serve for instance as a mask for monitoring crop growing conditions, as the basis for sampling stratification and for agricultural extension. Its accuracy is expected to increase as long as additional images are integrated into the development process.

### Dynamic Crop Mask Accuracy Metrics

<table>
<thead>
<tr>
<th></th>
<th>F1-Score Cropland</th>
<th>F1-Score Non Cropland</th>
<th>Overall Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid of season (31/05/2016)</td>
<td>91%</td>
<td>92%</td>
<td>92%</td>
</tr>
<tr>
<td>End of season (31/10/2016)</td>
<td>97%</td>
<td>97%</td>
<td>97%</td>
</tr>
</tbody>
</table>

The Crop Type product is a map of the main crop types or groups in each region. The top main crop types are considered for each region. The main crop types are defined as those covering a minimum area of 5% of the annual cropland in the region representing a cumulated area higher than 75% of the latter. For Belgium, the main crop types are Winter Wheat, Maize, Barley, Potatoes, Sugar beet and rapeseed. The crop types are identified over the previously generated crop mask.

### Crop Type Map Accuracy metrics

<table>
<thead>
<tr>
<th></th>
<th>F1-Sc Winter Wheat</th>
<th>F1-Sc Maize</th>
<th>F1-Sc Barley</th>
<th>F1-Sc Potatoes</th>
<th>F1-Sc Sugar beet</th>
<th>F1-Sc Rapeseed</th>
<th>KAPPA</th>
<th>OA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid of season (31/05/2016)</td>
<td>93%</td>
<td>25%</td>
<td>69%</td>
<td>52%</td>
<td>67%</td>
<td>90%</td>
<td>64%</td>
<td>73%</td>
</tr>
<tr>
<td>End of season (31/10/2016)</td>
<td>94%</td>
<td>68%</td>
<td>73%</td>
<td>89%</td>
<td>89%</td>
<td>81%</td>
<td>82%</td>
<td>87%</td>
</tr>
</tbody>
</table>
In Figure 8, (a) is L3A September 2016 false-color cloud free composite (NIR, RED, GREEN), b) is crop type classification output on (a) area, c) is L3A September 2016 false-color cloud free composite (NIR, RED, GREEN), d) is croptype classification output on (c) area.

**LAI estimation with optical images**

The two year field campaign of DHP acquisition allowed the team to validate the LAI retrieved with S-2A images for the winter wheat. The results show the added value of S2-A new spectral bands to estimate the LAI, compared to SPOT5 Take5, which tends to a systematic underestimation of the LAI value retrieved from 3.5. The new S2-A bands have two main impacts: (i) overcome the saturation effect around a LAI of 4 and (ii) decrease the spreading of the point around the 1:1 axis. These two effects reduce the RMSE from 1 to 0.7.
Tillage detection

The image processing has been realized in three main steps. First, the pre-processing of S1A SLC images has been realized using SNAP with S1 Toolbox. Secondly, the hourly rain data of 29 meteorological stations has been gridded at 10km over the whole study area. Thirdly, the pixels of the images which received rainfall exceeding 1mm within 3 hours before the acquisition have been masked. The pre-processing chain consisted in: applying the precise S1A orbits, calibrating, removing thermal noise, de-bursting, multi-looking (5x1) and terrain correcting with SRTM 1 sec. Since the analysis is performed on an object base, the images have not been filtered. In total, 17 images were used for orbit 110 (descending) and 16 images were used for orbit 161 (ascending). The time series ranges from 04/07/2015 to 17/02/2016.

The classifications achieved accuracies of 87% for field use, 86% and above 94% for tillage detection in winter wheat and cover crop respectively. However, those accuracies rely on the choice of good discrimination periods. This requires knowledge of the crop calendar and crop growth conditions to account for timing particularities in the farmers’ behaviour. Furthermore, the global overall accuracy of tillage detection is the product of the field use OA and of the tillage detection OA. This product gives a global OA of 78-80% (depending on the field use). To further improve this discrimination, one could test fields’ stratification between agro-
meteorological areas in order to decrease the variability in soils conditions, farming calendar and the way the tillage is realized.

![Tillage occurrence detection in Wallonia with S1A - SAR time series. R: Sigma0 VV, G: Sigma0 VH, B: ratio](image)

**Figure 10** Tillage occurrence detection in Wallonia with S1A - SAR time series. R: Sigma0 VV, G: Sigma0 VH, B: ratio

**Plans for Next Growing Season**

In the 2017 season, several airborne campaigns will be carried out along with satellite acquisitions. The BELAIR campaign will fly the APEX hyperspectral camera twice over the area while the BELSAR experiment will test a bistatic radar L-band acquisition for five dates along the crop cycle.

In addition, a RADARSAT-2 multiyear time series will be processed to test the quad-pol potential for agriculture monitoring.

**Publications**

1. Matton, Nicolas; Sepulcre Canto, Guadalupe; Waldner, François; Valero, Silvia; Morin, David; Inglada, Jordi; Arias, Marcela; Bontemps, Sophie; Koetz, Benjamin; Defourny, Pierre, *An Automated Method for Annual Cropland Mapping along the Season for Various Globally-Distributed Agrosystems Using High Spatial and Temporal Resolution Time Series*, 2015, Remote Sensing, Vol. 7, no.10, p. 13208-13232

2. Valero, Silvia; Morin, David; Inglada, Jordi; Sepulcre Canto, Guadalupe; Arias, Marcela; Hagolle, Olivier; Dedieu, Gérard; Bontemps, Sophie; Defourny, Pierre; Koetz, Benjamin,

3. Inglada, Jordi ; Arias, Marcela ; Tardy, Benjamin ; Hagolle, Olivier ; Valero, Silvia ; Morin, David ; Dedieu, Gérard ; Sepulcre Canto, Guadalupe ; Bontemps, Sophie ; Defourny, Pierre ; Koetz, Benjamin, Assessment of an Operational System for Crop Type Map Production Using High Temporal and Spatial Resolution Satellite Optical Imagery, 2015, Remote Sensing, Vol. 7, no.9, p. 12356-12379


5. Radoux, Julien ; Chomé, Guillaume ; Jacques, Damien ; Waldner, François ; Bellemans, Nicolas ; Matton, Nicolas ; Lamarche, Céline ; d'Andrimont, Raphaël ; Defourny, Pierre, Sentinel-2's Potential for Sub-Pixel Landscape Feature Detection, 2016, Remote Sensing, Vol. 8, no.6, p. 488.

6. Delloye, Cindy ; Weiss, Marie ; Baret, Frédéric ; Morin, David ; Defourny, Pierre, Accuracy assessment of GAI retrieval from SPOT5 Take5 according to crop type and crop development (BELCAM), Living Planet Symposium 2016 Prague, Czech Republic.

6. Brazil

6.1 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

- 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.

EO Data Received/Used

Mission/sensor: Landsat-8

• Space agency or Supplier: NASA
• Optical
• Number of scenes: 19
• Range of dates: 08/09/2013 – 01/06/2016 (will be extended to 05/2017)
• 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.

Mission/sensor: SPOT

• Space agency or Supplier: Airbus Defense and Space
• Optical
• Number of scenes: 2
• Range of dates: 21/02/2015 – 03/03/2015
• Beam modes/ incidence angles/ spatial resolutions: 10 m
- Processing level: TOA reflectance.

**Figure 11**  Footprints of the Satellite Images Used

In Figure 11, the raster image represents the area classified.
Figure 12  Satellite Images Used in the Classification, with Clouds Masked
Figure 13  Diagram Representing the Acquisition Dates and Cloud Cover for each Quarter of the Images

In situ Data

We collected 847 GPS points 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 14). GPS points were afterwards converted to polygons based on the images.

During 2015 and 2016, measurements during 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.

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; therefore, an annual visit is mostly sufficient. These sites are mostly Eucalyptus plantations, sugarcane, pastures, coffee plantations, citrus plantations, pine plantations). Land use changes occurred in a few of these sites, and they were discarded in some of the treatments. This complete dataset field inventory will be done again before April 2017.
During 2015 and 2016, of the 265 sites visited regularly, 96 sites were annual culture fields, while the others were mainly pasture and sugarcane. These sites presented a large variety of crop cycles, listed in the table and figure below. There are a very large number of combinations of land cover classes through the year. To see a bit more clearly, we have added different colors 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 throughout the year. For the sugarcane, not presented in the figure, the date of harvest could be almost anytime in the year. Some fields have a succession of 3 different cultures during the year.
<table>
<thead>
<tr>
<th>Month</th>
<th>Example of Crop Types Measured about every 3 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec 2014</td>
<td>soya, corn, potato</td>
</tr>
<tr>
<td>March 2015</td>
<td>soya, wheat, potato</td>
</tr>
<tr>
<td>May 2015</td>
<td>soya, wheat, potato</td>
</tr>
<tr>
<td>Aug 2015</td>
<td>soya, wheat, potato</td>
</tr>
<tr>
<td>Nov 2015</td>
<td>soya, wheat, potato</td>
</tr>
<tr>
<td>Feb 2016</td>
<td>soya, wheat, potato</td>
</tr>
<tr>
<td>Apr 2016</td>
<td>soya, wheat, potato</td>
</tr>
</tbody>
</table>

**Figure 15** Example of Crop Types Measured about every 3 Months
Figure 16  Crop Calendar (Main Crops)

Figure 17  Site Photos
Collaboration

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.

SIGMA - JECAM experiment on tropical agrosystems

This work is led by CIRAD and aims at testing a common methodology for the tropical sites of JECAM for agriculture mapping, based on Sentinel and SPOT datasets. This study is ongoing and first results should come by middle of 2017. There are 4 sites clearly involved, and others which will probably participate.

Results

The method for mapping land cover in this site was described in the JECAM poster presented at Kyiv.
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”. Once the “annual crop” mask is 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. The last option is to perform a date-by-date classification at the species scale; however, some species will have few training points. This was the method that we selected, but grouping some species together. Indeed, the diversity of intra-annual crop cycles are very variable.

Another main question is which remote sensing data can be used. Indeed, during the wet season, very few images are available. Therefore, we are developing a new classification program which can 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. The second algorithm showed better results and was kept for the rest of the study.

**Annual Land Cover Map**

The global accuracy for the 11 class nomenclature was 0.88 on the calibration dataset (see confusion matrix below) for February 2016. The highest confusion was between sugarcane and pasture, orange orchards and other perennial classes, and bare soil and annual crops. However, the confusion matrix is not independent from the calibration dataset, and accuracies may therefore be overestimated.
Table 3  Confusion Matrix

Visual interpretation of the obtained map (Figure 18) show good predictions for most of the classes. The clear distinction between sugarcane area in the NW and E, forest plantation in the Center West, annual crops in the south and pastures in the Center East is largely coherent with other large scale maps of the area such as the Probio Map (http://www.mma.gov.br).

The orange orchards are well predicted for large fields, but there is a confusion with natural vegetation for small polygons.
Crop Map at 3-month Time Step: The global accuracy was computed for each field inventory date, considering only the crop class that had more than 10 observations in the calibration dataset (see Table 4). The calibration dataset is therefore largely reduced to 115 to 222 observations. The global accuracies are given in the tables below, and highly depend on the date.
## Table 4  Accuracies of 3-Month Classifications

### Conclusions

While the algorithm used was able to deal efficiently with clouds or other no-data, there are at least three main issues with this ongoing work:
• The confusion in some classes (e.g. orange orchards) which can be solved either by adding field observations in the training dataset, or adding better predictive variables. The segmentation step can also have a high impact on the classification result, especially in small and fragmented areas such as riparian forests, and this should be quantified.

• The crop types have been predicted for each date independently, which reduces the number of observations for training the algorithm, and also reduced the number of classes.

• The “bare soil” class had a high confusion with crop. Indeed, in first growth stages of crops, the proportion of visible bare soil is high. In late growth stages, many crops become dry and are confounded with residues in harvested fields.

This JECAM site is particularly interesting to test classification algorithms including perennial tree-based agriculture (eucalyptus, pines, coffee, orchards), pastures, perennial crops (sugarcane), and annual crops.

To what extent have the project objectives been met? The joint work with other JECAM sites for classification of tropical agriculture is the priority.

Can this approach be called ‘best practice’? The method seems reliable enough, and was discussed with other JECAM sites from tropical areas.

**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. A general inventory will be conducted before April 2017, synchronously with a SPOT7 image acquisition.

We anticipate ordering the same type/quantity of EO data next year, including Sentinel 2 data.

**Publications**

One submitted paper:


Le Maire G., Dupuy S., Boury J., Lebourgeois V., Bégué A., Presentation of the JECAM Brazil – Botucatu (São Paulo) site activities , JECAM/GEOGLAM Science Meeting, Kiev, 11-12 October, 2016 (poster).

6.2 Brazil – Tocantins

**JECAM Test Site Name:** Tocantins – MATOPIBA

**Team Leader and Members:** Margareth Simoes, Rodrigo Ferraz, Pedro de Freitas, Balbino Evangelista, Elisandra Bortolon, Leandro Bortolon, Cleso Manzatto (the preceding all from Embrapa), Agnès Bégué & Beatriz Bellón (both from CIRAD)

**Project Objectives**

The original objectives for the site have not changed.

**Crop identification and Crop Area Estimation**

**Aim:** Support the Brazilian Low Carbon Agriculture Program (ABC Program)

- Cropland
- Crop types
- Agricultural systems & level of intensification: crop livestock forest integration; crop rotation; cropping patterns; agroforestry systems

**Main agricultural systems:**

- Double cropping system of summer soybean monoculture (mostly no-tillage or minority with conventional tillage), usually with a cereal crop (corn, millet or sorghum) at the end of the same season: 634,800 hectares for the whole state of Tocantins.

- Sugarcane crop (burning and/or mechanized harvesting): 31,150 hectares for the whole state of Tocantins.

- Pasture/livestock, mostly livestock on planted pasture (extensive production); different pasture conditions (good to degraded); integrated crop-livestock systems (only present in some farms but the adoption of these systems tends to grow in the region).

**Crop Conditions/Stress**

Despite the regional climate having a pronounced dry season, the annual grain-crops cultivation is carried out in the rainy season, so there are no pronounced water stress events during the
growing season of this type of crops. However, if there is any irregularity in rainfall, especially at the end of the rainy season (which is locally called "veranico"), there may be some level of water stress on non-irrigated crops, especially in areas where soils have sandy textures, such as Entisols, which are excessively or strongly drained.

Long-cycle crops, such as sugarcane, may be affected by different levels of water stress, depending on the conditions of culture, soil types and phenological stage. As for pastures, a strong decrease in biomass production during the dry season is frequently observed because of water scarcity conditions. Phytopathological damage and plant stress occur sporadically on localized areas.

**Soil Moisture**

Besides depressed areas (flood plains) with hydromorphic soils (soils saturated with water most of the year), most of the regional soils are well drained. The amount of soil moisture retention therefore depends on the mulch management and, significantly, on the texture of the soil (soil moisture retention being proportional to the amount of clay in the soil).

**Crop Residue, Tillage and Crop Cover Mapping**

Most of the area has adopted no-tillage/zero tillage systems. This technology consists in sowing directly on the straw-mulch of previous crop residues. Typically, in the double cropping system, soybean is sown directly over the second crop’s (cereal) residues, and in some cases the straw of desiccated grass (Brachiaria is sometimes planted after the second crop to add more straw to the mulch cover).

However, some fields undergo conventional tillage; either when cereal residues are collected for use as fodder, (soil is therefore left exposed), or when soils are limed (technique that involves the application of calcium and magnesium materials to soil to correct acidity). No tillage is required for sugarcane ratooning; however, in the burnt cane harvested fields, conventional tillage is still applied.

**Site Description**

The Tocantins JECAM site is part of the MATOPIBA Region, a new agricultural expansion area in Brazil.

**Location**

Municipality of Pedro Afonso and surroundings (Center-North Region of Brazil).
The climate is megathermal wet weather (Thornthwaite-Mather (1955)). The average annual rainfall is from 1700 to 1800 mm, with moderate winter water deficit. The potential evapotranspiration has an annual average variation between 1,400 and 1,700 mm and an average of 28% in summer (three consecutive months with higher temperature).

**Landscape topography**

There is a dominance of the topographic modeled type A: Areas with mild relief, slightly undulating with soft slopes (declivity equal to or less than 5%) in which, in most soils, the runoff is slow or medium. There is a subdominance of the topographic modeled type B: Areas with sloping surfaces (declivity greater than 5% and equal or less than 10%), usually with undulating relief, in which the runoff, for most soils is medium or fast.

**Soils**

Dominance of Yellowish-Red Oxisols and Entisols.
Yellowish-Red Oxisols - Medium to clay texture: they range from strongly drained to well drained depending on their texture and porosity, but can have adequate moisture.

Entisols (Quartzipsamments) - Sandy texture: they range from of excessively drained to strongly drained depending on their topographic position and the level of the water table; they may have moisture limitations in dry periods.

**Irrigation Infrastructures**

Centre-pivot irrigation systems.

**Crop calendar**

Double cropping system:

- Summer soybean crop - from November to February (harvest in January/February)
- Cereal crop - from March to May (harvest in April/June)

Sugarcane crop: annual cycle (12 months) or longer (18 months).

**Field size**

Mostly large (fazendas with fields of ~ 100 ha), and some smallholders.

**Agricultural methods**

Seeding, fertilization, pesticide application and harvest are carried out with mechanical equipment.

Concerning soil management, most of the area has adopted no-tillage/zero tillage systems. Very few fields undergo conventional management with plowing, harrowing and occasional liming.
Figure 20  (a) Cover Crop Millet Residues (b) Centre-pivot Irrigation over Sugarcane Plantation

Figure 21  (a) Rubber Tree (Hevea Brasiliensis) Plantation (b) Soybean Growing over Corn Residues
Figure 22  (a) Sugarcane Mill (b) Field Undergoing Conventional Tillage and Liming

Figure 23  (a) Cattle Grazing in Open Grassland Field (b) Confined Meat Cattle
## EO Data Received/Used (2017)

<table>
<thead>
<tr>
<th>Mission/Sensor</th>
<th>Supplier</th>
<th>Product</th>
<th>Optical/SAR</th>
<th>Number of scenes</th>
<th>Range of dates</th>
<th>Spatial resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat 8/OLI</td>
<td>NASA / USGS</td>
<td>OLI L1T</td>
<td>Optical (Band XS - Surface reflectance)</td>
<td>1</td>
<td>28/07/2016</td>
<td>XS = 30m</td>
</tr>
<tr>
<td>Terra/MODIS</td>
<td>NASA</td>
<td>MOD13Q1 L3</td>
<td>Optical (Bands: NDVI ; VI Quality)</td>
<td>46 (1 scene = 16 day composite)</td>
<td>OCT 2014 to SEP 2016</td>
<td>250m</td>
</tr>
</tbody>
</table>

![Figure 24 Landsat-8 OLI PXS](image)

Figure 24  Landsat-8 OLI PXS
In situ Data

Land use and land cover observations were carried out following the JECAM field data collection guidelines. 256 GPS waypoints were collected during the land use survey using the high resolution Landsat 8 image of the 28th of July printed in an A1 format for tracking the observations.

Attributes of the database include centroid position, date of entry, land use information (Crop/Non crop, cropping pattern) and georeferenced photo ID.
### Table 5  In situ Data Classes

<table>
<thead>
<tr>
<th>LULC Class</th>
<th>Legend</th>
<th>No. of occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Annual cropland</strong></td>
<td>C</td>
<td><strong>131</strong></td>
</tr>
<tr>
<td>Multiple cropping</td>
<td>MULCR</td>
<td>53</td>
</tr>
<tr>
<td>Single cropping</td>
<td>SINCR</td>
<td>78</td>
</tr>
<tr>
<td><strong>Other LCC</strong></td>
<td>NC</td>
<td><strong>125</strong></td>
</tr>
<tr>
<td>Grassland and meadows</td>
<td>GRAS</td>
<td>14</td>
</tr>
<tr>
<td>Fallows</td>
<td>FALL</td>
<td>19</td>
</tr>
<tr>
<td>Shrubland</td>
<td>SHR</td>
<td>47</td>
</tr>
<tr>
<td>Forest</td>
<td>FOR</td>
<td>37</td>
</tr>
<tr>
<td>Build-up Surface</td>
<td>BUIL</td>
<td>3</td>
</tr>
<tr>
<td>Water bodies</td>
<td>WAT</td>
<td>5</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td></td>
<td><strong>256</strong></td>
</tr>
</tbody>
</table>
Collaboration

The Tocantins site collaborates on the JECAM experiment protocol for the experiment on source inter-comparison and large area mapping. The objective is to compare different input data sources (in-situ, crowd-source, landcover-derived) to assess their accuracy and see the applicability for regional large-scale cropland mapping across the globe.

To date, the nomenclature of the in situ data collected from the 2015-2016 growing season for the Tocantins site has been adapted following the protocol established for JECAM and a new expanded site area (of 300km x 300km) has been proposed for further cropland mapping tests.

Results

An unsupervised object-based classification approach was used for LULC mapping.

Segmentation
« Multiresolution segmentation » (eCognition Developer):

Image Layers = B, V, R, NIR, MIR (Landsat 8 image at original 30m spatial resolution)

Scale parameter = 110

Shape = 0.8

Compactness = 1

**Figure 27** Segmentation Extract

**Classification**

**Figure 28** Extraction of the Median NDVI Value per Segmented Object from the MODIS Time Series
The next steps include the classification of the resultant median values. The classification results are expected to improve with respect to last year’s classification results, in particular for the sugarcane fields with a long cultural cycle (18 months) which should be differentiated from grassland fields with the new longer time series (24 months).

**Plans for Next Growing Season**

Classification tests are ongoing with time series clustering methods such as dynamic time wrapping (DTW) clustering, which seem more appropriate, regarding the input data, than the original k-means clustering approach.

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

**Publications**

Bellón, B., Bégué, A., Simões, M., Ferraz, R., Lo Seen, D., Lebourgeois, V. Presentation of the Brazil – Tocantins site activities. JECAM/GEOGLAM Science Meeting, Kiev, 11-12 October, 2016 (poster)

### 7. Burkina Faso

No report received.
8. Canada

8.1 CFIA (Canadian Food Inspection Agency), Ottawa

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

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

Res. Team: S. Admiral, M. Mesbah, D. Dow, T. Hotte


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.” *Note: this project is completed; no new EO project was submitted or funded.*

Objectives:

- Validation of biophysical and biochemical descriptors
- 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.

![Eddy Covariance Instruments and Flux Gradient Intakes](Figure 29)

CO$_2$, H$_2$O 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, yield mapping non-destructive PAI, lChl (Dualex), crop cover (nadir photos), soil April 2017
moisture & temperature, and intercepted PAR are performed. Other data are obtained from the weather station.

**Figure 30** Photograph showing Early Planted Soybean on left, Late Planted on right at the Main Research Field on 1 Sept 2016

**EO Data Received/Used**

The EO data used in 2016 are shown in Table 6. Figure 31 and Figure 32 provide examples.
### Table 6  EO Data Collected for CFIA in 2016

<table>
<thead>
<tr>
<th>Data</th>
<th>Supplier</th>
<th>Sensor</th>
<th># scenes</th>
<th>Dates</th>
<th>Mode/ resolution</th>
<th>Processing level</th>
<th>Challenges</th>
</tr>
</thead>
<tbody>
<tr>
<td>CHRIS-Proba</td>
<td>ESA</td>
<td>Optical</td>
<td>3 cloud free</td>
<td>May 9, Jul 11, Aug 29</td>
<td>MOD 3 17-m</td>
<td>Radiance</td>
<td>Cloud, spontaneous acquisition</td>
</tr>
<tr>
<td>Landsat-8</td>
<td>USGS</td>
<td>Optical</td>
<td>10 cloud free</td>
<td>Apr 29, May 6 and 22, Jun 16 and 23, Aug 3, 19 and 26, Sep 4 and 27</td>
<td>30-m</td>
<td>Radiance</td>
<td>Cloud/long revising cycle</td>
</tr>
</tbody>
</table>

**Figure 31  CHRIS-Proba, True Colour Image, 29 August 2016**
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 (LAI-2200C, PASTiS-57 sensors)
- APAR (using 1-m long integrated PAR bars and PASTiS-PAR)
- Soil moisture (continuous soil profiles & gravimetric sampling)
- Soil fertility sampling
- Destructive biomass, leaf area and yield mapping
- Non-destructive leaf chlorophyll (Dualex)
- Meteorological stations (rain gauge, net radiometers, PAR, anemometers, air temperature, relative humidity, soil temperature & moisture profiles)
- Flux gradient N₂O fluxes (using tunable diode laser).
Figure 33  Ultrasonic Anemometer Installed on the Eddy Covariance Flux Tower for Measuring CO₂, Latent and Sensible Heat Fluxes

In Figure 33, intakes for N₂O gradient flux measurement are in the background.

Figure 34  Automated Soil Respiration Chamber to Measure CO₂ Efflux from the Field Surface (LI-COR, Lincoln, NE)
Collaboration

This year, we did not collaborate with others.

Results

Two crops were monitored: soybean (F14) and corn (F14N). Soybean and corn were planted by the private producers. April, May and July were drier than normal and June was near normal for rainfall.
Figure 36  Daily Precipitation Measured at Field Site (April 12 to October 26) or at the airport site (before April 12 and after October 26)

The delay in the seeding was seen in the biomass sampling data. The rainfall in mid-August resulted in some enhanced growth in the late seeded soybean but not the early seeded soybean.

Figure 37  Dry Shoot Biomass of Soybean in 2016 (CFIA, Field 14)
The fraction of absorbed PAR was measured using longbars in early and late seeded soybean as well as corn. PASTiS-PAR and PASTiS-57 measurements were attempted but difficulties with the equipment prevented gaining meaningful data.
The delay in seeding was also seen in the leaf chlorophyll measurements obtained with the Dualex. Dualex units approximate µg m$^{-2}$ leaf chlorophyll.

Soybean yield measurements showed values slightly smaller in the drier areas of the field (west) and slightly higher values in the wetter areas (east, water feature in the centre).
Yield from the corn 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 the whole growing season. The cumulative evapotranspiration associated with the late seeded soybean (295 mm) was lower than that of the early seeded soybean (317 mm).

The cumulative dry biomass extracted from the CO₂ flux data indicated that the late seeded soybean accumulated about 25% less biomass than the early seeded site.

Biophysical products were derived by CNES from Landsat-8 and RapidEye data acquired over CFIA in 2013 and 2014, using the Sentinel-2 product processing stream. For Landsat-8 data, top

April 2017
of canopy reflectance in the green, red, NIR and SWIR-1 bands were used; for RapidEye, all five bands (blue, green, red, red-edge and NIR) were used.

The products include the estimates of four biophysical parameters: LAI, cover fraction (fCover), black and white sky fAPAR. The accuracy of the products is satisfactory. The two attractive aspects of the S2 products are as follows:

1) the products result from an inversion approach based on radiative transfer modelling;
2) the products issued from the two satellite sensors are consistent, which shows the robustness of the approach knowing that the reflectance information used for the two sensors is quite different.

The performance of assimilation strategies using different optimization algorithms based on JECAM CFIA-Ottawa datasets is in progress.

**Plans for Next Growing Season**

Next growing season, we will use a similar approach. The main experimental site will be planted in corn; the second sites will continue rotation of corn, soybean, and wheat. We do not anticipate destructive sampling in other fields because there is no more funding to support this activity. However, we will deploy available longbar fAPAR, PASTiS-PAR, and PASTIS-57 sites in representative fields as resources allow.

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

**Publications**


8.2 South Nation Watershed

Team Leader and members: Dr. Heather McNairn, Dr. Jiali Shang, 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

<table>
<thead>
<tr>
<th>Site Extent</th>
<th>Centroid:</th>
<th>45.332, -75.050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top left:</td>
<td>45.416, -75.214</td>
<td>Bottom Right: 45.249, -74.886</td>
</tr>
</tbody>
</table>

WEBs Sub-Watershed

<table>
<thead>
<tr>
<th>Site Extent</th>
<th>Centroid:</th>
<th>45.265, -75.176</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top left:</td>
<td>45.268, -75.214</td>
<td>Bottom Right: 45.248, -75.142</td>
</tr>
</tbody>
</table>

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-‘tileshed’ (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 6.2ºC, 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 2016.

Results

This site was quiet this year.

Plans for Next Growing Season

No plans.
8.3 Red River Watershed

Team Leader and Members: Heather McNairn, Tom J. Jackson, Jarrett Powers, Stephane Bélair, Aaron Berg, Paul Bullock, Andreas Colliander, Michael H. Cosh, Seung-Bum Kim, Ramata Magagi, Anna Pacheco, Amine Merzouki, Mehdi Hosseini, Krista Hanis-Gervais

1 Agriculture and Agri-Food Canada, Science and Technology Branch, Ottawa, ON K1A 0C6, CANADA

2 USDA-ARS Hydrology and Remote Sensing Lab, Beltsville, MD 20705, USA

3 Agriculture and Agri-Food Canada, Science and Technology Branch, Winnipeg, MB R3C 3G7, CANADA

4 Environment Canada, Meteorological Research Branch, Dorval, QC H9P 1J3, CANADA

5 University of Guelph, Department of Geography, Guelph, ON N1G 2W1, CANADA

6 University of Manitoba, Department of Soil Science, Winnipeg, MB R3T 2N2, CANADA

7 Jet Propulsion Laboratory, Pasadena, CA 91109, USA

8 Université de Sherbrooke, Département de géomatique appliquée, Sherbrooke, QC J1K 2R1, CANADA

Project Objectives

This year we focused on the Soil Moisture Active Passive Validation Experiment 2016 for Manitoba (SMAPVEX16-MB).

Site Description

• Location: Red River and Assiniboine River Basins, Manitoba (MB), Canada (see Figure 44). The site dimensions are approximately 26 km x 48 km.

• 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 (sand-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.

- Field size: Quarter Section - 64 hectares (160 acres).

![Image of map showing SMAPVEX16 intensive site](image)

**Figure 44** Location of the SMAPVEX16 intensive site relative to the city of Winnipeg (Manitoba)

- 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: more than 85% of the area is dominated by the following annual crops: canola, soybeans, wheat, corn, oats, winter wheat and beans. Only a small fraction (< 5%) is under grassland and pasture. The crop type distribution within the SMAP region of interest is described in Table 7.
<table>
<thead>
<tr>
<th>Crop Type</th>
<th>Percent Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybeans</td>
<td>29.88</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>24.12</td>
</tr>
<tr>
<td>Canola/Rapeseed</td>
<td>18.24</td>
</tr>
<tr>
<td>Corn</td>
<td>8.28</td>
</tr>
<tr>
<td>Oats</td>
<td>6.92</td>
</tr>
<tr>
<td>Deciduous Forest</td>
<td>2.29</td>
</tr>
<tr>
<td>Grassland</td>
<td>1.96</td>
</tr>
<tr>
<td>Beans</td>
<td>1.50</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>1.41</td>
</tr>
<tr>
<td>Sunflower</td>
<td>1.12</td>
</tr>
<tr>
<td>Others</td>
<td>4.28</td>
</tr>
</tbody>
</table>

**Table 7  2015 Crop Type Distribution within the SMAP Pixel**

**EO Data Received/Used**

Both passive (SMAP and SMOS) and active (RADARSAT-2, Sentinel-1A/B, RISAT-1, TerraSAR-X, ALOS-2 PALSAR) microwave satellite data were collected before, during and after SMAPVEX16-MB. Landsat-8 and Sentinel-2 imagery was also available, and AAFC programmed acquisitions of RapidEye. In addition, the Jet Propulsion Laboratory’s Passive Active L-band Sensor (PALS), mounted on a DC-3, flew over the SMAP pixel several times. For details, see the project report “SMAPVEX16-MB, SMAP Validation Experiment 2016 in Manitoba, Canada” at [http://www.jecam.org/?/project-reports/canadian-red-river-watershed](http://www.jecam.org/?/project-reports/canadian-red-river-watershed)
In situ Data

Extensive in situ measurements were taken, including the following:

- Soil moisture measurements using hand held Hydra Probes
- Soil core samples
- Soil and vegetation temperature measurements
- Surface roughness
- Crop measurements and biomass sampling:
  - Crop density and row direction
  - Sampling strategy for crops
  - Biomass and vegetation water content
  - Crop height
  - LAI
  - Crop phenology
  - Point multi-spectral crop scans
  - Field-scale multi-spectral scans
- Ground-based radiometer.

These measurements were also supported by the JPL PALS sensor. For details, see the project report “SMAPVEX16-MB, SMAP Validation Experiment 2016 in Manitoba, Canada” at http://www.jecam.org/?/project-reports/canadian-red-river-watershed

Results

See the project report “SMAPVEX16-MB, SMAP Validation Experiment 2016 in Manitoba, Canada” at http://www.jecam.org/?/project-reports/canadian-red-river-watershed

Plans for Next Growing Season

No information.

Publications

Project report “SMAPVEX16-MB, SMAP Validation Experiment 2016 in Manitoba, Canada” at http://www.jecam.org/?/project-reports/canadian-red-river-watershed
9. China

9.1 Anhui
No report was received this year.

9.2 Guangdong (Two Sites)
There are two JECAM sites in Guangdong, at Leizhou and Taishan. Neither of them reported this year.

9.3 Heilongjiang
No report was received this year.

9.4 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 Jinhu (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 45). 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 46) 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 45. The cloud and sun symbols mean Transplant and Direct-planting Rice Fields respectively.

Figure 45  Location of Jiangsu Test Site and the Distribution of the Sample Plots
Figure 46  Rice Fields in the Jiangsu Test Site

(a) Transplanting  (b) Direct-seedling

EO Data Received/Used

During rice growing season of 2016, 21 scenes of RADARSAT-2 images were received, including seven Quad-pol images and 14 Ultra-Fine images. The details of the SAR data are displayed in Table 8.

Table 8  EO Data Received in 2016 for the Jiangsu Site

<table>
<thead>
<tr>
<th>Space agency or Supplier/ Mission</th>
<th>Optical/SAR</th>
<th>Number of scenes</th>
<th>Range of dates</th>
<th>Beam modes</th>
<th>Incidence angles (Degree)</th>
<th>Spatial resolutions (Rng x Az, m)</th>
<th>Processing level</th>
</tr>
</thead>
<tbody>
<tr>
<td>MDA/ CSA (RADARSAT-2)</td>
<td>SAR</td>
<td>7</td>
<td>June 6 - Nov 21, 2016</td>
<td>FQ20W</td>
<td>38.6-41.3</td>
<td>5.2x 7.6</td>
<td>SLC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14</td>
<td>June 13 – Nov 28, 2016</td>
<td>UF6</td>
<td>34.0-35.3</td>
<td>1.6 x 2.8</td>
<td>SLC</td>
</tr>
</tbody>
</table>

In situ Data

During the rice growing season of 2016, six ground campaigns were conducted. Forty-two sample plots were selected; most of them coincided with the sample plots of 2012 and 2015. Rice variety, crop calendar, phenological stage, plantation geometry, and rice parameters were collected at each sample plot. In addition, soil and meteorological data in the test region were collected.

Collaboration

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

1. An automated method for rice phenology monitoring

An automated method of rice phenology retrieval was developed using a feature optimization strategy integrated support vector machine (SVM) and sequential forward selection (SFS). The flowchart of the method is displayed in Figure 47. The optimal polarimetric variables for each phenological stage were acquired, based on which eight rice phenological stages were retrieved automatically. The accuracies were higher than 90% except for the dough stage and the transition period between two stages.

![Flowchart of the Rice Phenology Retrieval](image)

**Figure 47** Flowchart of the Rice Phenology Retrieval

2. Further validation of the method of rice parameter estimation proposed in 2015

In 2015, a modified water cloud model (MWCM) for rice parameters estimation was proposed, in which the heterogeneity of the rice canopy were considered as well as the polarimetric information. We validate the method using R-Square and RMSE only. In 2016, we further validated the methods and compared the results with that of the traditional water cloud model (Figure 48).

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In CASE I, the heterogeneity of rice canopy in the horizontal direction is considered without the polarimetric information. In CASE II, the polarimetric variables from the improved polarimetric decomposition are used in the MWCM, while the heterogeneity of rice canopy in the horizontal direction is ignored. In CASE III, both the heterogeneity of rice canopy and the polarimetric information are considered in the MWCM.

During the whole rice growth cycle, $\Delta r$ (the difference between the relative error of the WCM and the modified WCM (Case I, II, III); $\Delta r=R_W - R_{\text{CASE I, CASE II, CASE III}}$) was largest for CASE III, implying that the estimation accuracy is best by considering both the heterogeneity of rice canopy and the decomposition components. From the seedling to the booting stage (from June 27 to Aug. 4), $\Delta r$ for CASE I (larger than 10%) is much larger than that for CASE II (2-3%), implying that the estimation accuracy is improved much by considering the heterogeneity of rice canopy during this period, whereas the estimation accuracy is just improved approximately 3% by applying the decomposition components. From the heading to the mature stage (from Aug. 28 to Oct. 15), $\Delta r$ for CASE II (approximately 5%) is larger than that for CASE I (less than 2%), implying the application of decomposition components in the MWCM could improve the estimation accuracy more than the consideration of the rice canopy heterogeneity during the reproductive phase of rice growth cycle. In sum, the heterogeneity of rice canopy is very essential to consider in the MWCM, especially during the vegetative phase. When the rice canopy becomes dense and uniform, the heterogeneity of the rice canopy decreases. The application of decomposition components in the MWCM could improve the estimation accuracy by 3-5% during the rice growth cycle.
Figure 48  Estimation Accuracies for the Three Cases of (a) LAI, (b) h, and (c) \( m_v \)

3. The multi-sphere ear scattering model

A novel rice ear scattering model, the multi-sphere ear scattering model, was developed by incorporating the micro-structure of rice ear panicles, including the ear grain parameters in particular. A virtual ear model (Figure 49) was used to simulate the ear morphology, and a multi-sphere scattering model was used to simulate the ear scattering. This novel multi-sphere ear scattering model provides a potential way of retrieving grain parameters from SAR imagery. In Figure 49, \( \phi_0 \) and \( \phi_N \) are the basal and distal elevation angle of the axis curve, obtained from ground measurements.
Figure 49  Virtual Rice Ear with $\varphi_0 = 74.39^\circ$ and $\varphi_N = 50.70^\circ$

Figure 50  Simulation Results over 100 Realizations
Plans for Next Growing Season

First, we will validate our methods with the dataset acquired in 2016. Second, we will further validate our methods at another place, Zhejiang, China. Third, we will improve the multi-sphere ear scattering model and retrieve ear biomass using the model.

We plan to acquire polarimetric SAR data at Zhejiang, China, in 2017.

Publications

Presentations:


Peer reviewed papers:


Long Liu, Yun Shao, Kun Li, and Zhi Yang. Modeling the scattering behavior of rice ears. IEEE Geoscience and Remote Sensing Letters. (Accepted)

9.5 Shandong

No report was received this year.
10. France

**JECAM Test Site Name**: Regional Space Observatory (in French OSR for Observatoire Spatial Regional), the area of study is approximately 50*50 km including the Auradé and the Lamasquère Fluxnet/ICOS sites (installed in 2004).

**Team Leader and members**: Eric Ceschia, Tiphaine Tallec, Aurore Brut, Olivier Hagolle, Frédéric Baup, Gérard Dedieu, Jean François Dejoux, Jordi Inglada, Valérie Demarez, Benoit Coudert, Vincent Rivalland, Silvia Valero, Claire Marais-Sicre, Milena Planells, Vincent Bustillo, Mireille Huc, Nathalie Jarosz, Bartosz Zawilski, Hervé Gibrin, Ahmad Albitar, Florian Helen, Rémy Fieuzal...

**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 approximately 50*50 km) including 2 experimental plots, Auradé and Lamasquère (which are Fluxnet/ICOS sites).
- 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 51  OSR including the Auradé and Lamasquère Fluxnet/ICOS Sites

Figure 52  Formosat-2 Image of the Area around the Auradé Site, 27 May 2006
EO Data Received/Used

**Sentinel 2:**
- Space agency or Supplier: CNES
- Optical/SAR: Optical
- Number of scenes: 230 scenes
- Range of dates: from 05-01-2016 to 21-10-2016
- Beam modes/ incidence angles/ spatial resolutions: the report contained an annex with details about this.
- Processing level: the report contained an annex with details about this.
- Challenges, if any, in processing and using the data: high amount of data to process and store.

**Landsat:**
- Space agency or Supplier: USGS
- Optical/SAR: Optical
- Number of scenes: 147 scenes
- Range of dates: from 29-09-2016 to 27-12-2016
- Beam modes/ incidence angles/ spatial resolutions: spatial resolution: the report contained an annex with details about this.
- Processing level: Level 2 or V2_THEIA
- Challenges, if any, in processing and using the data: high amount of data to process and store.

**Sentinel-1, SAR C band**
- Space agency or Supplier: CNES (PEPS)
- Optical/SAR: SAR
- Number of scenes: 289 images in 2016 (154 in 2015)
- Range of dates: from 06-11-2014 to 07-12-2015
• Beam modes/ incidence angles/ spatial resolutions: spatial resolution: 10m, incidence angle: 29°-46°

• Processing level: level 1

• Challenges, if any, in ordering and acquiring the data: some troubles downloading S1 images at the beginning of the PEPS service (not all the images were available after acquisition)

• Challenges, if any, in processing and using the data: high amount of data to process and store.

Figure 53  Auradé Site (black contour) and Surroundings from Sentinel-1 Image

Figure 53 shows the experimental site of Auradé (surrounded in black) and its surroundings. This is an RGB image of VV and VH backscatter from a Sentinel-1 image (20 m resolution) that was acquired on 5 May 2015. Vegetated areas appear in green.

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. Details concerning biomass, LAI and soil humidity measurements are presented in an annex of the report. Ground truth data of Land Use was collected 4 times during the year on approximately 450 plots (see Figure 56). Land Use monitoring campaigns have been carried since 2006 with approximately 450 plots monitored each year (see yellow and red fields on the map) and up to 1500 in 2015.

Figure 54  The Lamasquère Site around the Micrometeorological Station
Figure 55  The Auradé Site around the Micrometeorological Station

Figure 56  Land Use Monitoring Campaigns
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 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). The project ends in July 2017.

Partners of the S2-Agri project:

- Agriculture and Agri-Food Canada
- 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
- International Fund for Agricultural Development
- Instituto Nacional de Tecnologia Agropecuaria, Argentina
- Chouaib Doukkali University & Réseau National des Sciences et Techniques de la Géo-Information, Morocco
- Regional Center for Mapping of Resources for Development, Kenya
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): This project was financed in 2016 in response of the EO Work programme ‘EO-3-2016: Evaluation of Copernicus Services’. We answered that call 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). It aims to exploit the unprecedented capacity of S1 and S2 to develop an innovative portfolio of prototype 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. The prototypes should also be tested in Morocco and South Africa.

**Results**

Within the framework of the MAISEO project: irrigated crops were mapped over the OSR area and water requirements were estimated with the SAFY-WB model at a regional scale. The model was calibrated and validated against ETR flux measurements performed at the Lamasquère experimental site (see Figure 57, from M. Battude PhD Thesis, at CESBIO in 2017).
Within the framework of the frame of the CICC project: we used a large number of temporal Sentinel-1 together with Sentinel-2-like data to assess the potential of the Sentinel satellites for winter and summer crop monitoring. We applied an adapted multi-image filter to the Sentinel-1 images, taking advantage of the Sentinel-1 dense temporal series to reduce the speckle effect, while preserving the fine structure present in the image, like the crop fields boundaries. The time series of optical NDVI and radar backscatter (VH, VV and VH/VV) were analyzed and physically interpreted with the support of rainfall and temperature data, as well as the destructive in situ measurements (green area index (GAI) and fresh biomass, when available). We showed that a dense time series allows one to capture short phenological stages and thus to precisely describe various crop development. A better understanding of SAR backscatter and NDVI temporal behaviours under contrasting agricultural practices and environmental conditions will help many upcoming studies related to crop monitoring based on Sentinel-1 and -2, such as dynamic crop mapping and biophysical parameters estimation. Regarding crop mapping, we found that wheat and rapeseed could be better distinguished using VH and VV backscatters between March and July and using NDVI between November and December. Regarding summer crops, we recommend using VH/VV and VV to separate maize, soybean and sunflower during the heading/flowering phase. Results also showed that for barley and maize, both NDVI and VH/VV profiles are in good agreement with the destructive GAI and fresh biomass.
biomass measurements. Thus, VH/VV ratio could be successfully used for biophysical parameters retrieval and direct biomass assimilation in crop models. VH/VV is also able to detect post-harvest spontaneous regrowth. This is a promising result for applications such as the monitoring of regrowth and intermediate crops for estimating soil carbon storage in the perspective of climate change mitigation.

Figure 58 Observations of Winter Wheat and Rapeseed Fields: Temporal Behaviour of Optical NDVI, Radar VH/VV, VH, and VV, Rainfall and Temperature over Winter Crops

Figure 58 shows observations of winter wheat and rapeseed fields: temporal behaviour of optical NDVI, radar VH/VV, VH, and VV, rainfall and temperature over winter crops, i.e. 64 wheat crops (in blue) and 10 rapeseed crops (in red). Mean values are represented by dots and standard deviations are represented by the filled colour domains surrounding the curves. In the last plot (bottom), temperatures in red were measured at the Sentinel-1 acquisition time 6 a.m. The horizontal red line is the 0°C line. Vertical precipitation bars in blue are drawn in green the same days as the Sentinel-1 acquisitions and in red the two days before Sentinel-1 acquisitions, assuming that wet soil due to rainfall may still affect Sentinel-1 backscatter two days later. Vertical grey bars represent Sentinel-1 acquisition events.
Figure 59  Observations of Maize, Soybean and Sunflower Fields: Temporal Behaviour of Optical NDVI, Radar VH/VV, VH, and VV, Rainfall and Temperature over Summer Crops

Figure 59 shows observations of maize, soybean and sunflower fields: temporal behaviour of optical NDVI, radar VH/VV, VH, and VV, rainfall and temperature over summer crops, i.e. 57 maize crops (in blue), 8 soybean crops (in green) and 116 sunflower crops (in red). Mean values are represented by dots and standard deviations are represented by the filled color domains surrounding the curves. In the last plot (Bottom), temperatures in red were measured at the Sentinel-1 acquisition time 6 a.m. The horizontal red line is the 0°C line. Vertical precipitation bars in blue are drawn in green the same days as the Sentinel-1 acquisitions and in red the two days before Sentinel-1 acquisitions, assuming that wet soil due to rainfall may still affect Sentinel-1 backscatter two days later. Vertical grey bars represent Sentinel-1 acquisition events.

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

We have started some analysis of surface albedo from remote sensing based on different sensors including Sentinel 2 data. Our objective is to identify some management practices that could increase albedo in order to induce a cooling radiative forcing.
Plans for Next Growing Season

In the framework of the Sensagri and Bag’ages project (financed by the Adour Garonne Water Council), we plan to develop SAR data assimilation in our modelling approach of biomass, yield, C & water fluxes and budgets by using the SAFYE-CO2 model. We also plan to account for the effect of cover crops or crop regrowth on those fluxes and budgets.

Also in the framework of the Bag’ages project 9, micro-meteorological stations will be installed (see Figure 60), covering a soil (from very dark to clear) and climatic gradient from the south-west part of France to the Eastern Pyrenees. Those stations, installed on cropland with contrasted management, will allow us to monitor air/sol surface temperature, air humidity, precipitations, soil water content profiles from surface to 1m deep, ETR, incoming/outgoing shortwave radiation (albedo), incoming/outgoing longwave radiations. Automatic cameras will be used to monitor daily crop phenology/soil status/crop management. Those measurements will be used to validate high resolution albedo GAI and SWC products (some of them being developed within the frame of SENSAGRI).

![Figure 60](image.png)

Figure 60  Location of the 9 micro-meteorological stations that will be installed on agricultural plots in the frame of the Bag’ages project and that will complete the OSR setup

Finally, close to 1000 plots will be monitored 5 times a year to follow land cover (mainly on croplands) and crop management within the frame of the Sensagri project. Those data will be used for validation of dynamic high resolution land use maps.

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


11. **Italy Apulian Tavoliere**

**Team Leader and Members:** Annamaria Castrignanò¹, Sergio Ruggieri¹, Domenico Ventrella¹, Pasquale Campi¹, Michele Rinaldi², Piero Toscano³, Gabriele Buttafuoco⁴, Matteo Tomaiuolo¹, Alessandro Vittorio Vonella¹, Giacoma Girone¹

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. Further validate the simulation model AQUACROP to predict durum wheat yield and soil water content;
2. explore the potential of recently ESA launched satellite Sentinel-2 for its use in agriculture.

Owing to the Li-COR equipment malfunction, we could not apply the multivariate geostatistical method of data fusion, described in the previous report, aimed at the prediction of leaf area index (LAI), IPAR and crop height from a set of ground-truth Li-COR measurements by using multi-temporal Sentinel-2 multiband images as auxiliary variables.

**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 61 (Regione Puglia, 2009). The region is mostly cropped with durum wheat from November to June. The description of the area and of its main land use classes was already done in the previous reports.
EO Data Received/Used

Sentinel-2 carries an optical payload with visible, near infrared and shortwave infrared sensors comprising 13 spectral bands: 4 bands at 10 m, 6 bands at 20 m and 3 bands at 60 m spatial resolution with a swath width of 290 km. The 13 spectral bands guarantee consistent time series, showing variability in land surface conditions and minimizing any artefacts introduced by atmospheric variability. The mission orbits at a mean altitude of approximately 800 km and, with the pair of satellites in operation, has a revisit time of five days at the equator (under cloud-free conditions) and 2–3 days at mid-latitudes. Sentinel-2 combines a large swath, frequent revisit, and systematic acquisition of all land surfaces at high-spatial resolution and with a large number of spectral bands, all of which makes a unique mission to serve Copernicus. In particular, Sentinel-2 incorporates three new spectral bands in the red-edge regions, which are centered at 705, 740 and 783 nm.

The Sentinel-2 Payload Data Ground Segment offers data processing options with bottom-of-atmosphere (BOA) reflectance (Level-2a), through a software toolbox SNAP with Sen2cor tool made available to users, to derive and enhance cloud masks from the top-of-atmosphere reflectance (Level-1c)\(^1\). In this report, the Sentinel-2 atmospheric correction was performed

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based on the algorithm proposed in the Atmospheric/Topographic Correction for Satellite Imagery\(^2\).

Vegetation indices are simple numerical indicators that reduce multispectral (two or more spectral bands) data to a single variable for predicting and assessing vegetation characteristics\(^3\). Vegetation indices (VI) are among the oldest and most widely used tools to provide land-cover maps, land-change detection maps, and plants geophysical variables, such as chlorophyll content per unit leaf area (Ch), leaf area index (LAI) and leaf water content.

In this study, the following VIs were calculated: Normalized Difference Rededge Index (NDRE) as the difference of the reflectance at near infra-red (NIR) and Red edge spectral bands normalized by the sum of the reflectance at these spectral bands at 20-m spatial resolution:

\[
\text{NDRE} = \frac{\text{nir}(865\,\text{nm}) - \text{rededge}(705\,\text{nm})}{\text{nir} + \text{rededge}}
\]

Canopy Chlorophyll Content Index (CCCI) was calculated from the Normalized Difference Red Edge index (NDRE) because it is correlated with chlorophyll and leaf N\(^4\):

\[
\text{CCCI} = \frac{\text{NDRE} - \text{NDRE}_{\text{min}}}{\text{NDRE}_{\text{max}} - \text{NDRE}_{\text{min}}}
\]

CCCI was downscaled to 10-m resolution.

**AquaCrop Model Simulation**

For model application, the dataset collected at an experimental field in Capitanata area was used.

The application of the AquaCrop model\(^5\) to a given crop requires that a series of inputs is determined. The inputs are related to:

- Meteorological data: Daily values of maximum, minimum temperature, rain and reference evapotranspiration;

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3 http://www.esa.int/Our_Activities/Observing_the_Earth/Copernicus/Sentinel-2_overview

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Management data: sowing date of 1\textsuperscript{st} December 2014 was considered; quantity of nitrogen (150 Kg of N ha\textsuperscript{-1}); root growth data (1.2 m in depth).

Physiological parameters of wheat calibrated and validated in the last years were used.

Soil data: Water content at the field capacity (FC) and wilting point (WP) were measured at four points of the test sites (Table 9 and Figure 62).

Table 9  Water Content at the Field Capacity and Wilting Point collected in four points at an Experimental Field in Capitanata

<table>
<thead>
<tr>
<th>point</th>
<th>Y</th>
<th>X</th>
<th>FC (% in volume)</th>
<th>WP (% in volume)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A - 5</td>
<td>4589116.70</td>
<td>582784.55</td>
<td>39</td>
<td>28</td>
</tr>
<tr>
<td>B - 9</td>
<td>4588991.34</td>
<td>582848.16</td>
<td>36</td>
<td>27</td>
</tr>
<tr>
<td>C - 27</td>
<td>4589148.74</td>
<td>542730.26</td>
<td>33</td>
<td>25</td>
</tr>
<tr>
<td>D - 93</td>
<td>4588911.19</td>
<td>542755.32</td>
<td>40</td>
<td>30</td>
</tr>
</tbody>
</table>

Figure 62  Four Points in an Experimental Field in Capitanata

At each point, the daily soil water content was monitored.
For recording soil water status (W), 4 capacitive probes of 0.1 m in length (Decagon devices, 10HS, USA) were installed horizontally in the soil at 25 cm from the soil surface. The probes were linked to a Grillo datalogger (Tecno.El, ITA), which recorded the daily data of soil water content from December 15, 2015 to May 20, 2016.

The soil water status data in the effective root depth were used for the validation of the AquaCrop model. In particular, the measured data were compared with the output data from the model. The model performances were evaluated through two statistical tests:

1. the Relative Root Mean Square Error (RRMSE), calculated from the following equation:

\[
RRMSE = \sqrt{\frac{\sum_{i=1}^{n} (P_i - O_i)^2}{n}} \times \frac{100}{\bar{O}}
\]

where n is the number of observations, Pi is the value predicted by the model, Oi is the measured value, and \(\bar{O}\) is the mean of the measured values.

The validation is considered to be excellent when the RRMSE is <10%, good if the RRMSE is between 10 and 20%, acceptable if the RRMSE is between 20 and 30%, and poor if >30%.

2. The coefficient of determination \(R^2\) is defined as the squared value of the Pearson correlation coefficient. \(r^2\) signifies the proportion of the variance in measured data explained by the model. It ranges from 0 to 1, with values close to 1 indicating a good agreement, and typically values greater than 0.5 are considered acceptable in watershed simulations.

Figure 63 shows the comparison of the soil water content in the effective root depth measured by probes with the one simulated by AquaCrop Model at each point of the experimental field of Capitanata. The point a, b, c and d are listed in Table 9.

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Figure 63  Values of Soil Water Content in the Effective Root Depth Measured and Simulated by the AquaCrop Model at the Four Points during the 2016 Season

The values of the statistical tests listed in Table 10 show that model simulates adequately the soil water content over daily scale and in more points of the experimental area. The RRMSE is between 6 and 13% (excellent and good performance, respectively), and $R^2$ is > 0.86 (Figure 64).

Table 10  Relative Root Mean Square Error (RRMSE in %) and Coefficient of Determination ($R^2$) on Wheat for Daily Values of Soil Water Content Simulated by AquaCrop

<table>
<thead>
<tr>
<th>point</th>
<th>RRMSE (%)</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>10</td>
<td>0.90</td>
</tr>
<tr>
<td>B</td>
<td>13</td>
<td>0.86</td>
</tr>
<tr>
<td>C</td>
<td>6</td>
<td>0.96</td>
</tr>
<tr>
<td>D</td>
<td>6</td>
<td>0.97</td>
</tr>
</tbody>
</table>
Figure 64  Correlation between Soil Water Content Measured and Simulated at each point

The physiological parameters calibrated in the 2014 season have been used in the simulation model to predict the final biomass and yield of wheat at each of the 4 points in the field (Figure 65 and Table 11). Figure 65 and Table 11 show that the model was able to simulate a lower production at point C, where the field capacity and wilting point were lower.
APPLICATION OF SENTINEL-2 SATELLITE-DATA FOR UPSCALING LAI MEASUREMENTS TO THE STUDY AREA

In this report, it was not possible to apply the methodology described in the previous reports, to derive reference LAI maps from ground-based measurements over the study area within the JECAM site of Capitanata, owing to a malfunction of the Li-COR sensor.

However, we wanted to investigate the benefit of the Sentinel-2 mission for the agriculture domain, in particular for the rainfed durum wheat grown in a farm of Capitanata located within the JECAM site. The objective was to assess and model the spatial relationship between the yield map and the multi-band images of Sentinel-2 by using multivariate geostatistical
techniques. We had planned to analyse multi-temporal images of Sentinel-2, in order to select the one or ones which showed the strongest relationship with yield and then the highest potential for grain-yield prediction. Due to the persistence of wet meteorological conditions during the winter and spring seasons over the study area, only the images of February and May were free enough from clouds. At the time of reporting, only the multi-band image of February was jointly analyzed with the yield map.

Materials and Methods
The research was carried out at the Menichella Experimental Farm of CREA-SCA, located in the countryside of Foggia, southern Italy (41° 27’ N, 15° 36’ E, 90 m a.s.l.), within the study area of the JECAM site during the wheat season 2015-2016. The trial was conducted on two 5-ha fields cropped with rainfed durum wheat (\textit{Triticum durum} Desf. Cv “Claudio”), under continuous cultivation. The two fields were differently tilled: the field on the right was uniformly ploughed, whereas the field on the left was submitted to a tillage trial: the experimental design was strip plot with two treatments (ploughed, not ploughed), replicated three times.

The soil, that is very common in Apulian Tavoliere, is silty-clay Vertisol of alluvial origin, classified as Fine Mesic Typic Cromoxerert by Soil Taxonomy USDA (Soil Survey Staff, 1999). The meteorological conditions were mostly those typical of a Mediterranean environment, characterised by dry season between May and September and cold season from October-November to March-April. The field was harvested on July 12th 2016 and grain yield was normalised at 13% moisture.

Multivariate geostatistical techniques were applied to fuse on-line yield measurements, collected by a John Deere combine machine, with Sentinel-2 sensing data (RGB and NIR data) in order to assess the spatial relationship between crop and remotely sensed data and then evaluate the potential of Sentinel-2 data to predict wheat production. The set of geostatistical techniques, to perform sensor data fusion, has been thoroughly described in the previous reports, so here we give only a recall of the main procedures.

An overview of the geostatistical data fusion approach
The main geostatistical procedures applied to fuse the multiple data sets are briefly described below. All geostatistical analyses were performed with the software package ISATIS\textsuperscript{9}. The approach is based on fitting a Linear Model of Coregionalization (LMC) to the set of both direct

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and cross-experimental variograms, which consider all the studied variables as the result of the same independent physical processes, acting over different spatial scales.

A difficulty in the practical application of a multivariate approach occurs when the variables are of widely differing sizes. A solution is to standardize the individual variables to give each an average of zero and a variance of unity. Variogram modelling is further complicated by the presence of outliers in highly skewed data distributions. In this case, it is better to perform a normalization of data through Gaussian anamorphosis modelling. Gaussian anamorphosis is a mathematical function, which transforms a variable Y with a Gaussian standardized distribution into a new variable Z with any distribution: \( Z = \phi(Y) \). As this function needs to be known for any Gaussian value, a model is required. This is made by fitting a finite expansion of Hermite polynomials\(^{10}\).

Adopting a Gaussian model, an LMC was fitted to all experimental variograms of the transformed data, and then multicollocated cokriging (Castrignanò et al., 2009) was applied as a conditional expectation estimator. Finally, the estimates were back-transformed to the raw values of the variables through the anamorphosis functions previously calculated.

**Multi-collocated cokriging**

Ordinary cokriging is one of the most basic cokriging methods, which assumes the local mean to be constant but of unknown value. A way of integrating secondary fine-resolution information in primary sparse variable modelling is collocated cokriging, where the contribution of a secondary variable to the cokriging estimate relies only on the cross-correlation between the two variables\(^{11}\). The approach is quite similar to ordinary cokriging with the only difference being in the neighbourhood search. Since using all secondary exhaustive information contained within the neighbourhood may lead to an intractable solution, due to too much information, the secondary variable is used only at the target location and also at all the locations where the primary variable is defined within the neighbourhood. This solution has generally produced more reliable and stable results (Castrignano et al. 2009, 2012). The modified version, also referred to as “Multi-collocated cokriging” in the literature\(^{12}\), is less precise than full cokriging, and does not use all the auxiliary information contained within the neighbourhood, but it is much less computationally demanding. However, because the co-located secondary datum tends to screen the influence of more distant secondary data, there is actually little loss of information.

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The types of spatial data (yield and spectral data) involved in the study are the result of the measurements from different sensors, therefore their integration arises the problem called “the change of support problem” in geostatistics. The term “support” means the size or volume associated with each data value, but it also includes the geometrical size, shape and spatial orientation of the region associated with the measurements\textsuperscript{13}. The change of support creates a new variable, related to the original one but with different statistical and spatial properties. The crucial problem is to define an approach which relates two or more variables of different supports in a way that permits valid inference. Many of the statistical solutions to this problem were developed by Matheron\textsuperscript{14} in block (co)kriging, whose equations are valid regardless of the support of data. However, taking into account different supports in the calculation of autocovariance and cross-covariance functions is crucial to obtain valid inference. Once a consistent model for the point covariance functions was estimated, using the linear model of coregionalization described above, block cokriging was applied by replacing the cross-covariances in point cokriging by their block-averaged counterparts through variogram regularization\textsuperscript{15}. The regularized variograms were then calculated in different directions using a discretization of the blocks into equal cells, where the blocks were replaced by the union of the cell centers.

**Results**

In Figure 66, the maps of CCCI and Rededge are shown. With a visual inspection, an indirect spatial relationship between them is evident. This property can be explained since more vigourous plants (greater CCCI) have spectral signatures with rededge more shifted towards the visible range and with less reflectivity. The same sort of inverse relationship can be observed also for CCCI and rededge derived from the Sentinel-2 image for the two fields for which the yield maps were available (Figure 67).


To make more objective the relationship between yield and remote sensing data, we performed a set of statistical and geostatistical procedures. Since most data showed relevant shifts from normal distribution, as showed in the box plots (Figure 68), all data were previously transformed through Gaussian anamorphosis. A LMC was then fitted to the transformed data, which was then regularised to apply block kriging over the Sentinel-2 grid with mesh of 10 m. The regularised LMC included two basic spatial structures: a spherical model with range of 32 m and a spherical model with range of 300 m (Figure 69).
Figure 68  Box Plot of the Variables used in the Sensor Data Fusion Approach
Figure 70 shows the block-cokriged maps of blue, green, red and NIR bands and the map of yield. From the remote sensing images, there is a clear differentiation between the two fields, submitted to different tillage and with different agronomical history: the field, uniformly ploughed on the right, has less reflectivity in blue, green, and red and higher reflectivity in NIR, which is consistent with the previous results obtained for CCCI and rededge maps. Moreover, the field on the left shows a characteristic banding due to the different tillage treatments. These differences between the two fields may be due to differences in soil roughness and in crop growth and development. However, in the yield map this differentiation disappears and the pattern of yield variation seems to be affected by different factors.
Figure 70  Block-cokriged maps of Blue, Green, Red (a) and NIR, Yield (b) Data

Plans for Next Growing Season

Given the promising results obtained in the AquaCrop model validation, we are going to extend the application of the model to other sites, within the JECAM site, and predict soil water content and durum wheat yield at regional scale. Work is also underway to develop an approach for data assimilation in order to improve model prediction. Moreover, we realise that to improve LAI predictions, we need to increase the number of ESUs and one of the replicated
measurements (10-12) for each ESU. However, the realization of such plans of measurements, in support to validation activities, depends largely on funds for EO projects.

For the next durum wheat season (2016-2017), we will further investigate the capabilities of the Sentinel-2 and Sentinel-1 image data to supply valuable information on LAI, crop height and production. We will continue to jointly analyze crop attributes, yield data and Sentinel-1/2 images with geostatistical data fusion techniques to investigate the feasibility of generating accurate yield forecasts.

12. **Kenya**

No report was received.

13. **Madagascar**

**JECAM Test Site Name:** Antsirabe

**Team Leader and Members:**

**Leaders:**

Valentine Lebourgeois (Cirad UMR TETIS), Agnès Bégué, Stéphane Dupuy and Raffaele Gaetano (Cirad UMR TETIS)

**Members:**

Jacqueline Rakotoarisoa, Bodovololona Rabary (FOFIFA - National Center of Applied Research for Rural Development, Madagascar), Paulo Salgado (Cirad UMR SELMET)

**Project Objectives**

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

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

**Site Description**

- Location: Anstirabe 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 71  Rice Fields in an Irrigated Basin**
Figure 72  Irrigated Rice (bottom) and Rain Fed Corn Fields (top)

Figure 73  Rice Harvest
Figure 74  Irrigated (bottom) and Rain Fed (top) Fields

EO Data Received/Used

Landsat-8 images

- Space agency or Supplier: USGS
- Optical
- Number of scenes: 10 images
- Range of dates: October - June
- Beam modes/ incidence angles/ spatial resolutions: Multispectral / variable incidence angles / 15 meters pansharpened.
- Processing level: Orthorectified and converted to top of atmosphere reflectance.

Sentinel-2 images

- Space agency or Supplier: ESA
- Optical
- Number of scenes: 10 images

April 2017
JECAM Progress Report 2017

- Range of dates: October - June
- Beam modes/ incidence angles/ spatial resolutions: Multispectral / variable incidence angles / 10-60 meters.
- Processing level: Orthorectified and converted to top of atmosphere reflectance.

**SPOT-6/7 images**

- Space agency or Supplier: Airbus DS / SPOT Image via THEIA GEOSUD
- Optical
- Number of scenes: 2
- Range of dates: February
- Beam modes/ incidence angles/ spatial resolutions: Multispectral / variable incidence angles / 1.5 meters pansharpened.
- Processing level: Orthorectified and converted to top of atmosphere reflectance.

![Figure 75  Chronogram and Quicklooks of the 2015-2016 Satellite Acquisitions](image)
In Figure 75, the cloud percentage represents the cloud proportion over the ground database for each acquisition date.

**In situ Data**

In 2015-2016, the study area was expanded to cover 2/3 of the Vakinankaratra Region (7470 km²). Field surveys were conducted in the study zone over a 1.5 month period around the growing peak (February - March) of the cropping season in order to characterize the main cropping systems. A total of 1401 GPS Waypoints (1125 Crop, 276 Non-crop) were registered in the study area, chosen according to their accessibility and to be as representative of the existing cropping systems as possible. The data gathered during the field surveys concerned farmers’ practices (type of crop 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.

![Location of the Collected Waypoints](image)

**Figure 76  Location of the Collected Waypoints (Background Image: Landsat-8, Acquired 19 August 2015)**

**Collaboration**

During the GEOGLAM/JECAM, Sen2-Agri and SIGMA Joint Workshop in Kiev (14 – 16 oct 2016), it was decided to build a cross-site experiment on the characterization of small holder agriculture.

The sites which could be involved in this experiment are:
• Burkina Faso (Koumbia) – R. Gaetano (CIRAD)
• Madagascar (Antsirabe) – V. Lebourgeois (CIRAD)
• Kenya – C. Lelong (CIRAD)
• Senegal (Bambey): need to contact the PI (Valerie Soti, from CIRAD, AIDA research unit)
• Reunion Island: Stéphane DUPUY (Cirad, UMR TETIS)
• Mali & Bangladesh: Xavier Blaes (UCL) with Pierre S. Traore (ICRISAT) and Urs Schulthess (CIMMYT).

During an internal workshop, CIRAD researchers have built a preliminary workflow of the approach to be applied to all the sites (see Figure 77). This workflow relies on the combined use of Sentinel-2, Landsat-8 and SPOT-6/7 (or other very high spatial resolution data) imagery. The classification is supervised, based on a Random Forest analysis of a set of variables (reflectances, spectral indices, textures) extracted at object level after a segmentation of the area using very high resolution SPOT-6/7 images. The different steps of the workflow are currently being implemented through the use of Orfeo Tool Box functions orchestrated using python scripts in order to facilitate and automate the whole processing chain. The Random Forest analysis will be performed on R software.
Results

2016 was devoted to:

1. An In-depth Study of the Data Set Obtained over the 2014-15 Growing Season

We analyzed and optimized the performance of a combined Random Forest (RF) classifier / object-based approach and applied it to multisource satellite data to produce land use maps of a smallholder agricultural zone in Madagascar at five different nomenclature levels. The RF classifier was first optimized by reducing the number of input variables. Experiments were then carried out to:

   (i) test cropland masking prior to the classification of more detailed nomenclature levels,

   (ii) analyze the importance of each data source (a high spatial resolution (HSR) time series, a very high spatial resolution (VHSR) coverage and a digital elevation model (DEM)) and data type (spectral, textural or other), and

   (iii) quantify their contributions to classification accuracy levels.
The results show that RF classifier optimization allowed for a reduction in the number of variables by 1.5- to 6-fold (depending on the classification level) and thus a reduction in the data processing time. Classification results were improved via the hierarchical approach at all classification levels, achieving an overall accuracy of 91.7% and 64.4% for the cropland and crop subclass levels (Table 12), respectively. Spectral variables derived from an HSR time series were shown to be the most discriminating, with a better score for spectral indices over the reflectances. VHSR data were only found to be essential for implementation of the segmentation of the area into objects and not for the spectral or textural features they can provide in the classification step.

This work was published in Remote Sensing Journal and is available online:

http://www.mdpi.com/2072-4292/9/3/259

Figure 78 shows the Crop – Non Crop Map obtained via the hierarchical approach at level 1. Figure 79 shows the Crop Subclass Map obtained via the hierarchical approach at level 5.

<table>
<thead>
<tr>
<th></th>
<th>Cropland (level 1)</th>
<th>Land Cover (level 2)</th>
<th>Crop Group (level 3)</th>
<th>Crop Class (level 4)</th>
<th>Sub Class (level 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crop</td>
<td>Non Crop</td>
<td>Crop</td>
<td>Non Crop</td>
<td>Crop</td>
</tr>
<tr>
<td>Overall Accuracy</td>
<td>91.7%</td>
<td>96.6%</td>
<td>90.7%</td>
<td>70.2%</td>
<td>64.1%</td>
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<tr>
<td>Kappa</td>
<td>0.82</td>
<td>0.69</td>
<td>0.75</td>
<td>0.61</td>
<td>0.59</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.76</td>
</tr>
</tbody>
</table>

Table 12  Overall Accuracy and Cohen’s Kappa obtained in 2015-2016 with the Hierarchical Approach for each Level of the JECAM Nomenclature
Figure 78  Crop - Non Crop Map (Level 1) via the Hierarchical Classification Approach

Figure 79  Crop Subclass Map (Level 5) via the Hierarchical Classification Approach
2. The Use of the First Sentinel-2 Data

The same approach was applied over a dataset composed of a Landsat-8 and Sentinel-2 time series, and a SPOT 6 image as VHSR data. As for the previous growing season, results showed an improvement of f-score for more than 70% of the classes using the hierarchical approach at the more detailed level of the JECAM nomenclature (level 5 – Sub Class having 25 classes). Accuracy results (Table 13) observed at each level of the nomenclature were less satisfying than for the previous growing season, particularly for Non Crop classes (10 - 5% decrease for levels 3 to 5). This can be due to the lower number of learning data for Non Crop classes. For Crop classes, this accuracy loss was less important (1-3 %).

<table>
<thead>
<tr>
<th></th>
<th>Cropland (level 1)</th>
<th>Land Cover (level 2)</th>
<th>Crop Group (level 3)</th>
<th>Crop Class (level 4)</th>
<th>Sub Class (level 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crop</td>
<td>Non Crop</td>
<td>Crop</td>
<td>Non Crop</td>
<td>Crop</td>
</tr>
<tr>
<td>Overall Accuracy</td>
<td>90.9%</td>
<td>95.7%</td>
<td>80.5%</td>
<td>68.9%</td>
<td>72.8%</td>
</tr>
<tr>
<td>Kappa</td>
<td>0.68</td>
<td>0.67</td>
<td>0.73</td>
<td>0.57</td>
<td>0.41</td>
</tr>
</tbody>
</table>

Table 13  Overall Accuracy and Cohen’s Kappa Obtained in 2016-2017 with the Hierarchical Approach for each Level of the JECAM Nomenclature

We have not modified the project objectives.

Plans for Next Growing Season

Next growing season, we will maintain our current approach. We anticipate ordering the same type/quantity of EO data next year.

Publications


14. Mali
No report received.

15. Mexico
No report received.

16. Morocco
JECAM Test Site Name: Tensift

Team Leader and Members: Co-leaders Vincent Simonneaux and Said Khabba

Other members: Salah Er-Raki, Lionel Jarlan, Jamal Ezzahar, Younes Fakir, Olivier Merlin

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 crop parameters with multi-sensor, multi-spectral remote sensing of surfaces. Evapotranspiration from thermal infrared (energy budget approach), microwave (complementary to energy budget approach) and visible/shortwave data (FAO-56 coupled with NDVI time series). A PhD is currently working on remote sensing water stress detection.
- Soil Moisture: High resolution surface (0-5 cm) soil moisture, by disaggregation of SMOS satellite measurements based on thermal and visible MODIS/Landsat data (Merlin et al. 2013; Malbéteau et al. 2017b; Stefan et al. 2017) and/or 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 change. 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

- Location

The watershed is located in the Tensift region of Marrakech in Morocco (Figure 80), covering an area of about 20,000 km².

Figure 80 Location of the Tensift Watershed in Morocco

- Topography

It is composed of two main hydrological parts. South of the basin, the high Atlas peaks at over 4,000 m.a.s.l. Those mountains are the water tower of the Haouz plain. In the centre, a vast plain (450 m.a.s.l.) is occupied by rainfed and irrigated agriculture. In the north, the small chain
of arid mountains "Jbilets" has, in the present state of knowledge, little influence on the hydrological cycle in the region.

- Soils

Loam to Clay Loam soils

- Drainage class/irrigation

Drainage is correct, no hydromorphy reported.

Traditional irrigation is mainly gravity, but drip is rapidly spreading

- Crop calendar

Winter wheat (between December and May) occupies 80% of the acreage followed by olive trees occupy about 13% of the plain, the remaining area being occupied by citrus, apricot, market gardens, vineyards, fodder. These proportions change significantly in the irrigated area where tree crops dominate. Market gardening is developing and is mainly encountered between April and October

- Field size

High variability, depending on history of the sites. Traditional areas have small plots (0.25 ha); modern ones have 4 ha plots.

- Climate and weather

The plain is characterized by a semi-arid climate (rainfall 250 mm / year, ET0 is about 1600 mm/year). The mountains receive between 300 and 700 mm precipitation, ET0 is about 1000 mm/year.

- Agricultural methods used

The main irrigated areas (2000 km²) are located in the central and eastern part of the Haouz plain and rainfed cereals are grown on the rest of the plain.

Two observation sub-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. Olive trees represent less than 20% of the cultivated area. Soil texture is mainly Clay Loam. The growing season of winter wheat is December-May, 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 radar (ASAR) satellite time series.

- The Agafay plantation is a mandarin orchard located 20 km east of Marrakech with extent of 500 ha. The plantation benefits from drip irrigation. 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 fluxmeters. Sapflow measurements for separation of evaporation and transpiration have been carried on.

Figure 81  A Wheat Field in the Haouz Plain of Marrakech with the High Atlas Mountain in the Background

EO Data Received/Used

The EO images used since 2002 are shown in Table 14.
<table>
<thead>
<tr>
<th>Mission</th>
<th>Supplier</th>
<th>Optical/SAR Feature</th>
<th># scenes</th>
<th>Range of dates</th>
<th>Processing level</th>
<th>Challenge ordering</th>
<th>Challenge Using</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMOS</td>
<td>CATDS</td>
<td>Passive Microwave (L-band)</td>
<td>&gt;100</td>
<td>2002 onwards</td>
<td>L3</td>
<td>none</td>
<td>Spatial resolution</td>
</tr>
<tr>
<td>MODIS</td>
<td>LPDAAC</td>
<td>Optical</td>
<td>&gt;100</td>
<td>2002 onwards</td>
<td>L2-L3</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Landsat 7</td>
<td>USGS</td>
<td>Optical (shortwave infrared reflectances and TIR brightness temperature)</td>
<td>&gt;100</td>
<td>Since launch onwards</td>
<td>Surface reflectance and brightness temperatures</td>
<td>none</td>
<td>TIR data require atmospheric corrections (depending on applications)</td>
</tr>
<tr>
<td>Landsat 8</td>
<td>USGS</td>
<td>Optical (shortwave infrared reflectances and TIR brightness temperature)</td>
<td>&gt;100</td>
<td>Since launch onwards</td>
<td>Surface reflectance and brightness temperatures</td>
<td>none</td>
<td>TIR data require atmospheric corrections (depending on applications)</td>
</tr>
<tr>
<td>SPOT 5-Take5 experiment</td>
<td>CNES</td>
<td>VIS-NIR</td>
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<td>April-sept 2015</td>
<td>TOC reflectance</td>
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</tr>
<tr>
<td>Sentinel-1</td>
<td>ESA</td>
<td>SAR</td>
<td>&gt;100</td>
<td>2014 onwards</td>
<td>L1B</td>
<td>none</td>
<td>Soil moisture retrieval</td>
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<tr>
<td>Sentinel-2</td>
<td>ESA</td>
<td>VIS-NIR</td>
<td>10</td>
<td>Since dec 2015</td>
<td>ESA download, =&gt; no atmospheric corrections</td>
<td>We are waiting for processed images from THEIA</td>
<td></td>
</tr>
</tbody>
</table>

Table 14  EO Images Used since 2002
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).

Chichaoua’17 experiment

For the 2016-2017 season, an experiment comparing drip and traditional gravity irrigated wheat was installed including a lysimeter to monitor soil percolation. The objective is to evaluate the water budget and associated (irrigation, evaporation, transpiration, drainage) fluxes of two 1.5 ha drip-irrigated wheat fields, one field being irrigated according to the water needs estimated by the FAO method and the other field being irrigated exactly the same way except during controlled stress periods when irrigation is cut. Station-based instrumentation includes eddy covariance towers, radiometers in various spectral bands, lysimeters and ground heat flux, sap flow and soil moisture/potential/temperature sensors. The response of wheat to various levels of water availability is also characterized by manual measurements of carbon and water fluxes using a canopy chamber, and at leaf scale the water potential, stomatal conductance, chlorophyll content and fluorescence.

Thanks to this dataset, we want to analyze the link between Photochemical Reflectance Index (PRI) and the Light Use Efficiency (LUE) at canopy scale on wheat grown under different water regimes (irrigated or rainfed). The PRI is based on the short term reversible xanthophyll pigment changes accompanying plant stress and therefore the associated photosynthetic activities. Strong relationships between PRI and LUE were shown at leaf and canopy scales and over a wide range of species (Garbulsky et al., 2011). But very few previous works have explored the potential link with plant water status. In this context, we investigate the daily and seasonal dynamics of PRI, linking its variations to meteorological factors (global radiation and sun angle effects, soil water content, relative air humidity ...) and plant processes. We explore relationships between PRI and sapflow measurements (i.e. transpiration rate) to evaluate the potential of this index to detect and monitor a moderate plant water stress.
The Sidi Rahal monitoring station was set up in a rainfed wheat field in December 2013. Due to an unusual lack of precipitation in late 2015, the winter wheat crop had not been planted during the 2015-2016 season. As a result, the crop field remained in bare soil conditions from January to September 2016. This unique “bare soil” data set is being used to test new radar-based retrieval approaches of surface soil moisture and new formulations of soil evaporation.

**Tahanaout experiment**

A 1.4 km scintillometer transect has been running for one year on traditional agriculture areas, including olive trees and annual crops (wheat mainly) in the Haouz plain at the outlet of the high Atlas mountains. To complement this set-up and especially test aggregation of fluxes over heterogeneous surfaces, two eddy correlation towers are currently being installed under this transect.
Collaboration

The International Joint Laboratory TREMA associates several partners from the research and academic sector (University Cady Ayyad 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 Institute of Agronomy), and the Agues Segarra-Garrigues in Spain within a H2020 RISE project. The Tensift site is also part of the S2-AGRI project financed by the European Space Agency and will benefit from Sentinel-2 image surface reflectance processing in the framework of a THEIA project (CNES, French Space Centre).

Results

Based on a lot of work done by the team since 2002 regarding crop hydrological functioning, the research in 2016 focused on the surface evapotranspiration and 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 and L-band SMOS data have a spatial resolution of about 60 km and 40 km, respectively. The recent SMAP mission, launched in 2015, ensures continuity of L-band derived soil moisture products with similar resolution. In this context, downscaling methodologies have been developed to improve the spatial resolution of readily available passive microwave-derived soil moisture data. DISPATCH (DIrggregation baed on Physical And Theoretical scale CHange, Merlin et al. 2013) estimates the soil moisture variability within a 40 km resolution SMOS/SMAP pixel at the target 1 km resolution using MODIS data and the target 100 m resolution using Landsat data.

V. Stefan (PhD UPS 2013-2016) improved DISPATCH by integrating a physically-based energy balance model forced by meteorological data available within irrigated perimeters. The approach was validated over the Agues Segarra-Garrigues site in Spain (Stefan et al. 2017).
B. Ait Hssaine (PhD thesis, UCAM/UPS, 201--2018) is working on the retrieval of surface soil moisture at multiple scales by developing synergies between Sentinel-1 radar and 1 km resolution DISPATCH (disaggregated from SMOS using MODIS) data.

Y. Malbéteau (PhD UPS 2013-2016) improved the temporal resolution of DISPATCH data by assimilating the disaggregated soil moisture in a dynamic surface soil water balance model. The approach was tested on a daily basis over the Haouz plain (Malbéteau et al. 2017b). See Figure 83. In this figure, the black lines represent the irrigated areas. Since this technique is based on global scale SMOS, MODIS and ECMWF reanalysis data, it is easily transferable to other semi-arid areas. Moreover, the method has potential for retrieving irrigation amounts at the perimeter scale.

A. Mohamed (PhD isardSAT 2015-2018, seconded to UCAM for 9 months) is developing synergies between 1 km resolution DISPATCH (SMOS disaggregated using MODIS) and Sentinel-1 radar data to derive an enhanced soil moisture product at multiple resolutions.

A. Amazirh (PhD thesis, UCAM/UPS 2016-2018) is developing synergies between Sentinel-1 radar and thermal/optical Landsat-7, 8 data to retrieve the surface soil moisture at high spatio-temporal resolution (crop field scale) without any prior knowledge of soil roughness parameters.

Figure 83  Image of the Mean Volumetric Soil Moisture in 2014 over Tensift Haouz Region
Partition between Evaporation and Transpiration

The purpose is, beyond the estimates of evapotranspiration, to separate soil evaporation from plant transpiration. This would allow the assessment of irrigation efficiency, considering the objective is to minimize evaporation, and this a major stake in this area were water is scarce.

B. Ait Hssaine (PhD UCAM/UPS 2016-2018) is developing a calibration strategy to integrate both land surface temperature and near-surface soil moisture data in a two-source energy budget model. State-of-the-art evapotranspiration models are generally based on thermal/visible data only and rely on ad hoc assumptions to represent the evaporation/transpiration components. The new approach integrates microwave-derived surface soil moisture as additional constraint on soil evaporation, and subsequently on vegetation water status.

Y. Malbéteau (PhD UPS 2013-2016) developed a method for correcting the remotely sensed land surface temperature for topographic effects. Thermal-based evapotranspiration models can now be applied to hilly and mountainous agricultural areas (Malbéteau et al. 2017a).

L. Olivera (PhD UPS 2016-2019) is investigating different coupling schemes between the FAO-based water budget model and remote sensing data available in the shortwave, thermal infrared and microwave bands to estimate the root zone soil moisture and crop water needs at the daily/field scale.

G. Aouade is combining the isotopic approach (oxygen stable isotopes) and the physically-based modelling of water and energy exchange at the soil-vegetation-atmosphere interface to monitor and predict evapotranspiration partition. She has evaluated, in particular, the domain of validity and the performance of a double energy budget SVAT model recently developed by Meteo-France on the main crops of the region based on the Tensift observatory database.

Stress Detection

Z. Rafi (PhD UCAM 2017-2019) is testing the usefulness of (1) thermal, (2) “PRI” shortwaves reflectances (531 nm, 570 nm and between 680-690 nm) and (3) C-band microwave data to characterize the water status of crops. He is also evaluating the complementarity of those wavelengths to better represent the non-stomatal (evaporation) and stomatal (transpiration) fluxes in land surface models.

Remote Sensing of Irrigated Crop Water Budget Monitoring

A. Diarra evaluated the performance and the domain of validity of the two-source energy balance model (TSEB) for the monitoring of actual evapotranspiration \( ET_a \) as a first step towards its use for irrigation planning. Secondary objectives are to analyse the evapotranspiration partition between evaporation (E) and transpiration (T) and the ability to
detect water stress over irrigated annual crops. Within this context, TSEB was compared to the calibrated FAO-56 dual approach, taken as a reference tool for the monitoring of plant water consumption. TSEB computes $ET_a$ as the residual of a double component energy balance driven by the radiative surface temperature ($T_s$) used as a proxy of crop hydric conditions; the FAO-56 dual crop coefficient approach uses the Normalized Difference Vegetation Index (NDVI) as a proxy of the Basal Crop Coefficient ($K_{cb}$) and assesses the hydric status directly by solving a two layer soil water budget. Both approaches are evaluated using in situ forcings measured over four plots of wheat and sugar beet located in the Haouz plain (Marrakech, Morocco) that were instrumented with eddy covariance systems during the 2012 and 2013 growing seasons. Both models offer fair performance compared to $ET_a$ observations with Root Mean Square Error (RMSE) lower than 1 mm d⁻¹ apart from the FAO-56 dual approach on the sugar beet plot because of uncertain irrigation inputs. This highlights a major weakness of this model when water inputs are uncertain, a very likely case at the plot scale. By contrast, the TSEB model offers smoother performance in all cases. Finally, the partition of $ET_a$ between soil evaporation and plant transpiration is estimated indirectly by confrontation between simulated soil evaporation and surface (0–5 cm) soil moisture acquired spatially with ThetaProbe sensors and taken as a proxy of soil evaporation. TSEB evaporation is well correlated to surface soil moisture ($r=0.82$) for low Leaf Area Index (LAI) values (<1.5 m² m⁻²). In addition, TSEB predicted partition compares well to snapshot measurements based on the stable isotope method. This in-depth comparison of two simple tools to monitor $ET_a$ leads us to the conclusion that, if thermal images were available at high repetitivity (as planned in a future High spatial resolution thermal mission), the TSEB model could reasonably be used to map $ET_a$ and possibly for the decision-making process of irrigation scheduling.

Besides the thermal approach, we developed a simple SVAT approach based on NDVI forcing to monitor the crop water budget. The Sat-Irr tool (http://osr-cesbio.ups-tlse.fr/Satirr/) is an online software based on the FAO-56 approach aiming to help irrigation scheduling at the plot scale. All the technical processing step (data downloading, image correction, data processing, etc...) are totally transparent to the users. An experiment designed to evaluate the tool in terms of both the quality of irrigation advice and of the way the farmers perceived this new information is being carried out in the Tensift region. To this objective, about 8 farmers in different irrigated sectors have been trained on the use of Sat-Irr to receive their customized advice of the irrigation schedule. Surveys are carried out in parallel to evaluate the difference between what has been scheduled by the tool and what was done by the farmers and also to understand the main reasons for the gaps. In addition, a network of low cost soil moisture sensors has been installed on the monitored fields with the objective of testing the assimilation of soil moisture data to improve the performance of the Sat-Irr tool.
Plans for Next Growing Season

We anticipate ordering the same type and quantity of EO data next year, but as more imagery should be available through COPERNICUS / THEIA, there is less need to order others.

Publications

Articles


April 2017


Conferences


Vivien Georgiana Stefan, Olivier Merlin, Maria José Escorihuela, Bouchra AïtHssaine, Beatriz Molero, Jamal Ezzahar, Salah Er-Raki, Ahmad Al Bitar, and Yann Kerr. Towards a robust April 2017
evaporation-based disaggregation method of SMOS soil moisture by combining high-resolution shortwave/thermal and available meteorological data. European Geophysical Union 2016, Vienna, Austria.


Bouchra Ait Hssaine, Jamal Ezzahar, Lionel Jarlan, Olivier Merlin, Said Khabba, Aurore Brut, Salah Er-Raki, Bernard Cappelaere and Ghani Chehbouni. Combining a thermal-based two source energy balance model driven by MODIS observations and an aggregation scheme to estimate surface turbulent fluxes in heterogeneous conditions over small catchment in West Africa (Wankama, Niger). INTERNATIONAL CONFERENCE on ADVANCED TECHNOLOGIES FOR SIGNAL& IMAGE PROCESSING 2017, Marrakech, Morocco.

Maria Jose Escorihuela, Cyril Piou, Olivier Merlin, Mehrez Zribi, Omar Ali Eweys and Benjamin Koetz. Soil Moisture for dEsert Locust earLy Survey- SMELLS project. ESA Living Planet 2016, Praga, Tchec rep..


Photochemical Reflectance Index (PRI) as a Proxy of Light Use Efficiency (LUE) and Transpiration in Mediterranean Crop Sites. American Geophysical Union 2016, San Francisco, USA.

Le Dantec, Valerie; Chebbi, Wafa; Boulet, Gilles; Er Raki, Salah; Lili Chabaane, Zohra; Khabba, Said; Fanise, Pascal; Zawilski, Bartosz; Ceschia, Eric; Merlin, Olivier; Simonneaux, Vincent; Jarlan, Lionel. Photochemical Reflectance Index (PRI) as a proxy of Light Use Efficiency (LUE) and transpiration in Mediterranean crop sites. FLEX workshop 2017, Frascati, Italy.


Sabah Sabaghy, Jeffrey Walker, Luigi Renzullo, Ruzbeh Akbar, Steven Chan, Julian Chaubell, Narendra Das, R. Scott Dunbar, Dara Entekhabi, Anouk Gevaert, Thomas Jackson, Olivier Merlin, Mahta Moghaddam, Jinzheng Peng, Jeffrey Piepmeier, Maria Piles, Christoph Rüdiger, Vivien Stefan, Xiaoling Wu, Nan Ye, and Simon Yueh. COMPARISON OF DOWNSCALING TECHNIQUES FOR HIGH RESOLUTION SOIL MOISTURE MAPPING. IGARSS 2017.

Nan Ye, Jeffrey Walker, Xiaoling Wu, Thomas Jackson, Luigi Renzullo, Olivier Merlin, Christoph Rüdiger, Dara Entekhabi, Richard DeJeu, and Edward Kim. TOWARDS VALIDATION OF SMAP: SMAPEX-4 & -5. IGARSS 2016

Movie

“De l’eau, du blé et des hommes”, 2016 - 12 min - A film shot by M.-C. Burg, B. Mantaux and T. Chevallier in the framework of the undergraduate interdisciplinary exchange program of IRD Body/Sorbonne-Universités. With the participation of M. H. Kharrou (ORMVAH), O. Merlin (IRD), S. Khabba (UCAM), A. Chakir (IRD), A. Amazirh (PhD student), B. Aït Hssaine (PhD student), Z. Rafi (Master student) and Jamal El-Fakh (Master Student).
17. **Paraguay**
No report received.

18. **Russia**

18.1 **Stavropol**
No report was received this year.

18.2 **Tula**

**JECAM Test Site Name:** RUJECAM

**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), Kristina Li (ATI PFUR), Ekaterina Shishkonakova (V.V. Dokuchaev Soil Science Institute)

**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°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. We also used a UAV (unmanned aerial vehicle).

**In situ Data**

We made the following in situ observations:

- **Crop type:** Discrimination among crop types in georeferenced plots (27 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 84  “Fish-eye” Photo over Winter Wheat (Germination Phase)

Figure 85  Soil Sampling and Start of Acquisition of UAV Image
Figure 86  UAV Image of Test Site in Autumn

Figure 87  Field Work at the Test Point
Collaboration

Not reported this year.

Results

We conducted field visits once per month from April 2016 to August 2016.

It has been found that weeds on many fields affect the NDVI and LAI, calculated based on Landsat and MODIS data. See Figure 88. In the figure, zone 1 is the zone where the NDVI is predefined by barley, 2 is the zone of increasing influence of weeds, and 3 is the zone where NDVI is defined primarily by weeds. The effect of weeds differs from field to field due to crop type and crop development status.

Figure 88  Example of NDVI Time Profile (MODIS) for Test Plot with Spring Barley
Plans for Next Growing Season

In 2017, we plan to continue the same approaches, and also test the use of the UAV for field crop data collection.

In addition to MODIS and Landsat, we plan to test the use of RESURS-P multi- and hyperspectral data.

Publications


19. Saudi Arabia

No report was received this year.

20. Senegal (Bambey)

No report was received this year.

21. South Africa (Free State Province)

No report was received this year.
22. Spain (Barrax-Albacete)

Team Leader and Members: Fernando Camacho, Consuelo Latorre, David Vinué

Project Objectives

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

- Crop identification and Crop Area Estimation: Developing methods for crop identification and crop area estimation from high resolution. 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 (multi-temporal) 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 Tiesas” 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 centre of the area of study is located at 39.0544, -2.1007.
- 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.
- 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 89 shows examples of landscapes taken in July 2016 in the study area.
Figure 89  Examples of Landscapes taken in July, 2016 in Las Tiesas Site (Barrax, Spain)

EO Data Used

- **Space agency or Supplier:**
  
  * ESA through "[Copernicus Open Access Hub](https://data.copernicus.eu/)" by Copernicus.
  
  * NASA through the USGS Global Visualization service.

- **Optical/SAR:**
  
  * Optical Sentinel-2A imagery, 10m/pixel.
  
  * Optical Landsat-8 imagery, 30m/pixel

- **Number of scenes:** 2 per sensor
• **Range of dates:**
  
  
  * Landsat-8: 12 March and 18 July, 2016
  
  Both of them for winter and summer campaigns, respectively.

• **Beam modes/ incidence angles/ spatial resolutions:**

  * Sentinel-2A
    
    - 12 March, 2016: mean viewing incidence angle: azimuth=139.15°; 10 m spatial resolution.
    
    - 23 July, 2016: = mean viewing incidence angle: azimuth 152.11°; 10 m spatial resolution.
    
  * Landsat-8:
    
    - 12 March, 2016: mean viewing incidence angle: azimuth=148.12°; 30 m spatial resolution.
    
    - 18 July, 2016: mean viewing incidence angle: azimuth=127.57°; 30 m spatial resolution.

• **Processing level:**

  * Sentinel-2A: TOC reflectances imagery Level2-A processed from downloaded Level L1C granules by SEN2COR Toolbox installed in SNAP, by ESA.

  * Landsat-8: Landsat Surface Reflectance.

• **Challenges, if any, in ordering and acquiring the data:** At the time of ordering and downloading the Sentinel-2A data, complete tiles by granules were acquired, with all extra information necessary to perform SEN2COR. Actually, single granule (T30SWJ for the area of study) can be acquired if only TOA reflectances are needed.

• **Challenges, if and any, in processing using the data:** For Sentinel-2A, a range of spectral information for green, red and infrared is provided in a 10m spatial resolution. Short-wave infrared provided in 20m spatial resolution was re-scaled into 10m to be ingested in the processing chain. Figure 90 shows Sentinel-2 RGB true color composition over the study site.
Figure 90 True Colour Composition (RGB) of TOC Reflectance Sentinel-2A Images over Barrax 20 km² on 12th March (left) and 23th July 2016 (right)

In situ Data

Two field campaigns were carried out on 29th March and 12th July, 2016, where two main activities were conducted: a) for crop type identification, and b) for biophysical variable measurements.

Field works were deployed according to the protocol delivered as a result of the FP7 ImagineS Project16 (Camacho et al, 201617). This protocol is in accordance with other scientific developments, such as the VALERI project18 and the CEOS Land Product Validation group19, and shows the main elements and tasks to perform field campaigns, focused on ground data acquisitions.

Crop type

Since there are two growing seasons, winter and summer, two samplings were conducted, one on 29th March, 2016 and the other on 12th July, 2016, with 92 and 146 crop type plots identified respectively. Figure 91 shows the location of the identified crop types for both campaigns.

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16 http://fp7-imagines.eu/
18 http://w3.avignon.inra.fr/valeri/
19 http://lpvs.gsfc.nasa.gov

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Biophysical parameters

In March 2016, biophysical variables (LAI, LAIeff, FAPAR and FCOVER) were measured in 24 Elementary Sampling Units (ESUs) (Figure 91) using digital hemispherical photographs (DHP). Afterwards, the obtained data was processed with the CAN-EYE software to provide LAI, LAIeff, FAPAR and FCOVER. In July, 51 ESUs were sampled using DHP and including measurements with a LAI 2200C plant canopy analyzer and Accupar LP80 devices. These devices were used to measure LAIeff: DHP, AccuparLP80-Ceptometer and LAI 2200C, meanwhile LAI was measured by DHP, FAPAR was measured by DHP and AccuparLP80 and FCOVER was estimated by DHP. Figure 92 shows digital hemispheric photographs acquired at Las Tiesas-Barrax site during the field campaign carried out in July, 2016.

Figure 91  Points sampled for crop identification and biophysical parameters on 29 March and 12 July, 2016 in Las Tiesas-Barrax site, Spain
Figure 92  Examples of Digital Hemispheric Photographs (DHP) samples over different surfaces in Las Tiesas-Barrax site on 12th July, 2016

In Figure 93, the left shows measurements with LAI2200C over an alfalfa field. The right shows measurements with DHP over an alfalfa field.

Figure 93  Team Involved in the Field Campaign of Las Tiesas Site, Barrax (Spain)

Collaboration

No collaboration was reported this year.

Results

Ground Measurements

Figure 94 shows the distribution of vegetation types sampled during the field campaigns (data collected over 92 plots on 29th March and 146 plots on 12th July). It also shows that around 50% of the identified crops correspond to barley fields and bare soil, in March, and bare soil and corn fields in the case of July. The other 50% corresponds to a variety of crops, including alfalfa, corn, tree plantation (fruits), onion, sunflower, chickpeas, papaver, and garlic.
Land cover – 29th March, 2016  
Land cover – 12 July, 2016

Figure 94  Variety and Distribution of the Identified Crops for Both Campaigns, 29th March and 12 July, 2016

Because of the intense agricultural activity, frequencies of the observations have a great dissimilarity, including the variance due short-term and long-term crops, harvested areas and type of crops. For example, Figure 95 shows LAI frequency distribution for both campaigns.

Figure 95  LAI Frequency Distribution in March and July, 2016 Field Campaigns

Ground Based Maps of Biophysical Variables

For the very first time, Sentinel-2A imagery was used to perform high resolution ground-based maps of the biophysical variables over the site, and due the innovative of the process, as a first approach it was performed according to the CEOS LPV recommendations for validation.

Sampling was evaluated based on the convex-hull analysis performed and a quality flag image was generated. In Figure 96, clear and dark blue correspond to the pixels belonging to the ‘strict’ and ‘large’ convex hulls (Martinez et al., 20095). Red corresponds to the pixels for which
the transfer function is extrapolated. These maps show quite good quality, 64% on 12th March at 20x20 km² and 69% on 23rd July, 2016.

Transfer functions have been derived by multiple robust regressions between ESU reflectance and the biophysical variables (Martinez et al., 2009\(^2\)). Because the scene presents many senescent and harvested fields, we selected the NDVI as input for the transfer function (an exponential relationship with LAIeff 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 10 m resolution. Figure 97 shows the ground-based LAI maps derived from Sentinel-2A imagery in March and July after the transfer function was applied. Figure 97 also shows the difference between LAI values in both seasons, where the scene of July (Figure 97 right), corresponding to the summer season, showed the lowest LAI values.

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20 B. Martinez, F.J. Garcia-Haro & F. Camacho-de Coca. 2009. Derivation of high-resolution leaf area index maps in support of validation activities: Application to the cropland Barrax site. Agricultural and Forest Meteorology. 149 pp.130–145

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The Root Mean Square Errors (RMSE) values for the several estimated transfer functions are shown in Table 15. The results showed acceptable values of the Root Mean Square Error (RMSE) for all the variables undergoing study. The results also showed lower error values in July, maybe because the scene presented more senescent and harvested fields than the March scene, i.e. values of the biophysical variables close to 0.

Table 15  Root Mean Square Errors (RMSE) obtained for the LAIeff, LAI, FAPAR and FCOVER in Both Campaigns for Sentinel-2A Images

<table>
<thead>
<tr>
<th>Variable</th>
<th>RMSE values 12th March 2016</th>
<th>RMSE values 23rd July 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAI eff</td>
<td>0.4</td>
<td>0.2</td>
</tr>
<tr>
<td>LAI</td>
<td>0.5</td>
<td>0.08</td>
</tr>
<tr>
<td>FAPAR</td>
<td>0.14</td>
<td>0.05</td>
</tr>
<tr>
<td>FCOVER</td>
<td>0.12</td>
<td>0.06</td>
</tr>
</tbody>
</table>

The methodology applied to Sentinel-2 was demonstrated as reliable. As NDVI was applied by transfer functions in an exponential and a linear mode for LAI and FAPAR, respectively, the final data in biophysical maps is related as in Figure 98.
Inter-comparison with Landsat-8 Imagery

The main novelty during these campaigns was to adapt our methodology for Landsat-8 to Sentinel-2 imagery. Here, we compare the results of the ground based maps derived from both sensors (Landsat-8 and Sentinel-2). Good correlation between the NDVI values derived from both sensors Landsat-8 and Sentinel-2 were found (Figure 99). Despite the correlation showing acceptable results ($R^2=0.95$), slightly higher values can be observed in the results obtained by Sentinel-2 for high values of the NDVI (NDVI $> 0.6$) in July. This contrasts with the results obtained for low NDVI values, where Sentinel-2 showed lower values as compared to Landsat 8 results. This can be partly explained due to the differences in the spectral ranges of the bands, and partly due to the differences in the acquisition dates of the images (5 days).
Figure 99  Correlation between Sentinel-2 NDVI and Landsat-8 NNDI in the ESUs (12th March, 2016) (right), and Random Points over the Study Area (23th- 18th July, 2016 for Sentinel-2A and Landsat 8, Respectively) (left)

For the same date, and applying the same methodology to Landat-8 imagery, the visual analysis showed equivalent results, as shown in Figure 100, which confirms a good interoperability of both sensors for mapping biophysical parameters and monitoring its evolution from empirical approaches.

Figure 100  Ground-based Maps (20x20 km²) Retrieved at the Barrax Site with Landsat-8 and Sentinel-2 Images

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A statistical analysis was performed over the central area of the image (Table 16), focused at the experimental site (5x5 km). Results showed a slight overestimation of Sentinel-2 for each of the variables under study in July 2016, mainly in the estimation of LAI, where the difference between the two results is close to 0.6.

<table>
<thead>
<tr>
<th></th>
<th>NDVI</th>
<th>LAI</th>
<th>FAPAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>Std. Dev</td>
<td>mean</td>
</tr>
<tr>
<td>L8</td>
<td>0.31</td>
<td>0.696</td>
<td>0.786</td>
</tr>
<tr>
<td>S2</td>
<td>0.32</td>
<td>0.664</td>
<td>0.821</td>
</tr>
</tbody>
</table>

Table 16  NDVI, LAI and FAPAR Values over the 5x5 km Site Las Tiesas (Barrax), 12 March 2016

<table>
<thead>
<tr>
<th></th>
<th>NDVI</th>
<th>LAI</th>
<th>FAPAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean</td>
<td>Std. Dev</td>
<td>mean</td>
</tr>
<tr>
<td>L8</td>
<td>0.27</td>
<td>0.288</td>
<td>0.742</td>
</tr>
<tr>
<td>S2</td>
<td>0.32</td>
<td>0.344</td>
<td>0.845</td>
</tr>
</tbody>
</table>

Table 17  NDVI, LAI and FAPAR Values over the 5x5 km Site Las Tiesas (Barrax), 18-23 July 2016

Additionally, 28 random points representing all the NDVI range were compared around the whole image, for both analysis based on transfer functions with Sentinel-2A and Landsat-8 imagery, as shown in Figure 101 and Figure 102 for LAI and FAPAR for March and July images, respectively. Results showed similar FAPAR values for both sensors, unlike the results obtained for LAI, where Landsat-8 showed higher values for high LAI values, especially in March 2016.
Figure 101  Ground-based a) LAI maps and b) FAPAR Maps from Sentinel-2A and Landsat-8 versus NDVI map from Sentinel-2 at Barrax site, Spain (12 March 2016)
We have accomplished most of our initial objectives, including the performing of ground acquisition and up-scaling of biophysical measurements. We are currently working on analyzing methodologies for mapping biophysical variables from physically based and empirically based methods, per crop type and general.

Our guidelines for collecting LAI and FAPAR, as well as for upscaling and producing ground-based maps can be called “best practices”. It has been applied in the FP7 ImagineS to 50 field campaigns, as well to several ESA campaigns (e.g. SEN3EXP, VALSE2), and previously to many of the VALERI sites, showing good performance. It is also included as a best practice in the CEOS LPV protocol for global validation of LAI products.

We have not modified the project objectives, but we have not made progress in the classification of crop type from EO data in our study site.

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**Figure 102** Ground-based a) LAI maps and b) FAPAR Maps from Sentinel-2A (23 July 2016) and Landsat-8 (18 July 2016) versus NDVI Map from Sentinel-2 at Barrax Site, Spain

<table>
<thead>
<tr>
<th>NDVI</th>
<th>LAI values (L8 &amp; S2) Vs NDVI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0,18</td>
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<tr>
<td>0,19</td>
<td>0,21</td>
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<td>0,22</td>
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<td>0,36</td>
<td>0,87</td>
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<tr>
<td>0,37</td>
<td>0,92</td>
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</table>

<table>
<thead>
<tr>
<th>NDVI</th>
<th>FAPAR values (L8 &amp; S2) Vs NDVI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0,18</td>
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<td>0,19</td>
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<td>0,87</td>
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<tr>
<td>0,35</td>
<td>0,92</td>
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</tbody>
</table>
Plans for Next Growing Season

We plan the following for next growing season:

- As the methodological approach has been verified to be consistent with Sentinel-2 imagery, it will be used as the basis for next growing season’s campaigns.
- We plan to test machine learning algorithms for crop type identification.
- We plan to test empirical machine learning versus generic algorithms (physically based) for mapping crop biophysical parameters along the season.

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

Publications

None since last year’s report.
23. **Taiwan**

**JECAM Test Site Name:** Taiwan (TARI) site

**Team Leader and Members:**

Chi-Farn Chen, Ph.D., Center for Space and Remote Sensing Research (CSRSR), National Central University (NCU), Taiwan

Hong-Yuh Guo, Ph.D., Taiwan Agricultural Research Institute (TARI), Taiwan

Cheng-Ru Chen, Ph.D., Center for Space and Remote Sensing Research (CSRSR), National Central University (NCU), Taiwan

Nguyen-Thanh Son, Ph.D., Center for Space and Remote Sensing Research (CSRSR), National Central University (NCU), Taiwan

Tsz-Feng Lin, Master, Taiwan Agricultural Research Institute (TARI), Taiwan

Chien-Hui Syu, Ph.D., Taiwan Agricultural Research Institute (TARI), Taiwan

**Project Objectives**

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

- Crop identification and Crop Area Estimation using SAR data;
- Yield Prediction and Forecasting; and
- We are also working on automatic data collection by sensor networks.

**Site Description**

- Location: Changhua and Yulin counties covering approximately 3,170 km². See Figure 103.
- Topography: The elevation ranges from 0 – 1,777 m above mean sea level.
- Soils: Silty loam
- Drainage class/irrigation: Moderate – imperfect
- Major crop calendar: There are two rice-cropping seasons per year. The first crop is from February–March to June–July, and the second is from August–September to November–December.
• Field size: Ranging from 0.5 – 1.1 ha.

• Climate and weather: Subtropical monsoon with the occurrence of typhoons and drought events from time to time during the year.

• Agricultural methods used: Transplanting

Figure 103  Location of the Study Site with Reference to the Geography of Taiwan

EO Data Received/Used

• RADARSAT-2
  o Supplier: CSA/MDA
  o SAR
  o Number of scenes: 16
  o Range of dates: April – December 2016
  o Beam modes/ incidence angles/ spatial resolutions: Fine wide mode. VV/VH

• Sentinel-1
  o Supplier: ESA
  o SAR
SPOT-5, SPOT-6, SPOT-7
- Supplier: CNES
- Optical
- Number of scenes: > 25
- Range of dates: January – August 2016

LandSat-8
- Supplier: USGS
- Optical
- Number of scenes: 18
- Range of dates: January – December 2016

In situ Data
Field surveys were conducted to collect the following information:
- Agricultural land-use types
- Soil types
- Crop types, including rice and other cash crops
- Tillage systems
- Meteorological data

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

Results

1. Rice crop mapping
The research findings of rice crop mapping obtained for 2015 from Sentinel-1A data have been archived, using the following processing steps:

- Data pre-processing including radiometric calibration, speckle noise filtering, terrain correction and re-projection, image co-registration;
- Image classification using the normalized difference backscattering index (NDSI) and object-based image analysis (OBIA); and
• Accuracy assessment using rice crop map obtained from TARI in 2015.

The mapping results indicated the overall accuracy and Kappa coefficient achieved for VH data were 75.7% and 0.69, respectively, while those for VV data were 49.4% and 0.5, respectively (Figure 104 and Figure 105).

Figure 104  Results of Rice Crop Mapping using Sentinel-1A VH data: (a) Classification Map and (b) Ground Reference Data

Figure 105  Results of Rice Crop Mapping using Sentinel-1A VV data: (a) Classification Map and (b) Ground Reference Data
Rice yield estimation

We estimated rice crop yield in the study site following three main steps of data processing:

- Data pre-processing to construct input parameters, including weather data, soil data, crop genotype coefficients, crop management data, and rice crop map;
- Crop yield estimation by assimilating MODIS LAI data into the CERES-rice model using the particle swarm optimization (PSO) algorithm; and
- Error verification using the government’s rice yield statistics.

The robustness of the yield simulation approach was evaluated by using the government’s rice yield statistics collected from 46 townships. The crop yields achieved from the CERES-Rice model were spatially averaged for each township and compared with those from the government. The results indicated that the values of the root mean square error (RMSE) and the mean absolute error (MAE) were 17.3% and 12.7%, respectively, which were lower than 20%, indicating good agreement between the two datasets. The spatial distributions of simulated rice yields indicated the yield variability within the township, and higher yields were more concentrated in the north and south parts of the study region. The lower yields were especially observed for rice fields located along the coastal zones and in areas where the terrain was complex (Figure 106).
To certain extent, our objectives have been met. However, we are still developing algorithms for operational purposes in respect to “best practice”.

**Plans for Next Growing Season**

For the coming crop year, we will continue investigating the capability of RADARSAT-2 and Sentinel-1A data for crop identification and yield estimation.

We will also collect in-situ measurements for cross-validation with the results of rice crop mapping as well as yield estimation.

Next year, we plan to implement crop growth models (e.g., DSSAT, Oryza) and machine learning algorithms such as neural networks and support vector machines for rice yield estimation and forecasting.

**Publications**


24. Tunisia

JECAM Test Site Name: MERGUELLIL

Team Leader and Members: Zohra Lili Chabaane¹ and Bernard Mougenot², Zeineb Kassouk³, Mehrez Zribi², Gilles Boulet², Pascal Fanise², Vincent Simonneaux², Aîcha Chahbi¹, Sameh Saadi¹,², Safa Bousbih¹,², Wafa Chebbi¹,², Azza Gorrab¹.

¹Université de Carthage/Institut National Agronomique de Tunis (INAT) Tunisie, ²Centre d’Etudes Spatiales de la Biosphère (CESBIO), Toulouse France.

Project Objectives

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

- Crop identification and Crop Area Estimation: Crop types are discriminated using multitemporal NDVI data. A decision tree algorithm has been implemented for each year, and we intend to develop a more general and robust method. Information about land cover type is required to parameterize the models used (ET, Biomass, etc.).
- Crop Condition/Stress: Our main goal is to monitor crop consumption and irrigation requirements using the coupling of FAO-56 method and NDVI time series (see Results section). Crop water budget is useful operational information at plot scale (farmers) and at perimeter scale (irrigation managers). This type of product is also a valuable input for watershed integrated modeling, aimed at basin scale management, including groundwater. Crop water stress is monitored using thermal image processing, and the results are aimed at being assimilated into the crop water budget model.
- Soil Moisture: Soil moisture is the primary objective tackled using microwave data, relying on ground measurements for cal/val purposes. This type of information may also be input into the crop water budget model.
- Yield Prediction and Forecasting: based on NDVI relationships and a vegetation model.
- Crop Residue, Tillage and Crop Cover Mapping: We don’t study residues nor tillage (this will be done in 2017). Crop cover mapping is related to ‘Crop identification and Crop Area Estimation’ above.

Site Description

- Location
  
  Top left  Latitude: N35° 42' 20"
Figure 107  Tunisia Merguellil Site

The site is shown in Figure 107. The boundary of the upper watershed is in red, and the boundary of the irrigated area is in yellow.

- Topography: Alluvial plain.
- Soils: Variable texture, from fine sand to clay-loam.
- Drainage class/irrigation: Well drained soils.
- Crop calendar: See Table 18.
- Field size: Typically 1 to 4 ha.
- Climate and weather: Semi-arid mediterranean climate, rainfall around 250 mm/y, ET0 around 1500 mm/year.
- Agricultural methods used: Dry cereals and olive cultivation; Irrigation for cereals, vegetables and some fruit trees (apple, peach, etc.).
<table>
<thead>
<tr>
<th>Crop</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
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<th>Sep</th>
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<td>Melon early</td>
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<td>Tomato late</td>
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<td>Kids pepper late</td>
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<td>Olive trees</td>
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<td>Prune</td>
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<td>Harvest</td>
<td>Harvest</td>
<td>Prune</td>
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<td>Almond trees</td>
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<td>Harvest</td>
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<tr>
<td>Barley (dry cultivation)</td>
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<td>Harvest</td>
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<tr>
<td>Wheat (dry)</td>
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<td>Sow</td>
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<td>Harvest</td>
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<td>Forage</td>
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<td>Harvest</td>
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<tr>
<td>Cattle pasture</td>
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<td></td>
<td></td>
<td>Harvest</td>
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</tr>
</tbody>
</table>

**Table 18  Merguellil, Tunisia Crop Calendar**
Figure 108  Field LAI Measurements with Hemiview Canopy Images (L); Flux Tower Installed in Dry Cultivated Olive Trees (R)

Figure 109  Orchard with Olives and Orange Trees (L); Irrigated Chili (R)

Figure 110  Field with Residues and Ploughing in Progress (L); Flow Measurements on a Pipe for Irrigation (R)
EO Data Received/Used

The project acquired images from various sensors (see Table 19).
<table>
<thead>
<tr>
<th>Sensor</th>
<th># of Clear Images</th>
<th>Optical / SAR</th>
<th>Supplier</th>
<th>Pixel Size (m)</th>
<th>Proc. Level</th>
<th>Challenges Ordering</th>
<th>Challenges Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPOT 6-7</td>
<td>9</td>
<td>Optical</td>
<td>AIRBUS Defence and Space</td>
<td>5</td>
<td>Ortho TOA</td>
<td>Specific offer</td>
<td>Atmospheric parameters are obtained from a local AERONET photometer</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>(French Data Center THEIA) October 2015 – June 2016</td>
<td></td>
</tr>
<tr>
<td>Landsat-8</td>
<td>11</td>
<td>Optical Thermal</td>
<td>JECAM / USGS</td>
<td>30 60</td>
<td>TOA/TOC</td>
<td>October 2015 – September 2016</td>
<td>USGS processing to be compared with MAACS chain prototype (designed for 2A level for THEIA)</td>
</tr>
<tr>
<td>Sentinel-1</td>
<td>36</td>
<td>SAR</td>
<td>ESA</td>
<td>5-20</td>
<td>Free, high volume</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sentinel-2</td>
<td>21 (cloud-free)</td>
<td>Optical</td>
<td>ESA/CNES/ THEIA</td>
<td>10-20</td>
<td>Free, high volume</td>
<td>Processed</td>
<td></td>
</tr>
</tbody>
</table>

Table 19  Tunisia Site EO Data Ordered
In situ Data

- Crop identification ground campaigns for land cover classification training.

<table>
<thead>
<tr>
<th>Date</th>
<th>Number of plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>18/09/2015</td>
<td>72 plots</td>
</tr>
<tr>
<td>21/01/2016</td>
<td>74 plots</td>
</tr>
<tr>
<td>24/05/2016</td>
<td>151 plots</td>
</tr>
<tr>
<td>21/07/2016</td>
<td>135 plots</td>
</tr>
</tbody>
</table>

- Soil roughness and moisture observations on bare soil plots for SAR images processing validation (Sentinel-1), 23 plots every 12 days, winter 2015 to summer 2016
- Vegetation traits (LAI, fraction cover, biomass and yield on 15 fields) collected on cereals every month.

Figure 111 In situ Data

- Three permanent meteorological stations (including Temperature, Humidity, Wind Speed, Net Radiation, Rainfall)
- One Flux station on rain fed olive orchard (1/01 – 31/12/2016).
- Soil moisture probes with automatic acquisition (8 sites on dry cultivation)
- Surveys of monthly irrigation volumes at the perimeter scale.
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 an International shared Laboratory called NAILA (Managing water resources in Tunisian rural areas).

Results

This approach can be called ‘best practice’. The project objectives have not been modified.

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 first group i.e. Surface Energy Balance (SEB) methods use RS data to estimate heat exchange between land surface and atmosphere, by computing the sensible heat flux first and then obtaining the latent heat flux as the residual of the energy balance equation at the time of satellite overpass. 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 (fc) and the basal crop coefficient (Kcb). We developed in previous works the SAMIR tool (Satellite of Monitoring Irrigation) implementing this method using high resolution image times series (SPOT, Landsat, FORMOSAT, Sentinel-2) and this year for validation, sensible heat flux measurements were obtained using a large aperture scintillometer (XLAS).

Spatialized Estimates of Evapotranspiration

SAMIR Model / Validation

The objective of the work was to assess the operationality 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 (Rn + G = H + LE). The daily net radiation (Rn) was computed using MODIS daily data at the time of satellite overpass (i.e. providing half hourly Rn 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 Rn scaling, we used the ration of radiation measure at the station and daily value, for both global radiation (Rg) or Rn computed using the FAO method. Both methods gave similar results. The comparison between modelled daily and measured ET are shown in Figure 112.
SPARSE Model

In addition, spatially distributed estimates of ET were computed using the layer approach of the Soil Plant Atmosphere and Remote Sensing Evapotranspiration (SPARSE) model (Boulet et al., 2015) fed by low resolution remote sensing data (Terra and Aqua MODIS). The objective of the work was to assess the SPARSE model operationality and the accuracy of the modeled i) instantaneous H and ii) daily evapotranspiration as well as its components (soil evaporation and transpiration) over a semi-arid land surface, in a context of high land.

The SPARSE Model’s layer approach was run to compute instantaneous estimates of sensible heat flux H at the time of satellite overpass. The comparison between H estimates and large aperture scintillometer (LAS)’s H measurements over the study area along a pathlength of 4 Km showed that the SPARSE model presents satisfactory accuracy (Figure 113, Saadi et al., 2017, in preparation).

![Figure 113 Modeled Vs. Observed Sensible Heat Fluxes at Terra and Aqua Time Overpass](image)

In a subsequent step, daily modelled latent heat flux LE (i.e. ET) computed on the basis of modelled half hourly LE were compared to observed LE returned as a residual term of the surface energy budget using the daily scintillometer’s H measurements and net radiation (computed using instantaneous MODIS data and then extrapolated to daily time step). Results are shown in Figure 112.
Long term irrigation monitoring / WEAP

We propose a generic toolbox based on the FAO-56 method and the Crop Coefficient/NDVI approach used in Remote Sensing. A toolbox has been used in order to build a WEAP21 model of the Merguellil basin in Tunisia for the period of 2000-2014 (Le Page et al, 2016). The toolbox can be separated into three main areas:

1) preparation of different input datasets,

2) A collection of algorithms based on the analysis of NDVI time series (MODIS) is proposed: Separation of irrigated vs non-irrigated area, a simplified annual land cover classification, Crop Coefficient, Fraction Cover and Efficient Rainfall,

3) Synthesis against points or areas produces the output data at the desired spatial and temporal resolution for Integrated Water Modeling or data analysis and comparison.

Finally, the comparison to monthly statistics of three irrigated commands was performed over 4 years. Punctual evapotranspiration was compared to actual measurements obtained by flux towers on wheat and barley showing good agreements on a daily basis \(r^2=0.77\). This latter comparison showed a bad agreement which led us to suppose two things: First, the simple approach of (Evapotranspiration minus Efficient Rainfall) to estimate Irrigation at the monthly time step is not pertinent because only a subset of the irrigated commands is actually irrigated. Hence, a higher spatial resolution of remote sensing imagery is needed. Second, in this particular area, farmers have a different rationale about rainfall and irrigation water needs. These two aspects need to be further investigated.

The toolbox has proven to be an interesting tool to integrate different sources of data, efficiently process them and easily produce input data for the WEAP1 model on a long term basis. Yet some new challenges have been raised.

Soil Water Content Monitoring

Soil water monitoring using microwave data has been studied at various scales, from 1 km to 2 m. We present new results on the JECAM site.

We propose the MHYSAN model (Modèle de bilan HYdrique des Sols Agricoles Nus / Bare Soil HYdrological Balance Model, Gorrab et al, 2017) for simulating soil water balance of bare soils. This model was used to simulate surface evaporation fluxes and SM (soil moisture) content at daily time scale over a semi-arid, bare agricultural site in Tunisia (North Africa). Two main approaches are considered in this study. Firstly, the MHYSAN model was successfully calibrated for seven sites using continuous thetaprobe measurements at two depths. Then the possibility to extrapolate local SM simulations on distant sites based only on soil texture similarity was
tested. This extrapolation was validated using SAR estimates and manual thetaprobe measurements of SM made on these distant sites. Results show bias about 0.63 and 3.04 % and RMSE equal to 6.11 and 4.5 % for the SAR volumetric SM and manual thetaprobe measurements, respectively. In a second approach, the MHYSAN model was calibrated using seven very high-resolution SAR (TerraSAR-X) SM outputs ranging over only two months. The simulated SM were validated using continuous thetaprobe measurements during 15 months (Figure 114, Gorrab et al, 2017).

Although only seven dates of SM were used for calibration, the satisfying results we obtained could be attributed to the large SM variation captured by these seven images, allowing a good calibration of the soil parameters. These results highlight the potential of Sentinel-1 images for daily soil moisture monitoring using simple models.

![Figure 114](image)

**Figure 114**  Estimation of Times Series of Water Balance Variables, using Calibrated MHYSAN SAR Data and Validation Results

**Yield Estimates**

No field data in 2016.

**Plans for Next Growing Season**

We will use Sentinel-2A (2B launched in March), Sentinel-1A and B and Landsat TM images in 2017. We will test classification methods to improve the land use mapping to produce intermediate maps and introduce bare soils characteristics in relationships with practices. We will experiment with our tools as SAMIR and these operational data to validate the model on 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 changing the same type/quantity of EO data next year, as follows:

- as usual: Landsat-8, Sentinel-1 and 2 from ESA and THEIA (French land data services center),
- Terrasar-X (high resolution), 5 images
- SPOT 6 or 7 (2 images: high resolution for winter and summer crops) from THEIA
- Pléiades satellite images (2 or 3 full images) from THEIA, to improve and actualize orchard mapping
- if available: hyperspectral images (for soil characteristics).

**Publications**

**Papers**


**Conferences**


Marouen Shabou, Rafael Angulo-Jaramillo, Laurent Lassabatère, Gilles Boulet, Bernard Mougenot, Zohra Lili Chabaane, Mehrez Zribi. Large scale characterization of unsaturated soil properties in a semi-arid region combining infiltration, pedotransfer functions and evaporation tests, European Geosciences Union General Assembly, Vienna, Austria 17-22 April 2016.


25. **Ukraine**

**Team leader:** Prof. Nataliia Kussul, Deputy Director, Space Research Institute NASU-SSAU

**Team Members:**

Prof. Andrii Shelestov, Professor of Department of Information Security, National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”

Dr. Andrii Kolotii, Senior Scientific Researcher, Department of Space Information Technologies and Systems, Space Research Institute NASU-SSAU

Bohdan Yailymov, Scientific Researcher, Department of Space Information Technologies and Systems, Space Research Institute NASU-SSAU

Mykola Lavreniuk, PhD student, National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”

**Project Objectives**

The original objectives have not changed. They are:

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

**Site Description**

The main activities in 2016 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 20. The map of the site is shown in Figure 115.
Table 20  Geographical Coordinates of the Ukraine Test Sites

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

Figure 115  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 (Figure 116), winter rapeseed, spring barley, maize, soy beans (Figure 117), sunflowers, sugar beets and vegetables. Due to the relatively large number of major crops and other factors, there is no typical simple crop rotation in this region. Most producers use different crop rotations depending on specialization.

Figure 116  Winter Wheat Field (11 April 2016)
Figure 117  Soybean Field (29 July 2016)

EO Data Received/Used

Sentinel-1A

- Space agency or Supplier: European Copernicus programme /ESA
- SAR
- Number of scenes: 15
- Range of dates: March – September, 2016
- Spatial resolutions: 20 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 118  Sentinel-1 Images (VV + VH bands) of the JECAM Test Site, 30 May 2016

Sentinel-2A

- Space agency or Supplier: European Copernicus programme /ESA
- **Optical**
- Number of scenes: 5
- Range of dates: 2016-04-28, 2016-06-18, 2016-06-18, 2016-07-17, 2016-08-06
- Spatial resolutions: **20 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.**
In situ Data

Two types of ground data were collected (within the ESA Sen2-Agri Project):

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

Along the roads

About 7689 fields were observed for major crop and non-crop classes (Figure 120). Distribution of the crop classes is shown in Table 21 (Training set) and Table 22 (Validation set). These data were used for crop type map production of the JECAM test site in Ukraine and crop type map for the territory of Ukraine (within the ESA Sen2-Agri Project).
Figure 120  Crop Mapping Dataset Distribution
<table>
<thead>
<tr>
<th>Category</th>
<th>Woodlands</th>
<th>Forest and Steppe</th>
<th>Steppe</th>
<th>Mountains</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bare soil</strong></td>
<td>14</td>
<td>27</td>
<td>39</td>
<td>12</td>
</tr>
<tr>
<td><strong>Broadleaved woodland</strong></td>
<td>29</td>
<td>52</td>
<td>33</td>
<td>28</td>
</tr>
<tr>
<td><strong>Buckwheat</strong></td>
<td>2</td>
<td>8</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Build up surface</strong></td>
<td>11</td>
<td>26</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td><strong>Cabbages</strong></td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Coniferous woodland</strong></td>
<td>60</td>
<td>41</td>
<td>22</td>
<td>21</td>
</tr>
<tr>
<td><strong>Flax</strong></td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Fodder crops</strong></td>
<td>8</td>
<td>12</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td><strong>Fruit gardens</strong></td>
<td>1</td>
<td>15</td>
<td>20</td>
<td>33</td>
</tr>
<tr>
<td><strong>Grassland and meadows</strong></td>
<td>101</td>
<td>124</td>
<td>49</td>
<td>36</td>
</tr>
<tr>
<td><strong>Green peas</strong></td>
<td>0</td>
<td>14</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td><strong>Maize</strong></td>
<td>118</td>
<td>435</td>
<td>187</td>
<td>49</td>
</tr>
<tr>
<td><strong>Mixed woodland</strong></td>
<td>72</td>
<td>60</td>
<td>22</td>
<td>23</td>
</tr>
<tr>
<td><strong>Other cereals</strong></td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Potatoes</strong></td>
<td>10</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td><strong>Rapeseed</strong></td>
<td>22</td>
<td>89</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td><strong>Rye</strong></td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>18</td>
</tr>
<tr>
<td><strong>Shrub land</strong></td>
<td>61</td>
<td>38</td>
<td>73</td>
<td>6</td>
</tr>
<tr>
<td><strong>Soya beans</strong></td>
<td>48</td>
<td>208</td>
<td>54</td>
<td>46</td>
</tr>
<tr>
<td><strong>Spring barley</strong></td>
<td>2</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Spring wheat</strong></td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Sugar beet</strong></td>
<td>5</td>
<td>17</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td><strong>Sunflower</strong></td>
<td>38</td>
<td>424</td>
<td>609</td>
<td>19</td>
</tr>
<tr>
<td><strong>Tomatoes</strong></td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Water bodies</strong></td>
<td>24</td>
<td>37</td>
<td>35</td>
<td>25</td>
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<tr>
<td><strong>Wetland</strong></td>
<td>1</td>
<td>9</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td><strong>Winter barley</strong></td>
<td>12</td>
<td>104</td>
<td>108</td>
<td>49</td>
</tr>
<tr>
<td><strong>Winter wheat</strong></td>
<td>203</td>
<td>681</td>
<td>459</td>
<td>56</td>
</tr>
</tbody>
</table>

Table 21  Training Set Structure (in JECAM Guidelines Nomenclature)
## Table 22  Validation Set Structure (in JECAM Guidelines Nomenclature)

<table>
<thead>
<tr>
<th></th>
<th>Woodlands</th>
<th>Forest and Steppe</th>
<th>Steppe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare soil</td>
<td>16</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Broadleaved woodland</td>
<td>35</td>
<td>33</td>
<td>1</td>
</tr>
<tr>
<td>Buckwheat</td>
<td>6</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Build up surface</td>
<td>1</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>Coniferous woodland</td>
<td>20</td>
<td>46</td>
<td>5</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Fennel</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Fodder crops</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>Fruit gardens</td>
<td>6</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Grassland and meadows</td>
<td>135</td>
<td>55</td>
<td>36</td>
</tr>
<tr>
<td>Green peas</td>
<td>1</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Maize</td>
<td>88</td>
<td>109</td>
<td>19</td>
</tr>
<tr>
<td>Mixed woodland</td>
<td>41</td>
<td>26</td>
<td>5</td>
</tr>
<tr>
<td>Onions</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Other cereals</td>
<td>17</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Potatoes</td>
<td>1</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>11</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td>Rye</td>
<td>24</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Shrub land</td>
<td>21</td>
<td>25</td>
<td>33</td>
</tr>
<tr>
<td>Soya beans</td>
<td>85</td>
<td>102</td>
<td>2</td>
</tr>
<tr>
<td>Spring barley</td>
<td>7</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Spring wheat</td>
<td>4</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Sugar beet</td>
<td>9</td>
<td>13</td>
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</tr>
<tr>
<td>Sunflower</td>
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<td>68</td>
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<td>Tomatoes</td>
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<td>0</td>
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</tr>
<tr>
<td>Water bodies</td>
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<td>22</td>
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</tr>
<tr>
<td>Wetland</td>
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<td>17</td>
<td>8</td>
</tr>
<tr>
<td>Winter barley</td>
<td>19</td>
<td>20</td>
<td>52</td>
</tr>
<tr>
<td>Winter wheat</td>
<td>107</td>
<td>119</td>
<td>185</td>
</tr>
</tbody>
</table>
Observations of biophysical parameters

Seven field campaigns to characterize the vegetation biophysical parameters at the Pshenichne test site were carried out (Table 23). In total, 122 samples were collected (winter wheat – 42 ESU, maize – 37 ESU, soy beans - 43 ESU).

<table>
<thead>
<tr>
<th>Campaign No.</th>
<th>Date</th>
<th>Maize (ESU’s)</th>
<th>Soy beans (ESU’s)</th>
<th>Winter wheat (ESU’s)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2016-04-11</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>2016-05-09</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>2016-05-27</td>
<td>7</td>
<td>8</td>
<td>6</td>
<td>21</td>
</tr>
<tr>
<td>4</td>
<td>2016-06-28</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>2016-07-08</td>
<td>8</td>
<td>10</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>6</td>
<td>2016-07-15</td>
<td>8</td>
<td>13</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>7</td>
<td>2016-07-29</td>
<td>9</td>
<td>8</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>37</td>
<td>43</td>
<td>42</td>
<td>122</td>
<td></td>
</tr>
</tbody>
</table>

Digital Hemispheric Photographs (DHP) images were acquired with a 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. Ground data collection is performed according to the VALERI protocol.

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

We participate in the following collaborative projects:

2. Sentinel-2 for Agriculture project (ESA). Participation as Subcontractor and country level demonstration.

The 2nd JECAM experiment for estimation an impact of different sampling schemes and the 3rd JECAM experiment for comparison of different data sources to deliver accurate cropland maps and reliable accuracy indicators are included in this collaboration. These experiments were conducted within the EU FP7 project “Stimulating Innovation for Global Monitoring of Agriculture and its Impact on the Environment in support of GEOGLAM” (SIGMA). For them, we downloaded pre-processed Landsat-8 satellite data and restored the clouds and shadows for the participants’ test sites.

Ukraine

Time period: 01.03.2016-27.10.2016
Path/row: 181(25), 181(26), 182(25), 182(26), 180(25), 180(26)

Argentina

Time period: 01.07.2015 - 01.05.2016
Path/row: 225(84), 225(85), 226(84), 226(85), 225(86), 226(86)

Africa

Time period: 01.08.2015-31.08.2016
Path/row: 171(79), 171(80), 172(79), 172(80)

Brazil (Tocantins)

Time period: 01.10.2015-01.05.2016
Crop mapping was performed using Sentinel-1/SAR data together with Sentinel-2 optical imagery (Figure 121). There were 15 Sentinel-1/SAR images available during the period March–September 2016 while only 5 cloud-free Sentinel-2 images were available during the same period. When integrating Sentinel-1 and Sentinel-2 together, the overall accuracy reached 88.1%.
Biophysical Parameter Retrieval

Collection of biophysical parameters over the JECAM test site was performed within the ESA Sen-2 Agri project for validation. LAI products can be treated as an important outcome from Sen2-Agri to the Sendai framework.
To what extent have the project objectives been met?

In 2016, all project objectives were met. Crop maps were produced based on Sentinel-1 and Sentinel-2 data. Sentinel-1 is very efficient in cloudy periods (especially in 2016). The
combination of optical (Sentinel-2) on SAR data (Sentinel-1) allowed us to get 88.1% overall accuracy.

Can this approach be called ‘best practice’?

We think that the proposed approach of crop mapping could be considered as best practice. To get more accurate results, SAR and optical high resolution data were integrated, as well as using modern machine learning techniques.

Have you modified the project objectives? If so, in what way?

No, we have not.

Plans for Next Growing Season

Next growing season, we plan to maintain our current approach.

We anticipate ordering the same type/quantity of EO data next year. In addition, we are interested in Radarsat-2 data and continuation of the Take5 initiative.

Publications


Presentations:

1. Andrii Shelestov, “Large scale crop mapping in Ukraine using Google Earth Engine”, AGU Fall Meeting, 12-16 of December, 2016, San Francisco, USA
3. Andrii Kolotii, “Essential climatic variables estimation with satellite imagery”, AGU Fall Meeting, 12-16 of December, 2016, San Francisco, USA
7. Mykola Lavreniuk, “Crop Classification Strategies Using Hybrid Sentinel-1, Sentinel-2 and Landsat-8 Data Series in Ukraine”, ESA Living Planet Symposium, 9-13 of May, 2016, Prague, Czech Republic

26. **Uruguay**

This last year the Uruguay team did not have field activities. They are currently searching for funding. It is most likely that they will have some activities in the future, but as of today they are mostly dedicated to data analysis, with less dedication to the collection of field data.

27. **U.S.A.**

27.1 **Iowa**

**JECAM Test Site Name:** South Fork, 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

Tom Jackson, USDA-ARS-HRSL

Bill Kustas, USDA-ARS-HRSL

John Prueger, USDA-ARS-NLAE

Ali Sadeghi, USDA-ARS-HRSL

**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 Error! Reference source not found..
- 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.

![Student Collects Soil Moisture Data during SMAPVEX16 in South Fork IA](image)

**Figure 124  Student Collects Soil Moisture Data during SMAPVEX16 in South Fork IA**
Figure 125  Precipitation/Soil Moisture Station at South Fork, IA

Figure 126  Field Team for IOP2 of SMAPVEX16

EO Data Received/Used

We did not receive any EO data.

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. In addition, during the Spring and Fall, in situ
Crop residue studies were conducted to estimate residue amounts via field measures and roadside surveys. During the summer of 2016, a field experiment was conducted in conjunction with NASA called the Soil Moisture Active Passive Validation Experiment (SMAPVEX16).

**Collaboration**

The bulk of collaborations this year are involved with SMAPVEX16. The University of Florida deployed an L-band radar and radiometer to serve as a ground based calibration system for SMAP. George Mason University deployed a new soil moisture sensor at several locations to serve as a cross validation project with the existing sensors. NASA JPL flew the CFIS instrument in coordination with the OCO-2 satellite mission.

**Results**

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

**Plans for Next Growing Season**

We will continue to measure crop residue and will be performing soil moisture validation on the network.

**Publications**


**27.2 Michigan**

No report received.