JECAM
Joint Experiment for Crop Assessment and Monitoring

GEO GROUP ON EARTH OBSERVATIONS

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

# 2014 Progress Report

April 2014

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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 2013. 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 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 2014 is presented in this document. There are currently thirty-three JECAM test sites, of which four appear to be dormant, and a few have just started. Twenty-four sites submitted progress reports. 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 in 2014) are shown in Table 1. The entries of this table show the number of images for each sensor, where the sites reported them. (Where the use of a sensor was reported without a number of images, an 'x' appears.) The figures in this table give an idea of relative volume of data. However, a word of caution when reading these figures. Clearly, the area of one image in $km^2$ 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.

Since last year's report, the JECAM sites told us about 19 peer reviewed papers, 12 other publications and 19 presentations.

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.

All of the reporting sites included crop mapping as an objective. Fifteen of 24 include crop condition objectives. Seventeen also included crop yield forecasting research. Twelve of 24 included soil moisture monitoring research as an objective. Eight reported residue and tillage monitoring research as an

objective. Other objectives included biophysical variables, phenological events, cropping practices, crop calendar, $CO_2$ and water budgets/flux, and soil erosion.

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

| JECAM Site | COSMO SkyMed | RADARSAT-2 | TerraSAR-X | AWIFS | DMCII | ASTER | HJ-1 | Landsat | MODIS | Quickbird | Rapideye | SPOT-4/5/6 | Worldview-2 | Pléaides | Formosat-2 | Deimos | Chris |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Argentina | 1 | 18[1] | 7 | 6 | 7 | | | | | | 24 | 17 | | | | | |
| Belgium | | 11 | | | | | | x | | | 28 | 14 | | | | | |
| Brazil – Sao Paulo | | | | | | | | 4 | 220 | | | | 3 | | | | |
| Brazil – Tapajos | | | | | | | | x[2] | | | 48 | | | 3 | | 10 | |
| Burkina Faso | | | | | | | | 11 | | | | | | 7 | | | |
| Canada CFIA – Ottawa | | | | | | | | 8 | | | | 7 | | | | | 1 |
| Canada/Red River | | x | | | | | | x | | | x | | | | | | |
| Canada/South Nation | | | 8 | | | | | x | | | 15 | | | | | | |
| China/Guangdong (Taishan) | 12 | 6 | | | | | | | | | 4 | | | | | | |
| China/Heilongjiang | 4 | 5 | 5 | | | | 27 | | 21 | | 5 | x | | | | | |
| China/Jiangsu[3] | | | | | | | | | | | | | | | | | |
| China/Shandong | 4 | 4 | 1 | | x | | 21 | | 46 | | 5 | 18 | | | | | |
| France | | | | | | | | 7 | | | | 15 | | 3 | 16 | 8 | |
| Italy Apulian Tavoliere | | | | | | | | | x | | | | | | | | |
| Madagascar | | | | | | | | | | | | 25 | | 9 | | | |
| Morocco | | | | | | | | | | | | 36 | | | | | |
| Russia | | | | | | | | x | x | | | | | | | | |
| Saudi Arabia | | | | | | x | | x | | 4 | | | | | | | |
| South Africa | | | | | | | | 7 | 20 | | 11 | 135 | | | | | |
| Taiwan | | | | | | | | | x | | | x | | | x | | |
| Tunisia | 15 | | 2 | | | 2 | | 21 | | | | 25 | | | | | |
| Ukraine | | 14 | | | | | | 6 | x | | 29 | 17 | | | | | |
| Uruguay | | | | | | | | x | | | | | | | | | |
| U.S.A. | | | | 4 | | | | | | | | | | | | | |

There is already significant bi-lateral collaboration between JECAM sites planned and underway. Use of the site network to support research external to JECAM is now taking place, including:

[1] These scenes range in date from Oct 2010 – April 2012, but were received in 2013.
[2] All Landsat-8 coverages during 2014 were requested.
[3] The China/Jiangsu site ordered imagery in 2012, but in 2013, they focused on analysis and did not order imagery.

- ESA Sentinel 2 Simulation over JECAM sites
- IMAGINES project
- NASA SMAP Validation Experiment (SMAPVEX)
- EU FP7 SIGMA Project.

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. Support will include exploring the development of minimum datasets of in-situ and satellite data for a core number of sites and taking part in the NASA “cloud” prototype to enhance data sharing and multi-party data licensing.

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. 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 effectively 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) and the GEO Forest Carbon Tracking task.

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 Forest Carbon Tracking task, 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 Crop condition / Crop stress
- Land management
- Soil moisture.

The Guide to Interacting with Space Agencies and Commercial Data Providers has been provided to each JECAM test site, so that they could access EO data by contacting the space agencies and commercial data providers directly, rather than via the JECAM Secretariat.

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.

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

- Argentina
- Australia
- Belgium
- Brazil (2)
- Burkina Faso
- Canada (3)
- China (6)
- France
- Italy Apulian Tavoliere
- Madagascar
- Mali
- Mexico

- Morocco
- Paraguay
- Russia (2)
- Saudi Arabia
- South Africa
- Taiwan
- Tanzania
- Tunisia
- Ukraine
- USA (2)
- Uruguay.

The following sections provide a progress report for the JECAM test sites up to February 2014. Section 26 describes JECAM support to important multilateral and bilateral work.

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

## 3. Argentina

Team Leader and Members: Diego de Abelleyra, Santiago Verón, Carlos di Bella

Project Objectives

The original objectives for the site have changed.

- Yield Prediction and Forecasting. We are evaluating the correlation between several indexes and reflectance derived from optical satellite images (NDVI, SR, R and IR) and crop variables (fAPAR, biomass and yield). In addition, we are testing indexes derived from RADAR and considering meteorological data as complementary information.
- Crop identification and Crop Area Estimation. We are testing classification methods using optical and RADAR images and its combination. Among optical images, we are testing the effect of frequency and timing of acquisitions and resolution. Field observations of land use and crop type are carried out several times during a year to validate our classification results.
- Soil Moisture. During two field campaigns we measured gravimetrical superficial soil moisture several times during a year at crop and fallow fields with the aim to evaluate time windows of using different RADAR frequency images for soil moisture estimation.
- Crop Residue, Tillage and Crop Cover Mapping. We are registering fields of conventional and no tillage to test its identification using optical and RADAR images.

Site Description

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

Location Area 1 – Crop Monitoring - High acquisition frequency:

| | |
|---|---|
| **Centroid** | Latitude: 34.196300° S; Longitude: 59.576500° W |
| **Top left** | Latitude: 34.107537 S; Longitude: 59.684906 W |
| **Bottom right** | Latitude: 34.287877 S; Longitude: 59.465181 W |

Location Area 2 – Crop mapping - Low acquisition frequency:

| | |
|---|---|
| **Centroid** | Latitude: 34.1409° S; Longitude: 59.6867° W |
| **Top left** | Latitude: 33.8294S° S; Longitude: 60.0856° W |
| **Bottom right** | Latitude: 34.4579° S; Longitude: 59.3012° W |

- Topography: Flat - slopes between 0 and 1 %
- Soils: Mostly Mollisols. Silt loam / Silty clay loam textured.
- Drainage class/irrigation: Well drained soils / Mostly rain fed fields
- Crop calendar

Main grain crops are soybean, maize and wheat. Early wheat is planted in June/July while late wheat is planted at the end of July and August. Wheat heading occurs in mid October and its harvest takes place at the beginning of December. After a wheat crop, a late soybean crop is commonly planted in December, and is harvested in April. Also, a late maize crop can be planted after a winter crop. Soybean and maize are mostly planted as one season crop. In these cases, soybean is planted in November and harvested in March/April and maize is planted in October and harvested in March.

- Field size: Typical field size is 20 ha but there is high variability in plot size.
- Climate and weather: The climatic zone is temperate humid.
- Agricultural methods used: Mostly no till agriculture. Main rotation (three years): Maize, Soybeans, Wheat/Soybeans.

<u>EO Data Received during 2013</u>

RADARSAT-2

- Supplier: CSA
- SAR
- Number of scenes: 18
- Range of dates: October 2010 – April 2012
- Beam modes/ incidence angles/ spatial resolutions: Fine Quad Pol mode. FQ16 – FQ21
- Processing level: Single Look Complex

Several RADARSAT-2 were acquired from October 2010 to April 2012. We received 18 images for crop monitoring. We need to get more of the acquired images to include RADARSAT-2 in the analysis of land use classification and crop area mapping where the study area is larger.

TerraSAR-X:

- Space agency or Supplier: German Space Agency (DLR)
- SAR
- Number of scenes: 7
- Range of dates: Jan 2013 – Nov 2013
- Beam modes/ incidence angles/ spatial resolutions:

  - StripMap Dual. Polarization: HH/VV. Incidence angle: 30.9/32.2º. Resolution 7 m.
  - ScanSAR. Polarization VV. Incidence angle: 27.3/36.5. Resolution 20 m.
- Processing level: Single Look Complex
- Challenges, if any, in ordering and acquiring the data

The acquisition planning tool for Terrasar-X (EOWEB next generation) is excellent. It is easy to know the area and the date of each future scene. All images requested were acquired with success. We are near to finish our quota of 30 images in total.

Cosmo-Skymed:

- Supplied by CONAE
- SAR
- Number of scenes: 1
- Range of dates: March 2013
- Beam modes/ incidence angles/ spatial resolutions
  - StripMap Ping Pong. Polarization: HH/HV and HH/VV. Incidence angle: from 27 to 52°.
  - Resolution 15 m.
- Processing level: Single Look Complex

ResourceSAT/ AWIFS:

- Space agency or Supplier: ISRO
- Optical
- Number of scenes: 6
- Range of dates: Jan 2013 – May 2013
- Beam modes/ incidence angles/ spatial resolutions. Resolution: 56 m.
- Processing level: Geocoded
- Challenges, if any, in ordering and acquiring the data

If we have the possibility to obtain orthorectified images, it will improve significantly the time required for image processing that in general requires manual georreferencing.

DMCii:

- Space agency or Supplier: DMC International Imaging Ltd
- Optical
- Number of scenes: 7
- Range of dates: Jan 2013 – Dec 2013

If we have the possibility to obtain orthorectified images, it will improve significantly the time required for image processing that in general requires manual georreferencing.

RAPIDEYE:

- Space agency or Supplier: Blackbridge (through ESA)
- Optical
- Number of scenes: 24
- Range of dates: Feb 2013 – Jun 2013
- Beam modes/ incidence angles/ spatial resolutions. Resolution: 5 m.
- Processing level: Calibrated / Orthorectified

It was very useful to get the images orthorectified. Because of that, there is no need to manual georreferencing, an aspect that could take a lot of time in particular for time series analysis. As SPOT images, this dataset was obtained through the Agri-2 Sentinel-2 Take 5 project. They defined the acquisition time window that was the same in all study sites, but it was not the optimal for crop monitoring in the southern hemisphere.

SPOT-4:

- Space agency or Supplier: CNES (through ESA).
- Optical
- Number of scenes: 17
- Range of dates: Feb 2013 – Jun 2013
- Beam modes/ incidence angles/ spatial resolutions. Resolution: 20 m.
- Processing level: Calibrated / Orthorectified

Same comments as for RapidEye.

<u>In situ Data</u>

Intensive field measurements of crop and environmental variables were performed during the first three years of the project (2010-2013) to develop and calibrate methodologies for biomass and yield estimations and crop mapping. This includes the last agricultural campaign that ended in April 2013.

Measurements were performed at several times during wheat (August to December) and soybean (November to April) crop growing periods:

- Fraction of Absorbed Photosynthetic Active Radiation (fAPAR)
- Green Cover / LAI (Leaf Area Index). Digital images were taken using a Digital Camera with wide angle Lens.

- Crop wet and dry biomass. Periodical harvests were performed. Plants were weighed wet and after oven drying.
- Soil moisture measurements (0-5 cm). Gravimetric method (during first two years and at particular events).

Additional measurements:

- Crop Yield
- Plant density
- Row direction.

Since the current agricultural campaign (2013/2014), measurements at maturity of wheat and soybean crops are being performed to validate the developed methodology for yield estimation.

We also continue performing regional surveys during key crop developing stages with visual identification:

- Land use: Agriculture / Livestock
- Crop type: Wheat, Barley, early and late soybean, early and late maize.
- Tillage system.

**Figure 1: Field Campaign Photos. Left: Mature Wheat Field in San Antonio de Areco, Argentina. Right: Wheat Field in Shandong, during our Visit to China JECAM Site**

<u>Collaboration</u>

We started joint collaborations with the China JECAM site leaded by Prof. Bingfang Wu at RADI. A participant of JECAM China visited us during March 2013, and 2 participants from JECAM

Argentina visited RADI in Beijing, China. We participated in field campaigns of each other's JECAM site and started joint research activities sharing data from both JECAM sites.

In addition, we are participants of the EU FP7 SIGMA project that was approved during 2013 together with other JECAM sites from Europe and around the world.

Results

*Generation of daily normalized MODIS 250 time series*

We adapted several algorithms (Roujean et al. 1992, 2000 – Classic Approach and Vermote et al., 2009 – Alternative approach) for correction of BRDF effects that occur in MODIS daily data as the viewing and illumination angle changes from one acquisition to another (Fig. 1 and 2). The effect was a significant reduction in noise (high frequency variability), particularly for red and infrared reflectance.

Figure 2 shows a time series of MODIS Terra red reflectance at a crop field in San Antonio de Areco (Argentina) from 2007 to 2011 in a 4 crops rotation sequence: soybean (2007-2008), wheat-soybean (2008-2009), maize (2009-2010), soybean (2010-2011). The time series colours

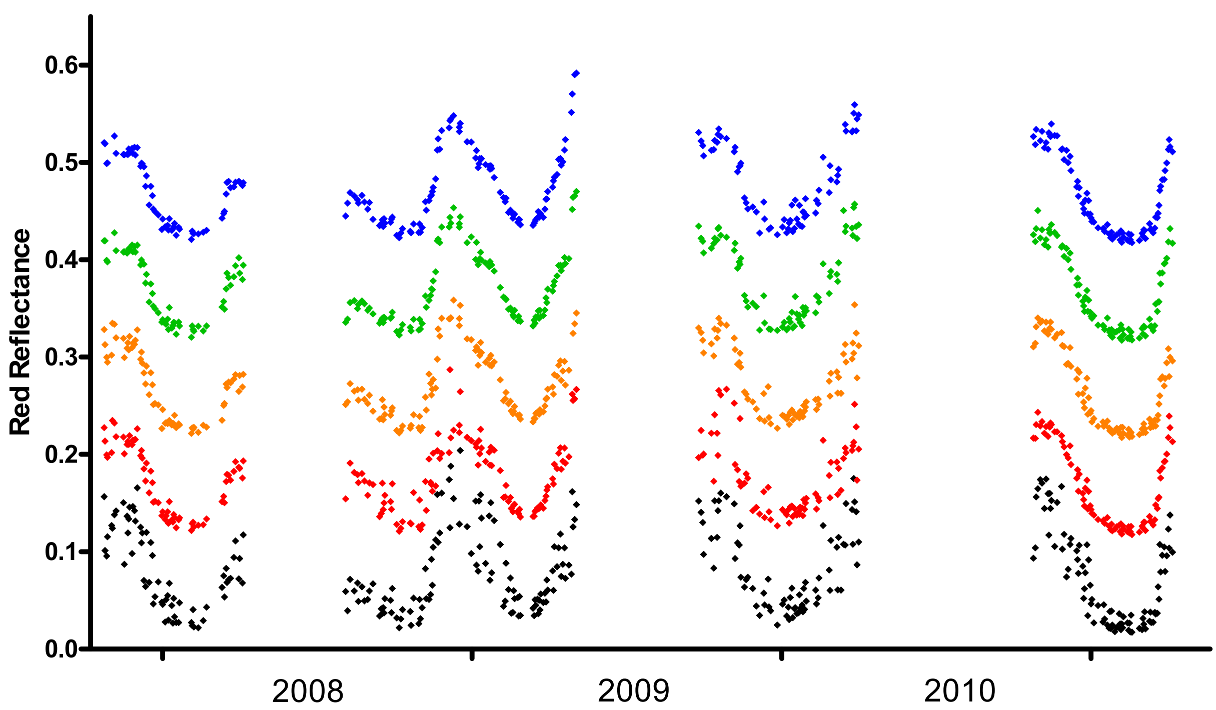



**Figure 2: Time Series of MODIS Terra Red Reflectance at a Crop Field in San Antonio de Areco (Argentina)**

are Filtered (uncorrected) (black), Classic SP (single period - red), Alternative SP (orange), Classic 3MP (3 multiple-periods - green), Alternative 3MP (blue).

Figure 3 shows a time series of MODIS Terra infrared reflectance at a crop field in San Antonio de Areco (Argentina) from 2007 to 2011 in a 4 crops rotation sequence: soybean (2007-2008), wheat-soybean (2008-2009), maize (2009-2010), soybean (2010-2011). Time series colors: Filtered (uncorrected) (black), Classic SP (single period - red), Alternative SP (orange), Classic 3MP (3 multiple-periods - green), Alternative 3MP (blue).

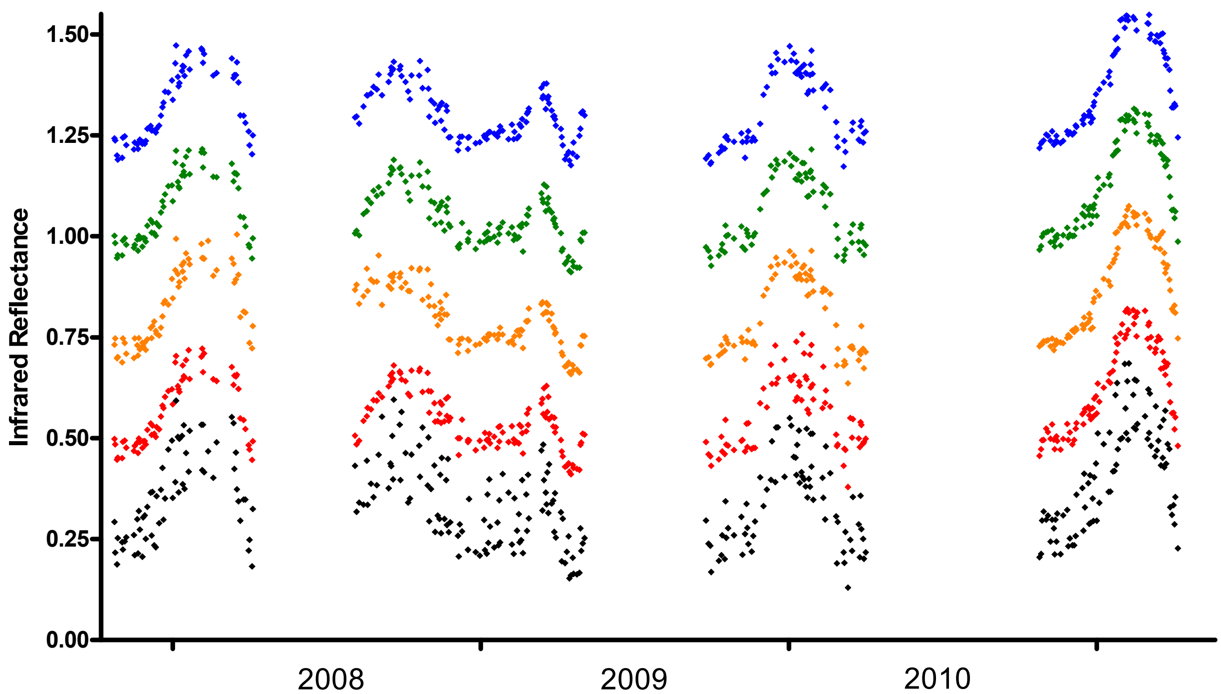



**Figure 3: Time Series of MODIS Terra Infrared Reflectance at a Crop Field in San Antonio de Areco**

We generated daily normalized time series of MODIS 250m red, infrared and normalized difference vegetation index (NDVI) for 2 stuy sites in Argentina (San Antonio de Areco and Montebuey). We are testing the use of daily data for crop yield estimations. Table 2 shows the determination coefficients between between field measured crop variables at San Antonio de Areco (Dry biomass and fAPAR) and index derived from MODIS time series normalized with different methods and uncorrected. The table shows i) fraction of intercepted photosynthetic active radiation (fIPAR) and the NDVI of the corresponding day (NDVId, and ii) peak dry biomass and the maximum NDVI (NDVImax) for each correction method. F: Filtered (uncorrected), CSP: Classic single period, ASP: Alternative single period, C3MP: Classic 3 multiple-periods, A3MP: Alternative 3 multiple-periods. In general, $r^2$ increased for correction methods.

| Dependent variable | Independent variable | Sensor | n | F | CSP | ASP | C3MP | A3MP |
|---|---|---|---|---|---|---|---|---|
| fIPAR | $NDVI_d$ | Terra | 20 | 0.31 | 0.33 | 0.81 | 0.49 | 0.86 |
| | | Aqua | 21 | 0.76 | 0.61 | 0.88 | 0.68 | 0.86 |
| Peak Dry Biomass | $NDVI_{max}$ | Terra | 36 | 0.48 | 0.59 | 0.58 | 0.54 (0.50) | 0.03 (0.51) |
| | | Aqua | 36 | 0.52 | 0.56 | 0.55 | 0.47 (0.54) | 0.01 (0.48) |

**Table 2: Coefficients of Determination**

We additionally performed MODIS BRDF corrected daily time series for China JECAM site and we are testing its contribution for yield estimation.

Experience with the COVE Planning Tool

We use tools offered by each satellite provider (i.e. TerraSAR-X) for searching and identifying possible modes and dates to get the required images. At least for SAR images, the acquisition mode is quite specific, and it is more useful to search for a particular mode of acquisition in a time window than having all the possible combination of modes for acquiring images in the area of interest.

Plans for Next Growing Season

Since 2010, we started acquiring satellite data and performing regular field measurements and regional surveys over the study site for generation and calibration of yield estimation and crop mapping methodologies. Future activities are oriented to validate crop yield and crop mapping methodologies generated during JECAM initial stage (2010-2013). Activities will also be compatible with the FP7 SIGMA Project. We anticipate ordering the same type and quantity of data next year.

Publications

Peer reviewed papers:

De Abelleyra D, Verón S. 2014. Comparison of different BRDF correction methods to generate daily normalized MODIS 250m time series. *Remote Sensing of Environment*, 140: 46-59.

Presentations:

De Abelleyra D, Verón S. 2013. JECAM Argentina. Preliminary results of two years of field data. 35º International Sympossium in Remote Sensing of Environment. Beijing, China. April 22-25, 2013.

De Abelleyra D, Verón S. 2013. Optical and Radar remote sensing for crop monitoring in the Argentine JECAM site. 2013 International Workshop on Using Remote Sensing for Crop Area Monitoring and Yield Estimation. September 11, 2013, Taichung, Taiwan

## 4. Australia

No report received.

## 5. Belgium

Team Leader and Members: Pierre Defourny, Aline Léonard, Damien Jacques and François Waldner.

Project Objectives

The original objectives for the site have not changed.

- Crop identification and Crop Area Estimation Cropped Land: developing a method for support crop area estimation on field for a resolution (minimum mapping unit) Nuts 3; Mapping Frequency: 2 maps / year 1 for winter wheat mapping, 1 maize mapping.
- Crop Condition/Stress: improve estimate of biophysical variables retrieval for crop growth monitoring; methodology development for maize and winter wheat Leaf Area Index (LAI) estimation from optical and SAR data in an operational perspective.
- Soil Moisture: Analysis of the sensitivity of SAR data to soil surface parameters (surface roughness and soil moisture) over agricultural fields, at various polarizations.
- Investigation of the options to scaling down evapotranspiration data coming from Meteosat Seconde Génération every 30 minutes.

Site Description

- Location: Belgium, Centroid: Latitude 49.75° N, Longitude 3.75° E
- Topography: Elevation varies between 20 and 200 meters, the topography is generally flat or slightly undulating.
- Soils: soil texture is loam.
- Drainage class/irrigation: soil drainage is moderately well-drained and irrigation infrastructure is not frequent.
- Crop calendar: Crop types are wheat, barley, potatoes, sugar beet, maize, alfalfa, etc. The crop calendar is: Wheat / barley: March-August; Maize: April - September.
- Field size : from 3 to 15 ha.
- Climate and weather: Climate at the site is moderately humid, with annual rainfall of about 780 mm which is relatively well distributed over the year.

EO Data Received/Used

RADARSAT-2

- Space agency or Supplier : Canadian Space Agency (CSA)
- SAR
- Number of scenes : 11
- Range of dates : from March 2013 to August 2013
- Beam modes/ incidence angles/ spatial resolutions : Fine Quad-Pol beam mode
- Processing level : SLC products
- Challenges, if any, in ordering and acquiring the data : no
- Challenges, if any, in processing and using the data : no

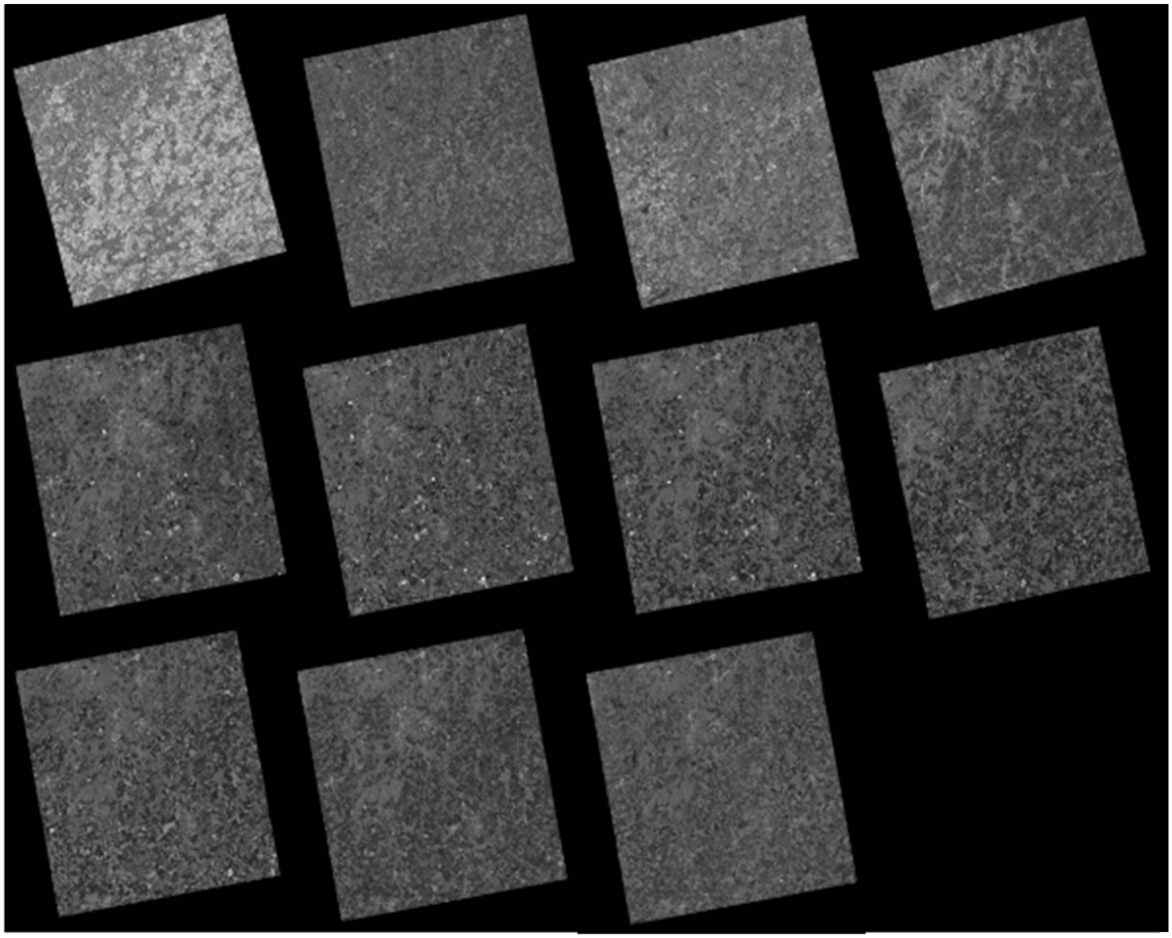


Figure 4: RADARSAT-2 Fine Quad-Pol over Belgium site from March to August 2013

SPOT-4

- Space agency or Supplier : CNES
- Optical
- Number of scenes : 14
- Range of dates : from February 2013 to June 2013
- Beam modes/ incidence angles/ spatial resolutions : 20 meters
- Processing level : Level 1C and 2A
- Challenges, if any, in ordering and acquiring the data : cloud issue
- Challenges, if any, in processing and using the data : no.

RapidEye

- Space agency or Supplier : ESA
- Optical
- Number of scenes : 28
- Range of dates : from February 2013 to June 2013
- Beam modes/ incidence angles/ spatial resolutions : 5 meters

- Processing level : Level
- Challenges, if any, in ordering and acquiring the data : cloud issue
- Challenges, if any, in processing and using the data : no
- Please provide sample pictures of the imagery provided in application

Landsat-8

- Space agency or Supplier : NASA
- Optical
- Number of scenes: …
- Range of dates : from April 2013 to …
- Beam modes/ incidence angles/ spatial resolutions : 5 meters
- Processing level : Level
- Challenges, if any, in ordering and acquiring the data : cloud issue
- Challenges, if any, in processing and using the data : no.

In situ Data

A field campaign was carried out during the 2013 growth season in a sample of 15 winter wheat fields located in Loamy Region in Belgium. The aim of the campaign was to collect a data set for the validation of retrieval of biophysical variables. Each field was visited between 6 and 8 times and, each time, plant height, phenological stage and the Leaf Area Index (LAI) were measured. LAI is defined as the one-sided green leaf area per unit of ground surface area ($m^2/m^2$) (Chen and Black, 1992). A non-destructive method for the measurement of the LAI is based on hemispherical pictures processed in the image analysis software CAN-EYE (www4.paca.inra.fr/can-eye). A NIKON PowerShot A590 IS camera equipped with a super wide fish-eye 0.25x with macro is used to take pictures from above the canopy, facing towards the soil (Figure 5).

**Figure 5: Hemispherical Picture Taken in a Wheat Field**

Depending on the date, between 8 and 12 photographs were taken in an area of 400 m² within the field. In the CAN-EYE software, all pixels of each image are classified as vegetation or soil (according to their respective colour). From the result, the model computes the gap fraction in concentric circle around the centre of the image, giving the proportion of green vegetation for different inclination angles which allows to implement the leaf area index (LAI) (Weiss and Baret, 2010). In the case of crops such as winter wheat, all main aerial plant organs (leaves, stems...) are green, it is therefore more appropriate to use the term of GAI, instead of LAI, to refer to the biophysical parameter retrieved from the CAN-EYE process (Duveiller et al., 2011). Cover fraction (fCOVER) which is defined as the fraction of the soil covered by the vegetation viewed in the nadir direction can be also derived from those pictures. Due to characteristics of hemispherical images, it is not possible to get a value in the exact nadir direction, therefore the cover fraction must be integrated over a range of zenith angles which is also done in the CAN-EYE software. In addition to these measures, almost one thousand fields were visited to identify the crop type (Figure 6). The aim was to build training and testing data sets in order to classify the satellite images and evaluate the quality of the result.

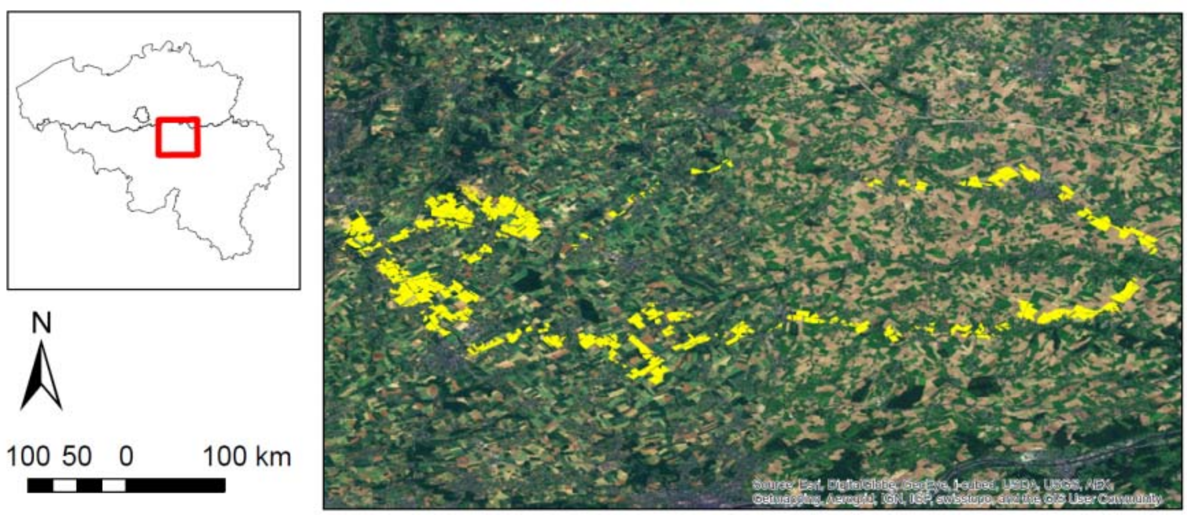



**Figure 6: Locations of Agricultural Parcels Visited during the Field Campaign for the Creation of Training and Testing Data Sets**

<u>Collaboration</u>

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 bio-physical variables.

In the MOCCCASIN project (Monitoring Crops in Continental Climates through Assimilation of Satellite INformation), an in-situ data collection protocol has been provided to the Russian team for field data collection (crop type, hemispherical photographs, phonological stages, etc.) A comparative exercise on early season winter crop mapping has also been carried out.

Due to the fruitful previous experience, the Tula site has been selected as demonstration site for multi-sensor crop type classification in ImagineS (Implementing Multi-scale AGricultural Indicators Exploiting

Sentinels) along with two other sites: the Free State site (South Africa) and the Kyiev site (Ukraine). The sites provided crop type observations; classification method inter-comparison is also on the agenda. It has been decided to extend the analysis at the regional administrative level of the Russian and the South African sites. Therefore, 13 of RapidEye and RADARSAT-2 wall-to-wall coverages for these regions were ordered – around 5000 and 200 images respectively.

A major goal of SIGMA (Stimulating Innovation for Global Monitoring of Agriculture and its Impact on the Environment in support of GEOGLAM) is to support GEOGLAM partly by coordinating JECAM activities. The consortium includes 13 JECAM site partners. A standardized field data collection protocol for crop type classification will be provided to the sites. In addition, efforts will be made to gather and pre-process minimum standardized data set for each site. Research activities will focus on multi-sensor cropland and crop type mapping while encouraging cross-site experiments.

The ESA project Sen2Agri (Sentinel-2 Agriculture) will develop products relevant for agriculture monitoring as 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.

Results

**Classification methods** of Earth observation data obtained by remote sensing, enabling us to produce a land cover map of anywhere in the world. This is a major asset when computing estimates of area of a particular land cover class (e.g. crop area). However, the commission and omission errors occurring during the classification process (partly due to mixed pixels) are not counterbalanced and therefore they bias the results. Because of this constraint, operational systems have to set up a sampling scheme of in-situ and/or survey data to assess area rather than making use of Earth observation data solely. For example, the last version of LUCAS, the crop acreage European monitoring system, is a two-stage systematic design scheme of unclustered points which are identified in the field. Remote sensing data are then used to produce a crop mask and a stratification of the territory to improve the efficiency of the sampling. This research explores ways for improving the accuracy of the information provided by Earth observation data classification by applying sampling directly to the satellite image in order to get a subset classified more accurately. The selection criteria used to build the sampling has to be as independent as possible of the land cover type, so ideally derivable a priori i.e. before the classification process. Using a series of 3 SPOT-5 images acquired during 2013 growing season in Belgium, this research seeks to develop an object-based method for the estimation of a priori misclassification probabilities of (i) the crop land and (ii) the crop type. The validation is done using the Integrated Administration and Control System (IACS), an annually updated vector GIS which contains information on most of the agricultural parcels in the Walloon region (field limits and crop type). First results show that a set of spectral and spatial object features, completely and automatically extracted from one image, are useful to produce a misclassification probabilities map of the crop land (Figure 7).

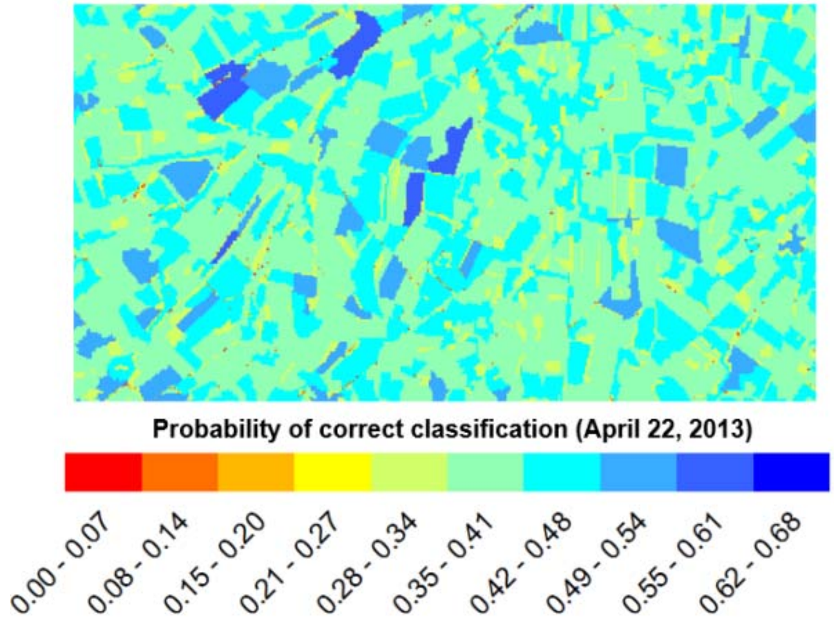



**Figure 7: Map of the Probability of Correct Classification Obtained with the Described Method**

From this output, a sampling of the image object can be performed based on a trade-off between the sampling rate (to maximize) and misclassification rate (to minimize) (Figure 8). The error of classification decreases using purposive sampling compared to a same-size random sampling.

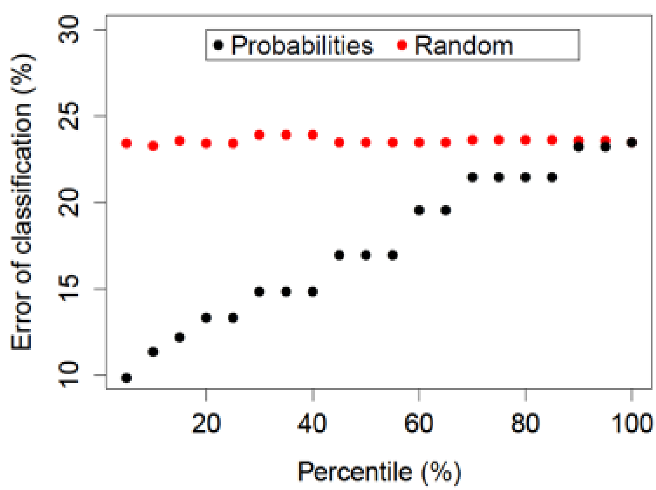



**Figure 8: The Decrease in Error of Classification using Purposive Sampling, Compared to a Same-size Random Sampling**

The influence of the sampling on the classification bias was studied via the evolution of commission and omission errors with the sampling rate. These results could be used as a significant input to operational agriculture monitoring systems. In the case of unbiased sampling, it could be directly used as an alternative estimator to field sampling for crop area (Figure 9). The crop area estimation is improved partly due to a balance between commission and omission error.

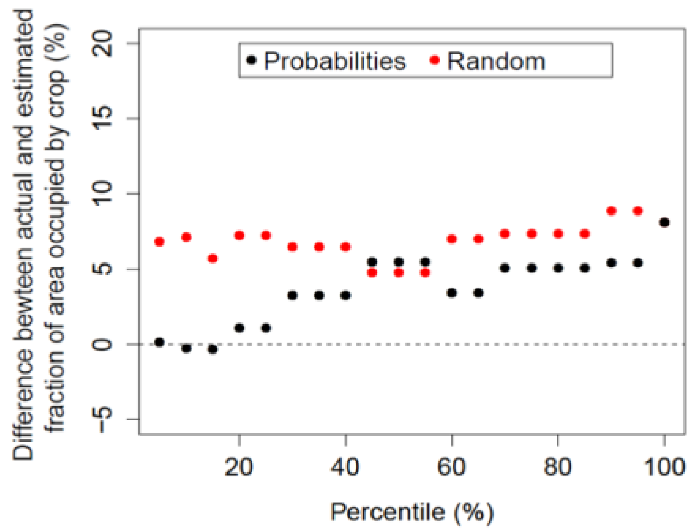



**Figure 9: Improvement in Crop Area Estimation Partly Due to a Balance between Commission and Omission Errors**

In any case, this technique could improve the efficiency of field sampling, given information on area where crop type has been identified with a high confidence level. The technique helps to prioritize field visits through the identification of areas hard to classify with remote sensing. That information could also be used for crop yield monitoring because it enables the team to follow parcels with low misclassification probabilities.

**Results of winter wheat LAI estimation from SAR data** The semi-empirical Water Cloud Model (WCM) was implemented to derive winter wheat LAI values from each linear polarization and surface soil moisture information during the 2013 growing season. The co-polarization was found the most relevant polarization to retrieve wheat LAI through this model. A combination of the retrieved LAI and their associated errors for each polarization is then computed to improve the LAI estimation. Results indicate that this LAI estimate is often enhanced and its uncertainty always reduced by comparison with the ones retrieved from a single polarization. Moreover, the time series reports reliable information about crop growth stage, such as booting and heading in winter wheat. Figure 10 shows reference LAI versus simulated LAI, after Water Cloud Model inversion using VV, HH and HV polarizations and, after LAI recalculation by weighting VV, HH, and HV retrieved LAI using the 2013 Belgian data set (n=22).

The project objectives have been completely met thanks to the synchronisation of the ground campaign with the acquisition of images during the growth season in Belgium. This approach can be called a 'best practice'. We have not modified the project objectives.

Experience with the COVE Planning Tool

We have not used the COVE acquisition planning tool provided by NASA. With the kind of data we use, we don't need this tool. So we are not interested in training on the use of COVE.

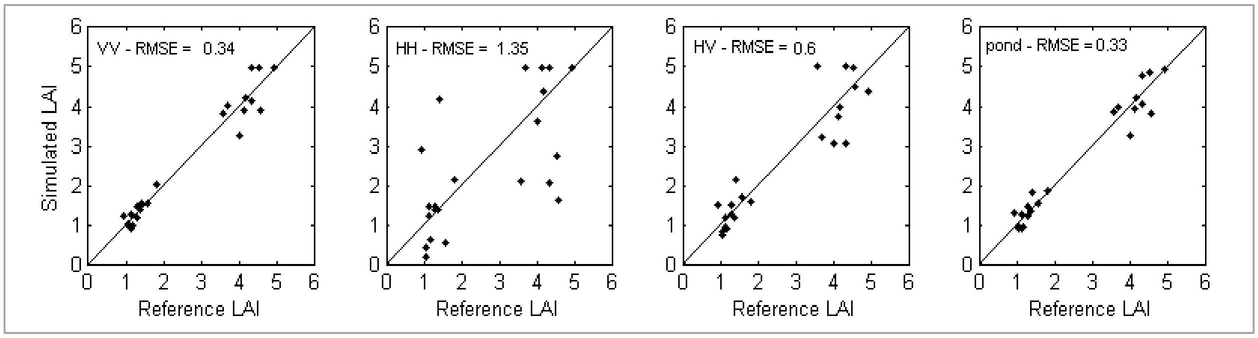



**Figure 10: Reference LAI Versus Simulated LAI, after Water Cloud Model Inversion using Different Polarizations**

Plans for Next Growing Season

We plan to continue this work in 2015, not this year. We anticipate ordering the same type/quantity of EO data in 2015.

Publications

Results have been presented during the poster session of the Global Vegetation Monitoring and Modeling International Conference (France, 3-4 February 2014):

- Advanced Sampling of Remote Sensing Images for Area Estimation. ***D. Jacques****, P. Defourny*
- Monitoring Green Area Index of Winter Wheat using C-band Multi-polarisation SAR Time Series. ***A. Leonard****, P. Defourny*

Damien Jacques presented his results during the SPOT-4 (Take5) Users' Day on October the 2nd: "Preparing for the Exploitation of Sentinel-2 Observations for Agriculture Monitoring".

# 6. Brazil

## 6.1 Sao Paulo

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

### Project Objectives

The project objectives for the site are:

- Crop identification and Crop Area Estimation.

### Site Description

- Location: Latitude -22.9677, Longitude -48.7274.
- Topography: slope <5% in centroid area.
- Soils: Ferralsols, 20% Clay (in centroid area).
- Drainage class/irrigation: Moderately to well drained, high water consumption for Eucalyptus stands.
- Crop calendar: Eucalyptus: 6 year rotations.
- Field size: 40 ha for Eucalyptus field.
- Climate and weather: Humid Tropical (Aw Koppen), weather stations.

Figure 11 shows a six year old Eucalyptus stand during harvest in the study area.

**Figure 11: Six Year Old Eucalyptus Stand during Harvest**

### EO Data Received/Used

Worldview 2

- Space agency or Supplier: DigitalGlobe

- Optical, 8 Bands
- Number of scenes: 3
- Range of dates: May 2010; Aug 2010; Jul 2013
- Beam modes/ incidence angles/ spatial resolutions: Pan_MS1_MS2, varying off-nadir angles
- Processing level: Ortho-ready standard imagery

MODIS TERRA

- Space agency or Supplier: NASA
- Optical, 250 m resolution bands (NIR and Red)
- Number of scenes: about 220
- Range of dates: Jan 2000 to Aug 2013
- Beam modes/ incidence angles/ spatial resolutions: 250m, and after filtering view angles <25°
- Processing level: TOC reflectance, NDVI product.

Landsat-5

- Space agency or Supplier: NASA
- Optical
- Number of scenes: 4
- Range of dates: February 4, 2010; August 31, 2010; June 15, 2011; September 19, 2011
- Beam modes/ incidence angles/ spatial resolutions: 30 m
- Processing level: TOA reflectance.

<u>In situ Data</u>

A land cover map was done based on Landsat images in 2011, from an object-based classification that was validated by in-situ measurements: 422 ground points were recorded in May 2012 with a GPS Nomad (Trimble Navigation Limited, Sunnyvale, CA). 33% of these points were Eucalyptus plantations and the others belonged to 21 other land cover types.

Many measurements were conducted on a large stand of about 200ha that was planted in 2009. These measurements, coordinated by the Eucflux project, are done regularly since 2009: Complete meteorological station (half hourly data); Biomass, tree height, LAI, and other canopy structural parameters (leaf angle, crown diameters, vertical leaf area distribution), nutrient contents (at 3 month intervals); litter-fall and ANPP (monthly); biomass of litter on the forest floor (monthly); soil moisture, soil respiration, soil temperature, foliage temperature (half hourly); evapotranspiration, net ecosystem exchange through an eddy-covariance system (half hourly); water budget, water content to 10 metre depth, ground water level (half hourly); in-situ NDVI sensors (half hourly).

**Figure 12: Worldview 2 Image, Average Off-nadir Angle 19°**

Collaboration

Our work is part of the SIGMA European Collaborative Project (FP7-ENV-2013 SIGMA — Stimulating Innovation for Global Monitoring of Agriculture and its Impact on the Environment in support of GEOGLAM — project no. 603719).

Other collaborations:

- Ramses Molijn, CITG, about sugarcane mapping. Status: on hold until next field campaign
- Consuelo Latorre, EOLAB, about validation of global product. Status: under discussion

Results

A land cover map was done for the year 2011 (field measurements in 2012). See Figure 13. This map focused on mapping of Eucalyptus plantations.

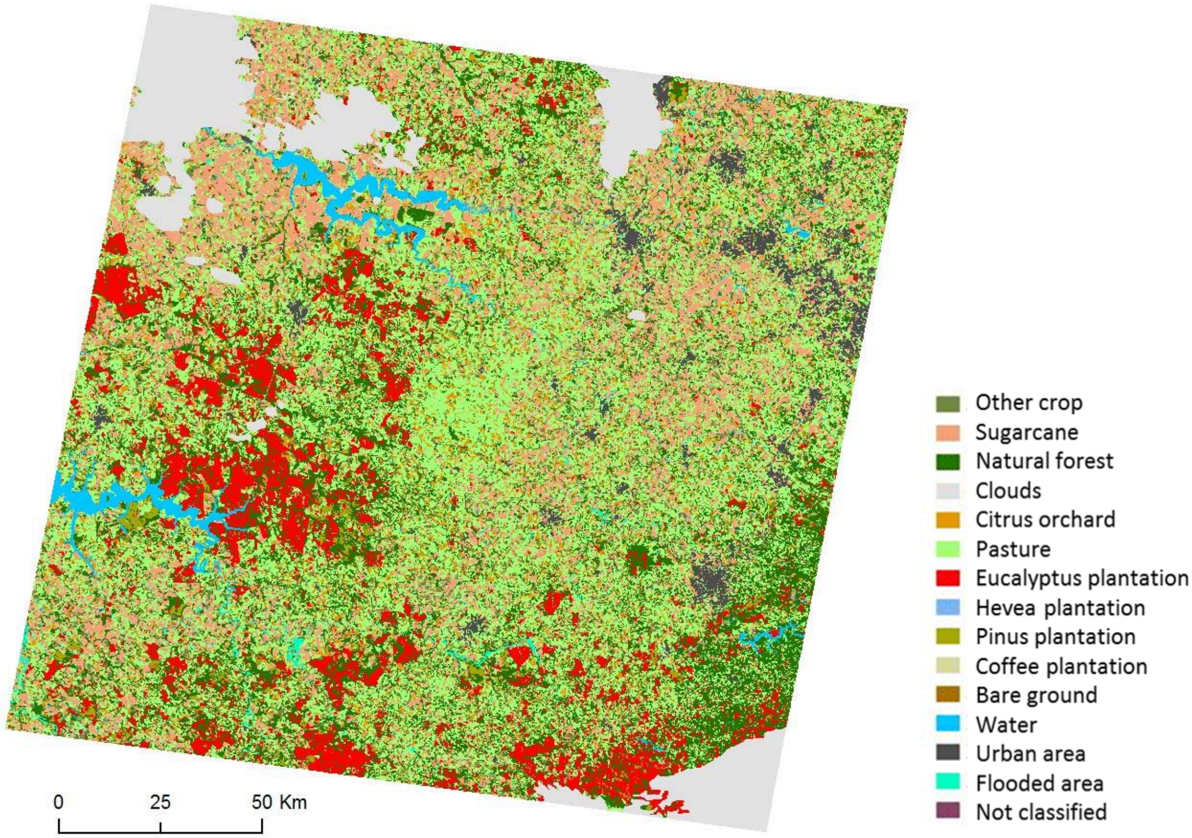



**Figure 13: Land Cover Map for 2011**

Regarding the extent to which the project objectives have been met, we have obtained a Eucalyptus map of the area, which has been validated. Other land uses were classified, but not validated.

Can this approach be called ‘best practice’? The approach consisted in the use of 4 images of 2 consecutive years, to be able to classify the Eucalyptus clear-cuts. For other land use, this approach may not be valid, and some adaptations will be necessary.

Experience with the COVE Planning Tool

We have not used this tool but we would be interested in a training session.

Plans for Next Growing Season

This year, a new classification map is scheduled. We anticipate ordering new types of images next year.

Publications

No presentations for the moment.

## 6.2 Brazil – Tapajos

Team Leaders: Margareth SIMÕES (EMBRAPA, Brazil) & Agnès BÉGUÉ (CIRAD France)

Members: Damien ARVOR (IRD France), Rodrigo FERRAZ (EMBRAPA, Brazil), Lucieta Martorano (EMBRAPA, BRAZIL).

Project Objectives

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

- Crop identification and Crop Area Estimation
- Yield Prediction and Forecasting (under discussion)
- Crop Residue, Tillage and Crop Cover Mapping
- Cropping practices and calendar.

Site Description:

**Location**: The study site is located in the state of Para, close to the city of Santarem, in the region called Médio Amazonas. It is located between the coordinates 2°45' and 4°10'S, and 54°45 and 55°30'W. The Tapajos National Forest is surrounded by the Tapajós River on its Western border, the Cuiabá-Santarém road (BR-163) on its Eastern side, and the BR-230 highway on its Southern boundary.

**Relief/Topography**: According to the RADAM-Brasil, the relief of the FLONA region consists in two main features: (i) Morfo-structural Unit of Medium Amazon Lowered Plateau, which consists of plain surfaces with dissected hills and ravines of the Tapajós River flank that are periodically flooded during the rains, with altitude about 100 m from mean sea level; (ii) The plateau region comprises the Tapajós-Xingu Plateau Morfo-structural Unit, whose altitude varies between 120 and 170 meters. This feature consists of an extensive surfaces tabular formation with erosive edges and slopes with strong or weak declivity. The gap between the plateau region and the lowered plateau on the bank of Tapajós River can reach 150 m.

**Soils**: The Tapajos National Forest site and surroundings lies in a region of Formação Barreiras stratigraphic unit composed of reds and variegated colors continental sediments, originated from fine sandstones, argillites, conglomerates and calciferous gray shale rocks. The soils originated from these rocks are, predominantly, Ferralsols and Acrisols according to the FAO/WRB (2006) classification system. In the Brazilian System of Soil Classification (EMBRAPA 2013), those soils are classified as Latossolos e Argissolos Amarelos. They are dystrophic (low cationic exchange capacity) kaolinitic yellowish colour soils, with a textural ranging from sandy to very clayish texture. They are deep moderate to well drained soils. The Ferralsols are found mainly on the plateaus with a flattened or soft corrugated relief while the Acrisols are found on the eroded flanks of tablelands.

**Drainage class/irrigation**: moderate to well drained soils.

**Crop calendar**: There are 3 main grain crops in the region:

- soybeans: seeding: from December to April – harvest: from March to July; ; First Crop:
- Corn First Crop: seeding: November to January – harvest: from April to June;
- Corn Second Crop: seeding: March to April – harvest: from August to September;
- Rice: seeding: October to December – harvest: from February to April.

**Field size**: There is a buffer of 30 km around the Flona Tapajos (Tapajos National Forest). We must still decide the exact area to study.

**Climate and weather**: According to the Köppen System, the Tapajós region climate is classified as Ami, i.e. tropical wet with less than 5°C thermal variation. Data from the Tapajos site register shows annual average temperature of 25.5°C, maximum of 30.6°C and minimum of 21.0°C. The registered average evapotranspiration in the period was 112 mm, with the highest values recorded in the period from October to January. The annual average precipitation is around 1.820 m. Unlike temperature, rainfall shows great variation during the year, with the greatest rainfall occurring in the months of January to May. The average values of cloudiness are between 3.1/10 to 4.0/10 in the dry season and between 7.1/10 to 8.0/10 in the rainy season.

**Agricultural methods used**: Conventional agriculture (grain: soybeans, corn), no tillage, agroforestry, small farmers agricultural system, livestock-crop integration system.

EO Data Received/Used

Pléiades

- Space agency or Supplier : Astrium (ex Spot Image)
- Optical
- Number of scenes : 3
- Range of dates : January 2014- March 2014 (in progress)
- Beam modes/ incidence angles/ spatial resolutions : 0.5m
- Processing level ortho
- Challenges, if any, in ordering and acquiring the data: very cloudy

**Figure 14: Regions for Pléiades Tasking**

Deimos

- Space agency or Supplier : Astrium (ex Spot Image)
- Optical
- Number of scenes : 10 (asked, not guaranteed).
- Range of dates : January 2014- December 2014 (in progress)
- Beam modes/ incidence angles/ spatial resolutions : 20 m
- Processing level ortho
- Challenges, if any, in ordering and acquiring the data: The number of images that can be ordered through the SIGMA project is not defined yet.

Rapideye

- Space agency or Supplier : Blackbridge
- Optical
- Number of scenes : 48
- Range of dates : 2011
- Beam modes/ incidence angles/ spatial resolutions : 5 meters
- Processing level ortho

- Challenges, if any, in ordering and acquiring the data: Clouds

Landsat

- Space agency or Supplier : USGS
- Optical
- Number of scenes: All
- Range of dates : January 2014- December 2014
- Beam modes/ incidence angles/ spatial resolutions : 30 m / 15m merged
- Processing level ortho
- Challenges, if any, in ordering and acquiring the data: cloud cover.

**Figure 15: Landsat-8 Image, 25 September 2013**

<u>In situ Data</u>

No in situ data has been collected yet.


iLPF
Embrapa
Amazônia Oriental
ESTAÇÃO EXPERIMENTAL
DE BELTERRA
Fazenda Nossa Senhora Aparecida
Projeto de Integração
Lavoura - Pecuária - Floresta
Unidade de Referência Tecnológica
Parceria
FINEP

Collaboration

Our work is part of the SIGMA FP7 project, ROBIN Fp7 project.

Results

We have no results yet; the work is in progress.  We have not modified the project objectives.

Experience with the COVE Planning Tool

We have not used the COVE tool but would be interested in training.

Plans for Next Growing Season

We are still planning the progress for next year.

Publications

There are no publications yet.

## 7. Burkina Faso

Team Leader: Stéphane Dupuy, Maison de la Télédétection

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

Project Objectives

The original project objectives have not changed. They are:

- Crop identification and Crop Area Estimation.

Site Description

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

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

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

EO Data Received/Used

Pléiades

- Space agency or Supplier : Airbus Defence and Space (ex Astrium services)
- Optical
- Number of scenes: 7
- Range of dates: three between 2012/09/14 and 2012/09/26 and four between 2013/09/20 and 2013/10/14
- Beam modes/ incidence angles/ spatial resolutions:
    - 2012: pansharpened (4 spectral bands) 0.5m
    - 2013: bundel (panchromatic: 0.5m and multispectral 2m)
- Processing level: ortho

The 2012 composite Pléiades image is shown in Figure 16.

Landsat-8

- Space agency or Supplier : USGS
- Optical
- Number of scenes: 11
- Range of dates: 2013/04/25 – 2013/05/11 – 2013/06/12 – 2013/07/14 – 2013/08/31 – 2013/09/16 – 2013/10/02 – 2013/10/18 – 2013/11/03 – 2013/12/05 – 2013/12/21
- Beam modes/ incidence angles/ spatial resolutions: bundle (15m and 30m)
- Processing level: ortho

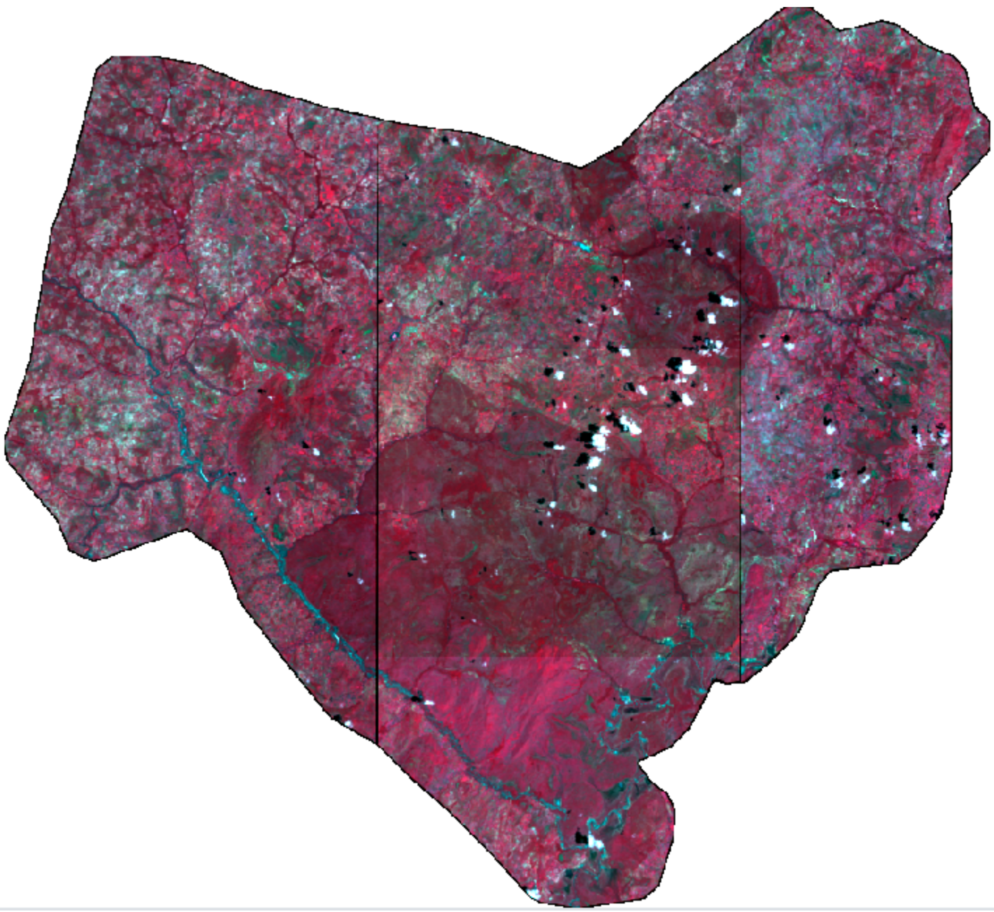


**Figure 16: Pléiades Image of Koumbia County Burkina Faso, 2012**

<u>In situ Data</u>

Field surveys of the agricultural plots were conducted in 2012 and 2013. In November 2012, 400 GPS waypoints were collected. In October 2013, 590 GPS waypoints were collected. Points were manually converted to polygons to reflect the surface data. Photos taken in October 2013 are shown in Figure 17.

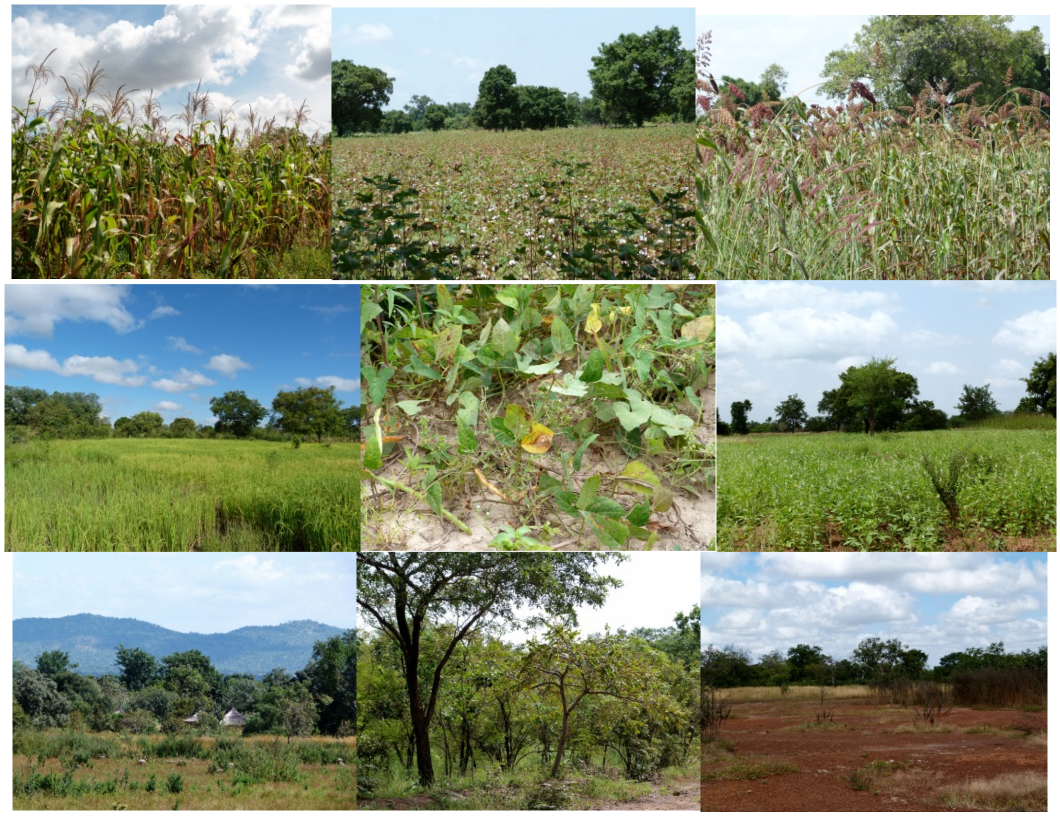


**Figure 17: Photos from October 2013: Maize, Cotton, Sorghum, Rice, Niébé, Sésame, Pasture, Forest, Rocks (© Cirad 2013)**

Collaboration

We are a member of the SIGMA project.

Results

This site has been recently selected and the image and ground data processing are still in progress.

Experience with the COVE Planning Tool

We have not used COVE.

Plans for Next Growing Season

We will need a higher image acquisition frequency.

Publications

None yet.

# 8. Canada

## 8.1 CFIA (Canadian Food Inspection Agency)

Team Leader: Dr. Elizabeth Pattey

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.

Site Description

- Location: The centroid is at latitude 45° 18’ 00”N, longitude 75° 46’ 00”W.
- Topography: flat to gently sloping.
- Soils: Clay-loam & silty clay loam.
- Drainage class/irrigation: Poorly to imperfectly drained, no irrigation.
- Crop calendar: May 1 to end of October.
- Field size: 27 ha + 17 ha.
- Climate and weather: Humid continental climate.

EO Data Received/Used

| Data | Supplier | Sensor | # scenes | Range of dates | Processing level |
|---|---|---|---|---|---|
| SPOT-5 | ESA | optical | 7 | Apr 28 – Oct 17 | Products |
| Landsat-8 | USGS | optical | 8 | Apr 21 – Sep 19 | Radiance |
| CHRIS | ESA | optical | 1 | August 3 | Radiance |

In situ Data

Two crop fields were instrumented with EC flux towers and soil respiration chambers and weather station and soil temperature and moisture profiles. Destructive biomass, yield map, LAI, SPAD were collected.

Figure 18: Canada CFIA Site, Corn Field

Collaboration

No comment.

Results

None yet.

Experience with the COVE Planning Tool

This tool was not used.  Training would be interesting.

Plans for Next Growing Season

Not sure.

Publications

None yet.

## 8.2 South Nation Watershed

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

Project Objectives

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

Site Description

Locations

South Nation Watershed

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

WEBs Sub-Watershed

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

The overall extent of the South Nation watershed is approximately 3,900 km$^2$, with a centroid at coordinates 45º 11’ 53.4”N, 75º 15’ 39.6”W. Nestled within the greater watershed are two smaller study basins of focused study and research, namely WEBs (centroid of 45º 15’ 49.1”N, 75º 10’ 41.9”W, approximately) and Casselman.

The WEBs (Watershed evaluation of Beneficial Management Practices) study basin comprises a sub-‘tileshed’ (tile drained watershed, see area in orange in Figure 19) area of approximately 950 hectares. Mean field sizes within the WEBs basin are 4.75 hectares, with the largest reaching over 24 hectares.

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).

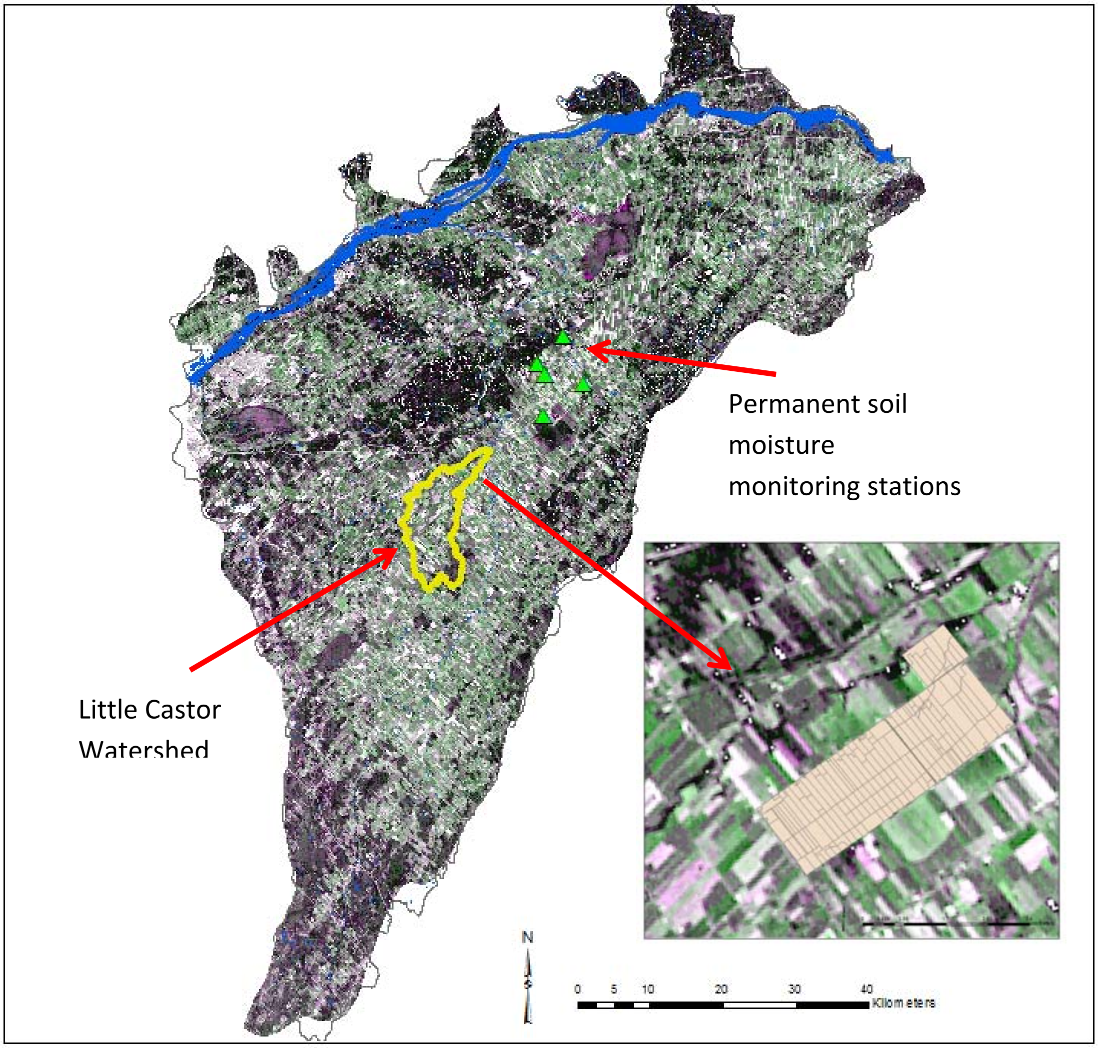



**Figure 19: South Nation Watershed JECAM Site**

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.

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

EO Data Received/Used

**Table 3: Summary of South Nation Data Acquisitions in 2013**

| # | Sensor | Date | SensorMode | Polarization Mode | Polarization channels | Beam |
|---|---|---|---|---|---|---|
| **1** | TSX | 05/06/2013 | Stripmap | Dual | VV+VH | stripNear_013R |
| **2** | TSX | 16/06/2013 | Stripmap | Dual | VV+VH | stripNear_013R |
| **3** | TSX | 27/06/2013 | Stripmap | Dual | VV+VH | stripNear_013R |
| **4** | TSX | 30/07/2013 | Stripmap | Dual | VV+VH | stripNear_013R |
| **5** | TDX | 10/08/2013 | Stripmap | Dual | VV+VH | stripNear_013R |
| **6** | TDX | 21/08/2013 | Stripmap | Dual | VV+VH | stripNear_013R |
| **7** | TDX | 01/09/2013 | Stripmap | Dual | VV+VH | stripNear_013R |
| **8** | TDX | 12/09/2013 | Stripmap | Dual | VV+VH | stripNear_013R |
| | | | | | | |
| **1** | RapidEye (RE2) | 18/05/2013 | | | | |
| **2** | RapidEye (RE1) | 27/05/2013 | | | | |
| **3** | RapidEye (RE5) | 30/05/2013 | | | | |
| **4** | RapidEye (RE3) | 12/06/2013 | | | | |
| **5** | RapidEye (RE1) | 19/06/2013 | | | | |
| **6** | RapidEye (RE3) | 06/07/2013 | | | | |
| **7** | RapidEye (RE3) | 15/07/2013 | | | | |
| **8** | RapidEye (RE3) | 20/07/2013 | | | | |
| **9** | RapidEye (RE5) | 26/07/2013 | | | | |
| **10** | RapidEye (RE5) | 05/08/2013 | | | | |
| **11** | RapidEye (RE5) | 10/08/2013 | | | | |
| **12** | RapidEye (RE3) | 17/08/2013 | | | | |
| **13** | RapidEye (RE2) | 21/08/2013 | | | | |
| **14** | RapidEye (RE5) | 29/08/2013 | | | | |
| **15** | RapidEye (RE3) | 05/09/2013 | | | | |

Landsat data was also acquired to support national crop monitoring.

In situ Data

During the 2013 growing season, a variety of crop production variables were collected at weekly intervals including: leaf area index (hemispherical photos), reflectance (Cropscan), crop height, and phenology and plant biomass. Measurements were done at corn, soybean and forage fields under controlled and uncontrolled drainage management. There are currently five permanent soil moisture monitoring stations, weather stations as well as field collected measurements of Leaf Area Index, Biomass, Crop-Scan, Leaf Chemistry, soil carbon flux.

a) b)

**Figure 20: Hemispherical Photos of Soybeans in: a) June (downward photos) and b) July (upward photos)**

a) b)

**Figure 21: Determination of Phenological Phases of Corn: a) Vegetative Phases and b) Reproductive Phases**

Collaboration

No comment.

Results

This section presents findings from multiple years of data, not only 2013. A variety of vegetation indices were derived from the RapidEye imagery, including the: NDVI, simple ratio (SR), red edge normalized difference vegetation (NDVIre), red edge simple ratio (SRre), modified triangular vegetaton index (MTVI2), and red edge triangular vegetation index (RTVI). Landsat and SPOT4/5 images were used to derive the land surface water index (LSWI) and the moisture stress index (MSI). TerraSAR-X and RADARSAT-2 images were used to derive backscatter and ratio indices. The response of crops to controlled and uncontrolled tile drainage at the field level was assessed and relationships between the vegetation indices and the ground measured variables were established (based on data from 2011 to 2012).

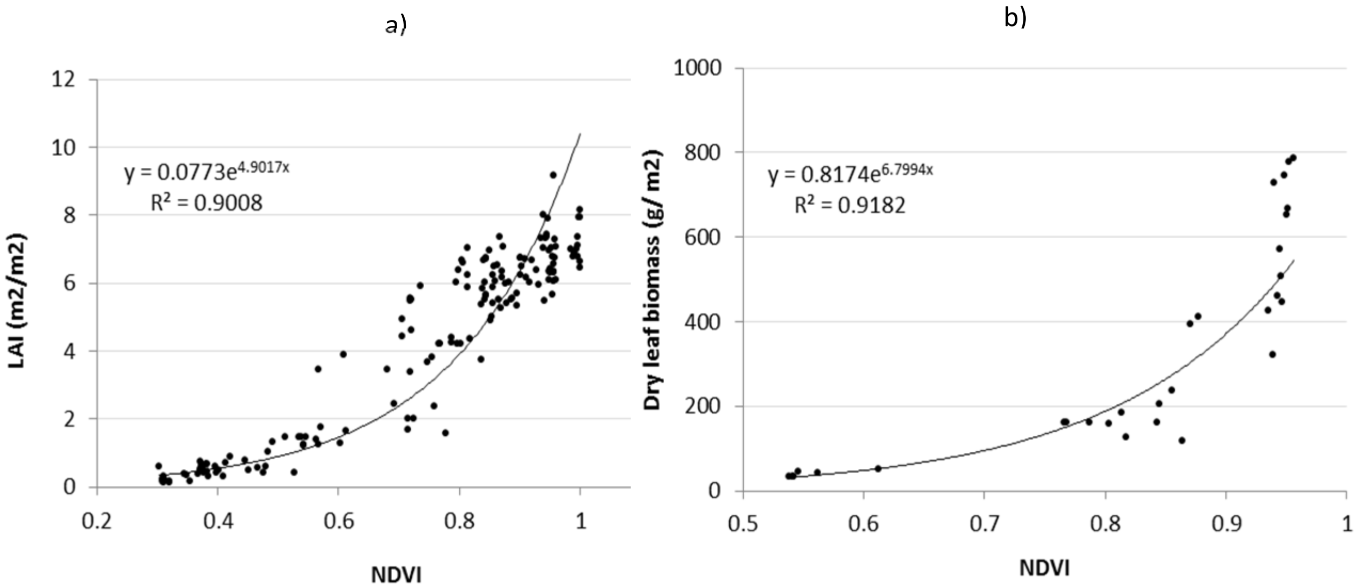



**Figure 22: Regression Analyses of Normalized Difference Vegetation Index and LAI (a) and Dry Leaf Biomass (b)**

Currently, we are estimating the leaf area index (LAI) and biomass at the watershed level between 2005 and 2012 using satellite derived vegetation indices. LAI is derived from VIs using a modified version of the Beer's law (calibration of function through curve fitting of ground measured LAI and satellite derived VIs). Biomass is derived using regression functions. Leaf area index and biomass maps will allow us to assess the impact of the drainage systems at the watershed level.

To evaluate the potential of SAR to deliver early season crop classification, we used a supervised decision tree classifier with TerraSAR-X (VV, VH) and RADARSAT-2 (HH, VV, HV/VH). Either the C-Band or X-Band data were capable of delivering highly accurate maps of corn and soybeans at the end of the growing season. Accuracies far exceeded 90% (Figure 23). Of particular interest was the finding that with three early season TerraSAR-X images, corn could be accurately identified by the end of June, a mere six weeks after planting and at a V6 vegetative growth stage (where the 6th leaf collar is visible). Identification this early in the season would assist in forecasting corn production. Soybeans required additional acquisitions given the variance in planting densities and planting dates in this region. In this case, accurate soybean classification required TerraSAR-X images until early August when seed development was beginning (R5 reproductive stage).

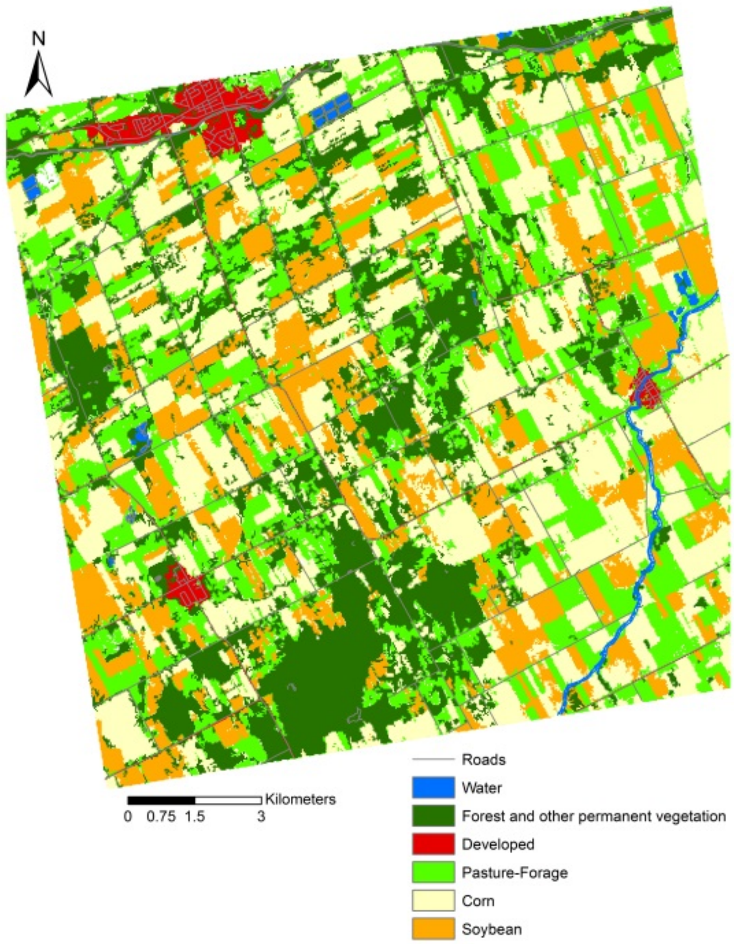



**Figure 23: An End-of-season Classification Map derived from TerraSAR-X (overall accuracy of 97.2%) (taken from McNairn et al. 2014)**

<u>Experience with the COVE Planning Tool</u>

This tool was not used.

<u>Plans for Next Growing Season</u>

It is still uncertain, but Rapid Eye acquisitions will continue.

Publications

McNairn, H., Kross, A., Lapen, D.R., Caves, R., and Shang, J. (2014). "Early Season Monitoring of Corn and Soybeans with TerraSAR-X and RADARSAT-2.", *International Journal of Applied Earth Observation and Geoinformation*, 28, pp. 252-259. doi : 10.1016/j.jag.2013.12.015

## 8.3 Red River Watershed

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

Project Objectives

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

- Crop identification and Crop Area Estimation
  - 2013 growing season crop inventory maps were created (30m resolution) covering all Manitoba as a part of the Agriculture and Agri-Food Canada annual EO-based national crop inventory program.
  - Object-based crop inventory mapping with high resolution (5 m) EO data were tested resulting in very high classification accuracies. Such results indicated that this kind of crop mapping can replace a major part of the direct field observation at the location of the monitoring sampling framework.
  - Methods to accurately estimate the area of target crops in this study site are being tested and developed.
- Crop Condition/Stress
  - Nothing for 2013 – Leaf area index, biomass and cropscan were measured in 2012 and will be measured again in 2014.
- Soil Moisture
  - The site currently has nine automated in situ monitoring stations set up to capture larger scale variation in soil moisture to support calibration and validation of remotely sensed and modelled soil moisture data products. In the fall of 2013, three additional stations were installed in the north end of the site to assist in flood forecasting and prediction. The data from these stations is collected every 15 minutes and transmitted to a central server, where it undergoes a quality control filtering before it is released for distribution. This JECAM site is a calibration site for the SMAP mission and soil properties and soil moisture variability around these monitoring stations were well characterized during a six week intensive field campaign in 2012 (SMAPVEX 12).
- Crop Residue, Tillage and Crop Cover Mapping
  - Nothing for last year.

Site Description

- Location: Red River and Assiniboine River Basins, Manitoba (MB), Canada (see Figure 24).
- Topography: The majority of the soils in the study area are derived from lacustrine-based depositions and are very flat. The northern edge of the study area is more influenced by glacial-till deposition and has a lower relief ridge and swale topography.
- Soils: The majority of soils have a clay surface texture as a result of lacustrine deposits. Soils in the southwest region of the study area have sandier surface textures (sands-loamy sands)

overlaying heavier clay deposits. Soils in the northern region are generally finer textured loams-clay loams with the occurrence of stones as a result of glacial-till deposits.

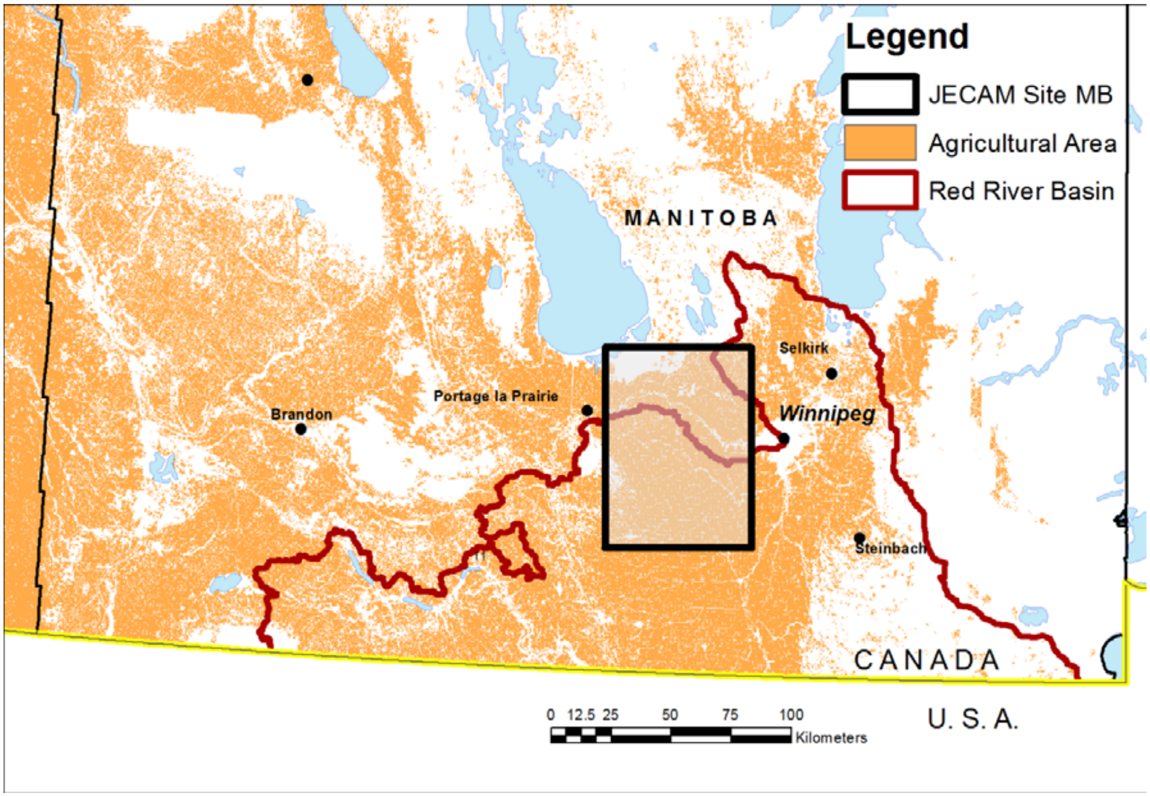



Figure 24: Location of the JECAM Monitoring Site in Southern Manitoba, Canada

- Drainage class/irrigation: The majority of the soils are imperfect to poorly drained. A large network of surface drains is in place to allow the production of annual crops. A limited amount of irrigation exists in the area near Portage la Prairie and Carmen on lands devoted to the production of potatoes and high-value horticultural crops. Tile drainage is installed on a small percentage of land around Carmen on imperfectly drained soils that are used for high value crop production.
- Crop calendar: Late April – early June (seeding), August – early October (harvest).
- Field size : Quarter Section - 64 hectares (160 acres).
- Climate and weather: The study area falls into the Humid Continental climate zone with cold winters and warm summers. Precipitation is distributed throughout the year with the majority of precipitation falling in the spring and summer months.
- Agricultural Crops used: Land is primarily used for the production of annual crops. Primary crops include: wheat, oats, canola, soybeans, corn. Potato production and other horticultural crops are produced near Carmen and Portage la Prairie. Conventional and minimum tillage systems are used for most annual crop production. The more marginal land in the northern areas is used for forage and pasture production.

**Figure 25: Example of the General Morphology and Landscape of the JECAM Monitoring Site in Manitoba, Canada**

<u>EO Data Received/Used</u>

Landsat 8, RADARSAT-2, RapidEye were used for 1-3 time intervals during the growing season of 2013.

<u>In situ Data</u>

Presently there are 12 in situ soil moisture monitoring stations in the Red River basin site as indicated in Figure 26. Crop types of 4018 fields covering all fields of 105 sections within the area covering the monitoring site in MB were recorded for developing methodologies to estimate crop areas very accurately (Figure 28).

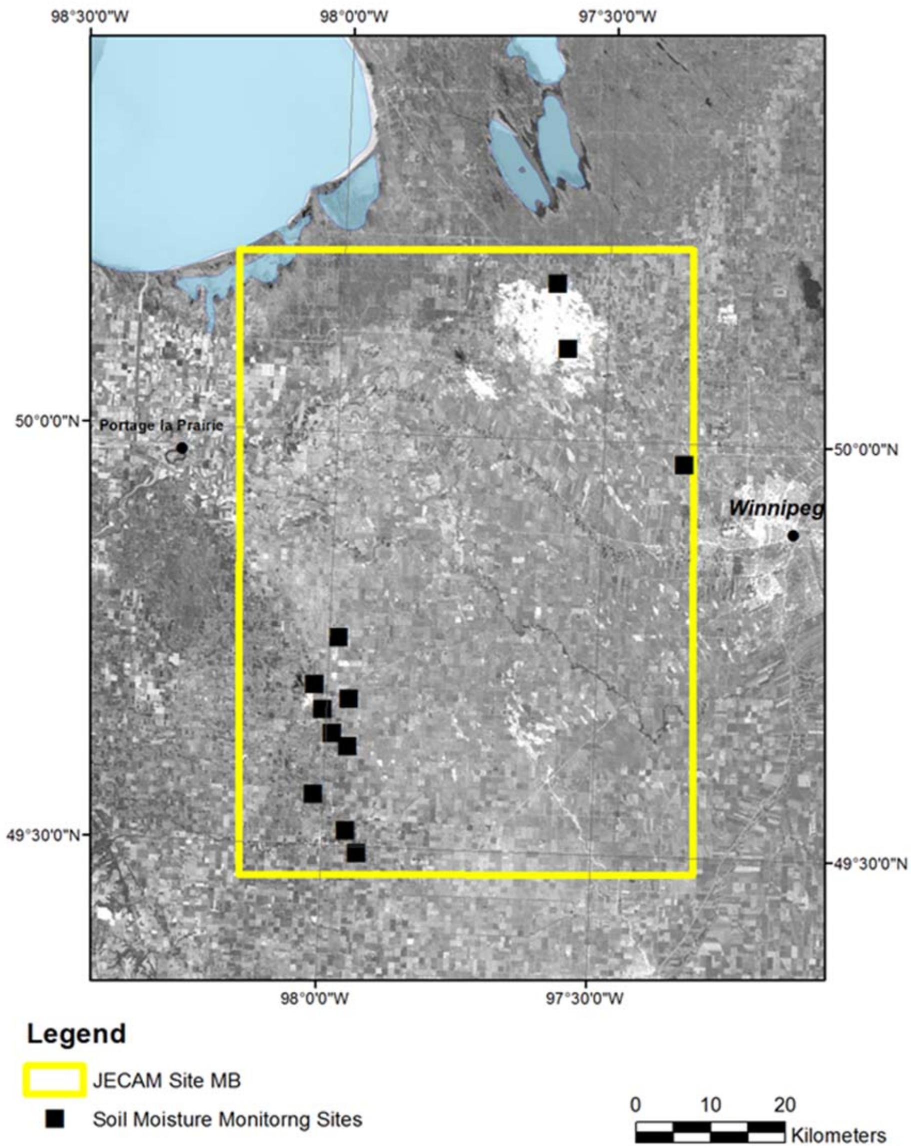



**Figure 26: Location of the 12 In situ Soil Moisture Monitoring Stations within the JECAM Monitoring Site in Southern Manitoba, Canada**


**Figure 27: Photos of Station 8 of the In situ Soil Moisture Monitoring Network within the Red River Basin**

<u>Results</u>

A crop types map (30 m resolution) was created for the whole area including the JECAM monitoring site (Figure 29) for 2013 growing season.  Methods for accurate crop area estimation based on the annual crop inventory and crop types identified at the locations of the sampling framework of the monitoring sections are being developed.

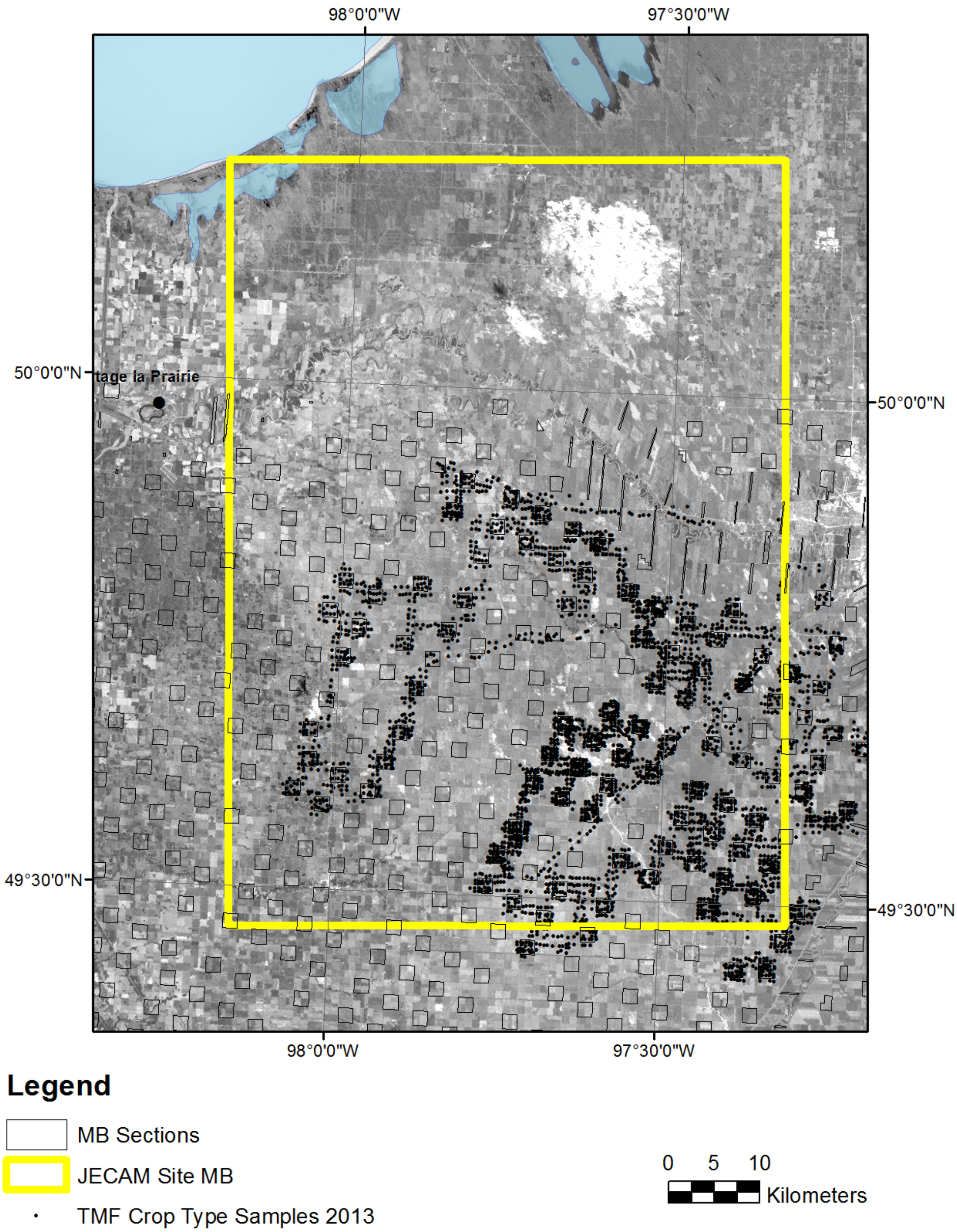



**Figure 28: Crop Type Sampling at 4018 locations within Fields in the JECAM Monitoring Site in Southern Manitoba**

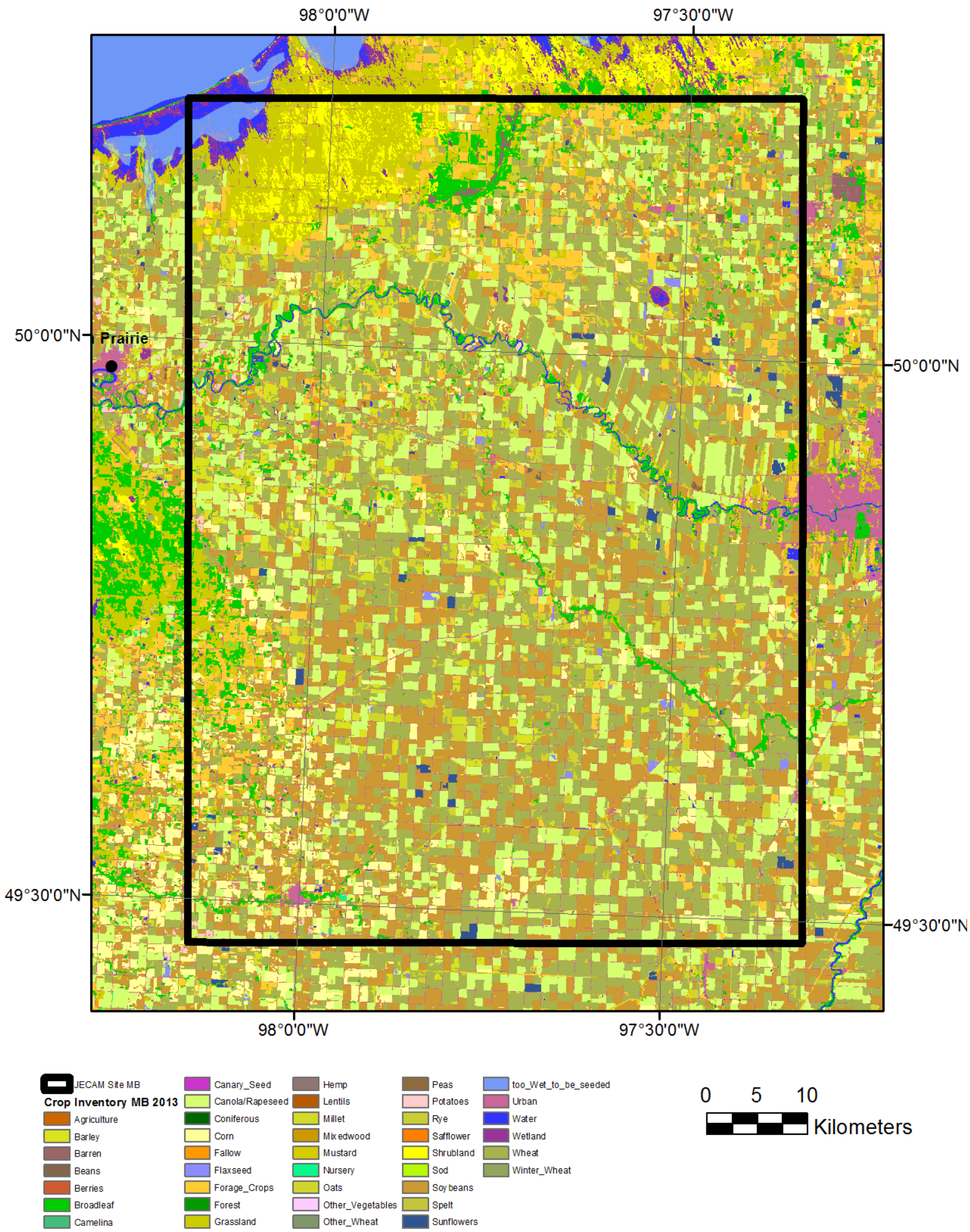



Figure 29: Crop Type Sampling at 4018 Locations within Fields in the JECAM Monitoring Site in Southern Manitoba

Plans for Next Growing Season

The EO-based 2014 crop inventory map (30 m resolution) will be created for the JECAM monitoring area. The accuracy of crop classes is estimated to be around 85%. Field work will be done to record crop types for all fields within some of the monitoring sections located in the JECAM monitoring area (Figure 28). Results will be applied to develop methods for very accurate crop area estimations.

Crop conditions will be monitored at several time intervals in an area south of the JECAM monitoring site (Figure 24). Methods to derived crop condition from radar and optical satellites will be developed.

Soil moisture mapping from active and passive microwave is being piloted over this site due to the high quality soil moisture validation available.

Publications

Roy, S. 2014. Simulation of Spatial and Temporal Variability of Soil Moisture Using the Simultaneous Heat And Water (SHAW) Model: Applications to Passive Microwave Remote Sensing, Graduate Thesis, University of Guelph, Department of Geography.

Rowlandson, T. L., A. A. Berg, P. R. Bullock, E. R. Ojo, H. McNairn, G. Wiseman, and M. H. Cosh, 2013: Evaluation of several calibration procedures for a portable soil moisture sensor. Journal of Hydrology, 498, 335-344.

# 9. China

## 9.1 Anhui

No report received.

## 9.2 Guangdong

No report was received for the JECAM site in Guangdong province at Xuwen. However, a report was received for a new site in development in Guangdong province at Taishan, and that report is reproduced here.

Team Leader and Members: Prof Wu Bingfang (Leader), Jiratiwan Kruasilp, Zheng Yang, Zhang Miao, Zhang Ning, Zeng Hongwei, Zou Wentao.

Project Objectives

The original project objectives have not changed. They are:

- Crop identification and Crop Area Estimation
    - Object-based Image Analysis and The Support Vector Machine (SVM) classification method
    - The fusion of SAR and Optical satellite data
    - Statistical analysis
- Crop Condition/Stress
    - NDVI
    - The ground truth information
- Yield Prediction and Forecasting
    - Artificial Neural networks (NN) method
- Phenological Events and Estimation of Rice biophysical variables
    - Multiple regression analysis
    - Leaf Area Index (LAI) measured with Hemispherical lens.

Site Description

- Location

  Upper Left: 22°14'46.50"N, 112°27'47.06"E, Upper Right: 22°14'44.95"N, 113° 2'58.88"E

  Lower Left: 21°46'21.54"N, 112°24'56.16"E, Lower Right: 21°47'25.90"N, 113° 1'39.96"E
- Topography

  Coastal plain and Mountain

- Soils

  Soils in the study site are mainly lateritic red soil.

- Drainage class/irrigation

  Most of the rice cultivated areas have an irrigation system.

- Crop calendar

  The predominant crop in the study area is rice, with some sugarcane and vegetables. Sowing of main rice takes place in late March and June, to be harvested in July. The second rice crop is sown in August and is harvested from late October to November.

- Field size

  The size of the rice plots is 5 to 15 hectares.

**Figure 30: Photos of Taishan (Guangdong) Site**

- Climate and weather

The climate is characterized by relatively high temperatures. The average temperature is 22$^{o}$ Celsius and the warmest month is July with an average temperature of 28$^{o}$ Celsius. The coolest month is January, with an average temperature of 14$^{o}$ Celsius. The rainfall is evenly distributed over the entire year. In summer, the rainfall comes from tropical cyclones. The average amount of rainfall is 2402.8 mm.

<u>EO Data Received/Used</u>

COSMO-SkyMed :

- Supplier: Agenzia Spaziale Italiana, ASI
- SAR
- 12 scenes
- April to November 2013
- Beam modes/ incidence angles/ spatial resolutions: Wide region/ 22.73 degree/ 30 meters
- SARscape module has been used to process the Wide region mode of the satellite.

RADARSAT-2:

- Supplier: MDA/CSA
- SAR
- 6 scenes
- March to November 2013
- Beam modes/ incidence angles/ spatial resolutions: Fine Quad mode/ FQ10 (29.1 – 30.9 degrees)/ 8 meters
- The data sometimes are cancelled if there are the high priority orders.

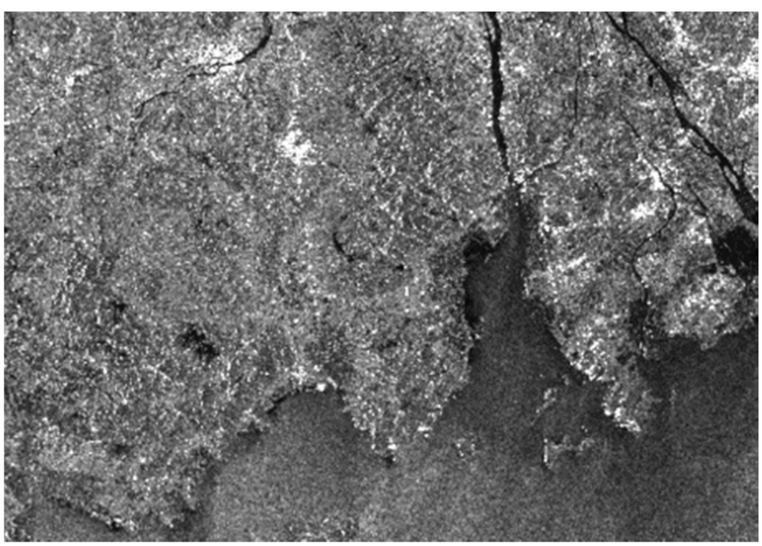


**Figure 31: COSMO-SkyMed Image of Taishan Site**

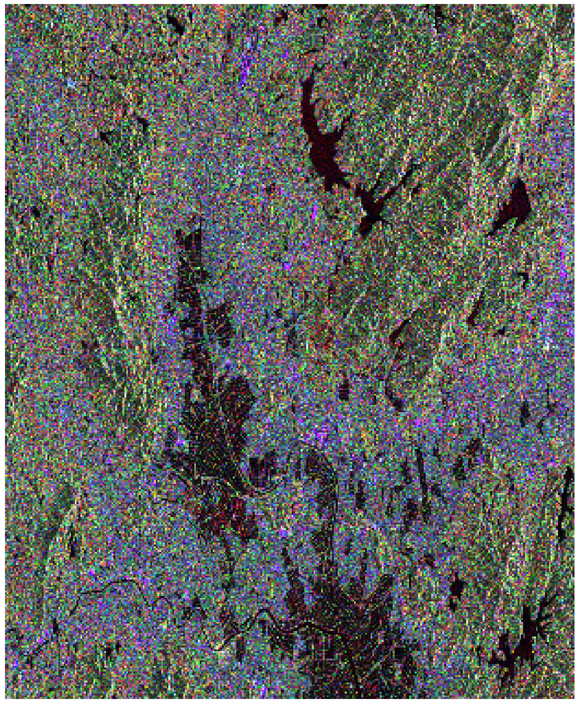


**Figure 32: RADARSAT-2 Image of Taishan Site**

RapidEye:

- MDA
- Optical
- 4 scenes
- June to October 2013
- Level 1B
- It is very difficult to acquire optical satellite imagery because the sky is almost always covered by cloud.

In situ Data

Field measurement of rice parameters were conducted in parallel to the Satellite data acquisition. The main variables and methods are shown in Table 4.

The principle rice cropping systems in the study site is the double rice crop. Sowing of main rice takes place in late March and June, to be harvested in July. The second rice crop is sown in August and is harvested from late October to November. Thus, all the variables were measured once a month from April to November in 2013.

Since the study area is located in the coastal area, the sky is almost always covered by cloud. The rainfall is evenly distributed over the entire year. In 2013, a severe tropical storm intensified into a typhoon and lashed the area with heavy rain. Hence, the water level in the rice field is higher than the normal situation.

**Figure 33: RapidEye Image of Taishan Site**

**Table 4: In situ Methods at Taishan Site**

| Variables | Equipment/Methods |
|---|---|
| LAI | LAI 2000 and Hemispherical lens / The digital hemispherical photos analyzed using the CANEYE image analysis. |
| Fractional of vegetation cover | Hemispherical lens/ The digital hemispherical photos analyzed using the CANEYE image analysis. |
| Rice variety and transplanting date | Interview |
| Biomass | Oven dried and weight |
| Yield | Oven dried and weight |
| Density/canopy height | Tape measured / Count |
| Number of bunch | Tape measured / Count |
| Water level in the field | Tape measured |

**Figure 34: In situ Measurements, Taishan Site**

Collaboration

We did not collaborate with other JECAM sites. However, we have participated in the research team from the Geo-informatics and Space Technology Development Agency (Public Organization): GISTDA, Thailand. We proposed that Thai and Chinese researchers jointly perform field survey in both Thailand and China's study. The research shall apply crop condition and production monitoring technology for both study sites.

Results

The correlation between the RADARSAT-2 backscatter coefficient and biophysical parameters is shown in Table 5.

**Table 5: Correlation between RADARSAT-2 Backscatter Coefficient and Biophysical Parameters**

| Polarization | Plant height | Days after transplanting | Leaf area index | Biomass |
|---|---|---|---|---|
| HH | 0.7810 | 0.6832 | 0.6609 | 0.8403 |
| HV | 0.5295 | 0.4614 | 0.4371 | 0.5115 |
| VH | 0.5806 | 0.5055 | 0.4772 | 0.4335 |
| VV | 0.3934 | 0.2793 | 0.2515 | 0.5901 |

| | | | | |
|---|---|---|---|---|
| HH/VV | 0.7132 | 0.7814 | 0.7793 | 0.7827 |

The correlation between backscattering coefficient (dB) and LAI is shown in Figure 35.

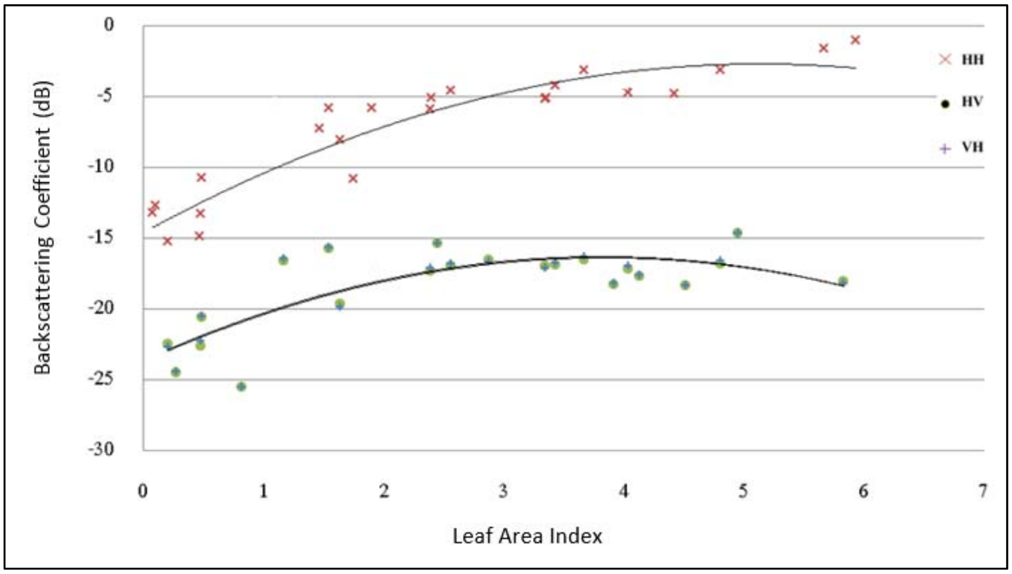



Figure 35: Correlation between Backscatter Coefficient and LAI

The RADASAT-2 Quad-polarization data provides the four polarizations HH, HV, VH and VV. Generally, HH-polarization shows the highest stepwise change of all four polarizations. The stepwise change in HV/VH-polarization was greater than VV-polarization. It can be seen from the table that HV and VH polarization has very similar backscattering and is the lowest backscattering value. The correlation between VV-polarization and rice crop age is the lowest.

Experience with the COVE Planning Tool

We did not use the COVE Planning Tool to order Satellite data. Nonetheless, the tool is quite straightforward to search and preview the information that users are looking for, while an error occurred after addition of multiple products to the Cart. We definitely would like to participate in a short training course to gain an understanding of the functions of the COVE Planning Tool.

Plans for Next Growing Season

We hope to carry out field experiments synchronous with some satellites through the study site in 2014. We will order the same type of SAR data and additional optical imagery such as MODIS and Landsat-8.

Publications

Not yet.

## 9.3 Heilongjiang

Team Leader: Wu Bingfang

Members: Zhang Miao, Zeng Hongwei, Zou Wentao, Li Zhongyuan, Chang Sheng, Inkendo J.K., Zheng Yang, Chen bo, Yu Mingzhao, Meng Jihua, You Xingzhi, Xu Jin, Cheng Zhiqiang

Project Objectives

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

- Crop identification and Crop Area Estimation
    - Support vector machine, Decision tree, Object-oriented method
    - Multi-temporal optical data
    - Integration of Optical and SAR data
- Crop Condition/Stress
    - Crop Growing Conditions Over the Growing Season
    - NDVI, NDWI, Vegetation condition index, temperature condition index, crop water stress index, etc.
- Estimation of Biophysical Variables
    - fAPAR, LAI-Radiation transfer model
- Yield Prediction and Forecasting
    - Biomass-modified CASA model
    - Harvest index
- Crop residue cover and tillage mapping
    - crop residue cover
    - Tillage-classification
- Phenological Events
    - Crop mature date prediction.

Site Description

- Location
    - Top-Left: Latitude: 48.286°N Longitude: 126.831°E
    - Bottom-Right: Latitude: 48.046°N Longitude: 127.239°E
- Topography: Plain
- Soils: Soils in the study site are mainly chernozem.
- Drainage class/irrigation
    - The soil drainage class is submersion of basins. Almost no irrigation infrastructure can be found in this JECAM site.
- Crop calendar
    - Crops in the study area are dominated by soybean, spring corn and spring wheat.
    - The crop calendar for spring wheat is from mid-April to late July, for soybean is from mid-May to end of September and for maize is from mid-May to late October.

- Field size: Typical field size is 5 to 20 ha.
- Climate and weather
  - The climatic zone is cold temperate continental climate.  Mean annual precipitation is about 555 mm, concentrated from July to September.

**Figure 36: Heilongjiang Agricultural Fields**

<u>EO Data Received/Used</u>

China Environmental Satellite (HJ-1 CCD, HJ-1 IRS):

- Supplier: China Centre for Resource Satellite Data and Applications (CRESDA)
- Optical
- 19 scenes of HJ-1 CCD images, 8 scenes of HJ-1 IRS
- From mid-April to late September, 2012
- Level 2 Product
- We had no difficulty in acquiring HJ-1 data, nor did we have any difficulty in processing and using HJ-1 data.

MODIS:

- Supplier: NASA
- Optical
- 21 scenes, from April 15th to September 30th, 2013
- Beam modes/ incidence angles/ spatial resolutions: H26V04, 250m/500m/1km
- Level 2
- We have no difficulty in processing and using MODIS data, but the resolution is too coarse for the study site.

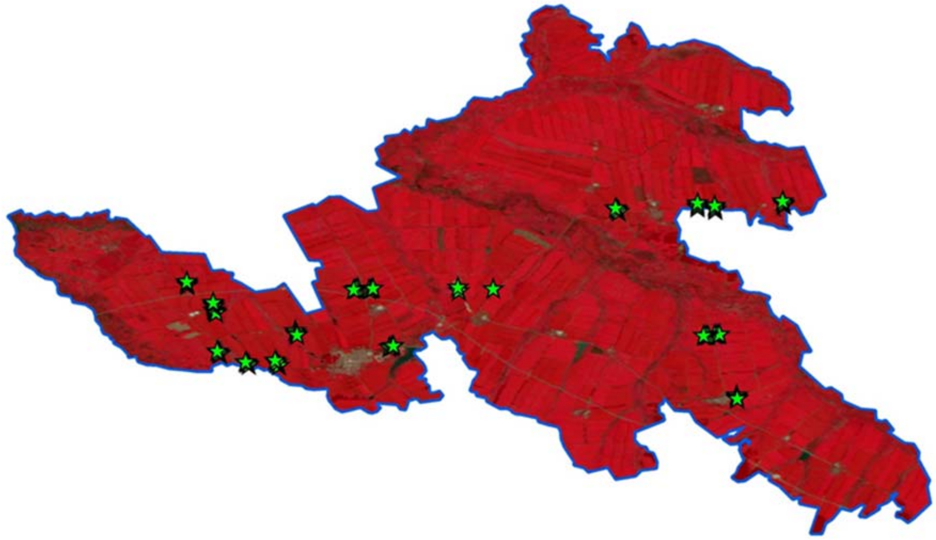


Figure 37: Distribution Map of Field Samples in China Heilongjiang JECAM site

RADARSAT-2:

- Supplier: MDA/CSA
- SAR
- 5 scenes
- May 30th, June 13rd, July 14th, August 17th, and September 14th, 2013
- Beam mode: Fine Quad Polarization
- We submitted an order requesting 8 RADARSAT-2 scenes but got 5 scenes.
- We used next ESA SAR toolbox (NEST 4B) to process RADARSAT-2 data and we have no difficulty in processing it yet.

TerraSAR-X:

- Supplier: DLR
- SAR
- 5 Stripmap
- April 14th , May 12th , two images on July 8th, and August 4th, 2013
- We used next ESA SAR toolbox (NEST 4B) to process TerraSAR-X data but it does not support the data type we acquired. So we have not processed TerraSAR-X data yet.

COSMO-SkyMed:

- Supplier: E-GEOS
- SAR
- 4 Stripmap high resolution images
- August 10th and 28th and September 10th and 26th, 2013

- We acquired the data through the Dragon III project between China and Europe. The data were not yet processed.

Rapideye

- Supplier: Dragon III project
- Optical
- 5 images
- June 23$^{rd}$, August 25$^{th}$ and 27$^{th}$, and two images on September 18$^{th}$, 2013
- We acquired the data through Dragon III project under Sentinel -2 Agricultural plan. We have no difficulty in processing and using the data.

In situ Data

The main variables measured and the instruments we are using are shown in Table 6. All the variables were measured once a month from April to September except for above ground biomass (AGB), yield and harvest index. AGB, yield and harvest index were measured once a year. It needs to be mentioned that the measurements of soil chemical variables were conducted twice, before the planting of crops (in May) and at growing peak (August). For the canopy water content and chlorophyll content, the frequency of the measurements were carried out every three to five days starting from one month before the harvest.

**Table 6: Heilongjiang In situ Data**

| Main variables | Instruments or processing method |
|---|---|
| Spectral reflectance | HR-768 portable spectroradiometer (Spectra Vista Corporation, NK, USA) |
| FPAR | WinSCANOPY |
| LAI | WinSCANOPY |
| Fractional of vegetation cover | WinSCANOPY |
| Dry amount of above ground biomass | Oven dried and weight |
| Yield | Oven dried and weight |
| Harvest index | Calculated by yield and AGB |
| Density/canopy height | Tape measured |
| Chlorophyll content of leaf | Spectrum CM1000 |
| Soil moisture and temperature | Soil moisture and temperature instruments |
| Soil chemical variable | Room measurement |

Figure 38: In situ Measurements in Heilongjiang

The biggest challenge is weather conditions during the field observations. If it is sunny in the morning and cloudy at noon, this may influence measurements of field spectral and FAPAR. Besides, soil moisture and temperature have great spatial divergence which increased the difficulty of the measurements.

Collaboration

We collaborated with Argentina JECAM site over the China Heilongjiang site. We exchanged field measurement data over the site with the researchers working on Argentina JECAM site – Diego de Abelleyra and Santiago Veron from INTA, Argentina.

Results

**Crop condition and crop stress**

Based on China Environmental Satellite (HJ-1) CCD and IRS data, the NDVI was derived and compared with that of last year to generate crop condition map for Hongxing Farm. Figure 39 shows the crop condition of the JECAM site on 13 August 2012 compared with 17 August 2011. Water stress and nitrogen content of the crop canopy over the Hongxing Farm were also estimated.

Figure 39: Crop Condition of Heilongjiang Site on 12 August 2012 Compared with 17 August 2011


**Crop Maturation Date**

The models for optimal soybean harvest date prediction were developed through the linear regression between remote sensing indicators and observed optimal harvest date. NDVI and NDWI were used to predict optimal soybean harvest date. The map of optimal harvest dates in 2011 is shown in Figure 40 and the validation results in Figure 41.

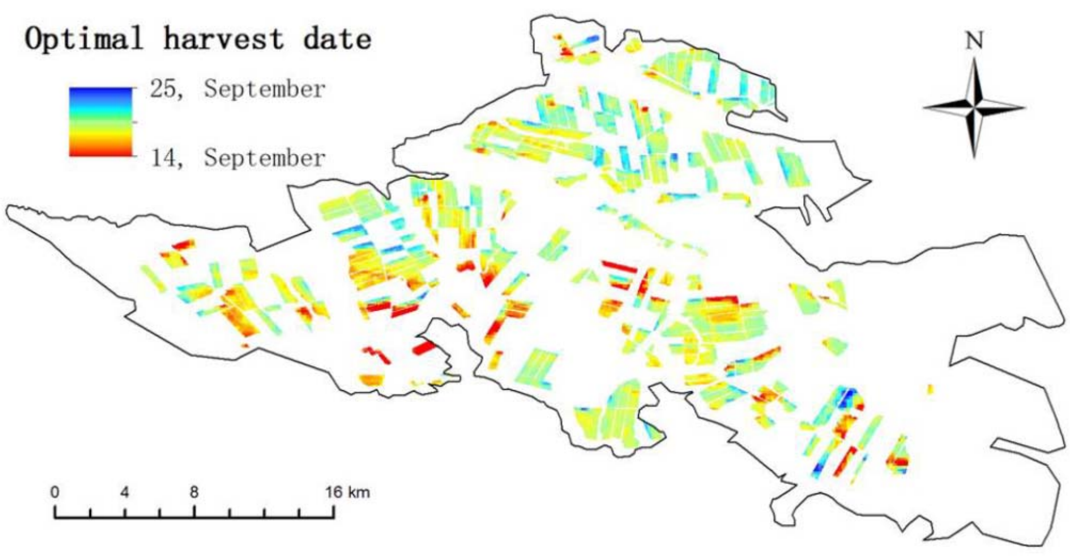



Figure 40: Predicted Optimal Soybean Harvest Date Map, 2011

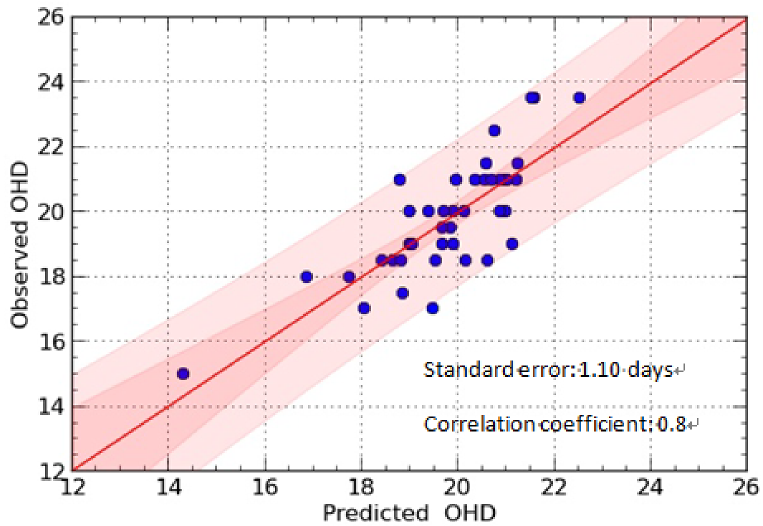



**Figure 41: Validation Results**

**Crop Yield**

Predicted crop yield maps for 2010 (a), 2011 (b) and 2012 (c) for multiple crops are shown in Figure 42.

Experience with the COVE Planning Tool

We did not use the COVE Planning Tool to acquire or order EO data.

Plans for Next Growing Season

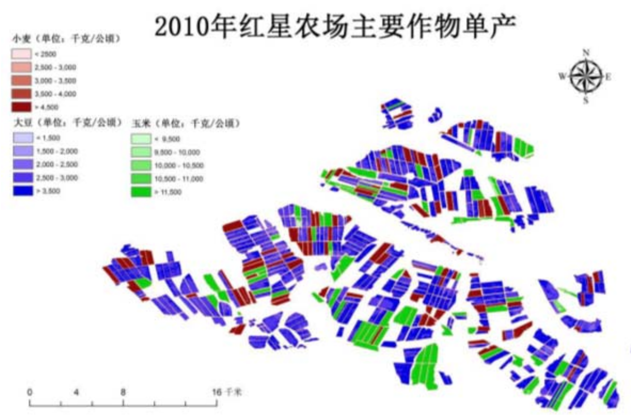
We have some additional measurements compared with that in 2012, including land surface temperature, soil water content, leaf water content and nitrogen content of crop canopy and etc. In 2014 and the future, we will measure the same variables same as in 2013.

In 2013, we acquired some high resolution optical images, such as Rapideye and Spot-4 images over the same study site through 'TAKE-5' plan. We anticipate ordering some Rapideye, UK-DMC2 and other high resolution images in 2014 and the future continuously.

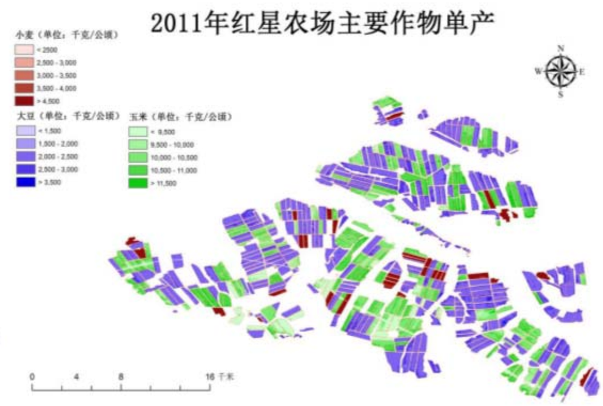
Publications

Dong Taifeng, Wu Bingfang, Meng Jihua, Li Qiangzi, Zhang Miao. Study of a Vegetation Index Based on HJ CCD data's top-of-atmosphere reflectance and FPAR Inversion. Oral presentation in the 35th International Symposium on Remote Sensing of Environment (ISRSE35), April 2013, China, Beijing.

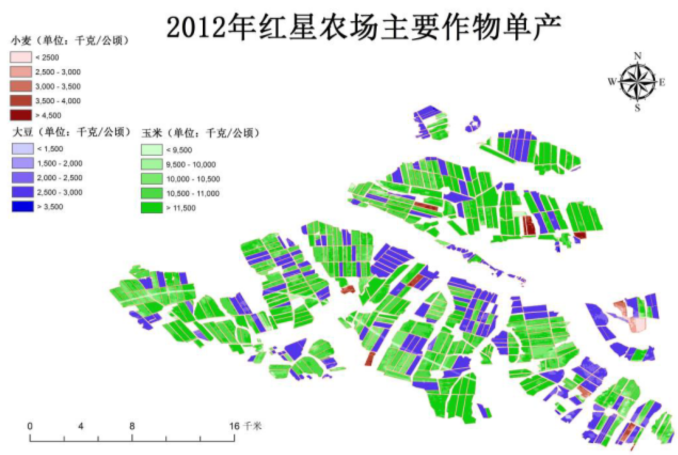
Cao Xin, Li Qiangzi, Zheng Xinqi. Extract effect of segmentation scale on orient-based crop identification using HJ CCD data in Northeast China. Poster presentation in the 35th International Symposium on Remote Sensing of Environment (ISRSE35), April 2013, China, Beijing.




(a)




(b)




( c)

**Figure 42: Predicted Crop Yield for 2010 (a), 2011 (b), 2012 (c)**

Meng Jihua, Dong Taifeng, Zhang Miao, You Xingzhi, Wu Bingfang, 2013. Predicting Soybean Mature Date with Satellite Data. Oral presentation in the 9th European Conference on Precision Agriculture 2013 (ECPA2013, Lleida, Catalonia, Spain).

## 9.4 Jiangsu

Team Leader: Yun Shao

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

Project Objectives

The original objectives of the site have not changed.

- Crop identification and Crop Area Estimation

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

- 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, with area of 600km$^2$ (Figure 43). The terrain is flat, with the average altitude mostly less than 10m. The climate belongs to the transition region between the subtropical and the temperate zone, with four distinct seasons. The annual average temperature of the test site is about 13 to 16℃. 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 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 44) and have a certain impact on rice yields. The size of rice field parcels is 1700m$^2$ or so. In this study, forty-one 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 43. The cloud and sun symbols mean Transplant and Direct-planting Rice Fields respectively.

**Figure 43: Location of Jiangsu Test Site and the Distribution of the Sample Plots**

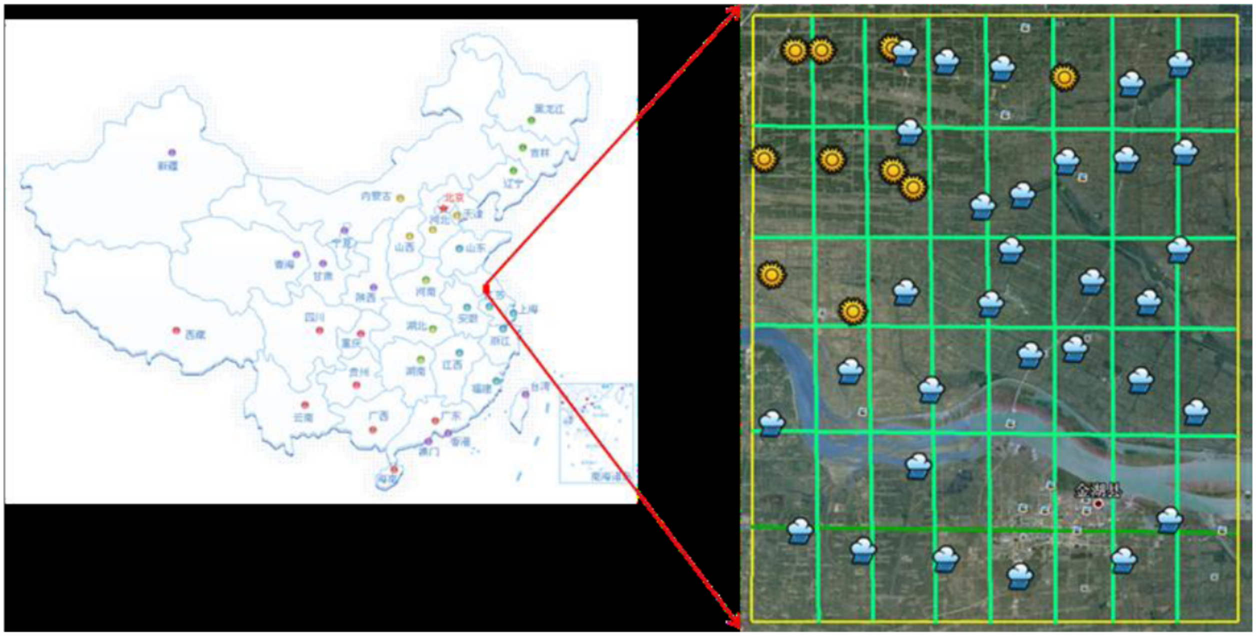


**Figure 44: Rice Fields in the Jiangsu Test Site**

(a) Transplanting (b) Direct-seedling

EO Data Received/Used

From late June to early November 2012, twelve RADARSAT-2 images were acquired, including eleven polarimetric images and one Multi-look Fine image. The details of the SAR data are displayed in Table 7. No more SAR data was acquired in 2013.

| Dates | Mode | Product | Resolution (m) | | Image Size ($km^2$) | Incidence Angle ($^o$) | Look | Polarization |
|---|---|---|---|---|---|---|---|---|
| | | | Range | Azimuth | | | | |
| 6/27/2012 | FQ20W | SLC | 5.2 | 7.6 | 565 | 38.89 | 1 | HH/HV/VH/VV |
| 7/11/2012 | FQ9W | SLC | 5.2 | 7.6 | 571 | 27.53 | 1 | HH/HV/VH/VV |
| 7/21/2012 | FQ20W | SLC | 5.2 | 7.6 | 565 | 38.89 | 1 | HH/HV/VH/VV |
| 7/28/2012 | MF22W | SLC | 3.1 | 4.6 | 603 | 31.73 | 1 | HH |
| 8/4/2012 | FQ9W | SLC | 5.2 | 7.6 | 571 | 27.53 | 1 | HH/HV/VH/VV |
| 8/14/2012 | FQ20W | SLC | 5.2 | 7.6 | 565 | 38.89 | 1 | HH/HV/VH/VV |
| 8/28/2012 | FQ9W | SLC | 5.2 | 7.6 | 571 | 27.53 | 1 | HH/HV/VH/VV |
| 9/7/2012 | FQ20W | SLC | 5.2 | 7.6 | 565 | 38.89 | 1 | HH/HV/VH/VV |
| 9/21/2012 | FQ9W | SLC | 5.2 | 7.6 | 571 | 27.53 | 1 | HH/HV/VH/VV |
| 10/15/2012 | FQ9W | SLC | 5.2 | 7.6 | 571 | 27.53 | 1 | HH/HV/VH/VV |
| 10/25/2012 | FQ20W | SLC | 5.2 | 7.6 | 565 | 38.89 | 1 | HH/HV/VH/VV |
| 11/8/2012 | FQ9W | SLC | 5.2 | 7.6 | 571 | 27.53 | 1 | HH/HV/VH/VV |

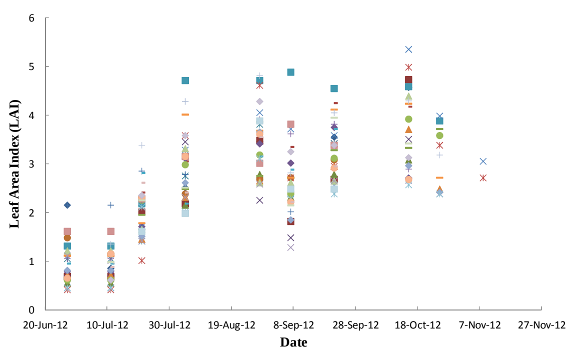
**Table 7: Technical Parameters of RADARSAT-2 Data Acquired in 2012**

In situ Data

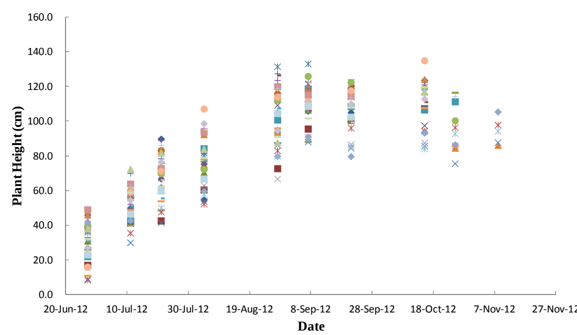
During the growing season in 2012, 12 ground campaigns were conducted (see Figure 45). No field work was conducted in 2013. We mainly concentrated on data analysis in 2013.

In 2012, field data was collected from three representative rice plants in each sample plot. The following were measured: variety, crop calendar, phenological stage, plantation geometry, plant structural information (plant height, number of leaves, leaf length and width, number of stems and of ears), plant biomass (dry and wet weight). Figure 46 displays Leaf Area Index (LAI), plant height, fresh and dry weight of transplanting rice in the whole growing season. Different symbols mean different fields. Figure 47 shows the same parameters for the 13 direct-seedling fields. Again, different symbols mean different fields.

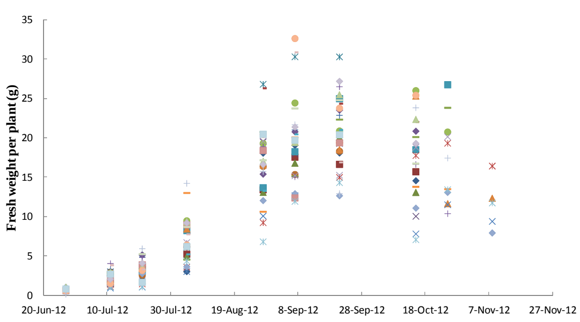
**Figure 45: Field Work - Jiangsu**



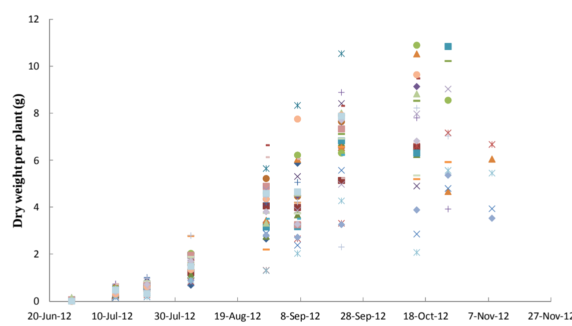

LAI




Plant Height

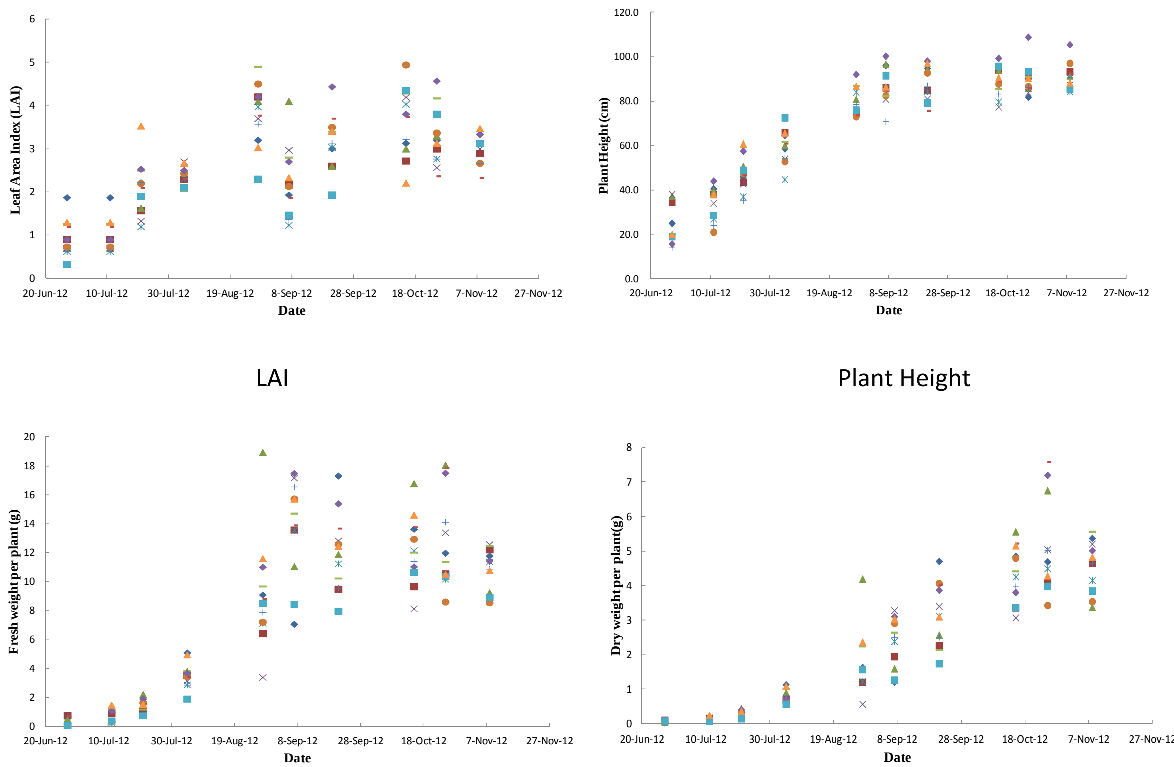



Fresh Weight




Dry Weight

**Figure 46: Rice Parameters Collected from 29 Transplanting Fields during the Whole Growing Season**




LAI

Plant Height

Fresh Weight

Dry Weight

**Figure 47: Rice Parameters Collected from 13 Direct-seedling Fields during the Whole Growing Season**

<u>Collaboration</u>

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

<u>Results</u>

**Rice Identification and Rice Area Estimation**

Double bounce is one of the dominant scattering mechanisms of rice as it grows above the flooded soil. The Freeman-Durden decomposition was introduced to extract the contribution of double bounce, volume and surface scattering. Figure 48 shows the distribution of typical features in the Freeman triangle. Rice (red and pink plots) can be discriminated from other surface features, such as forest, urban and water etc. Transplanting and Direct-seedling rice fields can be classified due to their different fields structures (Figure 44).

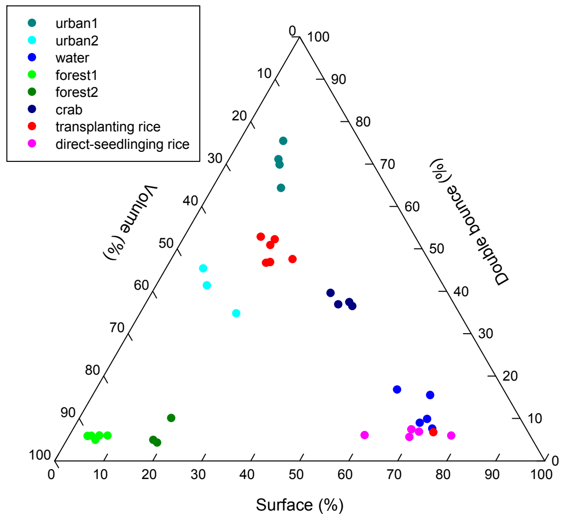



Figure 48: The Distribution of Typical Features in the Freeman Triangle

Figure 49 shows the result of rice identification using the contribution of the three Freeman components. Transplanting rice fields appear in red colour because of their large double bounce scattering. Direct seedling rice fields appear in blue colour as there is no flooding in fields only 5 days after seedling. The area of the rice crop can be calculated using this map.

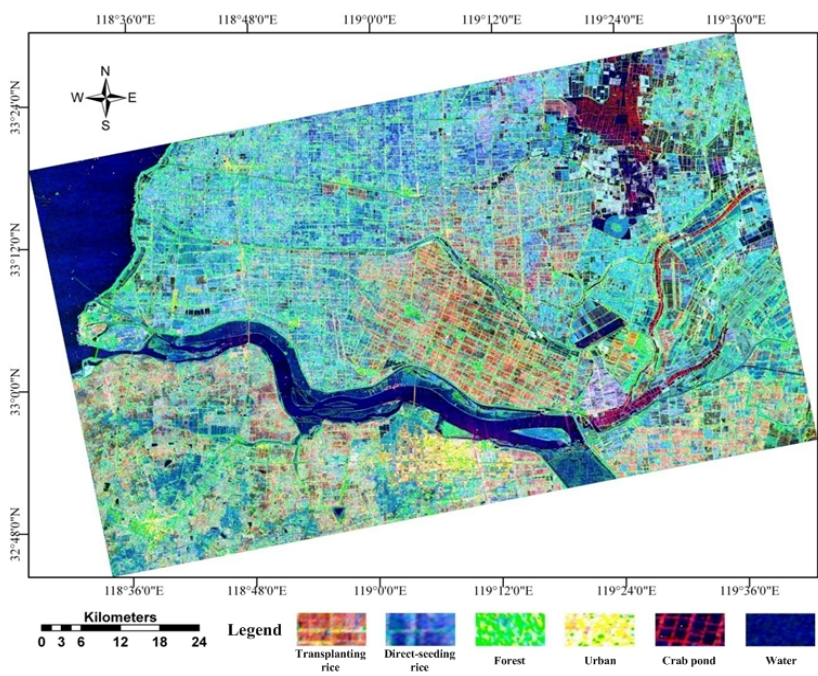
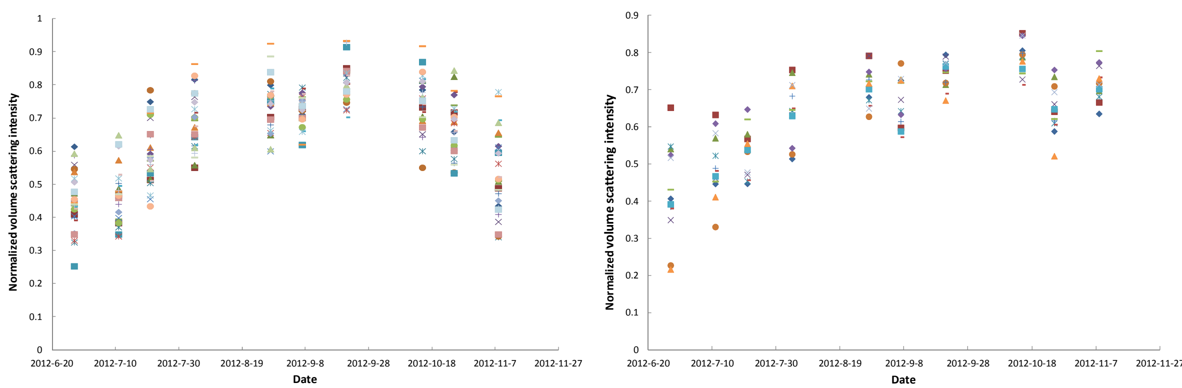



Figure 49: Rice Identification using the Contribution of Double Bounce Scattering (5-15 days after planting)

**Rice yield Prediction and Forecasting**

The key problem of rice yield estimation is inversion of rice parameters from SAR data. Backscattering coefficients and polarimetric parameters were extracted from multi-temporal SAR data and investigated for rice yield estimation. The Freeman-Durden decomposition is most sensitive to rice growth change. And its volume scattering component has the highest correlations with rice parameters (Figure 46 and Figure 47), with the correlation coefficients up to 0.8 (Figure 50). The volume scattering component is the best polarimetric parameter for rice parameter estimation in the Jiangsu test site.




Transplanting rice

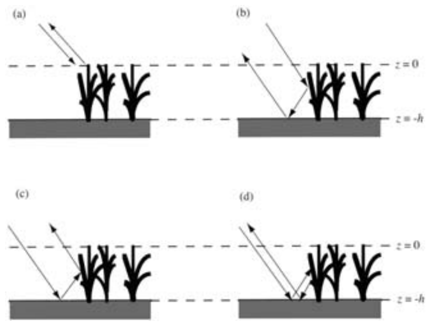
Direct-seedling rice

**Figure 50: The Normalized Volume Scattering Intensity in the Freeman-Durden Decomposition**

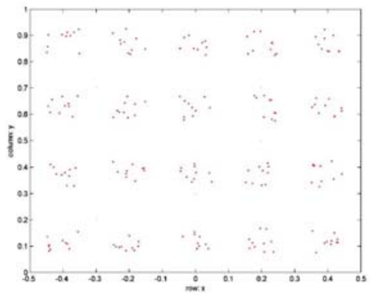
In order to understand the physical meaning of rice backscatter, a coherent scattering model using the Monte-Carlo method was introduced for rice parameter estimation. Figure 51 shows the model structure and the simulation results.

At this time, rice identification and rice area estimation with polarimetric SAR data has been completed. Models for rice parameters (biomass, plant height) inversion with polarimetric SAR data have been developed. However, we have not considered the influence of environmental stress on rice yields. We will introduce environmental stress into our model in 2014.

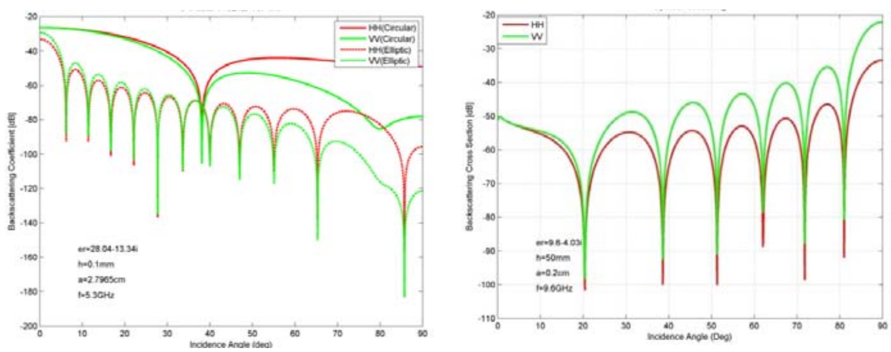
In addition, we acquired SAR data on August 14, 2012 during the elongation or heading stage of rice. However, the rice at this time was severely affected by thunderstorms, so this data cannot be used. We also missed rice backscatter during the milk stage. Missing data from two important stages can affect the accuracy of rice parameter estimation.



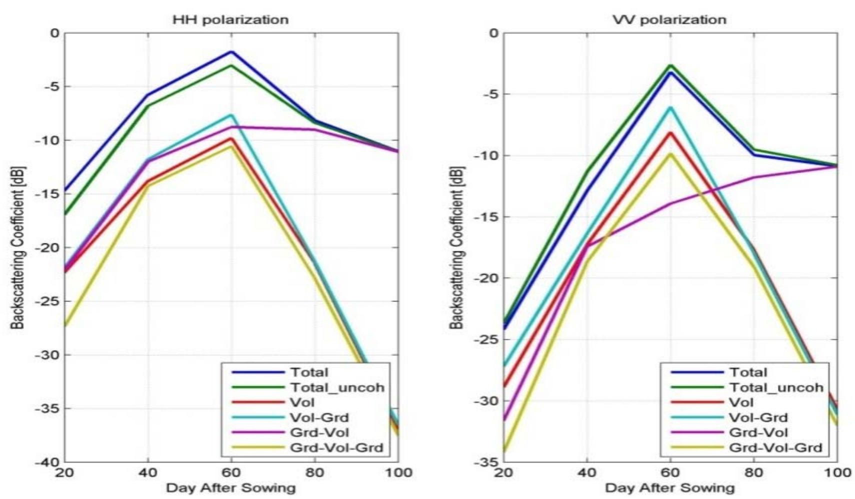
Dominant Scattering Mechanisms



Distribution of Rice Clusters



Backscatter Coefficients of Rice Leaf and Stem




Backscatter Coefficients of Rice from Different Scattering Mechanisms

**Figure 51: Monte-Carlo Model Structure and Simulation Results**

<u>Experience with the COVE Planning Tool</u>

We did not use the COVE planning tool in 2013.

Plans for Next Growing Season

We will evaluate our methods for rice mapping and introduce environmental stress into our model of rice yield estimation.

Publications

Y Shao, K Li, B Brisco, L Liu and Z Yang. 2013. The Potential of Polarimetric and Compact SAR Data in Rice Identification. Proceedings of 35th International Symposium on Remote Sensing of Environment (ISRSE35).

Y Shao, K Li, L Liu and Z Yang. 2013. Rice Montoring with Polarimetric RADARSAT-2 data. Proceedings of the 33rd Asian Conference On Remote Sensing.

## 9.5 Shandong

Team Leader: Wu Bingfang

Team members: Zhang Miao, Zeng Hongwei, Zou Wentao, Li Zhongyuan, Chang Sheng, Inkendo J.K., Zheng Yang, Chen bo, Yu Mingzhao, Meng Jihua, You Xingzhi, Xu Jin, Cheng Zhiqiang

Project Objectives

The original objectives of the site have not changed.

- Crop identification and Crop Area Estimation
  - Support vector machine, Decision tree
  - Multi-configuration SAR data
  - Integration of Optical and SAR data
- Crop Condition/Stress
  - Crop Growing Conditions Over the Growing Season
  - NDVI, NDWI, Vegetation condition index, temperature condition index, crop water stress index, etc.
- Estimation of Biophysical Variables
  - fAPAR, LAI-Radiation transfer model
  - chlorophyll content-Radiation transfer model/regression analysis
- Yield Prediction and Forecasting
  - Biomass-modified CASA model
  - Harvest index
- Crop Residue
  - Crop residue biomass estimation
- Phenological Events
  - NDVI threshold method

Site Description

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

- Climate and weather: The climatic zone is temperate, semi-arid, monsoon climate. The annual mean temperature is about 13.1℃. The annual mean precipitation is about 582 mm, concentrated from late June to September.

**Figure 52: Photographs of Shandong Site**


<u>EO Data Received/Used</u>

China Environmental Satellite (HJ-1 CCD, HJ-1 IRS):

- Supplier: China Centre for Resource Satellite Data and Applications (CRESDA)
- Optical
- 15 scenes of HJ-1 CCD images, 6 scenes of HJ-1 IRS
- From late-March to early October, 2013
- Level 2 Product
- We no difficulty in acquiring HJ-1 data, nor in processing and using HJ-1 data.
- Sample locations were same as the previous year.

MODIS:

- Supplier: NASA
- Optical
- 46 scenes
- From October 10th, 2012 to September 30th, 2013
- Beam modes/ spatial resolutions: H27V05, 250m/500m/1km
- Level 2
- We have no difficulty in acquiring MODIS data, nor in processing and using MODIS data. However, the resolution is too coarse for the study site.

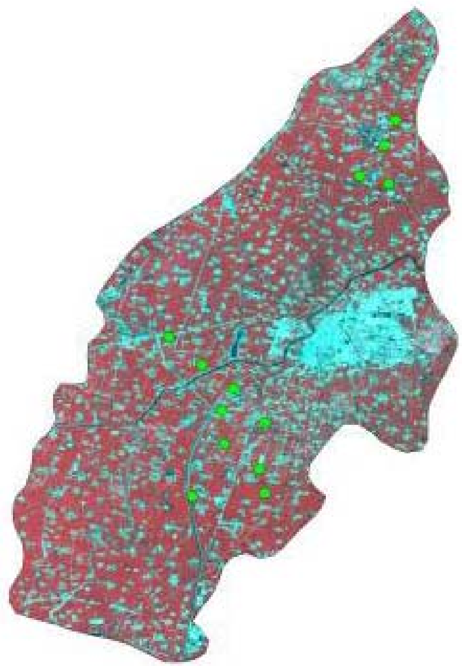


**Figure 53: Sample Distribution Map in Yucheng Site**

RADARSAT-2:

- Supplier: MDA/CSA
- SAR
- 4 scenes
- July 9th, August 2nd, and September 2nd and 26th, 2013
- Beam modes/ spatial resolutions: Fine Quad Polarization
- We submitted an order requesting 7 scenes RADARSAT-2 images but got 4 scenes.
- We used next ESA SAR toolbox (NEST 4B) to process RADARSAT-2 data and we have no difficulty in processing it to date.

TerraSAR-X:

- Supplier: DLR
- SAR
- 1 Stripmap
- July 8th, 2013
- We tried to acquire 7 to 8 images but only got 1 image.
- We used next ESA SAR toolbox (NEST 4B) to process TerraSAR-X data but it does not support the data type we acquired. So we have not processed TerraSAR-X data yet.

COSMO-SkyMed:

- Supplier: E-GEOS

- SAR
- 4 Stripmap high resolution images
- July 10th, August 12nd and 30th, and September 17th, 2013
- We acquired the data through Dragon III project between China and Europe. The data have not yet been processed.

Rapideye:

- Supplier: Dragon III project
- Optical
- 5 images
- June 12rd, August 13th and 31th, September 1st, and September 3rd, 2013
- We acquired the data through Dragon III project under Sentinel -2 Agricultural plan. We have no difficulty in processing and using the data.

SPOT-4:

- Supplier: SPOT-4 TAKE-5 plan
- Optical
- 18 images
- February 19th to June 14th, 2013
- The data was provided as level 2A products.

<u>In situ Data</u>

The main variables measured and instruments we are using are shown in Table 8.

All the variables were measured once a month from April to September except for yield and harvest index. Yield and harvest index were measured once a growing season.

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

**Table 8: In situ Variables and Instruments - Shandong**

| Main Variables | Instruments or Processing Method |
|---|---|
| Spectral reflectance | HR-768 portable spectroradiometer (Spectra Vista Corporation, NK, USA) |
| FPAR&LAI | SUNSCAN Canopy Analysis system |
| Dry amount of above ground biomass | Oven dried and weight |
| Yield | Oven dried and weight |
| Harvest index | Calculated by yield and AGB |
| Density/canopy height | Tape measured |
| Chlorophyll content of leaf | SPAD 502 Plus |


**Figure 54: In situ Measurements at Shandong Site**

Collaboration

We collaborated with the Argentina JECAM site over the China Shandong site. We conducted joint field measurements over the site with Diego de Abelleyra from Argentina in April 2013.

Results

**New Method for Crop Condition Mapping**

Based on the China Environmental Satellite (HJ-1) CCD and MODIS data, the NDVI was adjusted using uncropped arable land ratio derived from HJ-1 CCD images. Figure 55 shows the crop condition of the North China Plain covering our JECAM site. The map shows the condition of the crop compared to the previous year. Further research will focus on incorporating inter-annual variation of crop phenology into crop condition assessments. We will try to use the accumulated temperature to normalize inter-annual comparisons of NDVI.

**Crop mature time**

The models for optimal soybean harvest date prediction were developed through linear regression between remote sensing indicators and observed optimal harvest date. NDVI and NDWI were used to predict optimal soybean harvest date. The map of optimal harvest date is shown in Figure 56.

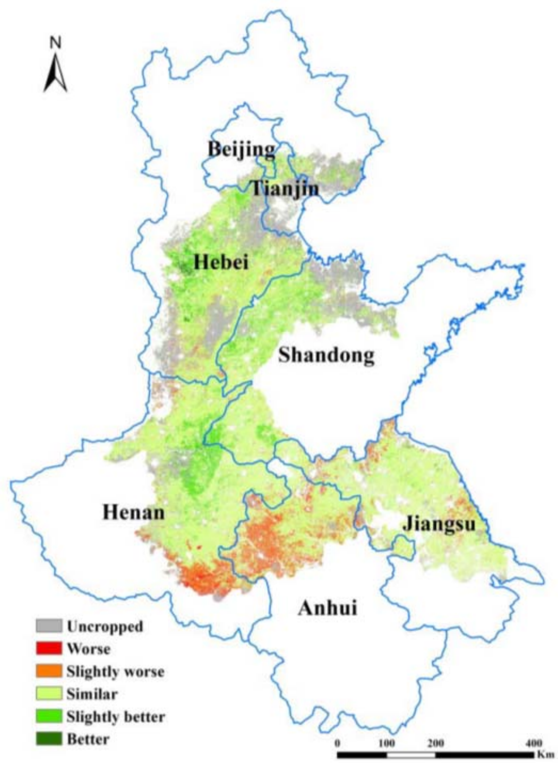



**Figure 55: Crop Condition Map of North China Plain Uncropped Arable Land Ratio Adjusted NDVI for Early May, 2011**

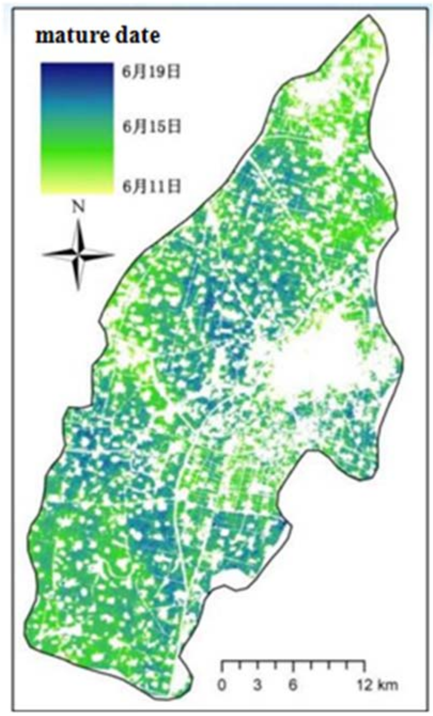



**Figure 56: Predicted Optimal Winter Wheat Harvest Date Map**

**Land cover and land use mapping**

A Land Cover and Land Use map for China Shandong JECAM site was generated by the object-oriented method using multi-temporal HJ-1 CCD images with the CART/SVM classifier. See Figure 57. By using Landsat TM5 and ETM+ data, land cover and land use maps for 2005 and 2000 were also produced.

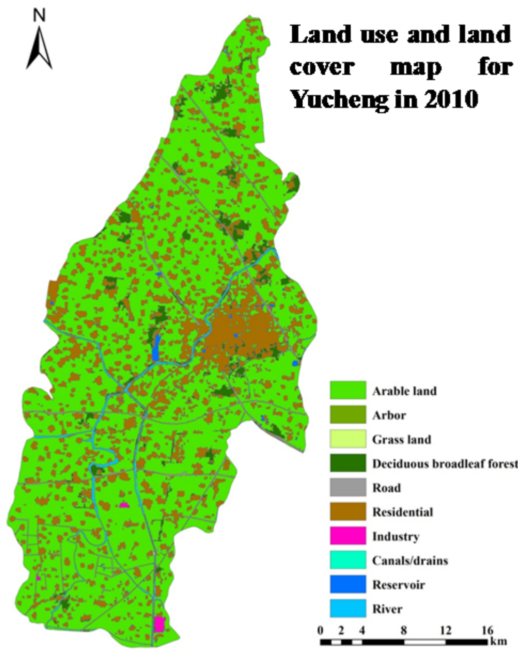



Figure 57: Land Cover/ Land Use Map of China Shandong JECAM Site, 2010

**Crop residue biomass**

A spectral angle index was developed based on bands reflectance of HJ-1 CCD & IRS sensors to estimate crop residue biomass for winter wheat in China Shandong JECAM site. The estimated crop residue map for China Shandong JECAM site is shown in Figure 58.

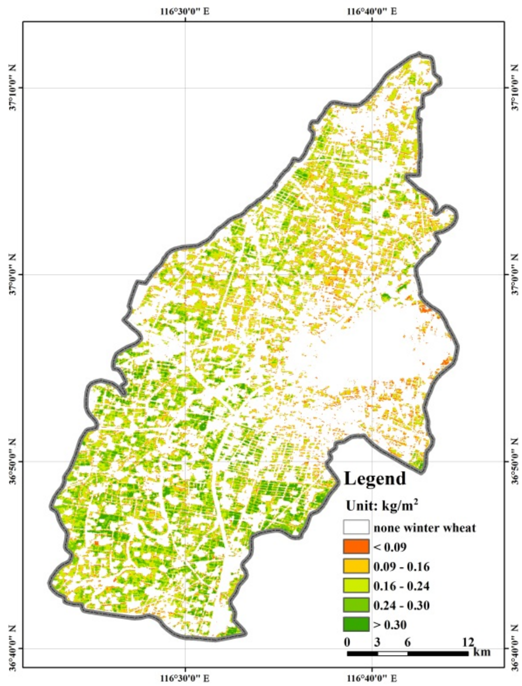



**Figure 58: Estimated Winter Wheat Residue Biomass, Shandong JECAM Site, 15 June 2011**

Experience with the COVE Planning Tool

We did not use COVE Planning Tool to acquire or order EO data.

Plans for Next Growing Season

In 2014 and the future, we will measure same variables same as we did in 2013.

In 2013, we acquired some high resolution optical images, such as Rapideye, SPOT-4 and DMC-2 images over the same study site. We anticipate ordering some Rapideye, UK-DMC2 and other high resolution images in 2014 and the future continuously. SAR data are also expected to be acquired in 2014.

Publications

Miao Zhang, Binfang Wu, Qiangzi Li, Jihua Meng, Xin Du, Taifeng Dong, Xingzhi You. Fallowed cropland mapping for better crop monitoring in Huang-Huai-Hai Plain using HJ-1 CCD data. Oral presentation in the 35th International Symposium on Remote Sensing of Environment (ISRSE35), April 2013, China, Beijing.

Wu Bingfang, Zhang Miao, Hongwei Zeng, New indicators for global crop monitoring in CropWatch. Oral presentation in the 35th International Symposium on Remote Sensing of Environment (ISRSE35), April 2013, China, Beijing.

Meng Jihua, Wu Bingfang, Du Xin, Zhang Miao. Estimating regional winter wheat leaf N concentration with MERIS by integrating a field observation based model and histogram matching. Transactions of the ASABE, 2013, 56(4): 1589-1598.

Wu B, Meng J, Li Q, et al. Remote sensing-based global crop monitoring: experiences with China's CropWatch system[J]. International Journal of Digital Earth, 2013 (ahead-of-print), DOI:10.1080/17538947.2013.821185.

Zhang Miao, Wu Bingfang, Meng Jihua. Quantifying winter wheat residue biomass with a spectral angle index derived from China Environmental Satellite data, submitted to International Journal of Applied Earth Observation and Geoinformation, under review.

Miao Zhang, Bingfang Wu, Mingzhao Yu, et al. Crop condition assessment using an uncropped arable land ratio to adjust NDVI, submitted to Remote Sensing, under review.

Miao Zhang, Piccard Isabelle, Bydekerke Lieven, Bingfang Wu. Comparison of field campaigns for crop monitoring in China (Yucheng) and Europe (Belgium). Oral presentation in global vegetation monitoring and modeling, February 3rd to 7th, Avignon, France.

## 10. France

Team Leader: Eric Ceschia

Team Members : Aurore Brut, Olivier Hagolle, Frédéric Baup, Gérard Dedieu, Jean François Dejoux, Jordi Inglada, Valérie Demarez, Benoit Coudert, Vincent Rivalland, Silvia Valero, Claire Marais-Sicre, Valérie Le Dantec, Patrick Mordelet

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
- $CO_2$ and water fluxes/budgets.

Site Description

The JECAM Test Site Name is OSR (observatoire spatial regional).

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

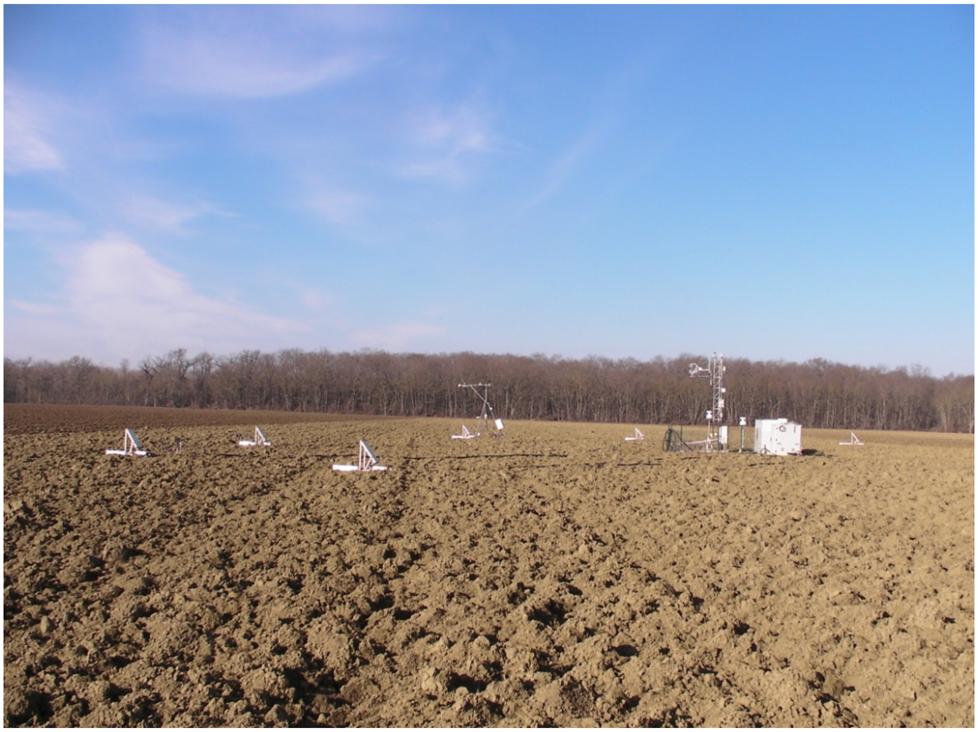


**Figure 59: The Lamasquère Site Around the Micrometeorological Station**

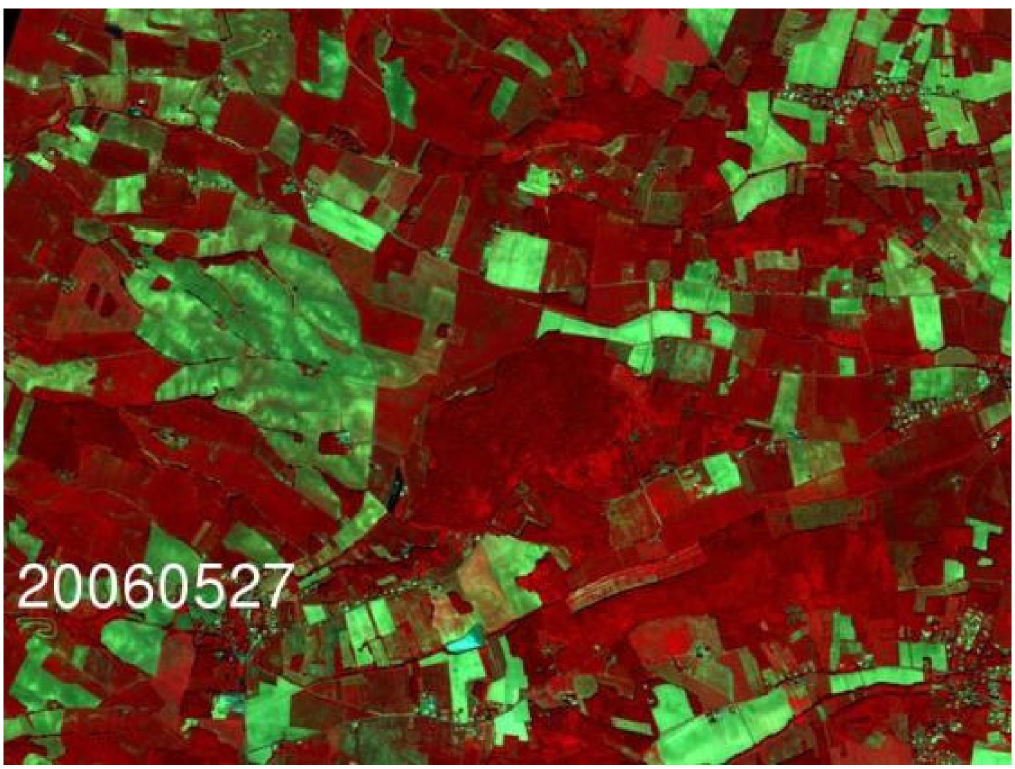



**Figure 60: Formosat-2 Image from the Area around the Auradé Experimental Plot and its Micrometeorological Station (27 May 2006)**

EO Data Received/Used

CNES/SPOT-4 (Take5) experiment

- Optical
- 28 images, among which 8 cloud free
- February -2013 – End of June 2013.
- Mode: XS mode
- Level 2A : images available at http://spirit.cnes.fr/take5/

Landsat-8

- Supplier: USGS
- Optical
- April-December 2013
- 18 images among which 7 clear (on average)
- Level 1T.

Spot-5:

- Supplier: Astrium
- Optical
- Mode /spatial resolution: 10m MS
- 7 images cloud free
- July 15th to December 18th, Level 2

Formosat2:

- Optical
- Mode/ spatial resolution: 8m MS
- 16 images cloud free
- February 16th to November 28$^{th}$
- Level 2

Deimos1:

- Optical
- Mode / spatial resolution: 22m MS
- 8 images cloud free
- April 24th to September 23th
- Level 2

Pléiades:

- Optical
- Mode / spatial resolution: 70cm MS

- 3 images cloud free
- June 6th to August 21th
- Level 1A.

In situ Data

Both Auradé and Lamasquère sites are ICOS sites and therefore biomass, soil humidity, meteorological, and flux measurements are standardised following 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 $CO_2$ and $N_2O$ fluxes (automatic chambers), net CO2, water, sensible heat fluxes by means of the eddy-covariance method.

Collaboration

The sites are involved in several collaborative projects such as GHGeurope (http://www.ghg-europe.eu/), ICOS (http://gaia.agraria.unitus.it/home), Fluxpyr (http://ecofun.ctfc.cat/?p=605) including many partners. The Fluxpyr and GHGEurope projects are finished but the ICOS network will be running for the next 20 years.

Results

JECAM did not change anything in our plans. In fact, it did not provide us with Earth Observation data, it did not provide contacts, our in situ data were not requested by anybody from the JECAM network. We (CNES, based on CESBIO suggestion, and with a contribution from ESA), provided SPOT-4 (Take5) data for about 10 JECAM sites in all continents, with image acquisitions every 5 days during 5 months to simulate the future Sentinel-2 data. We did not get any feedback yet from the users.

As seen from here, JECAM looked like an empty shell in 2013. It may change next year, as users of JECAM sites provide results, and as our lab is implied in an ESA funded project to produce sample products (land cover, biophysical variables), on several JECAM sites (8 or 10).

Experience with the COVE Planning Tool

We have not used the COVE acquisition planning tool provided by NASA. We do not feel that we need a training course in COVE.

Plans for Next Growing Season

We will hold the course next growing season. The type/quantity of EO data to be ordered next year will be about the same, apart from the SPOT-4 (Take5) experiment that will not be repeated. (SPOT-4 is off).

## 11. Italy Apulian Tavoliere

Team Leader and Members: Annamaria Castrignanò, Domenico Ventrella, Anna Maria Stellacci, Pasquale Campi, Daniela De Benedetto, Michele Rinaldi, Alessandro Matese, Piero Toscano, Emanuele Tarantino.

Project Objectives

The main objectives of the project were to collect soil and crop data in order to: 1) calibrate a simulation model of crop growth and production and 2) implement a data fusion method aimed at integration of remote sensing data with ground-based data. The lack of granted projects obliged us to restrict the surveyed area to a field of 3 ha.

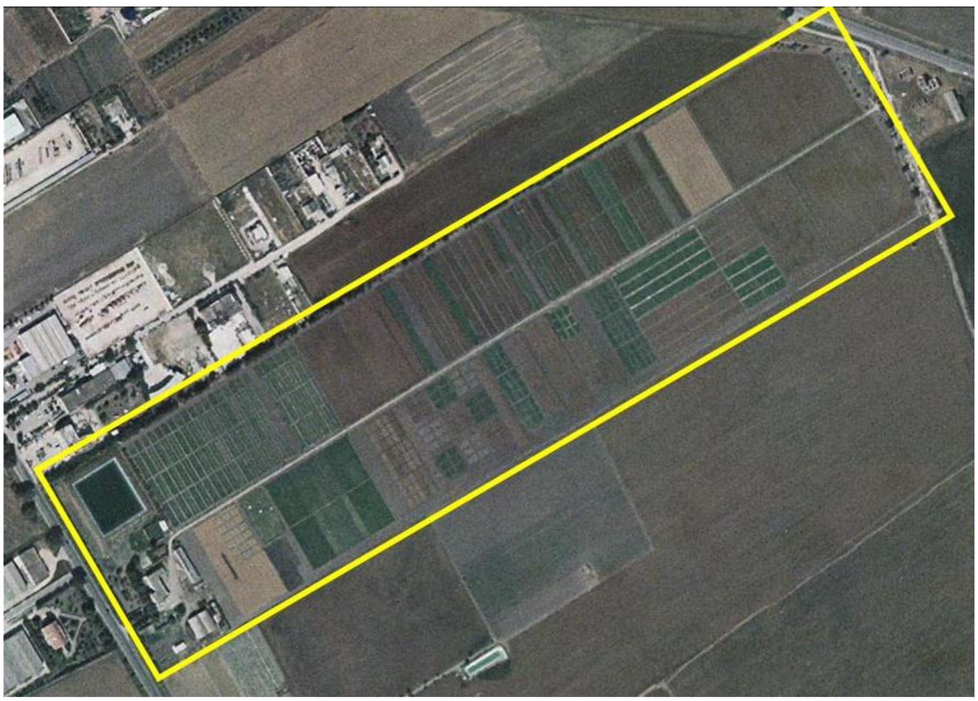


**Figure 61: Google photo of the experimental farm of the Research Unit for Cropping Systems in Dry Environments (CRA-SCA)**

Site Description

The interest of our study is focused on "Capitanata area", a plain of about 4000 km$^2$ located in the northern part of Apulia Region (south-eastern Italy). This area is characterized by farms with average size up to 20 ha, highly productive soils cultivated under intensive and irrigated regime. Winter durum wheat (Triticum durum L.) represents the main cereal crop often grown in rotations with irrigated horticultural species. Among these, processing tomato crop (Lycopersicon aesculentum Mill.) is well represented. In particular, two-year rotation (tomato-wheat) and three-year rotation (tomato-wheat-wheat) are the typical farming rotations of this important productive area.

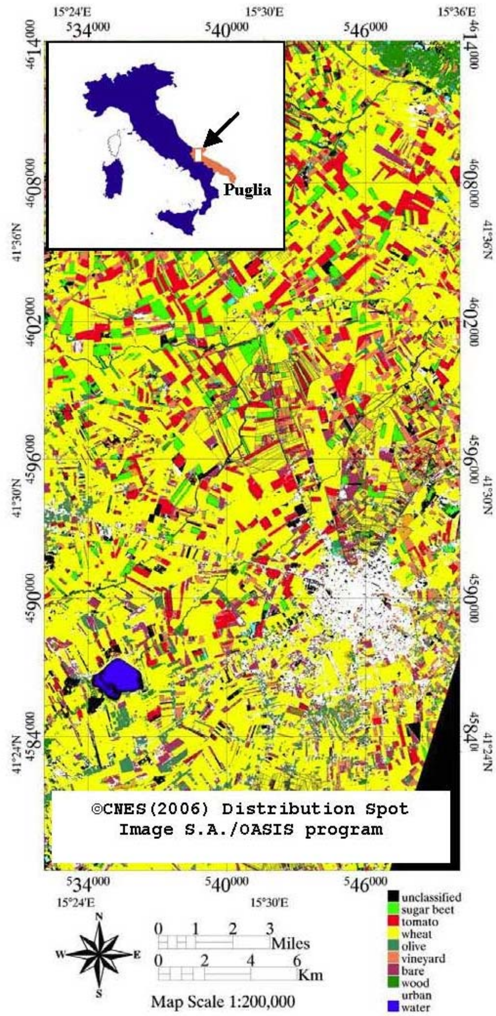



**Figure 62: Land Use Map of an Area within the Capitanata Plain**

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

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

**Figure 63: Photo of Capitanata**

EO Data Received/Used

Moderate resolution imaging spectroradiometer (MODIS) land data products include the NDVI and the Enhanced Vegetation Index (EVI)[4]. The MODIS 13Q1 Vegetation Indices were acquired from the Earth Observing System (EOS) data gateway of the NASA Land Processes Distributed Active Archive Center[5].

One MODIS 13Q1 image is a composite of 16-day images containing processed NDVI and EVI data at 250-m spatial resolution[6], fitting the spatial and temporal requirements for this study. A maximum of 64 observations are taken over the 16 days, and only the higher quality cloud-free filtered data are combined to create a 16-day composite image. The MODIS VIs rely on the MODIS level-2 daily surface reflectance products which are atmospherically corrected[7].

For this study, we used MOD13Q1 MODIS EVI/NDVI including the reflectance of the B (blue), R (red), NIR and MIR (near and middle infrared) bands, freely obtained from the USGS data server (http://glovis.usgs.gov/) corresponding to the whole development of durum wheat and extracted for the whole study area.

[4] Justice CO, Smith R, Gill AM, Csiszar I (2003). A review of current space-based fire monitoring in Australia and the GOFC/GOLD program for international coordination. Int J Wildland Fire 12:247–258

[5] Shi L, Wang H, Zhang W, Shao Q, Yang F, Ma Z, Wang Y (2013) Spatial response patterns of subtropical forests to a heavy ice storm: a case study in Poyang Lake Basin, southern China. Nat Hazards DOI 10.1007/s11069-013-0800-1

[6] Huete A, Didan K, Miura T, Rodiriguez EP, Gao X, Ferreira LG (2002). Overview of the radiometric and biophysical performance of the MODIS vegetation indices. Remote Sens Environ 83:195–213

[7] Vermote EF, El Saleous NZ, Justice CO (2002) Atmospheric correction of MODIS data in the visible to middle infrared: first results. Remote Sens Environ 83:97–111

Prediction Model of Wheat Yield

The Delphi system was described in the paper "Durum wheat modelling: the DELPHI system, 11 years of observations in Italy"[8] and is based on AFRCWHEAT2 model (Porter, 1984, 1993a, 1993b, Semenov, 1993, Semenov and Porter, 1995). The model has been calibrated and "tuned" for durum wheat and Italian conditions since 1995 and is currently used by one of the major pasta manufacturers to make yield and quality predictions for durum wheat in the major Italian supply basins.

Dates of emergence, double ridges, terminal spikelet, anthesis, beginning and end of grain-filling and physiological maturity are calculated by the model for a specific cultivar.

To account for the range of cultivars currently grown in the study areas, model parameters were calibrated by using experimental data of 4 different cultivars (Simeto, Duilio, Iride and Svevo), which are among the most widely used in Italy.

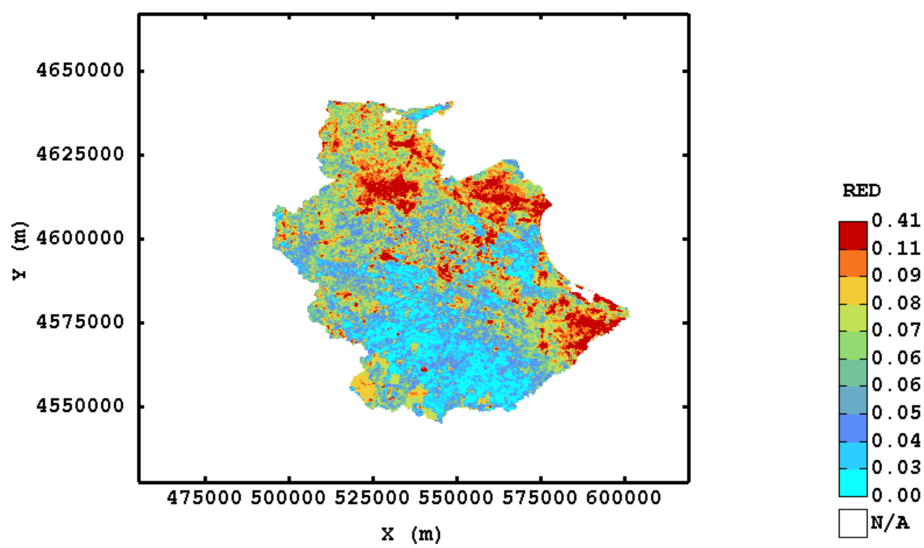



**Figure 64: MODIS Image, April 2013**

System

An operational tool has been developed in the Delphi system, to estimate phenological development, biomass growth and quantity of grain in durum wheat. A database that stores and updates meteorological data from weather stations, and the main characteristics of soil and agronomical data, is linked to the crop simulation model. The first output is the phenological phase, then biomass and grain quantity are calculated (yield data output).

[8] Toscano, P., Ranieri, R., Matese, A., Vaccari, F.P., Gioli, B., Zaldei, A., Silvestri, M., Ronchi, C., La Cava, P., Porter, J.R., Miglietta, F. (2012). Durum wheat modeling: The Delphi system, 11 years of observations in Italy, European Journal of Agronomy: 108-118.

**Input data**

- Meteorological data: Daily values of maximum, minimum, dry and wet bulb temperature, solar radiation, sunshine hours, rainfall, wind and humidity;
- Physiological parameters: sowing date and number of seeds/$m^2$ (phenological data input);
- Soil data: the soil hydrological profile (2m in 40 layers, hydrological data input); soil total nitrogen content profile (2m in 40 layers);
- Agronomic data: quality and quantity of nitrogen ($NH_4$, $NO_3$, nitrogen data input); roots growth data (roots data input).

<u>In situ Data</u>

**Crop Data at Field Scale**

At the harvesting time (June 2013), grain and straw yields were measured in the middle of the test sites of size varying between 50 and 100 $m^2$. Plant samples were randomly collected in five points of each test site for determining dry weight of grain and straw and the values were expressed as t $ha^{-1}$.

Leaf area index of the three varieties of winter durum wheat were measured in all the test sites with a LAI-2000 instrument (LI-COR Inc., Lincoln, NE, USA) (Welles and Norman, 1991) using a fisheye lens on 5 dates in 2013 (March 12, April 4, April 22, May 2 and May 15). In each plot, three measurements of LAI were taken between two rows of the wheat plants.

**Figure 65: The Trial Area and Li-Cor Plant Canopy 2000**

**Calibration of Crop Model**

Measurements of water content have been performed in one of the test sites growing durum wheat (cultivar Grecale) with the aim of analyzing the performance of the AquaCrop[9] model for a rain fed crop in a Mediterranean area.

[9] Steduto P., Hsiao TC., Fereres E., Raes D. (2012). Crop Yield response to water - FAO Irrigation and Drainage Paper 66, Rome (Italy), 500pp.

Durum wheat was sown on 7th December 2012. The durum wheat crops were grown using conventional agro-techniques (150 kg ha-1 N). The dates of the main phenological stages, used for the AquaCrop calibration to calculate growing degree days (GDD), were collected. For calibration, the LAI values were measured with an area meter (LAI-2000 Plant Canopy Analyzer, Li-Cor USA).

For monitoring soil water status (W), capacitive probes of 0.1 m in length (Decagon devices, 10HS, USA) were installed horizontally in the soil at two depths (10 and 45 cm from the soil surface). See Figure 66. The probes were linked to a Grillo datalogger (Tecno.El, ITA), which recorded the daily data of soil water content from February 1 to May 15 2013.


**Figure 66: Photos of Decagon Device**

For the calibration process, a series of inputs were used. Climate inputs concern the daily data of air temperature and rainfall measured at the meteorological station at the CRA farm (Figure 67) and reference evapotranspiration (ETo) calculated by Penman-Monteith formula[10].

**Figure 67: Meteorological Station on the Farm**

Cultivar specific inputs were as follows. Crop development was expressed as growing degree days (GDD). LAI or canopy ground cover was expressed as CC = 1 – exp (−K*LAI); K (extinction coefficient) was assumed to be equal to 0.65 for durum wheat. The minimum effective rooting depth was 0.05 m and the maximum effective rooting depth was 1.2 m.

[10] Allen R.G., Pereira L.S., Raes D., Smith M. (1998). Crop evapotranspiration: guidelines for computing crop water requirements. Irrigation and Drainage paper No. 56, FAO, Rome, 300 pp.

**Table 9: Soil Inputs (Physical Properties)**

| Soil characteristics | Foggia |
|---|---|
| Depth (m) | 1.2 |
| Saturated hydraulic conductivity (mm $d^{-1}$) | 100 |
| Water content at field saturation (% volume) | 50 |
| Water content at field capacity (% volume) | 39 |
| Water content at wilting point (% volume) | 23 |

**Environmental data at Capitanata scale**

The monitoring network is composed by 22 weather stations (Figure 68). Each station is equipped with the main meteorological parameters sensors: temperature and air humidity, soil temperature, global solar radiation, wind speed, wind direction, rainfall, connected to a data-logger.

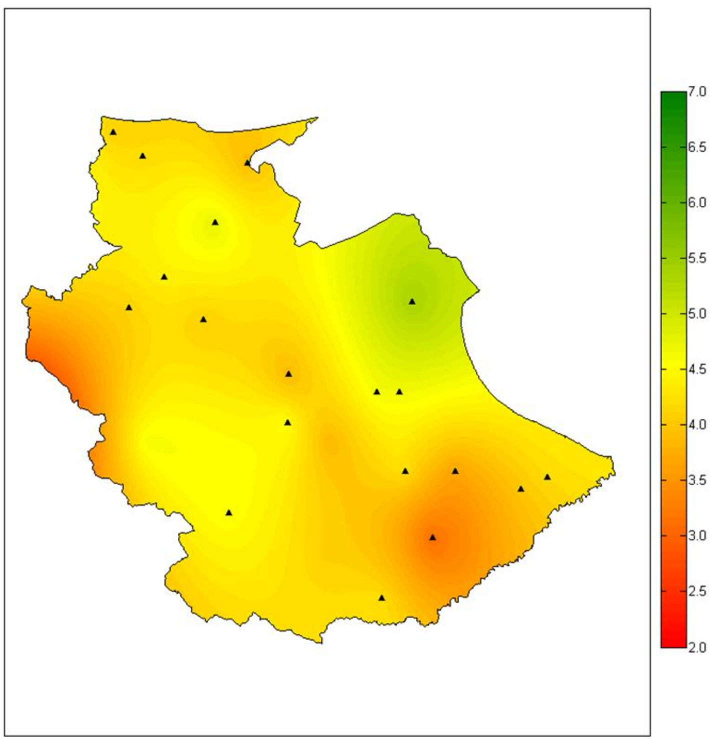



**Figure 68: Study Area Map based on Delphi Model Yield Output (t/ha) with Locations of Weather Stations (▲)**

Soil data were retrieved from the soil maps of Regional Agencies and from the National Center for Soil Mapping (http://www.soilmaps.it/) and constitute a compromise between data generalization and intensity of soil surveys conducted in the study areas during the experimental period[5]. Crop management inputs typically considered include sowing date, plant density, fertilizer date (type and amount), while irrigation is not required because Italian durum wheat is basically not irrigated. The agronomic data were provided by the Agricultural Consortia.

**Multicollocated cokriging**

This multivariate geostatistical technique is a way of integrating secondary information, such as the multi-spectral remote sensing data, in primary variable (sparsely distributed yield/biomass predictions) modelling. The contributions of secondary variables to cokriging estimates rely on the cross-correlations with the primary variable. To perform multivariate geostatistical analysis on yield/biomass data predicted by Delphi model jointly with MODIS data, the Remote Sensing (RS) multispectral data were collocated into the file containing the sparse crop predictions by migrating the RS data to the location up to a maximum distance of 250 m equal to the size of MODIS pixel. The approach is quite similar to ordinary cokriging with the only difference in the neighbourhood search, since the secondary variable is used only at the target location and all the locations where the primary variable is defined[11].

Collaboration

We were contacted by Dr. Consuelo Latorre from EOLAB, to support the validation work of Copernicus Global Land products based on SPOT-5, by using the ground data collected in the Italian site of JECAM. Our team decided to accept the invitation, therefore on-the-ground measurements of LAI and FAPAR will be carried out from spring 2014 to 2015.

Results

Figure 69 shows the development of LAI for the three cultivars of durum wheat, while Table 10 shows the statistics for yield and straw biomass. This shows clearly how the Grecale outperforms the other two cultivars in the study site.

| CULTIVAR | YIELD (t ha$^{-1}$) | | STRAW BIOMASS (t ha$^{-1}$) | |
|---|---|---|---|---|
| | mean | Standard Error | mean | Standard Error |
| SVEVO | 5.18 | 0.12 | 9.13 | 0.59 |
| SIMETO | 4.90 | 0.10 | 7.01 | 0.24 |
| GRECALE | 6.39 | 0.75 | 16.06 | 2.38 |

**Table 10: Yield and Straw Biomass of the Three Durum Wheat Cultivars**

[11] Castrignanò, A., Costantini, E., Barbetti, R., Sollitto, D. (2009). Accounting for extensive topographic and pedologic secondary information to improve soil mapping. Catena 77: 28-38.

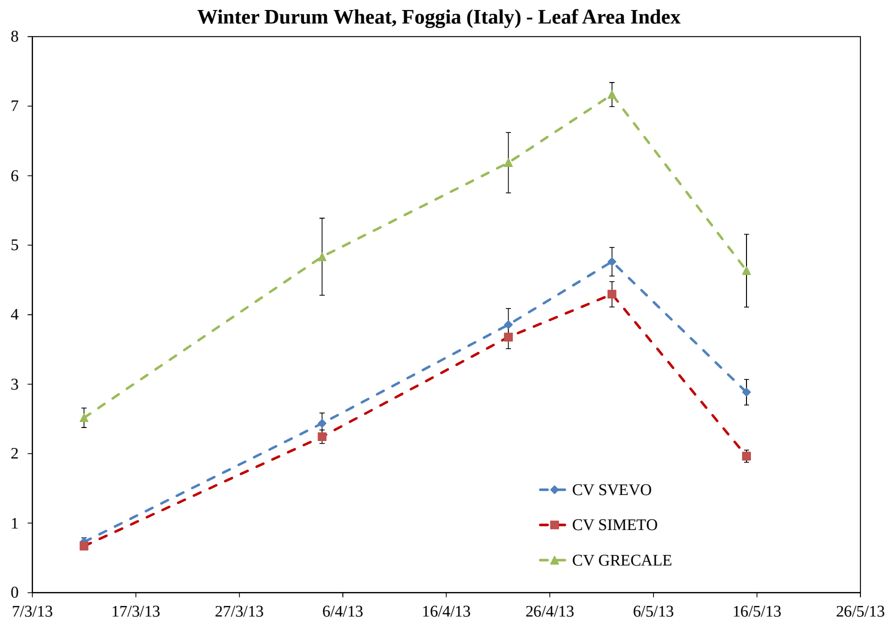



Figure 69: LAI Development of the Three Durum Wheat Cultivars

| Parameter description | Parameter value | | Unit |
|---|---|---|---|
| | default | calibrated | |
| Plants per m2 | 450 | 270 | n. |
| Maximum canopy cover (CCx) | 96 | 96 | % |
| GDD from sowing/transplanting to emergence/recovered tr. | 80 | 115 | °C |
| GDD from sowing/transplanting to maximum rooting depth | 1200 | 1100 | °C |
| GDD from sowing to start senescence | 1700 | 1700 | °C |
| GDD for sowing/transplanting to maturity | 2400 | 2200 | °C |
| Reference harvest index, $HI_0$ | 48 | 35 | % |

Table 11: Results of Calibration of the AquaCrop Model for Durum Wheat

Table 11 and Figure 70 show the results of the calibration of the AquaCrop Model for Durum Wheat.

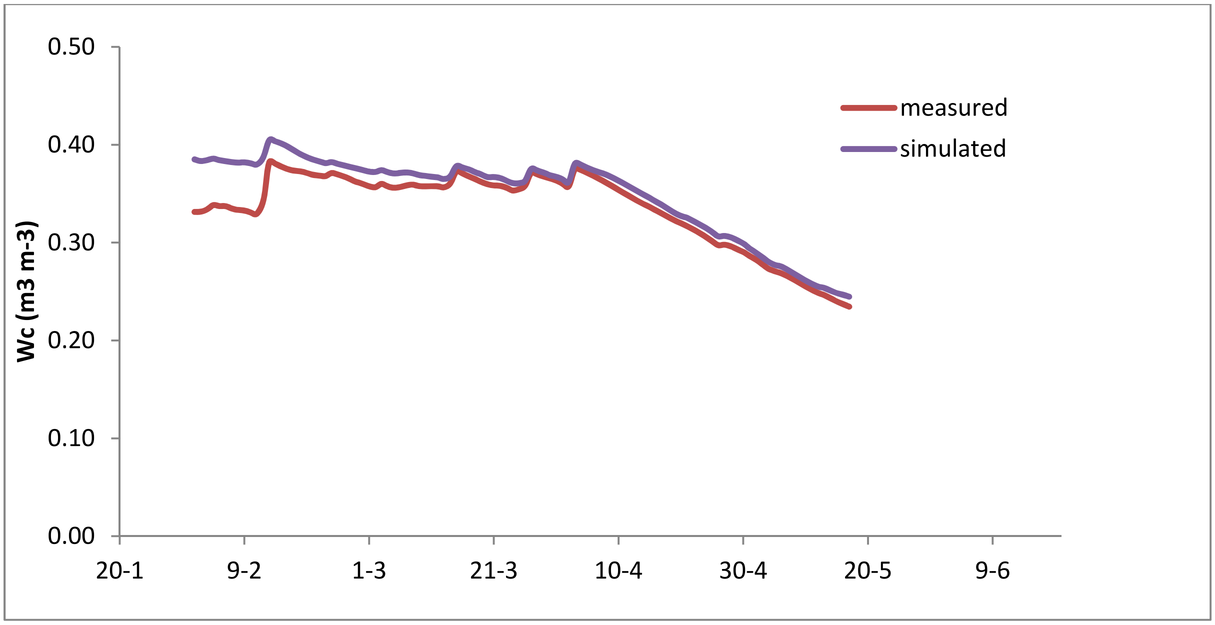



**Figure 70: Results of the Calibration of the AquaCrop Model for Durum Wheat**

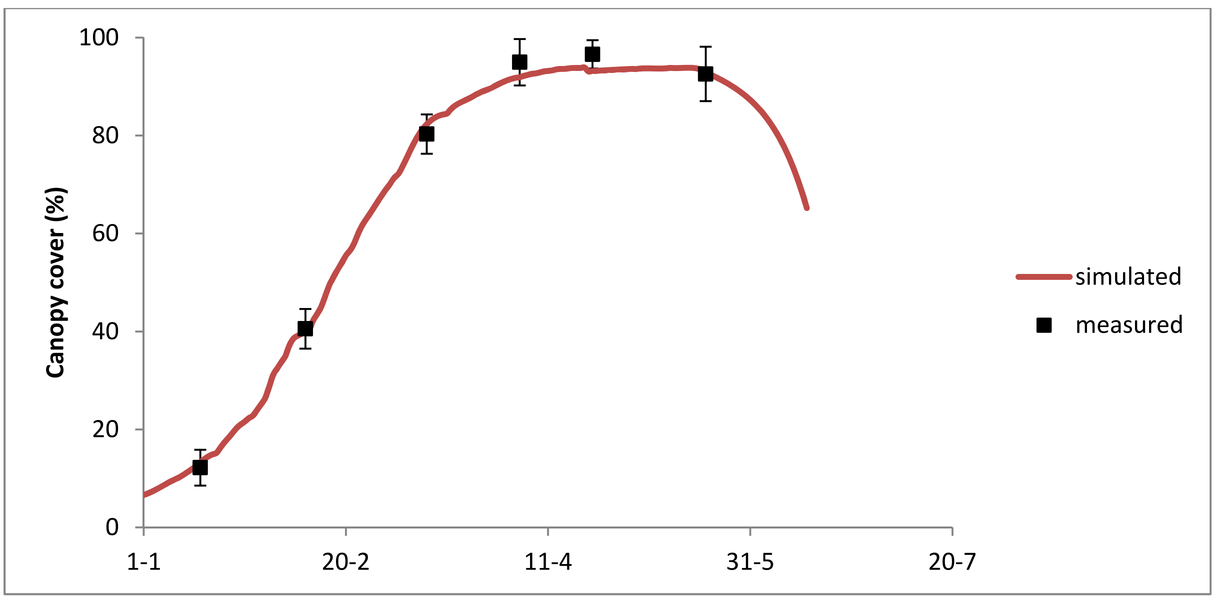
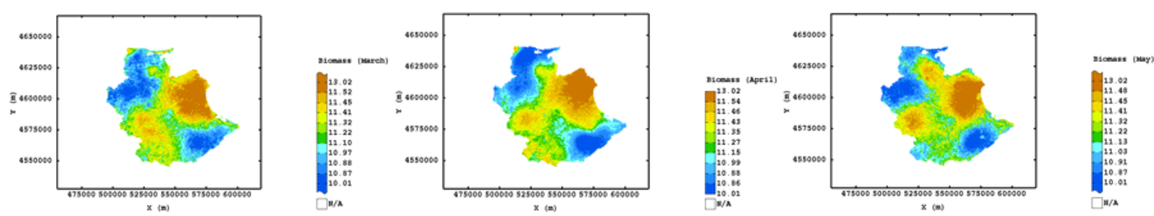



**Figure 71: Canopy Cover of Durum Wheat Measured and Simulated by the AquaCrop Model after Calibration**

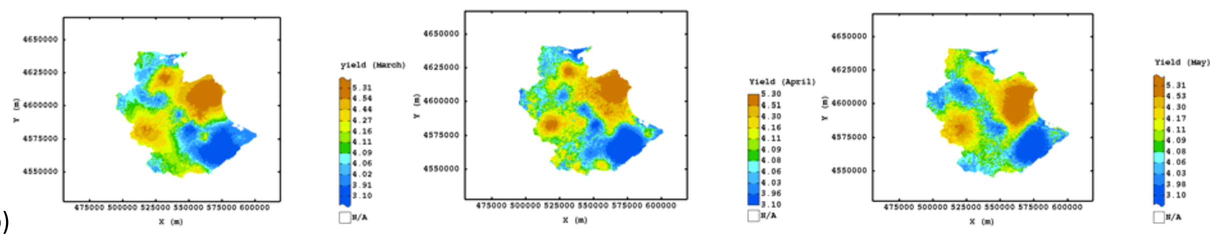
Figure 71 shows the canopy cover of durum wheat measured and simulated by the AquaCrop Model after calibration. These results can be considered only preliminary, because the calibrated model needs to be validated on a larger area of Tavoliere during the next season of durum wheat.

As regards the methodology of sampling, we think that the study site for collecting on-the-ground measurements of LAI needs to be improved, to make it more suitable for validation of RS products. We are going to follow the guidelines for a field campaign of the IMAGINES project for the next season of durum wheat.

Figure 72 shows the results of spatialization of point Delphi predictions through an integration of sparse data with exhaustive RS data for three dates of recording. The approach proved to be quite suitable and flexible to integrate data of different types, however the next objective will be to apply this technique to real data of yield and biomass, measured at the elementary sampling Units (ESU) selected according to the guidelines of IMAGINES project.



(a)



(b)

**Figure 72: Interpolated Delphi Predictions of Durum Wheat Biomass (a) and Yield (b) by Using MODIS Images of March, April and May**

<u>Experience with the COVE Planning Tool</u>

We have never used COVE but we are interested in taking a short training course on-line.

<u>Plans for Next Growing Season</u>

As stated above, we plan to modify the sampling approach according to the guidelines of IMAGINES project and produce high resolution maps of LAI/FAPAR/FCover based on SPOT-5 images.

<u>Publications</u>

Toscano, P., Ranieri, R., Matese, A., Vaccari, F.P., Gioli, B., Zaldei, A., Silvestri, M., Ronchi, C., La Cava, P., Porter, J.R., Miglietta, F. (2012). Durum wheat modeling: The Delphi system, 11 years of observations in Italy, European Journal of Agronomy: 108-118.

Castrignanò, A., De Benedetto, D., Girone, G., Guastaferro, F., Sollitto, D. (2010). Characterization, Delineation and Visualization of Agro-Ecozones Using Multivariate Geographical Clustering. Italian Journal of Agronomy 5: 121-132.

## 12. Madagascar

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

Team Members: Jacqueline Rakotoarisoa and Fidiniaina Ramahandry Andriandrahona (FOFIFA - National Center of Applied Research for Rural Development, Madagascar); Elodie Vintrou, Eric Scopel, Julie Dusserre and Pierre Todoroff (Cirad UR AIDA).

Project Objectives

The original project objectives have not changed. They are:

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

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

Site Description

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

(a) (b)

**Figure 73: Irrigated Rice Fields (a) in a Basin, (b) Cultivated on Terraces**

**Figure 74: Rain fed Rice and Associated Maize**

**Figure 75: Agricultural Landscape Mainly Composed of Rice and Maize**

EO Data Received/Used

SPOT

- Space agency or Supplier: ASTRIUM - SPOT Image via SEAS-OI satellite receiving station or CNES SPOT4 Take5 experiment.
- Optical
- Number of scenes: 25 images (60*60 km)
- Range of dates: October - June
- Beam modes/ incidence angles/ spatial resolution: Multispectral / between -31 and + 31 / 10-20 meters resolution
- Processing level:
    - SEAS-OI images: Delivered in level 1A then manually orthorectified and converted in top of atmosphere reflectance
    - SPOT4 Take5 images: Delivered either in level 1A, 3 (ortho) or in top of canopy reflectance.

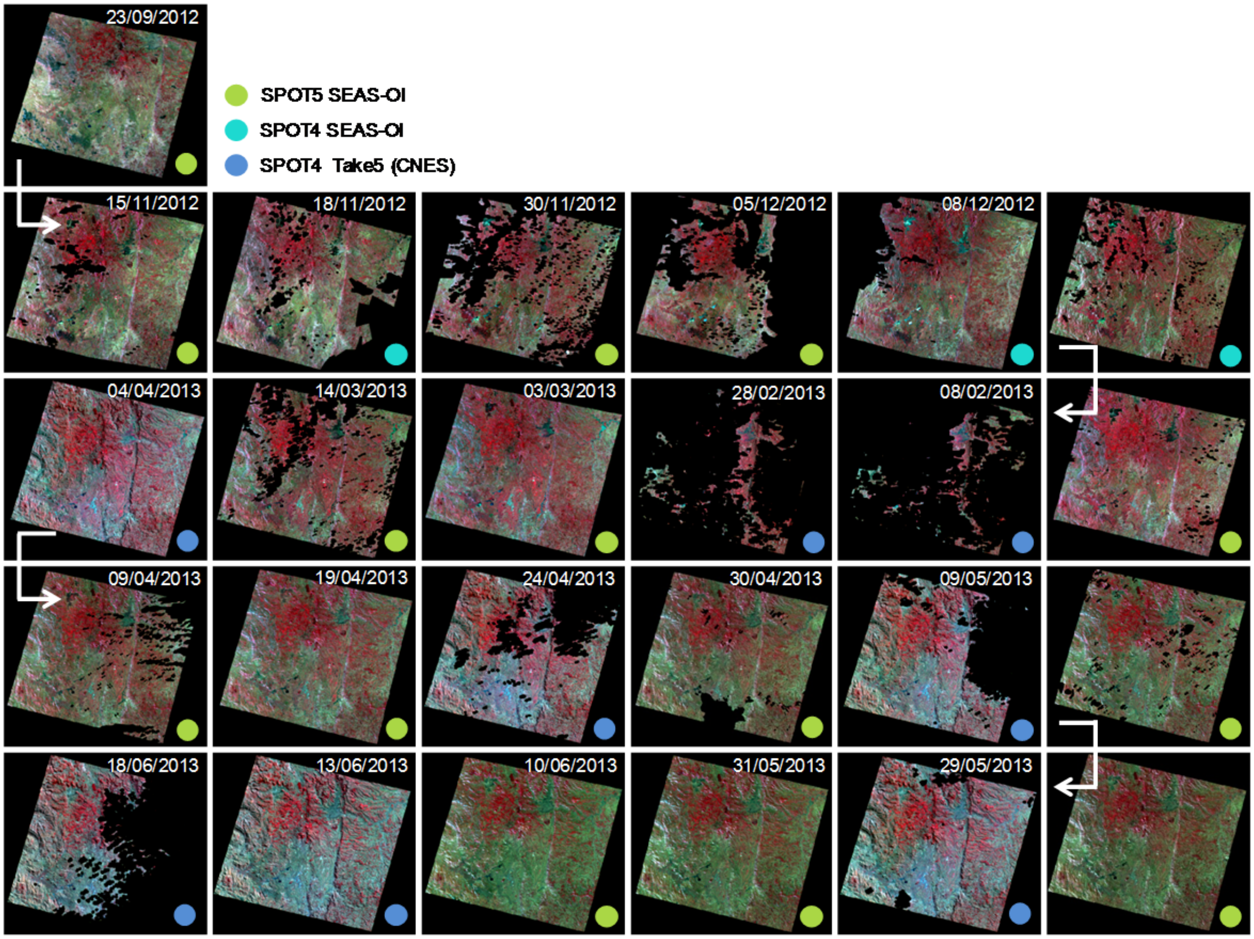





**Figure 76: SPOT satellite time series (black parts represent masked clouds)**

PLEIADES

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



**Figure 77: Pansharpened PLEIADES Image - 3 March 2013**

In situ Data

**Data Collected for Crop Characterization**

During the 2012-2013 cropping season, about 400 GPS waypoints were sampled in different fields, chosen to be spatially distributed in the study zone and representative of the existing agricultural systems. The data gathered during the field survey was a representative sample of farmers' practices (type of crop, irrigation, presence of associated crops).

**Data Collected for Estimate of Crop Production**

During 2013 harvest season, about 100 rice fields were sampled in order to obtain information on the farmers' practices (cultivar, planting date, irrigation, fertilization, harvest date) and the yield (dry biomass, grain yield on 1m² inside the field). However, the first analyses of the data on crop production showed incoherences when compared to the satellite images (georeferencing accuracy problems of the GPS points) making the data set difficult to use.

**Figure 78: Rice Yield Measurements**

Collaboration

We are one of the SIGMA project sites.

Results

This first year of acquisitions led to the following results:

1. One crop / non-crop map was produced by object based image analysis of SPOT and DEM and ground data with an overall accuracy of 80 % (first results currently being improved).

2. On the basis of static (toposequence, SPOT textural indices...) and temporal information (time series of NDVI, ...) extracted on a ground training database, data mining tools were used so as to:

(i) find discriminating sequential patterns of the different cropping systems plots (to extract such patterns expressing correlations over time, the PrefixSpan algorithm was used) and

(ii) establish rules defining if a plot is more likely to be cropped or not (and which crop) according to its spatial, temporal, dynamic and static attributes (for this point, several machine learning algorithms are available in the WEKA tool; more precisely, the following methods were applied on the data set: Random Forest, Naïve Bayes, Support Vector Machine (SVM) and Rule based classifier). Best classification results were obtained with SVM (81 % and 49 % of overall accuracy for crop / non-crop map and cropping systems map respectively).

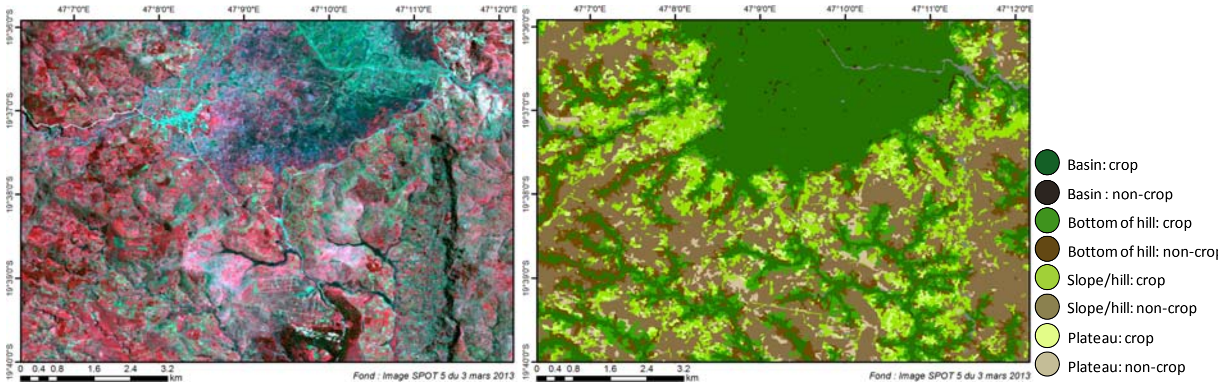



**Figure 79: Illustration of Crop / Non-crop Map (Classified by Toposequence Class) Obtained by Object Based Image Analysis**

Due to geo-referencing problems in the ground database collected for estimation of agricultural production, we were not able to obtain satisfying results when observed yields were compared to spectral indices calculated from satellite imagery.

Experience with the COVE Planning Tool

We have not used COVE, but might be interested in a training session.

Plans for Next Growing Season

For next growing season, the approach will not be modified except that RADARSAT-2 images (provided by SEAS-OI satellite receiving station) are currently acquired in one part of the study zone. We anticipate ordering the same type/quantity of EO data next year, except that we will add RADARSAT-2 imagery (6 images through the cropping season).

Publications

Vintrou, E., Lebourgeois, V., Bégué, A., Ienco, D., Teisseire, M., Todoroff, P., Ramahandry, F., 2014. Crop mapping in complex landscape by multi-source data mining and remote sensing for food security. Sentinel-2 for Science Workshop, Frascati, Italy, 20-22 May (submitted).

## 13. Mali

No report received.

## 14. Mexico

No report received.

## 15. Morocco

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

Team Member: (JECAM correspondent) Michel LE PAGE (michel.lepage@cesbio.cnes.fr)

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.

During 2013, we have been working on the following topics:

- Crop condition and stress with Remote sensing-FAO-56 method and Tseb: Phd of A Diarra began in 2013.
- Yield prediction: Phd of J. Toumi began in 2013.
- Irrigation driving: design of the Irrigation Priority Index and optimization of water delivery into an irrigated district (Belaqziz et al 2013 and 2014). Real time and life sized experiment of irrigation driving of a winter wheat field (Le Page to be published in 2014).
- Assimilation of Remote Sensing into a SVAT model (Tavernier et al, 2013).

Site Description

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

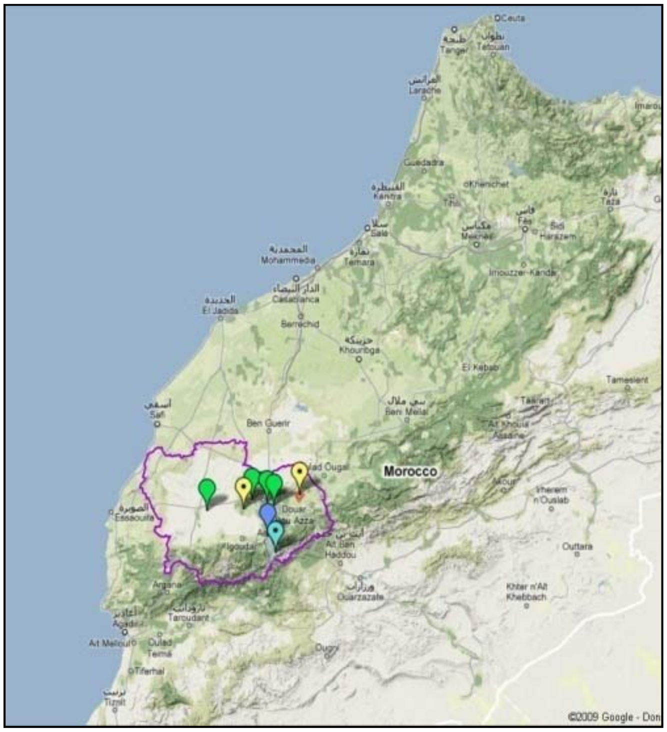



Figure 80: Location of the Tensift Watershed in Morocco

Two test sites are considered for JECAM:

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

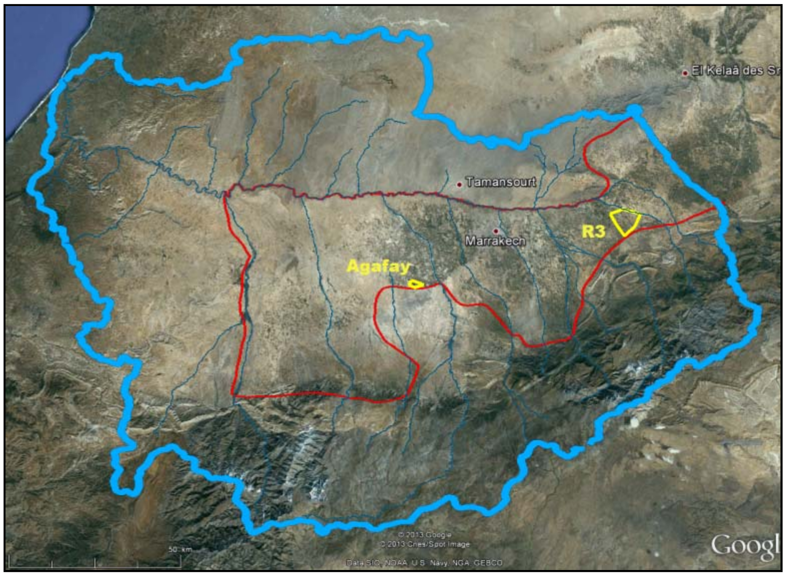



Figure 81: Location of the Haouz Plain (red) and the Two Sites (yellow) in the Tensift Watershed (blue)

Figure 82: A Wheat Field in the Haouz Plain of Marrakech, with the High Atlas Mountain in the Background

EO Data Received/Used

We have not received any EO through JECAM. The process of acquiring imagery through JECAM is unclear. The EO images used during 2013 are shown in Table 12.

| | SPOT4 (Take5) | SPOT5 | SPOT6 |
|---|---|---|---|
| Space agency or Supplier | CNES | Astrium | Astrium |
| Optical/SAR | Optical | Optical | Optical |
| Number of scenes | 20 | 12 | 4 |
| Range of dates | Feb 2013 to June 2013 | Dec 2012 to June 2013 | July 2013 |
| Spatial resolutions | 20 meters | 10 meters | 5 meters |
| Processing level | Ortho + atmospheric corrected | Ortho corrected | Ortho corrected |
| Challenges, if any, in processing and using the data | | SMAC atmospheric correction but problems with the photometer | |

Table 12: EO Images Used during 2013

<u>In situ Data</u>

See Table 13.

Table 13: In situ Data for Tensift, Morocco Site

| Group | Parameter | Instrument | Acquisition mode | Sampling | Site | Period(s) |
|---|---|---|---|---|---|---|
| Vegetation | Fraction cover, LAI, Biomass | Hemi-photo | O | 10 days | R3 | Field campaigns<br>2003, 2004, 2006,2012, 2013 |
| | | Destructive cut | | Annual | Agafay | |
| | Yield (wheat) | Survey | O | Annual | R3 | |
| Land cover And Agricultural practices | Land cover | Survey | O | Annual | R3+Agafay | 2002, 2004,2006<br>2010-… |
| | | Remote sensing | A | Annual | R3, Agafay | 2001-… |
| | Plowing | Survey | O | Agricultural Season | R3 | Since 2006 |
| | Sowing | | | | | |
| | Irrigation | Survey | O | By water turn | R3 | 2002, 2006, 2008-... |
| | | | | Drip (daily) | Agafay | 2006-... |

| Group | Parameter | Instrument | Acquisition mode | Sampling | Site | Period(s) |
|---|---|---|---|---|---|---|
| **Water and Energy Budget** | Rn | Radiometer | A | 30 min. | Intensive sites (table) | |
| | G | Flux plates | | | | |
| | H | Turbulent fluxes | | | | |
| | LE | | | | | |
| | Vertical profiles of temperature | | | | | |
| | Vertical profiles of humidity | Reflectrometry probes | | | | |
| | Surface humidity | Capacitive probes | O | 1-7days | | |
| | Water fluxes | Fluxmeter | A | 30 min. | R3 | |
| **Weather** | P | Weather station | A | 30 min. - 1hr | 15 stations (Figure 82) | |
| | U | | | | | |
| | RH | | | | | |
| | Ra | | | | | |
| | R0 | | | | | |
| | Rain | | | | | |
| | Rain | Pluviometer | O | Daily | 36 pluvios (Figure 82) | From the 60's for some pluviome-ters |
| **In Situ remote sensing measuremen ts** | Réflectance / NDVI | Cropscan | O | 15 days | R3, wheat | Field campaign |
| | Ts | Thermoradiome ter | A | 30 mns | Intensive sites (table) | |
| | Optical depth and water vapor | CIMEL photometer | A | 15 mns | Saada | 2004-... |

Collaboration

We have been solicited by the SenSyF project (http://www.sensyf.eu/) through Miss Julia Amoros, but only to use the dataset of Spot4-Take5 imagery and the land use cover we have collected.

Results

**Figure 83: Border Irrigation of a Wheat Field and Eddy-covariance Measurement in the Background**

Experience with the COVE Planning Tool

We were not aware of this tool and are interested in a short course.

Plans for Next Growing Season

We have not ordered high resolution imagery for the 2013-14 season, but are willing to renew the irrigation experiment for next year.

Publications

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**Others**

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## 16. Paraguay

No report received.

## 17. Russia

There are two Russian sites, of which one reported and the other did not.

Team Leader: Igor Savin

Team Members: Yuri Verniuk, Igor Kim, Arseny Jogolev, Viktor Nagorny.

Project Objectives

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

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

Site Description

- Location: The site is located in the south of Tula region of Russia (Plavsk district).
- Topography: The territory is characterized by slightly undulated plane, dissected by small rivers 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 sowing in September. The flowering is at the end of May, harvesting in July.
- Field size: Typical field size is near 100 hectares.
- Climate and weather: The climate is temperate with moderately cold winter (air temperature is near -10$^{o}$C) and warm summer (air temperature is near +25$^{o}$C). Amount of precipitation is near 450 mm per year.

EO Data Received/Used

We used only 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.

In situ Data

We made the following in situ observations:

- Crop type: Discrimination among crop types in georeferenced plots. Frequency: once per crop season
- Soil moisture content: Measurements in selected georeferenced representative points. Frequency: before crop sowing, in the middle of the season, after crop harvesting.
- Crop phenology: Visual determination of phenological states. Frequency: each month during the growing season.
- 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.

**Figure 84: Typical Landscape of the Russian JECAM Site**

**Figure 85: Winter Wheat Emergence**

**Figure 86: Winter Wheat Mid-season**

Figure 87: Soil Erosion in Spring after Snow Melt

Figure 88: First Field Visit after the Winter

**Figure 89: Crop Status Assessment**

Collaboration

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

Results

We have collected field data and tried to use them to elaborate the method for winter crop identification and monitoring based on MODIS and Landsat. The results are not very good. The quality of crop masks which have been built based on MODIS was low. Three fields with winter crop were not identified during the autumn period due to bad status of crop before the winter. We don't plan to modify the project objectives. We plan to test other algorithms and other satellite data in the coming year.

Experience with the COVE Planning Tool

We have not used the COVE acquisition planning tool, but we are interested in COVE training.

Plans for Next Growing Season

We plan to hold the course. We plan to increase the amount of EO data ordered; we will order additionally HYPERION data and RADARSAT-2 data (3-4 times per growing season).

Publications

We have published two peer-review papers in Russian:

1. Зверев А.Т., Савин И.Ю., Фисенко Е.В. Разработка метода оценки и прогноза повреждения сельскохозяйственных посевов по космическим снимкам // Известия высших учебных заведений. Геодезия и аэрофотосъемка. 2013. № 2. –с.81-84

2. Савин И.Ю., Зверев А.Т., Фисенко Е.В. Космический мониторинг агрофитоценозов // Современные наукоемкие технологии. 2013. № 8-1. – с.14-18

## 18. Saudi Arabia

Team Leader: Prof. Virupakshagouda Patil

Team Members: Prof. Khalid Ali Al-Gaadi, Dr. Rangaswamy Madugundu, Dr. Elkamil Hamed Mohamed Tola, Dr. Samey Abd El Gaid El Said Marey, Eng. Mohamed El-Siddig Ali Abass, Eng. Ahmed Galal Ahmed Kayad, Eng. Ahmed Mahmoud Hassan Zeyada.

Project Objectives

The original project objectives have not changed. They are:

- **Crop Identification and Crop Area Estimation**: Water scarcity, fast dwindling of finite water resources and steady increase in the demand for food are the major obstacles for attaining sustainability of agriculture in Saudi Arabia. It is becoming increasingly difficult to maintain equilibrium between the vital water security and food Security. This critical equilibrium emphasizes the Kingdom's need for strategic technologies and methods to optimize use of inputs without reducing agricultural production. The wide ranges in crop yields, climate variables and efficiencies explain the large variation in the estimated crop productivity. Mapping of agricultural fields, cropping patterns, and areas of individual crops are the key factors for the efficient management of resources. Also, mapping of agricultural crops can provide a very strong database for the identification of crop type, and to determine the annual change of cropping patterns.
- Crop condition/ stress
- Yield prediction
  - Water use (evapotranspiration) mapping
  - Crop productivity
  - Crop water productivity.

Site Description

- Location: The study was carried out on Todhia farm, which comprises 47 center pivots spread across an area of 6,967 ha, and is located between Al-Kharj and Haradh regions. This commercial farm lies within latitudes 24º10' 22.77" and 24º12' 37.25" N and within longitudes 47º56' 14.60" and 48º05'08.56" E (Figure 90). Periodic ground truth data for crop type mapping was collected for wheat, alfalfa, Rhodes grass, corn and barley crops on the day of ASTER pass during the year 2012 (February to October).

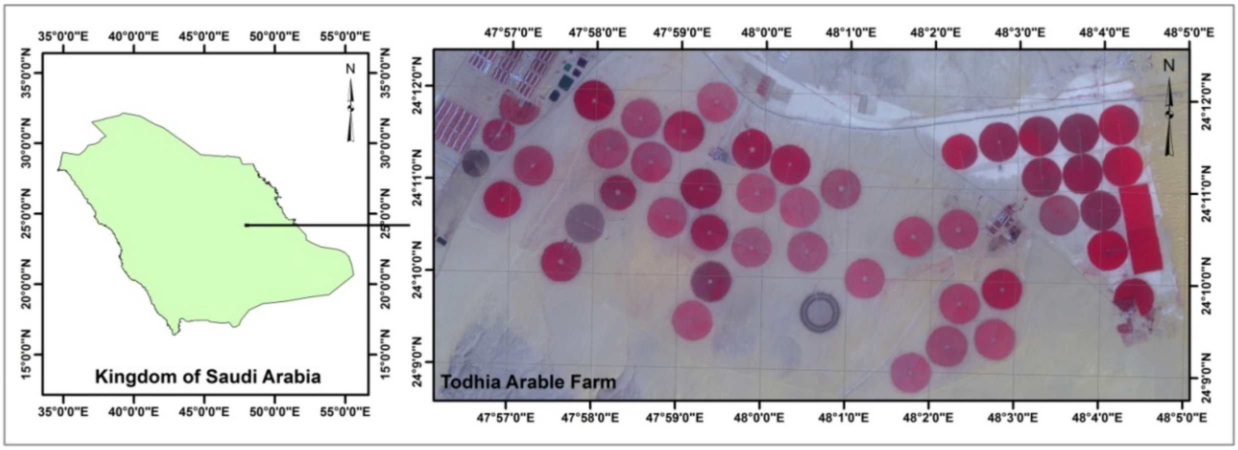



Figure 90: Location of Todhia Arable Farm in Eastern Region of Saudi Arabia

- Topography: Flat terrain with slight undulations in the desert environment. The elevation ranges from 329 m to 453 m.
- Soils: Sandy clay loam.
- Drainage class/irrigation: In natural conditions, the site is considered as very poorly drained soil drainage class.
- Crop calendar: Fields are under excessive irrigation throughout the growing season/year.
- Field size: 2500 ha.
- Climate and weather: Hot dry weather.
- Agricultural methods used: High input agriculture.
- Other Site Specifications: The irrigation infrastructure is central to the irrigation system. Variable Rate Irrigation Systems (VRIs) of Valley were deployed on two centre pivot systems for determining variable rate irrigation schedules for alfalfa, Rhodes grass, corn and barley.

EO Data Received/Used

Quickbird (Not used for this report, but will be used soon)

- Space agency or Supplier: Digital Globe
- Optical
- Number of scenes : 4 Scenes
- Range of dates: June 2012 to May 2013
- Beam modes/ incidence angles/ spatial resolutions: 4 m (multispectral) resolution
- Processing level: Level 1A
- Challenges, if any, in ordering and acquiring the data: No
- Challenges, if any, in processing and using the data: No

ASTER

- Supplier: Japan Space Systems
- Optical

- Mode: ASTL 1B

LANDSAT

- Supplier: USGS
- Optical

In situ Data

i. **Normalized Difference Vegetation Index** (NDVI): NDVI(G) was measured in the field on the dates of satellite pass, using the Crop Circle (Model: ACS-470) of Holland Scientific, USA. It was calibrated by configuring with a 670-nm filter in channel 1, an NIR filter in channel 2 and a 550-nm filter in channel 3 of the sensor socket for measuring NDVI(G). Map mode measurement with two samples per second was used for field data collection. To determine field data coordinates, an Omnistar GPS receiver (Model 9200-G2) was connected to the Crop Circle at a baud rate of 9600. Field data measurements were recorded by the crop circle at 1m above the canopy.
ii. **Leaf area index** (LAI): LAI measurements on the ground (LAI(G)) were made on the dates of satellite pass using the Plant Canopy Analyzer (Model: PCA – 2200) of Licor Biosciences, USA. At each measurement location, one above canopy and five below canopy readings were recorded to compute a single LAI value. Above and below canopy measurements were made with a ‘‘fisheye’’ optical sensor with 148º angle of view. Respective geo-locations were collected using a handheld Trimble GPS receiver (Model-Geo XH 600). An azimuth mask of 180º view cap was used on the PCA-2200 sensor during data collection to block the bright sky, and eliminating the shadowing effect of instrument operator.
iii. **Spectral Reflectance**: To detect the spectral differences between crop responses to imposed treatments on alfalfa and wheat at both farms, the hyperspectral spectroradiometer “FieldSpec-3” by ASD (Analytical Spectral Devices) was used to collect canopy reflectance data. The FieldSpec-3 spectroradiometer has a spectral range of 350 nm to 2500 nm with a field of view of 25 degrees. At the initial stages of crop, in-vitro measurements using “direct contact probe” were made in the lab by collecting geo-referenced samples. At the later stages, in situ measurements were taken by holding the spectroradiometer at a height of 1.5 meters above the canopy with the viewing angle of 25 degrees.
iv. **Crop canopy temperature** (ºC): Canopy temperature measurements were made using a hand-held infrared thermometer of Spectrum Technologies, Plainfield, IL, USA. The mean of three measurements was recorded at the centre of the plot and approximately 0.5 m above the canopy with a 30 angle of view, detecting radiation in the 8–14 µm wave bands. Measurements were recorded between 12:00 to 16:00 hours on cloudless, bright days.

Figure 91: Wheat Crop at Different Growth Stages

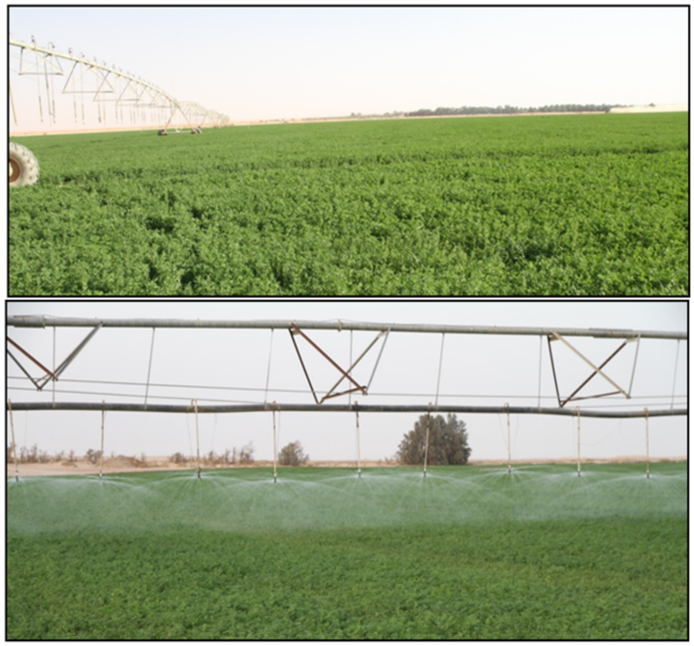


Figure 92: Alfalfa Field under Centre Pivot Irrigation System

Figure 93: Team Collecting Wheat Growth Data

Collaboration

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

Results

The results are very positive, and we have achieved about 90% of the project objectives. The approach can be called 'best practice'.

**Crop identification and Crop Area Estimation**: A research study was conducted to explore the potential of suitable cropping patterns based on water demand so as to enhance water and food security in Saudi Arabia. The results of that study showed a great potential for enhancing food and water security in Saudi Arabia through producing different crops in regions where their production is high. In light of the above background, the main goal of this study was to develop crop type maps using high spatial resolution ASTER satellite imagery, for wheat, alfalfa, corn and Rhodes grass crops cultivated under pivot sprinkler irrigated systems in a commercial farm located in the eastern region of Saudi Arabia.

Time series of ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) images (ASTL 1B), pertaining to Path 164 and 165 were procured from Japan Space Systems and used in this study to generate crop type maps.

*Spectral reflectance calculation*: The acquired images were geo-referenced using an image to image correction method. Landsat ETM+ images were considered a master image of the UTM geo-coordinate system with the WGS84 datum. Then geo-corrected images were radiometrically calibrated using pre-calibrated coefficients and converted to reflectance.

*Crop type mapping*: Classification And Regression Tree (CART) analysis was used for the analysis of the pre-processed ASTER images for crop spectral signature identification. CART analysis was done by using Erdas Imagine (Ver. 2010) software. It involved Segmentation (object creation), Training data preparation, Decision rule preparation, Classification, Classification check and pruning/manual editing. Decision rules were prepared by using the spectral profile of crops. The accuracy assessment for crop type classes was done by referring to the actual cropping pattern adopted on the farm.

Crop type maps were developed through CART analyses performed on 15 images acquired from February 2012 to May 2013. The minimum accuracy value of 58.1% was observed for the image acquired on February 13, 2013, while the maximum accuracy value of 96.2% was observed for the image acquired on October 7, 2012. Taking into consideration the Kappa coefficient, it was observed that the crop signature identification for 80% of the acquired images was performed within the substantial agreement range (Kappa Coefficient = 0.61-0.80). The overall accuracy of crop signature identification obtained in this study (76.7%), was found to be within an acceptable range compared to previous studies. On the average, the results indicated that the overall accuracy of crop signature identification performed for alfalfa, barley, corn, Rhodes grass, and wheat crops was 78.1, 81.3, and 61.8, 71.1, and 57.1%, respectively. Based on the results of this study and previous studies, it can be inferred that the key parameters to distinguish between crops are the number and timing of image acquisition, spatial resolution of images and crop ecology.

**Crop Condition / Stress**

*Crop Water Stress Index (CWSI):* In this study, a multinode wireless sensor network (WSN) system was mounted onto a centre pivot outfitted with a commercial variable rate irrigation (VRI) system. Data from the WSN was used to develop Crop Water Stress Index (CWSI) maps. An integrated crop water stress index (CWSI) was used as a threshold to schedule irrigations. This was done in both 2012 and 2013. In 2013, the wheat crop experienced moisture stress during the reproductive stage, which was reflected in higher CWSI values. The mean CWSI increased gradually from 0.191 in February to 0.201 in March and to 0.395 in May 2013. See Figure 94.

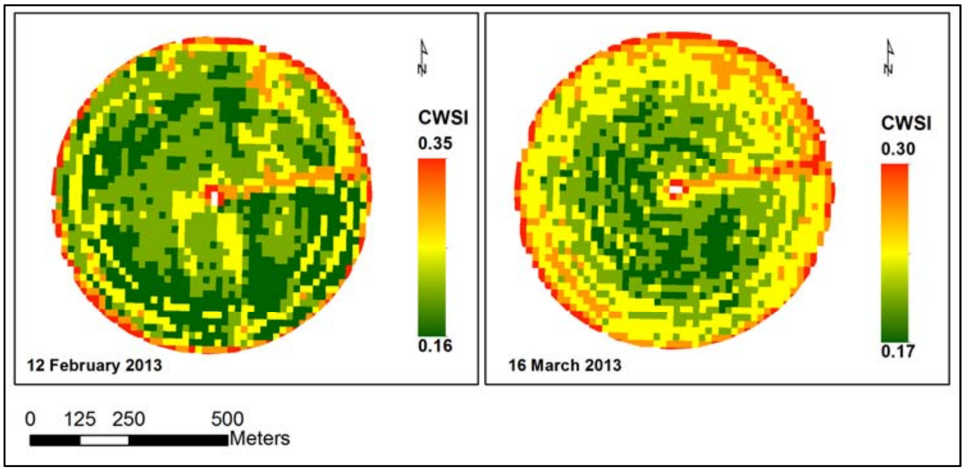
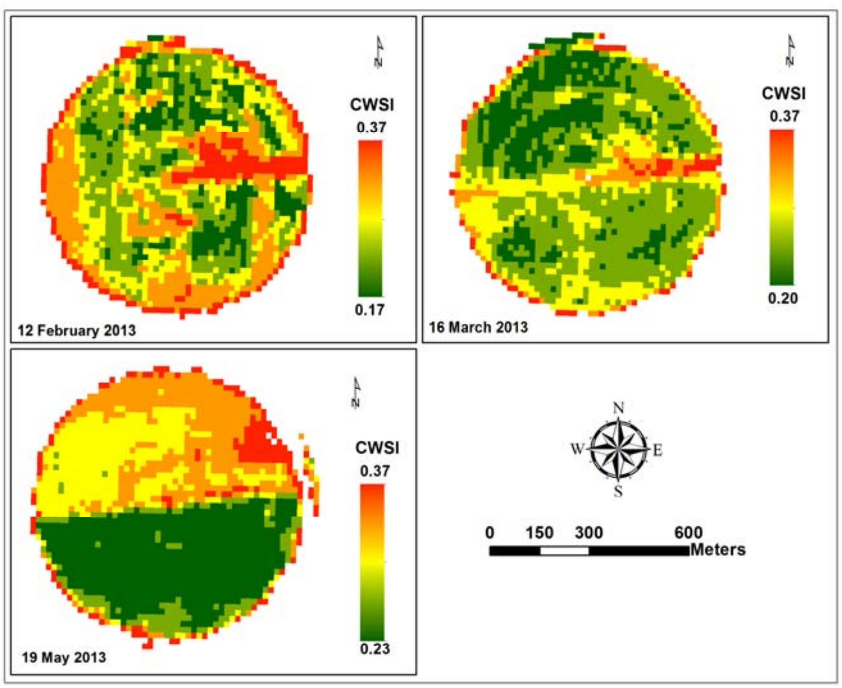



Figure 94: Crop Water Stress Index Map of Wheat Crop for the Season 2013

CWSI maps were also done for the alfalfa crop in 2012 and 2013. The observed variability in CWSI indicated the possibility of moderating the effect of high temperature during summer months (June to September) by adopting optimum irrigation practices. See Figure 95.




Crop Water Stress Index (CWSI) Maps of Alfalfa crop
for the Season 2013

Figure 95: Crop Water Stress Index Map of Alfalfa Crop (2013 Season)

**Yield Prediction**

Time series satellite images of ASTER (Advanced Space borne Thermal Emission and Reflection Radiometer) were procured to generate crop type, Evapotranspiration, crop productivity and water productivity maps. Periodic ground truth data of bio-physical parameters were recorded for four crops (wheat, alfalfa, Rhodes grass and corn). The acquired images were radiometrically corrected and geo-rectified. Classification And Regression Tree (CART) and Spectral Mixture Analysis (SMA) methods were used for crop spectral signature identification. Accuracy assessment for crop type classes was done using the Accuracy Assessment module of Erdas Imagine version 2010. Crop water productivity mapping (WPM) was achieved in four steps namely: Crop type mapping; crop productivity mapping (CPM); Water use (evapotranspiration) mapping (WUM) ; and Water productivity mapping (WPM). Field measured crop yields were related to spectral indices (NDVI, LAI) and wavebands to develop crop yield models and the best fit yield models were extrapolated to larger areas using remotely sensed data to obtain CPM. Water use map (WUM) was prepared by using crop evapotranspiration (ET) fractions obtained from ASTER thermal data by applying the Surface Energy Balance Algorithm for Land (SEBAL) model. WPM was generated for the whole farm by dividing the crop productivity map (CPM) by the water use map (WUM). The SEBAL was applied on additional ASTER images acquired during the 2012 (November 15) and 2013 (February 13, March 16 and May 19) cropping seasons to derive ET for assessing crop water productivity and irrigation performance. Crop productivity was estimated using NDVI-based crop yield models developed for the ear-head emergence stage of wheat and barley, the flag leaf stage in corn and the flowering stage in alfalfa and Rhodes grass.

*Water Use (ET) Mapping*

ET values were estimated through the analysis of ASTER images using the SEBAL model. The major ground-based measurements used for the estimation of ET values were the NDVI and the LAI.

The accuracy of ASTER predicted Evapotranspiration results using the SEBAL model was tested against the weather-station recorded ET data. The distribution pattern of ASTER predicted and weather-station recorded ET values is illustrated in Figure 96. Both the values followed a similar pattern throughout the study period. The correlation between the ASTER predicted and weather-station recorded ET was further investigated by regression analysis. The results showed a strong linear relationship between the predicted and the weather-station recorded ET with $R^2$ of 0.78 (Figure 97). The mean deviation of the ASTER predicted ET from the weather-station recorded ET was found to be 10.49%. The ASTER predicted ET (Figure 98) was then used to assess the performance of the implemented irrigation schedules for all the test crops. The mean values of both ASTER predicted ET and the actual quantity of irrigation water applied to biennial and seasonal crops are presented in Figure 99 and Figure 100, respectively.

During 2011-2012 season, the quantity of irrigation water applied to alfalfa, Rhodes grass and wheat crops were lower than the required quantity as per the predicted ET. However, during 2012-2013 season, alfalfa, wheat and barley crops were irrigated with more than the required quantity of water.

On the other hand, corn received higher than the required quantity of water during 2011-2012 and lower than the required quantity during 2012-2013.

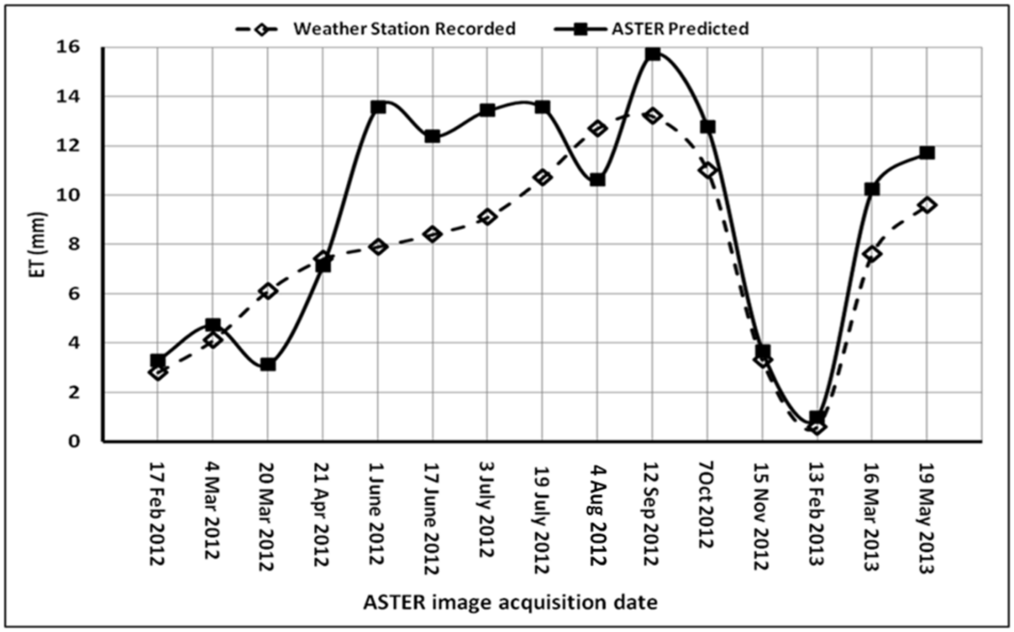



**Figure 96: Temporal Variation in ASTER Predicted and Weather-station Recorded ET**

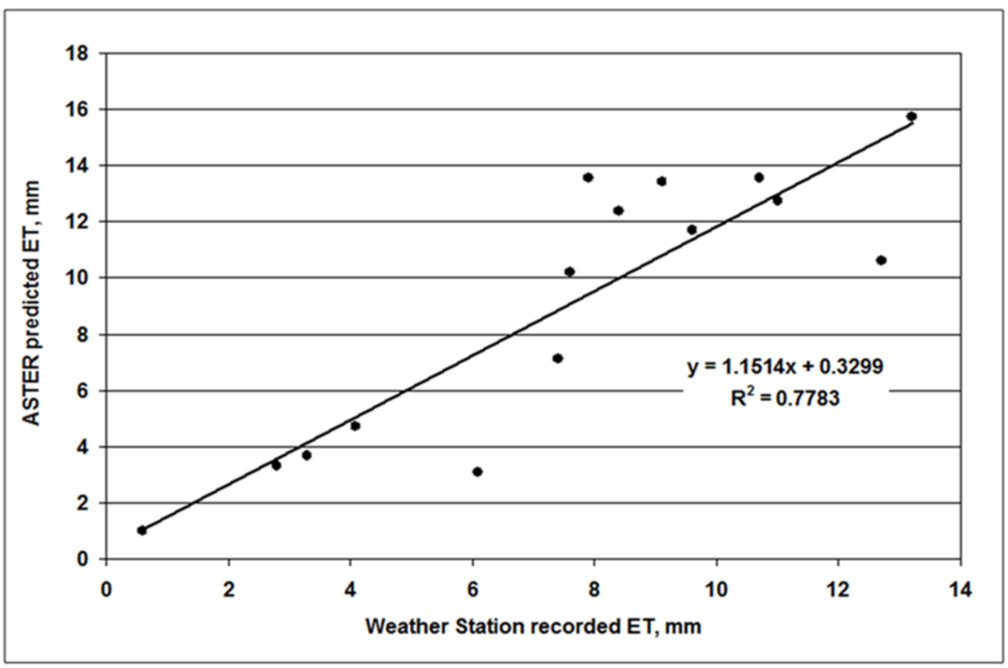



**Figure 97: Regression between ASTER Predicted and Weather-station Recorded ET**

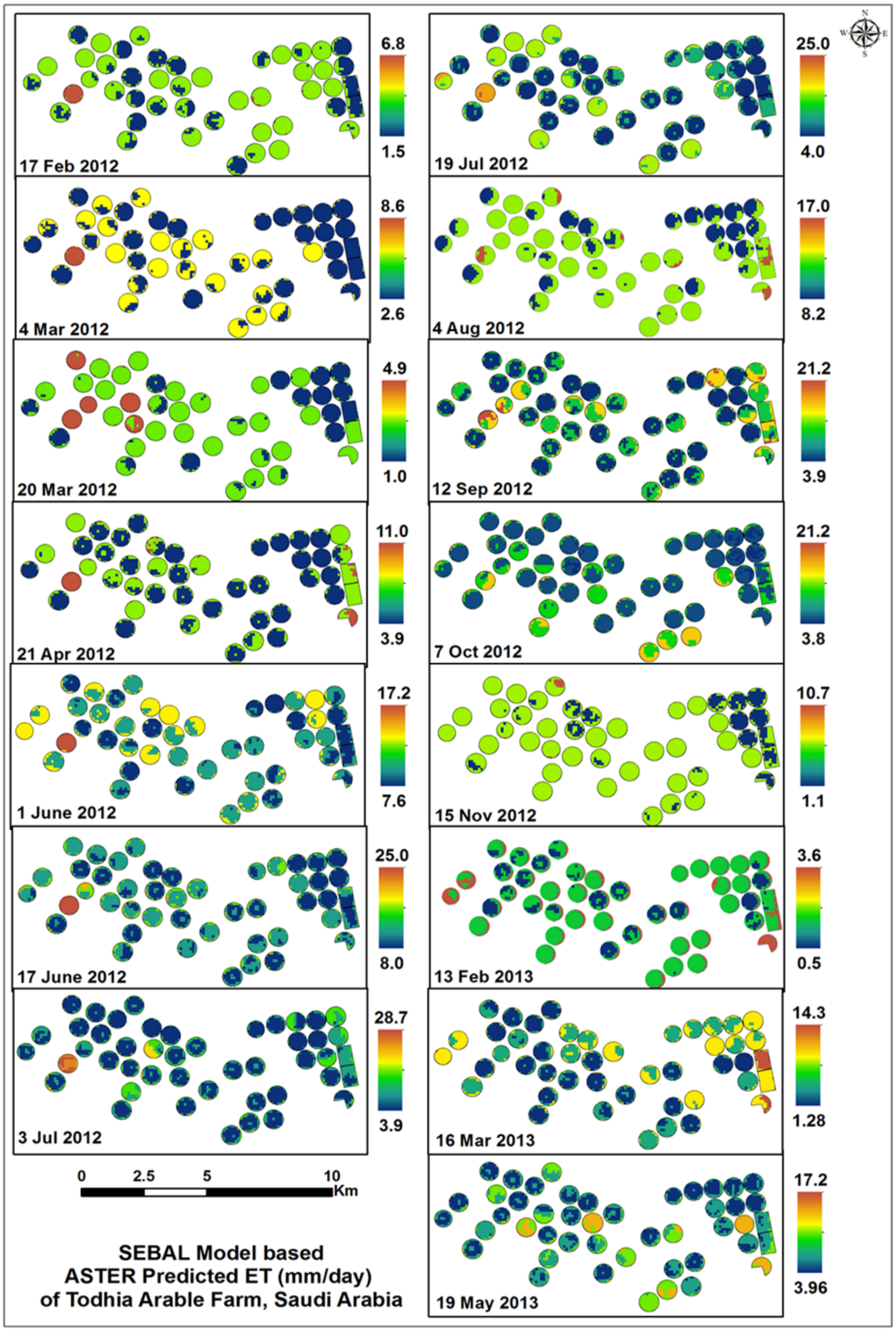



Figure 98: SEBAL Model based ASTER Predicted ET (mm/day) for the Study Site

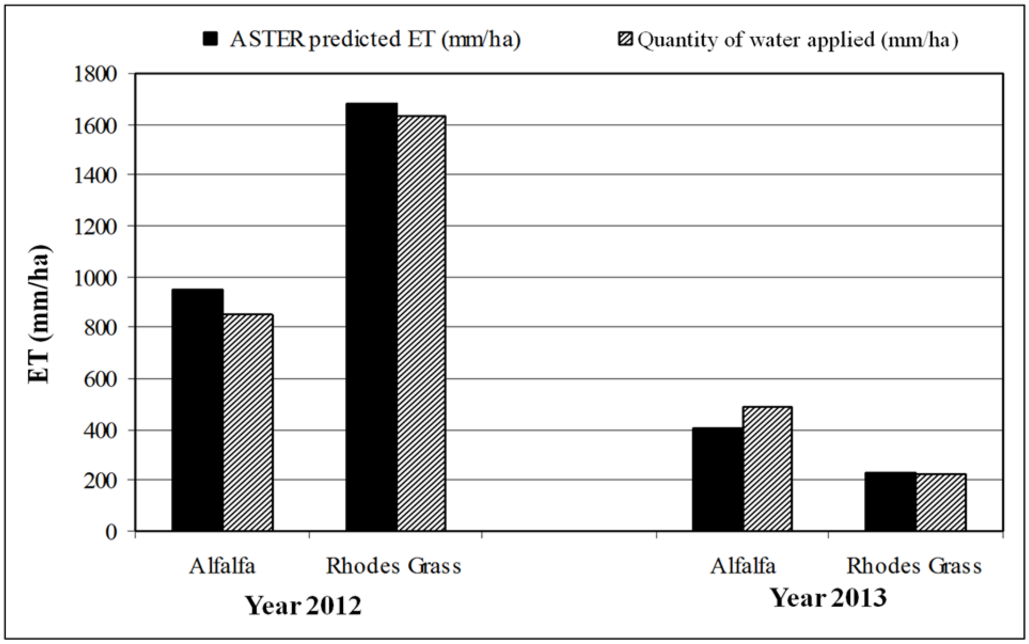



Figure 99: ASTER Predicted ET and the Quantity of Water Applied to Biennial Crops

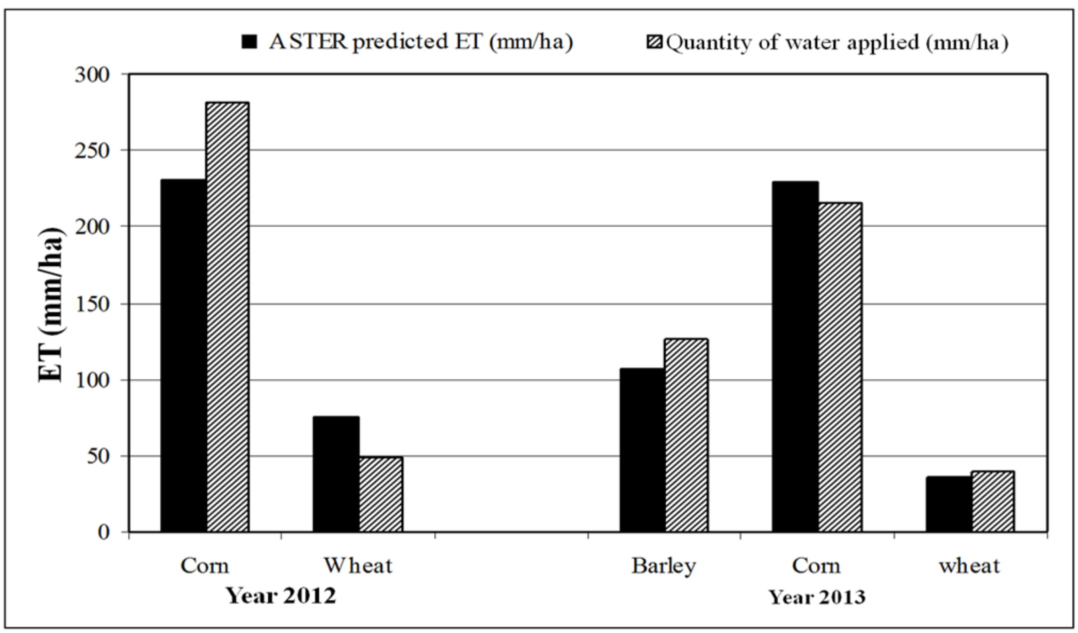



Figure 100: ASTER Predicted ET and the Quantity of Water Applied to Seasonal Crops

The deviation of predicted ET from the actual quantity of water applied to all the crops was determined in terms of overall mean error (Figure 101). The results indicated that the accuracy of ET prediction was higher for alfalfa, corn, and Rhodes grass crops, while the accuracy of ET prediction was lower for wheat and barley.

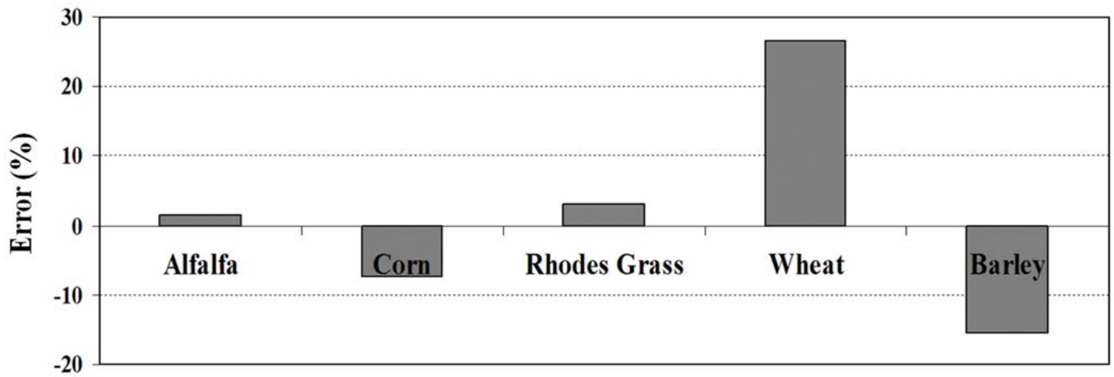



**Figure 101: Accuracy Assessment of ET Prediction vs. Actual Quantity of Water Applied**

*Crop productivity*

Crop yield is a very important end-of-season observation which integrates the cumulative effect of weather and management practices over the entire crop growing season. The remote sensing approach provides yield assessment and possible variation across fields. Crop yield data were collected from the records of the Todhia Arable Farm and correlated with the respective field's NDVI derived from ASTER images. The best relationship was obtained when the crops were in mid-season (growth stage). The best fit NDVI based yield models which were used for yield prediction for all the crops.

The relations between recorded yields against ASTER NDVI derived yields were assessed for all the crops and images, and the best fit models were used for crop yield predictions. In seasonal crops, the best response was observed on the Julian days 43 (2013), 169 (2012) and 64 (2012) for the barley, corn and wheat crops respectively, when the crops were at peak growth stage. In biennial crops (alfalfa and Rhodes grass), which have a growth period of 30 to 45 days between two harvests, the best response was observed on the Julian day 201 and 281 of the year 2012 for Rhodes grass and alfalfa, respectively.

The results of the predicted and actual ET/crop water use, crop yield and crop water productivity for both seasonal and biennial crops are presented in Table 14. It was observed that crop yields varied significantly at both temporal and spatial scales. For biennial crops (alfalfa and Rhodes grass), the 2013 figures apply up to May 19.

| Crop | Year/ Season | Predicted | | | Actual | | |
|---|---|---|---|---|---|---|---|
| | | Crop Yield (kg/ha) | ET ($m^3$/ha) | WP (kg/$m^3$) | Crop Yield (kg/ha) | Water use ($m^3$/ha) | WP (kg/$m^3$) |
| Corn | 2012-Season 1 | 13510(±3020) | 9050 | 1.49(± 0.14) | 10930(±1940) | 9892 | 1.11(± 0.09) |
| | 2012-Season 2 | 14060(±2710) | 14013 | 1.00(± 0.12) | 11190(±2090) | 18242 | 0.61(± 0.08) |
| | 2013-Season 1 | 12690(±2980) | 22962 | 0.55(± 0.16) | 10900(±2710) | 21580 | 0.51(± 0.12) |
| Wheat | 2012-Season 1 | 6000(±520) | 7517 | 0.80(± 0.02) | 5530(±680) | 4831 | 1.15(± 0.03) |
| | 2013-Season 1 | 7370(±380) | 3667 | 2.01(± 0.03) | 6510(±620) | 3982 | 1.63(± 0.02) |
| Barley | 2012-Season 2 | 7210(±420) | 10648 | 0.68(± 0.04) | 6910(±1120) | 12594 | 0.55(± 0.02) |
| Alfalfa | 2012 | 42450(±6230) | 94890 | 0.46(± 0.04) | 35100(±5840) | 84852 | 0.41(± 0.04) |
| | 2013 | 15530(±3160) | 40566 | 0.38(± 0.01) | 21000(±2720) | 48641 | 0.43(± 0.02) |
| Rhodes grass | 2012 | 58210(±10430) | 168224 | 0.36(± 0.03) | 60390(±5440) | 163294 | 0.37(± 0.04) |
| | 2013 | 24580(±4220) | 23022 | 1.07(± 0.07) | 15140(±3220) | 22053 | 0.69(± 0.02) |

**Table 14: Predicted and Actual Crop Yield (Kg/Ha), ET/Water Use ($M^3$/Ha) and Water Productivity (Kg/$M^3$)**

*Crop Water Productivity*

The prediction of crop water productivity (WP) for 2013 is shown in Figure 102, and was very accurate for the alfalfa and corn crops. The results of this study showed that spatial distribution of ET could be predicted with an overall accuracy of 90%. The obtained results were better than expected, as most remote sensing techniques used for estimating evaporation (E) have accuracies of 70-85% compared with ground based measurements.

On an annual/seasonal basis, deviation of about 19% was observed between ASTER predicted ET and weather station recorded ET. When focusing on a finer timescale, the model resulted in a large deviation (–49% to +63%). The model over-estimated for the ASTER images of 1 June 2012 (63%), 17 June 2012 (47%), 3 July (47%), 13 February (63%) and 16 March 2013 (34%); while it under-estimated for 20 March 2012 (49%), 21 April 2012 (4%) and 4 August 2012 (16%). This might be due to gradation of individual pixels' evaporative response which reflects upon the diversity of crops, growth stages, and gradients in soil moisture conditions across the fields.

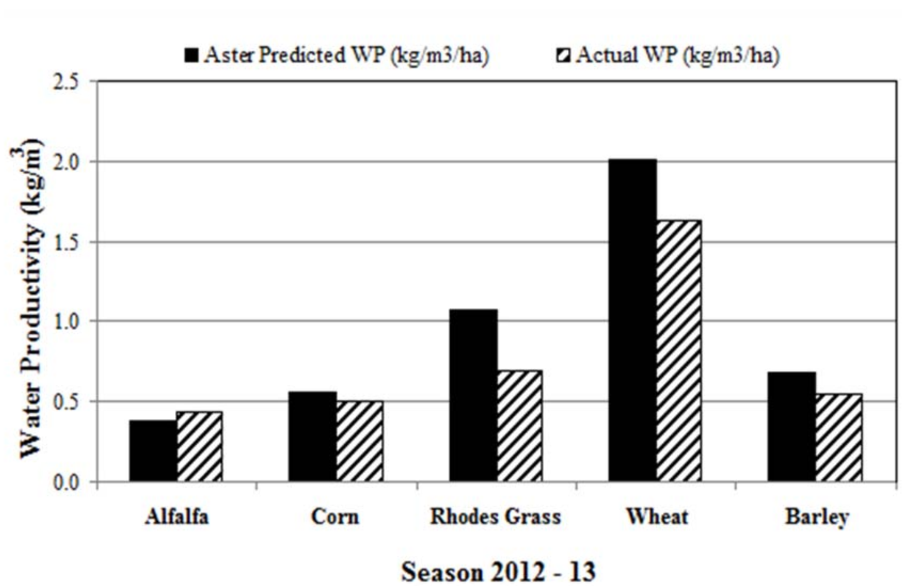



**Figure 102: ASTER Predicted versus Actual Crop Water Productivity for the Year 2013**

As indicated by the regression models, the yield of all the crops showed a visible and significant trend across a range of NDVI values. The $R^2$ values were moderate and ranged between 0.5211 (Rhodes grass) and 0.6214 (corn). This research was supported by previous studies of the wheat crop where the lowest crop yield prediction accuracy was obtained, and accurate wheat yield predictions were possible using only one image, provided the image was acquired towards the middle of the growing season when most wheat crop canopies were fully developed.

The water productivity of alfalfa observed in this study (0.38 – 0.43 kg/m$^3$) was in agreement with the values reported previously (0.18 – 0.60 kg/m$^3$). The cuttings made in the cooler months of January – March, November 2012, and February 2013 recorded higher WP (0.63 – 0.81 kg/m$^3$) than the cuttings made in the hotter months (i.e. 0.23 – 0.40). It is evident that alfalfa, being a C3 plant, is adapted to cuttings made in the cooler season, but loses its efficiency during the summer season. This large amount of variation may be attributed to the influence of both spatial and seasonal climatic variations of ET, alfalfa productivity and water use efficiency. Similar results were reported when comparisons were made between yield and ET for individual cuts, where the relationship varied across the growing season changed depending on cutting time. Better correlation between ASTER predicted and field recorded WP for the whole farm was observed with the $R^2$ of 0.7967 ($p<0.01$) as shown in Figure 103. Meanwhile, among the three seasonal crops, there were considerable differences between predicted and actual WP in wheat and barley (C3 plants) but not in corn (C4 plant). In the case of wheat, the ASTER predicted WP ($kg/m^3$) values ranged from 0.80 to 2.01. For corn, the ASTER predicted WP was between 0.55 and 1.49 $kg/m^3$. WP values of 0.44 – 1.07 $kg/m^3$ were observed in Rhodes grass. In the case of barley, the ASTER Predicted and actual WP values were 0.68 (± 0.04) and 0.55 (± 0.02) $kg/m^3$, respectively.

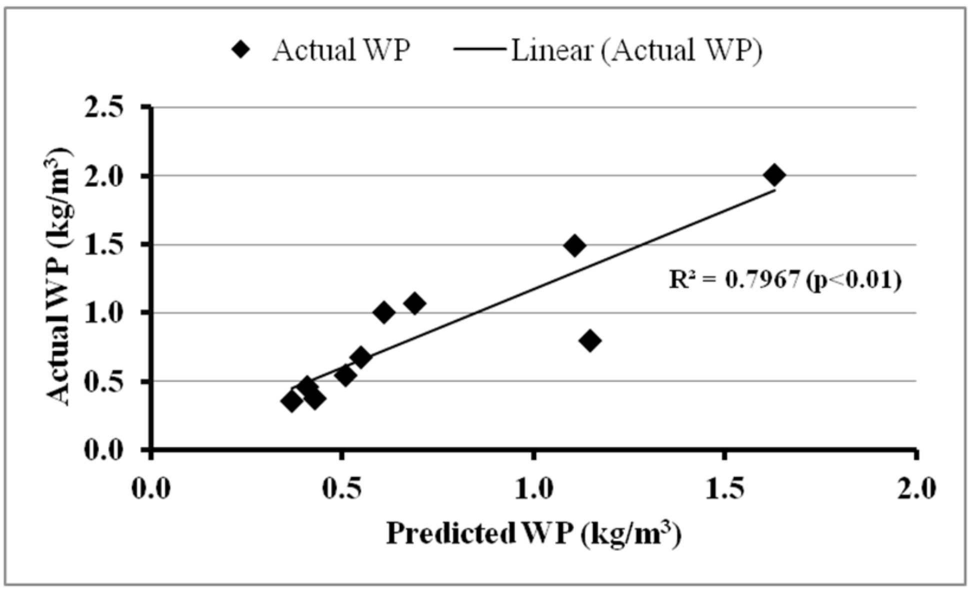



**Figure 103: Regression between ASTER Predicted versus Actual Crop Water Productivity**

This study concludes that the SEBAL algorithm using ASTER images provided realistic estimates of ET, crop productivity and water productivity for the crops (corn, wheat, barley, Rhodes grass and alfalfa) cultivated under a centre pivot irrigation system in Saudi Arabia. There was close agreement between the predicted and actual values of crop productivity and water productivity. However, the predicted daily ET values deviated greatly with the meteorological data, especially in the summer months (June to September), an issue that needs further empirical research.

The SEBAL model can be applied to ASTER/Landsat-8 satellite imagery to obtain realistic estimates of ET, crop productivity and water productivity for the crops cultivated in Saudi Arabia.

The actual ET data should be collected for different agricultural regions using Eddy Covariance Systems to determine the crop water requirements accurately for efficient irrigation water management.

Experience with the COVE Planning Tool

We have not used COVE yet, but we will use it in future. We are interested in a short training course.

Plans for Next Growing Season

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

Publications

1. V.C. Patil, K.A. Al-Gaadi, R. Madugundu, E.Tola, S.A. Marey, A. Al-Dosari, C.M. Biradar and P.H. Gowda. 2014. Assessing crop water productivity in desert farming System of Saudi Arabia, Journal of Special Topics in Applied Earth Observations and Remote Sensing (Under revision).

**International Conference**

1. V.C. Patil, K.A. Al-Gaadi, M. Rangaswamy, E. Tola, and S. Marey. 2013. Crop Water Productivity Mapping Using Aster Imagery For Irrigated Fields Of Al-Kharj Region In Eastern Province Of Saudi Arabia. IEEE International Geoscience and Remote Sensing Symposium (IGARSS 2013) July 21 – 26, 2013. Melbourne, Australia.

## 19. South Africa

Team Leader and Members:

| | | |
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Project Objectives

The original project objectives have not changed. They are:

- Crop identification and Crop Area Estimation
- Crop condition/ stress
- Soil moisture
- Yield prediction and forecasting

Site Description

See www.JECAM.org for the site description.

EO Data Received/Used

For multi-temporal monitoring through earth observation data over the 2 sites, the archived and operational datasets, available for MODIS TERRA and SPOT VEGETATION are utilized. The following shows some of the recent earth observation data, for which the entire time series have been made available, for the area (including the 2 sub sites sites).

SPOT VEG decadal NDVI

- Space agency or Supplier: Devcocast
- Optical
- Number of scenes: 1 per Africa
- Range of dates: Every 10days
- Spatial resolution: 1000 m
- Processing level: NDVI completed product

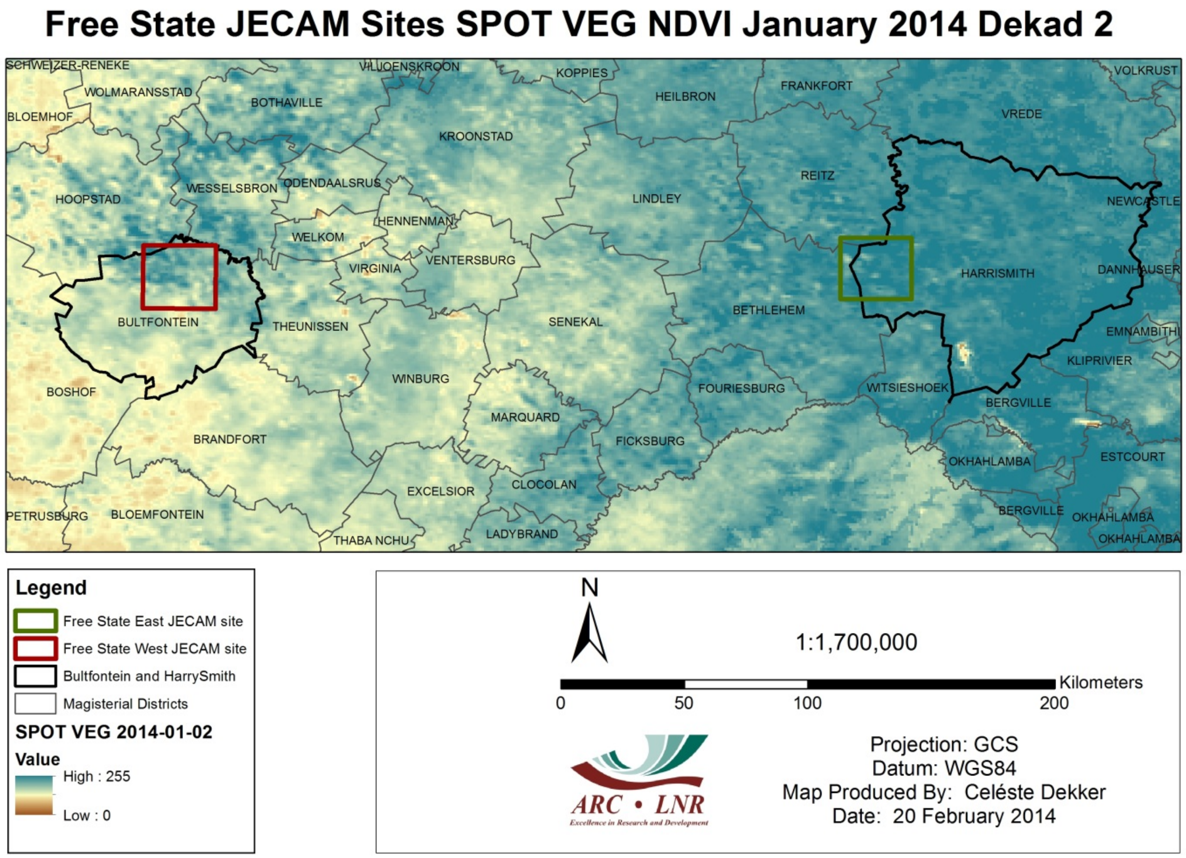



**Figure 104: Spot Veg NDVI for January 2014**

MODIS 16-day NDVI

- Space agency or Supplier: Nasa Reverb-Echo
- Optical
- Number of scenes: 4 per SA.
- Range of dates: Monthly, and every 16 days
- Spatial resolution: 250-I000 m
- Processing level: Q1

SPOT4 take 5 & RapidEye Imagery

- Space agency or Supplier: CNES, USGS
- Optical/SAR: OPTICAL
- Spot 4 data covering Bothaville region in the Free State. In addition within the Spot 4 scene footprint there are RapidEye scenes acquired during this same time frame.

- Number of scenes: 11 cloud free Rapid Eye scenes (see Figure 105 for scene distribution), and 17 primarily cloud free Spot 4 scenes,
- Range of dates: Feb 2013-June 2013
- Processing level: 3A for RapidEye and 2A for Spot 4
- Challenges in ordering and acquiring the data. None
- Challenges in processing and using the data. We are awaiting the newly processed Spot 4 scenes for download.

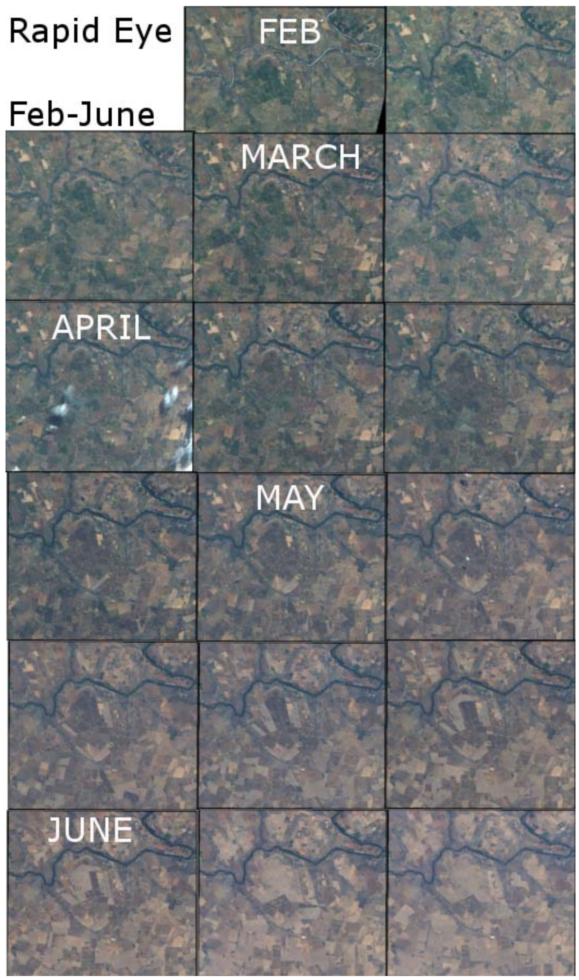



**Figure 105: RapidEye scenes for JECAM Site – Free State**

SPOT 5

- Space agency or Supplier - South African National Space Agency (SANSA)
- Optical
- Number of scenes - Spot5: 54 x Multispectral (10m) & 54 x PanMerge (2.5m)
- Range of dates -
- Spatial resolutions - Multispectral (10m) & PanMerge (2.5m)
- Processing level - Level 3 - Ortho-rectified

- Challenges in ordering and acquiring the data - No
- Challenges in processing and using the data – No.

**Figure 106: Spot Image with Field Boundaries – an Area in the Free State**

Landsat 7

A few Landsat 7 scenes were used to assist in the identification and location of centre pivot irrigation structures for field boundary updates, which were mapped from the Spot 5 imagery.

Landsat 8-OLI

3 Landsat scenes from April-June 2013 were used in crop type identification.

<u>In situ Data</u>

Weather station data from the automatic weather station network of the ARC-ISCW have been collected at/near each of the 2 sub-sites. Data were collected for the following elements:

- Temperature
- Humidity
- Rainfall
- Solar Radiation
- Wind
- Potential evapotranspiration (Derived).

The stations are Bultfontein (western site) and Harrismith (eastern site).

Figure 107: Automatic Weather Station near Bultfontein

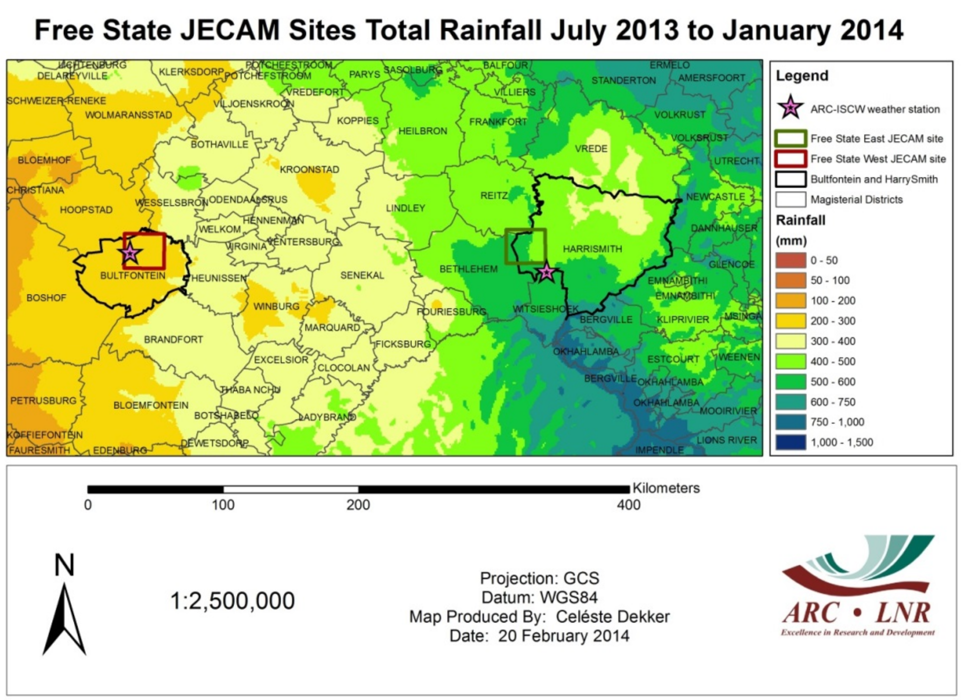



Figure 108: Total Rainfall: July 2013 to January 2014

Rainfall GIS data available for the sites are shown in Figure 108. The time series of available data from the ARC-ISCW weather stations close to the sites are also shown for the current summer rainfall season, starting in July 2013, for Bultfontein in Figure 109. A similar time series is available for Harrowsmith.

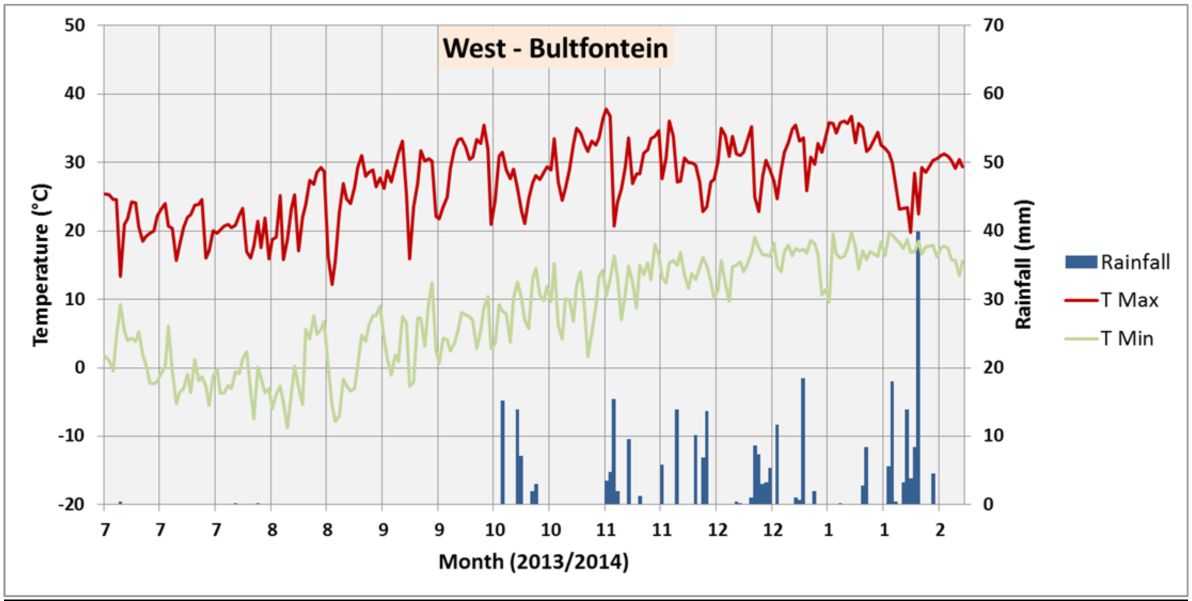



Figure 109: Time Series Graphs of Climate Parameters (July 2013- Feb 2014) (Bultfontein)

Collaboration

Our collaborators are shown in Table 15.

| Collaboration Partner Contact Person | Subject | Status |
|---|---|---|
| Dr. Fernando Camacho de Coca<br>Managing director: Earth Observation Laboratory (EOLAB)<br>http://www.eolab.es<br><br>Pr. Pierre Defourny<br>Earth and Life Institute - Environmental Sciences<br>Universitécatholique de Louvain<br>Belgium | Free State JECAM site offered as study site for IMAGINES project | Networking on going |
| Dr Benjamin Koetz,<br>European Space Agency, ESA-ESRIN<br>Exploitation & Services Division, Project Section<br>email: Benjamin.Koetz@esa.int | Collaboration requested to use JECAM site in ESA Agricultural project | Networking on going |

Table 15: Collaborators with South African JECAM Site

Results

**Crop identification and Crop Area Estimation**

Crop areas for the main summer and winter grain crops are estimated annually using the PICES (Producer Independent Crop Estimation System). A crop type map based on multi-temporal imagery (Landsat) is produced annually for the site as well. This is part of an operational system for crop area and yield estimation in South Africa. The system is based on a stratified point frame where the selected point sample is observed by observers based in very light aircraft. Figure 110 is an example of the point sample for an area in the north western Free State Province. The colours denote the crop type at the point.

See: http://www.youtube.com/watch?v=rthWOBaBhMI

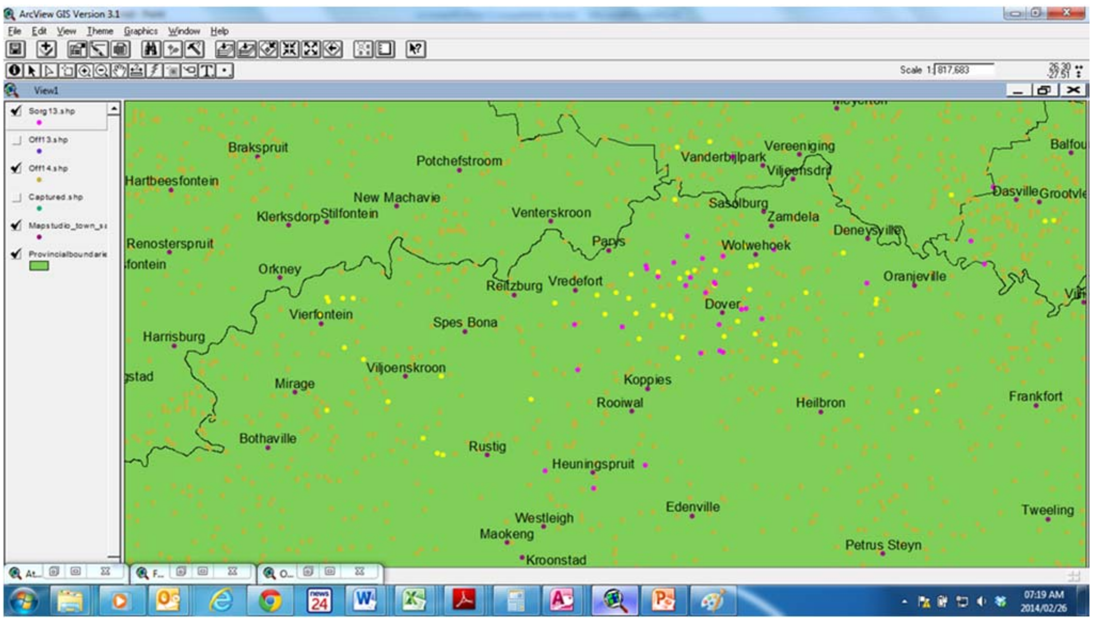



Figure 110: Typical PICES Sample Selection in the North Western Free State Province

Currently analysis is still underway for using Spot 4 take 5 and RapidEye data for Crop Type mapping, Acreage estimation and testing for its effectiveness in yield modelling. The Spot 4 Take 5 data and Landsat data in conjunction with the PICES data have been used to investigate the feasibility of Crop Type mapping with time series analysis. Figure 111 below shows some preliminary findings of how the time series RapidEye imagery can be used to discriminate crops. Similar results have been obtained with Landsat-8.

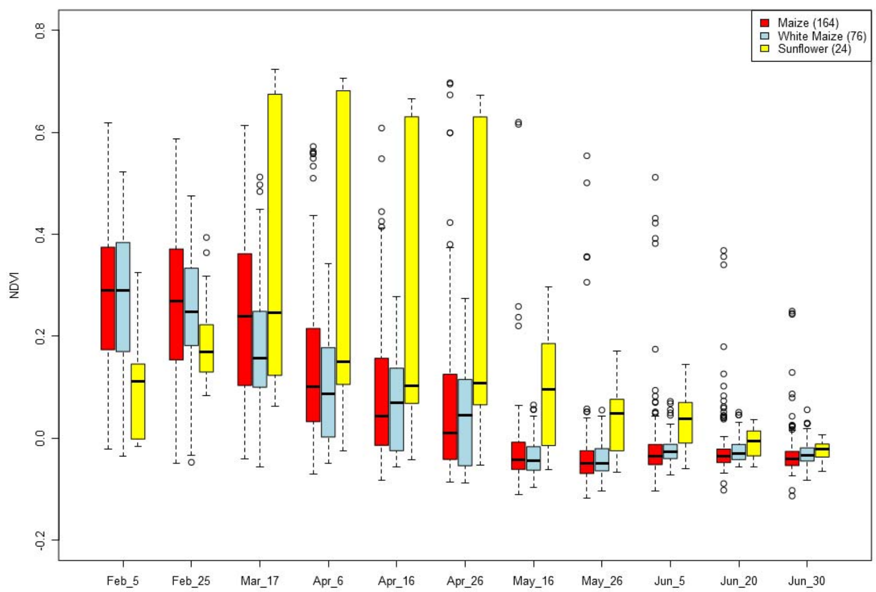



**Figure 111: Crop Type Discrimination using Time Series Imagery (Preliminary Results with RapidEye)**

**Crop Condition/Stress**

The monthly UMLINDI bulletin is produced from climate data and course resolution remote sensing imagery (MODIS, Spot Vegetation) and covers the JECAM site. It reflects the past month's growing conditions, sources of stress and current crop condition.

(See: http://www.arc.agric.za/Pages/Home.aspx ).

**Soil Moisture**

Soil moisture is modelled at 3-hourly time-steps; it is updated monthly for South Africa and includes the JECAM site. This is semi operational and work is currently underway to fully operationalise this monitoring (see http://sahg.ukzn.ac.za/soil_moisture for example results - operational outputs will be available from mid-year 2014).

The soil moisture status is reflected in the ARC-ISCW UMLINDI Bulletin. The data reflects the Soil Saturation Index (SSI), which is defined as the percentage saturation of the soil store in the TOPKAPI hydrological model. The model uses satellite derived rainfall (TRMM 3B42RT) and incoming solar radiation (LSA-SAF DSSF) in addition to inputs from the SA Weather Service's NWP model (Unified model). The modelling is intended to represent the mean soil moisture state in the root zone.

Further information from: sinclaird@ukzn.ac.za

**Yield Prediction and Forecasting**

Time series data for the site are available. Figure 112 shows the time series of NDVIs from MODIS, as seasonal curves, for the summers of 2008/09 – 2013/14, with 2013/14 terminating in January 2014, for the western sub-site, at Bultfontein. Also indicated are the estimated historical maize yields per season, made available by the South African Crop Estimated Committee.

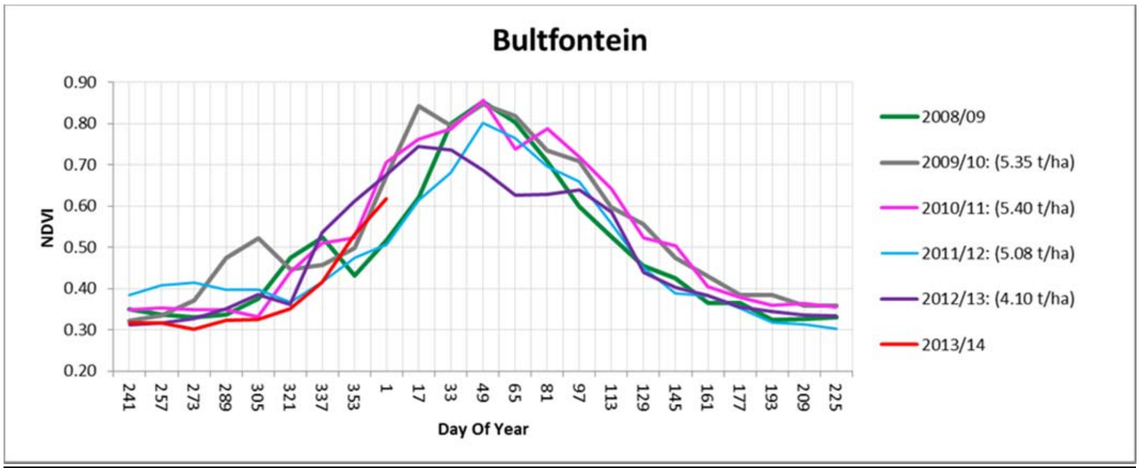



**Figure 112: MODIS NDVI's and Estimated Yields for Bultfontein site (Free State Province)**

Yield data is collected annually in field in the growing season from a selected number of sample sites for wheat and maize. In-field survey data is used to estimate the yield for these crops. Table 16 reflects the points collected in the JECAM site and the estimated yield.

| | Free State White maize Dryland | Free State Yellow maize Dryland | Free State White maize Irrigated | Free State Yellow maize Irrigated |
|---|---|---|---|---|
| Count (No of Points) | 190 | 103 | 4 | 11 |
| Min (Tons/Ha) | 0.00 | 0.00 | 4.62 | 5.74 |
| 25th(Tons/Ha) | 2.23 | 1.89 | 8.20 | 9.04 |
| Median(Tons/Ha) | 3.33 | 3.29 | 9.99 | 12.50 |
| 75th(Tons/Ha) | 4.81 | 5.09 | 10.68 | 14.74 |
| Max(Tons/Ha) | 10.07 | 9.85 | 11.00 | 15.59 |
| Mean(Tons/Ha) | 3.50 | 3.50 | 8.90 | 11.73 |
| SD(Tons/Ha) | 1.90 | 2.27 | 2.93 | 3.58 |
| CV%(Tons/Ha) | 54 | 65 | 33 | 31 |

**Table 16: Maize Yields from Sample Points in Free State Province**

Based on the methodologies described above and after discussion and verification by the national Crop Estimates Committee, the estimated area planted in Maize and expected production as at 27 August 2013 (end of season) is reflected in Table 17. Based on the methodologies described above and after discussion and verification by the Crop Estimates Committee, the estimated area planted in Wheat and expected production as at 28 January 2014 (end of season) is reflected in Table 18.

| JECAM SITE | Area planted<br>2013 | | | 7th forecast<br>2013 | | |
|---|---|---|---|---|---|---|
| | White (Ha) | Yellow (Ha) | Total (Ha) | White Tons | Yellow Tons | Total Tons |
| Free State | 725 000 | 505 000 | 1 230 000 | 2 573 750 | 2 171 500 | 4 745 250 |

**Table 17: Area and Production Estimates for Free State Maize 2013 Production Year**

| **JECAM Site** | **Area planted (Ha)** | **6$^{th}$ forecast (Tons)** |
|---|---|---|
| **Free State** | **90 000** | **252 000** |

**Table 18: Area and Production Estimates for Free State Wheat 2013 Production Year**

The Free State JECAM site is used as an indicator of the grain production in South Africa. The methodologies developed and tested are incorporated into the operational crop estimation and monitoring system. A continual improvement approach is adopted and as new methodologies emerge, these are incorporated. This results in an operational system that is continually updated and is at the cutting edge of technology. The research team regards the system as being based on current best practices.

Experience with the COVE Planning Tool

We have not used the COVE acquisition planning tool provided by NASA. We are interested in taking a short training course, because it will assist the team in utilizing available data sources.

Plans for Next Growing Season

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

Publications

Sinclair S. and Pegram G.G.S., (2013), "A sensitivity assessment of the TOPKAPI model with an added infiltration module", J. Hydrol., 479, 100-112.

Sinclair S. and Pegram G.G.S., (2013), HYLARSMET: A Hydrologically Consistent Land Surface Model for Soil Moisture and Evapotranspiration Modelling over Southern Africa using Remote Sensing and Meteorological Data, WRC Report No. 2024/1/13, Water Research Commission, Pretoria, South Africa.

Tsoeleng, L., Knox, N., Mashalane, M., Sibandze, P., Mangara, P., Kganyago, M., Oliphant, T., Mahlangu, N., Mudau, N., Mapurisa, W., Meyer, B., Agricultural Crop Identification. Oral Presentation: SA-GEO Conference, University of Fort Hare, 2013.

## 20. Taiwan

Team Leaders: Prof. 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.

Team Members: Nguyen-Thanh Son, Ph.D., CSRSR, NCU, Taiwan; Cheng-Ru Chen, Ph.D. candidate, Department of Civil Engineering, NCU, Taiwan; Wilson, M.Sc., TARI, Taiwan.

Project Objectives

Taiwan is a relatively populated island with a majority of residents being settled in western plains where the soils and climate are suitable for rice cultivation. Rice is not only the most important commodity in Taiwan, but it plays a critical role in the livelihoods of large rural populations. The rice agriculture in this island is monitored yearly due to official initiatives to estimate the harvested rice area and rice production. Agronomic planners need such information to devise timely plans for ensuring sustainable social and economic development. Rice fields in Taiwan are generally small and fragmented, generally smaller than one hectare. Thus, rice monitoring is traditionally implemented by manually interpreting aerial photos. However, it is time-consuming to interpret small-scale rice fields and costly to acquire a bunch of high-resolution aerial images over a large region.

Because rice crop monitoring requires information of crop phenology, remotely sensed data used for the mapping must also have adequate spatial and temporal resolution. The Moderate Resolution Imaging Spectroradiometer (MODIS), which has the spatial resolution of land bands of 250 m and 500 m with a wide coverage swath of 2,330 km, can be used to acquire phenological information of rice crops over a large region due to its high temporal resolution of 1−2 days; thus it is widely used for crop monitoring. However, the low spatial resolution of MODIS data makes it difficult for collectively mapping rice-cropping patterns from small-scale rice fields. SPOT-5 data demonstrates its effectiveness for mapping small crop fields at a subnational level due to its better spatial resolution of 10 m. However, the data acquisition is costly and the swath coverage of SPOT is narrow, making it challenging to collectively investigate temporal responses of rice crop phenology from small patches of rice fields. This problem can be partially overcome by a spatiotemporal fusion of low and high temporal resolution data with high spatial resolution data to create a new dataset having a better spatiotemporal resolution.

For this 2013 progress report, we considered the advantages of MODIS and SPOT images to generate a new dataset at SPOT spatial resolution and MODIS temporal resolution for mapping rice crops in Taiwan. As the case study, we processed the MODIS-SPOT data fusion for 2011 using the spatial-temporal adaptive reflectance fusion model (STARFM). A phenology-based approach was a developed for mapping rice-cropping systems in the study region using wavelet transform and phenological information of rice crop phenology.

Site Description

The study site is the major cultivation region of rice in west Taiwan and includes three counties, Changhua, Yunlin, and Chiayi. The study region covers approximately 40 km × 120 km. See Figure 113. The inset shows the false-color composite SPOT image (RGB = 321) acquired on 27 January 2011.

As much as 95% agriculture land is located in alluvial plain. The study area is subtropical. Typhoons frequently sweep across the island bringing significant precipitation during the summer. The average annual precipitation is approximately 1,500 mm, concentrated during the period from May to September. The irrigation system in the region has been well developed for agricultural development. In recent years, water scarcity has occurred due to the development of industrial zones. Thus, farmers often use underground water to irrigate their fields.

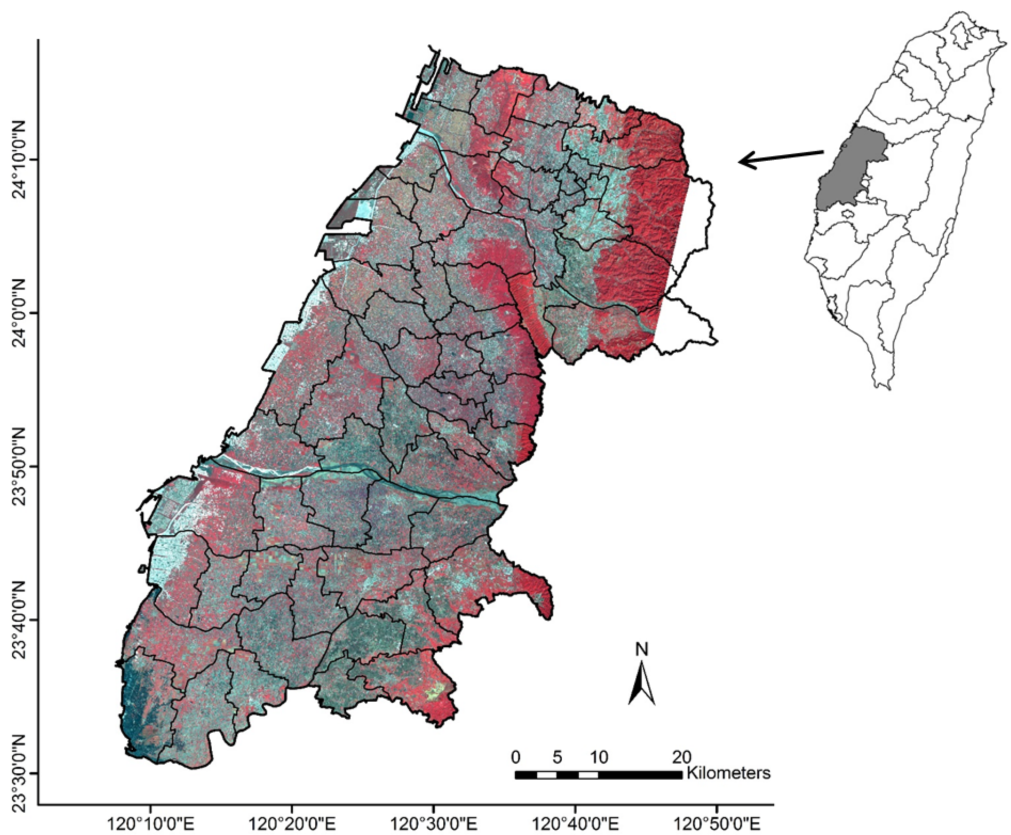



**Figure 113: Location of the Taiwan Study Site**

Rice cultivation in the study region is dependent on the availability of water for irrigation. The year can be divided into two main rice-cropping seasons. The first crop lasts from February−March to June−July, and the second is from July−August to November−December (Table 19). Note that the second crop might not be practiced in some areas due to local climatic constraints. Short-term rice varieties (110−130 days) are commonly practiced in the region due to their high productivity.

| Rice cropping seasons | Sowing period | Harvest period |
|---|---|---|
| First season | February-March | June-July |
| Second season | July-August | November-December |

Table 19: Rice Growing Seasons in the Study Region

EO Data Received/Used

See Table 20: Characteristics of Satellite Data used for Rice Crop Mapping.

| Satellite/Instrument | Spatial Resolution | Revisit Frequency | Remark |
|---|---|---|---|
| SPOT-5 | 10 m | 15 days | DOY 027<br>DOY 208 |
| FORMOSAT-2 | 8 m | 1~25 days | Validation |
| MODIS | 500 m | 8 days/ daily | MOD09A1 |

Table 20: Characteristics of Satellite Data used for Rice Crop Mapping

In situ Data

TARI has been monitoring rice growth as well as collecting rice parameters at experimental sites in the study region (Figure 114). Figure 115 shows rice at different growing stages in the study sites. These rice parameters are being collected monthly. We have developed basic algorithms for rice crop mapping and monitoring with optical images (including satellite and airborne) and SAR images.

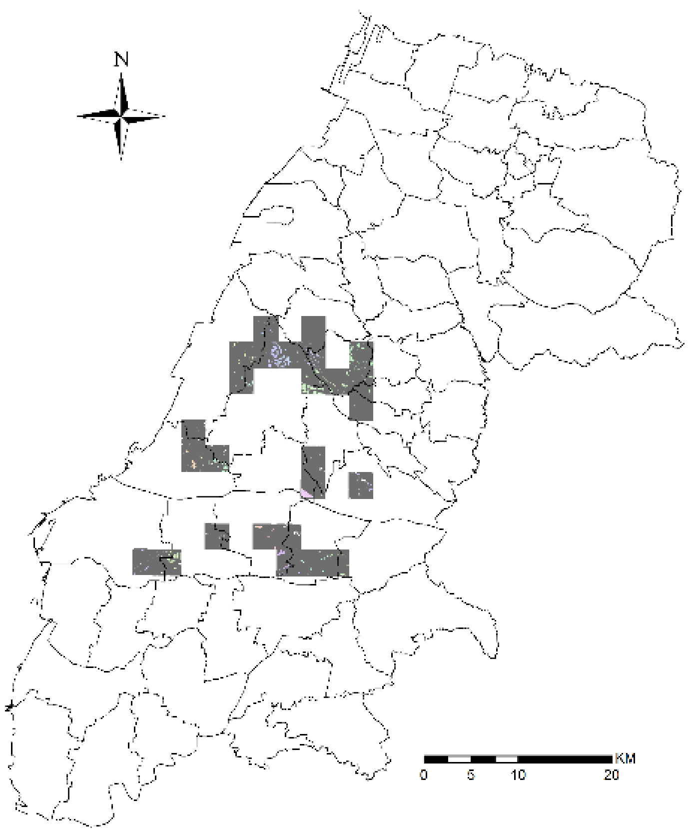



Figure 114: Experimental Sites for Field Surveys

**Figure 115: Photos Taken during the Field Surveys in 2011**

Collaboration

We have not collaborated with other study sites.

Preliminary Results

The results achieved from the phenology-based classification of the filtered time-series NDVI data indicated comparable spatial distributions of rice crops with the ground reference maps obtained from the government (Figure 116). The classification results were compared with the ground reference data and there was close agreement between these two datasets. The overall accuracies and Kappa coefficients were respectively 89.6% and 0.79 for the first crop and 83.2% and 0.66 for the second crop.

The lower accuracy level was observed for the second crop rice because rice in this season occupied a smaller area and was spatially scattered; thus was easily omitted or spectrally confused with other land-use types (e.g., upland crops) during the classification.

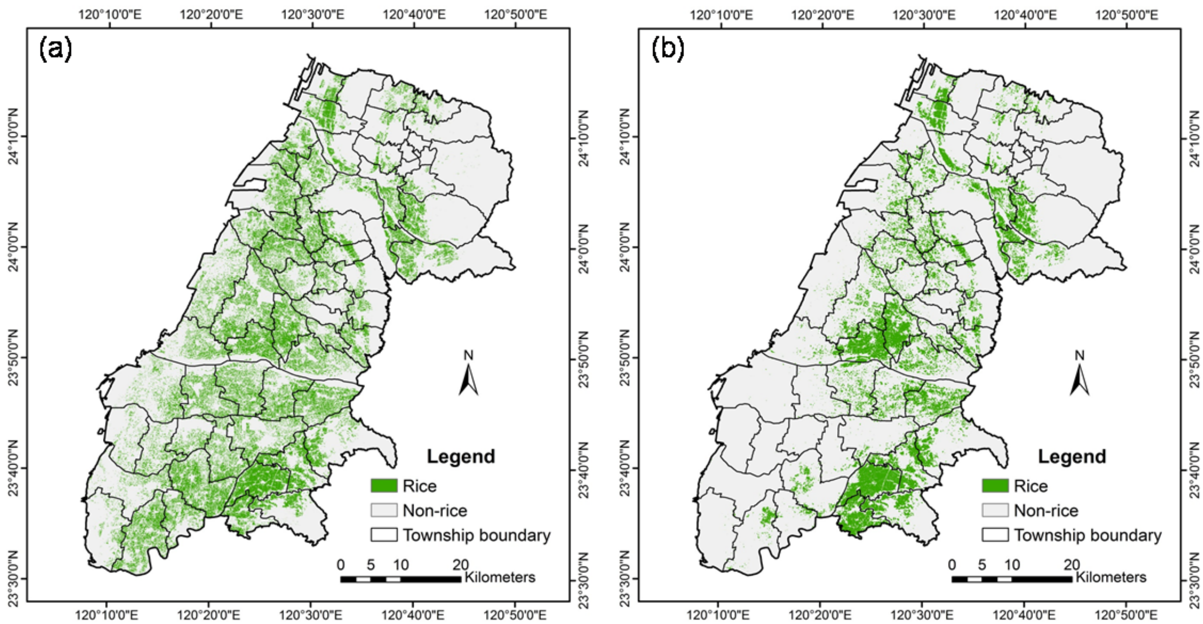



Figure 116: 2011 Classification Results: (a) First Crop, and (b) Second Crop

The relationship between the rice-harvested areas derived from data fusion (STARFM-derived rice area) and those from the government's rice area statistics at the township level for each year was examined. The results indicated a close correlation between the two datasets, reaffirming the consistency with the mapping results. The $R^2$ coefficients indicating the adequacy of the regression model were approximately 98% and 90% of the variability in the data for the first and second crops, respectively.

The relative error in area (REA) achieved for the first crop was approximately 5.5%, while the value for the second crop was −2.2%. The larger REA was observed for the second crop because many parts of the study region were allocated to cultivating upland crops (e.g., sweet potatoes, soybeans, peanuts, and corn) during this cropping season. Small and spatially scattered rice parcels were easily under-predicted, consequently leading to increased errors.

Experience with the COVE Planning Tool

We have not used the COVE acquisition planning tool provided by NASA. We are interested in taking a short training course to be able to run the COVE planning tool.

Plans for Next Growing Season

We anticipate ordering the same type/quantity of EO data next year, and will also try to apply SAR images for crop identification, crop area estimation and crop condition estimation. Mosaicking FORMOSAT-2 images will be applied for the comprehensive examination. Future activities are oriented to correlate the rice crop yield model with rice phenological information, an algorithm we developed in 2013. We are also conducting field collection at experimental sites with the TARI researchers.

Publications

C.R. Chen, C.F. Chen, N. T. Son, L.Y. Chang. (2013). Blending multi-temporal SPOT and MODIS imageries for rice crop phenology detection. ACRS 2013 Conference, Bali, Indonesia.

C.F. Chen, C.R. Chen, N. T. Son, N.B. Chang, L.Y. Chang. (2014). Mapping rice crops in Taiwan with multitemporal MODIS-SPOT data fusion. In prep. for Remote Sensing journal (SCI).

**Presentation**

C.F. Chen. (2013). Rice crop monitoring using time-series satellite data. International Cooperation in Using Remote Sensing for Crop Area Monitoring and Yield Estimation Workshop, TARI, Taiwan.

## 21. Tanzania

No report received.

## 22. Tunisia

Team Leader and Members: Vincent Simonneaux, Mehrez Zribi, Gilles Boulet, Bernard Mougenot, Pascal Fanise, Zohra Lili Chabaane.

Project Objectives

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

- Crop identification and Crop Area Estimation: Crops types are discriminated using multitemporal NDVI data. Empirical algorithms have 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 modelling, aimed at basin scale management, including groundwater. Crop water stress is monitored using thermal image processing, and the results are aimed at being assimilated in the crop water budget model (see below).
- 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: Yield prediction is done using empirical relationships with remotely sensed indices.
- Crop Residue, Tillage and Crop Cover Mapping: We don’t study residues nor tillage (although this was done some years ago). Crop cover mapping is related to ‘Crop identification and Crop Area Estimation’ above.

Site Description

- Location

| | |
|---|---|
| Top left | Latitude: N35° 42' 20" |
| | Longitude: E9° 41' 45" |
| Bottom right | Latitude: N35° 23’ |
| | Longitude: E10° 07’ |

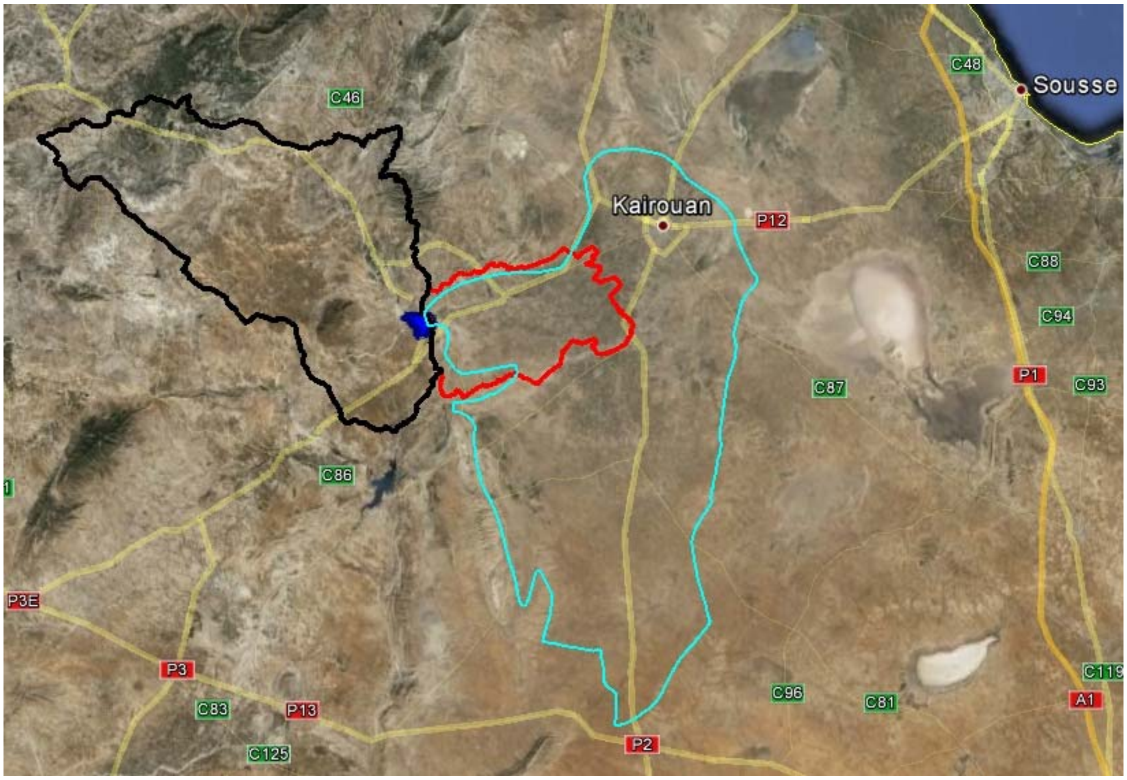



**Figure 117: Tunisia Merguellil Site**

The site is shown in Figure 117. The boundary of the upper watershed is in black, in red the boundary of the irrigated area, and in cyan the boundary of the aquifer.

- Topography: Alluvial plain.
- Soils: Variable texture, from fine sand to clay-loam.
- Drainage class/irrigation: Well drained soils.
- Crop calendar: See Table 21.
- 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.).

<u>EO Data Received/Used</u>

Although the project acquired images from various sensors (see Table 22 below), only Landsat-7 and 8 images were until now systematically acquired in the framework of JECAM, starting in May 2013. In addition, we acquired:

- SPOT images from ASTRIUM-Geo (level 1A) with financial support of CNES
- TERRASAR radar images (2)

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

**Table 21: Merguellil, Tunisia Crop Calendar**

- COSMO-Skymed radar images (15)
- ASTER images through NASA.

**Table 22: Tunisia Site Optical Data Ordered**

| Sensor | # Images | Optical /SAR | Supplier | Pixel Size | Proc. Level | Challenges Ordering | Challenges Processing |
|---|---|---|---|---|---|---|---|
| SPOT-5 | 13 | Optical | SPOT Image/ CNES | 10 | 1A | Specific offer for French Labs (special price) | Problem of getting atmospheric parameters. Global server (H20, aerosols, ozone) are a significant advance but local photometer is better |
| SPOT-4 | 12 | Optical | CNES | 20 | Ortho + BOA ref | Special acquisition during SPOT end of life ("SPOT4-Take5" experiment) | Processing developped in CESBIO using specific chains for time series of fixed angle sensors (FORMOSAT-2, Landsat, Sentinel-2) |
| Landsat-7 | 13 | Optical | USGS | 30 | Radiance | | Not yet processed |
| Landsat-8 | 8 | Optical | USGS | 30 | TOA ref | | Not yet processed |
| ASTER | 2 | Optical | NASA | 15 | AST_05 AST_07 AST_08 | Data acquired though a STAR (science team acquisition request) done in Sept 2012. This programming was quite unsuccessful, only two clear images were acquired (Jan and March 2013). 3 or 4 cloudy dates were acquired while some other clear dates were missed for unknown reasons. | Not yet processed |

**Figure 118: (L) Flux Tower in Irrigated Barley  (R) Well and Pipe for Irrigation**

In situ Data

- Radiometric measurements (CropScan : 16 bands VIS-MIR, including Landsat TM bands) for image radiometric corrections.
- Crop identification ground campaigns for land cover classification training.  Data collected during three campaigns with about 150 plots observed each time.
- Vegetation traits (LAI, fraction cover, biomass) collected on annual crops and olive trees.
- Three permanent meteorological stations (including Temperature, Humidity, Wind Speed, Net Radiation, Rainfall).
- Two Flux stations on irrigated wheat and rain fed olive orchard (energy, water, carbon.
- One X-LAS scintillometer transect (1 km) starting spring 2013 (area-averaged surface heat flux).
- Soil moisture probes with automatic acquisition (5 sites on dry cultivation) + campaigns for soil surface moisture (20 sites).
- Surveys of irrigation amounts at the plot, farm and perimeter scales achieved in 2013 (about 300 ha).  Whereas the calibration of models can be done on the few flux plots (ET measurements), they might be poorly representative of larger areas.  Irrigation volumes at scale ranging from plot to perimeter allow a necessary validation.  However, this type of data is complex to gather, for sociological or technical reasons (people are reluctant to give it, meters are often broken, several water sources are used, fields are scattered in the landscape …).

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.

LAI data was provided to the IMAGINE project (IMPLEMENTING MULTI-SCALE AGRICULTURAL INDICATORS EXPLOITING SENTINELS), involving several JECAM sites (Ukrainia, Russia, South-Africa).  The contact person is Dr. Fernando Camacho de Coca, Earth Observation Laboratory (EOLAB), Parc Cientific Universitat de Valencia).

Results

Although data acquired in the frame of JECAM (starting May 2013) has not yet been processed, we present here an example of the processing of similar data. High resolution SPOT-5 NDVI time series for the years 2009 and 2012 were processed to compute evapotranspiration and irrigation consumption. Monitoring the crop water budget is a major opportunity offered by remote sensing today.

Various methods have been developed to compute evapotranspiration (ET) using remote sensing, which belong basically to two broad families, either using thermal remote sensing used to solve the energy budget of the surface, or using SVAT modeling forced by remotely sensed information of vegetation properties (e.g. fraction cover, leaf area index, crop coefficients…). The latter group includes the coupling of the dual crop coefficient method described in FAO paper 56 (Allen, 1998), coupled with NDVI time series providing spatialized estimates of the fraction cover and the basal crop coefficient. Given that several parameters are specific to each land cover type (i.e. NDVI-Kcb relations, root depth and irrigation practices), this method basically requires high resolution image time series (SPOT, Landsat, FORMOSAT and forthcoming Venus and Sentinel-2).

**Coupling FAO-56 and Kcb Derived from NDVI Time Series**

The FAO-56 method relies on the so-called “reference evapotranspiration” (ET0), which is the evapotranspiration of a well-watered short grass, and can be computed using the Penman-Monteith equation. The ET of any actual vegetation is then obtained by simply multiplying ET0 by coefficients accounting for vegetation transpiration limited by the actual amount of active vegetation (Kcb), a stress coefficient accounting for water availability in the soil (Ks) and a coefficient accounting for soil evaporation (Ke), also accounting for soil surface water content. The key input of remote sensing, the vegetation index (e.g. NDVI), can be related to crop coefficients by linear relations. Conversely, a shortcoming of the method is the lack of information about the actual soil water status, linked to irrigation inputs. Opposite to rainfall, irrigation inputs cannot be known exhaustively on large areas, thus the necessity to simulate irrigation inputs based on assumed rules reproducing the farmer’s behaviour (when, how much…). An obvious improvement of this method will be available in the near future; additional information will be used about the actual soil water status, from thermal images (stress monitoring) and SAR images (soil water content).

$$ET = (Kcb * Ks + Ke) * ET0$$

$$Kcb = a * NDVI + b \text{ (a specific relation for each vegetation type).}$$

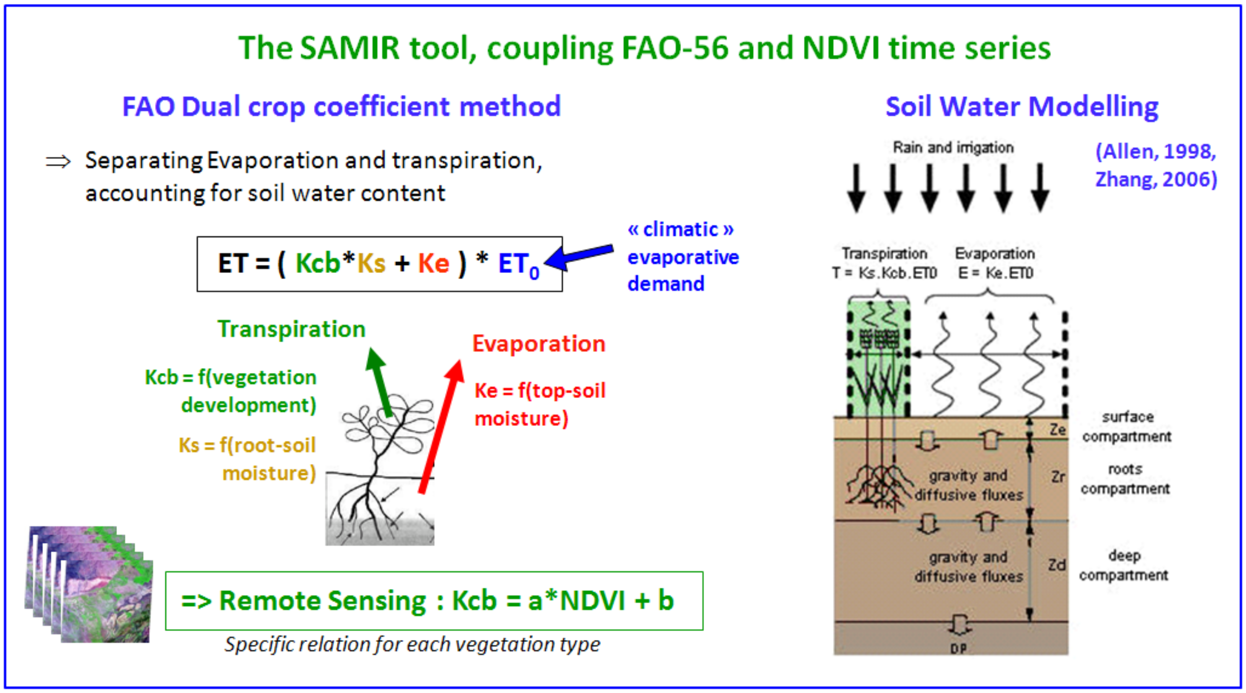



**Figure 119: The SAMIR Tool, Coupling FAO-56 and NDVI Time Series**

The method was calibrated on an irrigated barley site, and irrigation practices were calibrated using the total monthly irrigation volumes observed at the scale of two irrigated perimeters (about 100 ha each) for both years studied. There was an overall agreement for 2008-2009 (observed / simulated irrigation depths are respectively 172/183 mm in Ben Salem II and 212/186 mm in Mlelssa). However, higher discrepancies appear for year 2011-2012 (observed / simulated irrigation depths are respectively 68/100 mm in Ben Salem II and 80/131 mm in Mlelssa). See Figure 120. As irrigation is done by aspersion, it is expected that consumed volumes are 10 to 15% higher than actual crop requirements. For the 2008-2009 year, the underestimates of the model can be linked to areas outside the perimeter using water during summer (trees). The overestimates in December can be linked to a problem of initialization of soil water content. For the year 2011-2012, the underestimates in December and January can be linked to the behaviour of farmers, who bring water despite not having an actual instantaneous need, anticipating for the next month (soil water filling). These results show that the model is very sensitive to irrigation practices, which may vary from one area to another and also from one month/season to another. This study is still going on.

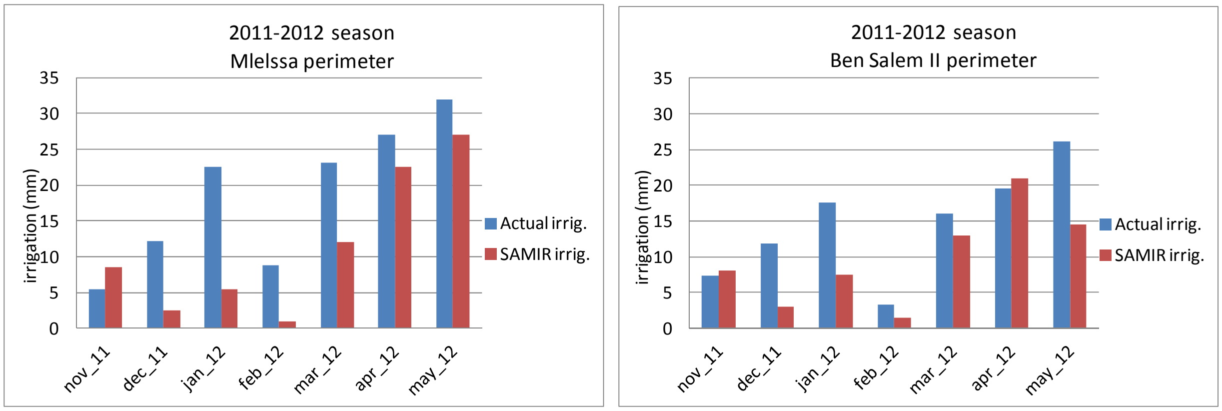



**Figure 120: Comparison of Observed and Simulated Irrigation in 2011-2012**

<u>Experience with the COVE Planning Tool</u>

We have not used COVE, but would be interested in a short training course.

<u>Plans for Next Growing Season</u>

We plan more or less the same approach, although less plot scale irrigation will be collected. We anticipate ordering the same type and quantity of EO data next year.

<u>Publications</u>

No publications are specifically linked with JECAM (Landsat images were not yet processed), but here are the publications related to the Tunisian experiment in 2013:

**Papers**

Mehrez Z.; Azza Gorrab; Nicolas Baghdadi; Zohra Lili-Chabaane; Bernard Mougenot, 2013, Influence of Radar Frequency on the Relationship Between Bare Surface Soil Moisture Vertical Profile and Radar Backscatter, IEEE Geoscience and Remote Sensing Letters, 2013, PP99, pp. 1-5

Chahbi A., Zribi M., Lilli-Chabaane Z., Duchemin B., Shabou M., Mougenot B., Boulet B. Estimation of the dynamics and yields of cereals in a semi-arid area using remote sensing and the SAFY growth model, 2014. IJRS, accepted.

**Conference**

Amri, R., Zribi M., Lili-Chabaane Z., Boulet G., Szczypta C., Calvet J.C., Mougenot B., Simonneaux V., 2013, FAO-56 Dual approach combined to multi-sensor remote sensing for estimating evapotranspiration in semiarid-region. EGU General Assembly, 7-12 april 2013, Vienna, Austria.

**Student thesis**

Amri, R., 2013, Estimation régionale de l'évapotranspiration sur la plaine de Kairouan (Tunisie) à partir de données satellites multi-capteurs. PhD de l'Université Paul Sabatier - Toulouse III, Avril 2013.

Zagouani Refka, 2013, Spatialisation de l’évapotranspiration et estimation des volumes d’irrigation dans la plaine de Kairouan (Tunisie). Mémoire de Master 2, Institut National Agronomique de Tunisie, Tunis.

## 23. Ukraine

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

Team Members: Prof. Andrii Shelestov, Head of Department of Software Engineering, National University of Life and Environmental Sciences of Ukraine; Dr. Sergii Skakun, Head of Laboratory for Satellite Monitoring, Space Research Institute NASU-SSAU; Andrii Kolotii, PhD Student, Space Research Institute NASU-SSAU; Ruslan Basarab, PhD Student, Space Research Institute NASU-SSAU; Andrii Mironov, PhD Student, Space Research Institute NASU-SSAU; Vadym Ostapenko, PhD Student, Space Research Institute NASU-SSAU; Bohdan Yailymov, PhD Student, Space Research Institute NASU-SSAU

Project Objectives

The original objectives have not changed.

- Crop identification and Crop Area Estimation
- Crop Condition/Stress
- Yield Prediction and Forecasting.

Site Description

The main activities in 2013 were carried out for the JECAM test site in Kyiv region. Two other test sites that feature other agro-climatic zones are under establishment, and will be covered in 2014. These test sites include: Lviv region (rape seed identification using SAR imagery), and Crimea (crop damage assessment due to droughts, irrigation, illegal crop fields detection).

- Location

The site consists of two parts:

- o the whole Kyiv region (28,000 sq. km) intended for crop mapping and acreage estimation;
- o intensive observation sub-site (25x15 sq. km) indented for crop biophysical parameters estimation. This sub-site consists of two research farms of 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 23. The map of the site is shown in Figure 121 while the map of the intensive observation sub-site is shown in Figure 122. The research fields are outlined in black.

**Table 23: Geographical Coordinates of the Ukraine Test Sites**

| | | |
|---|---|---|
| **Kyiv** | | |
| **Centroid** | | Latitude: 50.355<br>Longitude: 30.715 |
| **Site Extent** | **Top left** | Latitude: 51.54<br>Longitude: 29.26 |
| | **Bottom right** | Latitude: 49.17<br>Longitude: 32.17 |
| **Sub-site for Intensive Observation (Pshenichne and Velyka Snitynka research farms of NULESU).** | | |
| **Centroid** | | Latitude: 50.075<br>Longitude: 30.11 |
| **Site Extent** | **Top left** | Latitude: 50.14<br>Longitude: 29.96 |
| | **Bottom right** | Latitude: 50.01<br>Longitude: 30.26 |

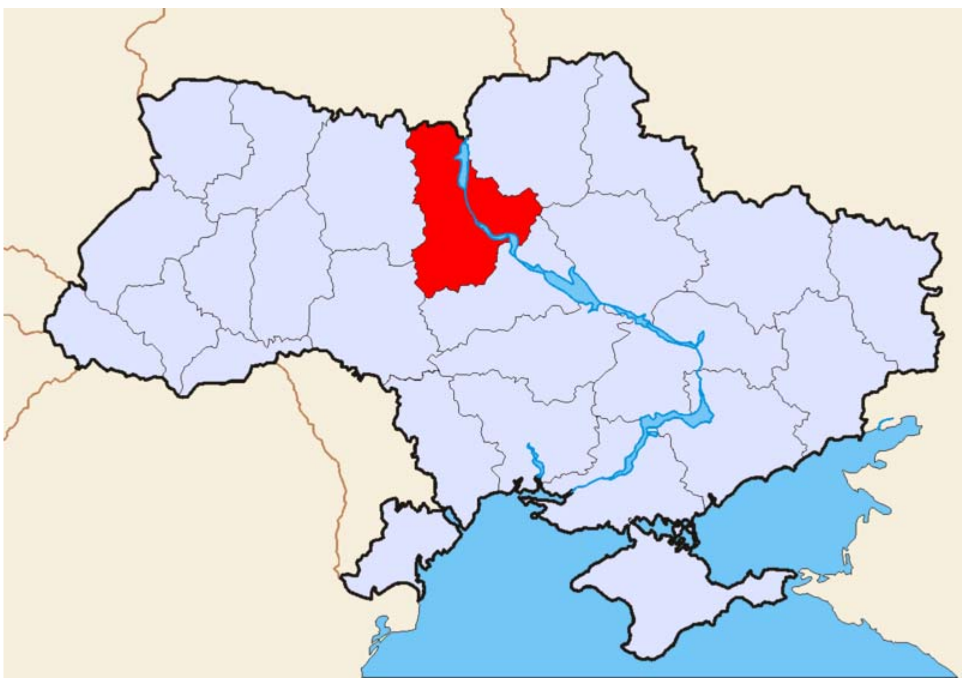
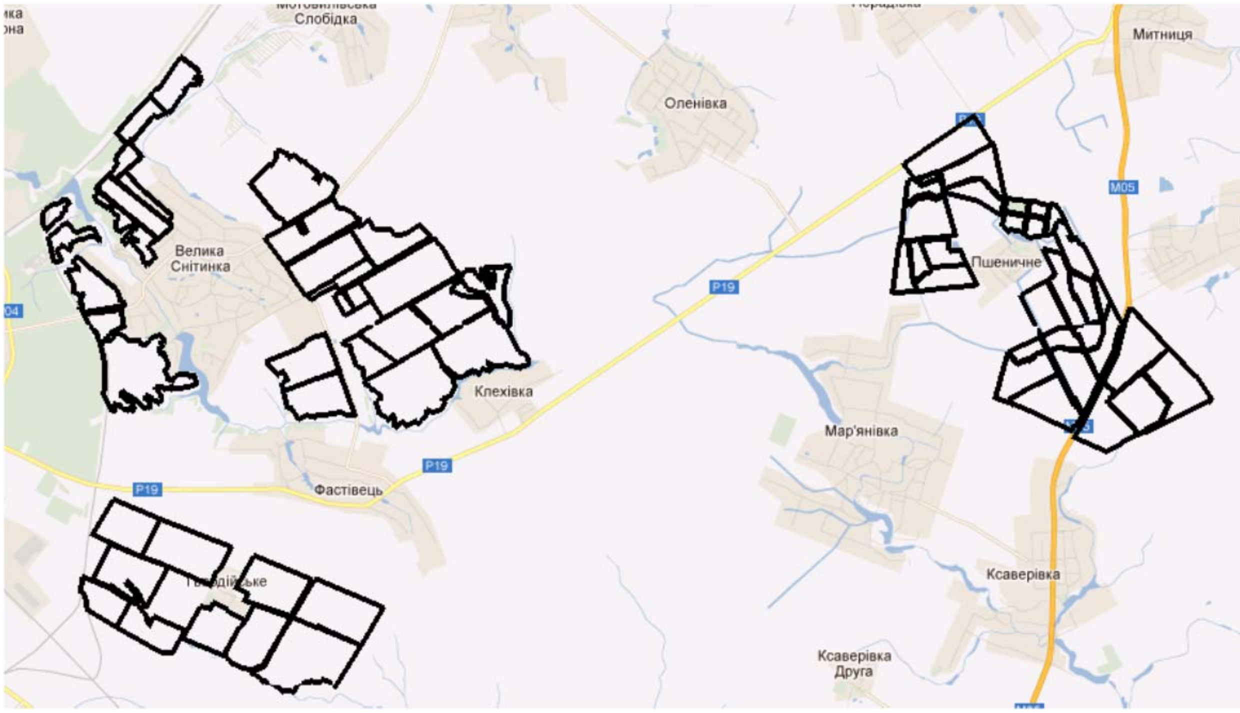


**Figure 121: Administrative Map of Ukraine and Location of Kyiv Region (red colour)**

**Figure 122: Map of Intensive Observation Sub-site (Pshenichne and Velyka Snitynka Research Farms of NULESU)**




For winter wheat yield forecasting, the whole territory of Ukraine was considered. Forecasting was done at oblast level. Oblast is a sub-national administrative unit that corresponds to the NUTS2 level of the Nomenclature of Territorial Units for Statistics (NUTS) of the European Union.

- Topography: The landscape is mostly flat with slopes ranging from 0% to 2%. Near 10% of the territory is hilly with slopes about 2-5%.
- Soils: The soils of the cultivated land are mainly different kinds of chernozems.
- Drainage class/irrigation: Soil drainage ranges from poor to well-drained. Irrigation infrastructure is limited. About 6% of the territory is drained (1700 km$^2$). About 4% (1200 km$^2$) 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, winter rapeseed, spring barley, maize, soy beans, sunflower, sugar beet, potatoes, and vegetables. Due to the relatively large number of major crops and other factors, there is no a typical simple crop rotation in this region. Most producers use different crop rotations depending on specialization.

Figure 123: Maize (left) and Wheat (right)

EO Data Received/Used

Landsat-8

- Space agency or Supplier: USGS
- Optical
- Number of scenes: 6
- Range of dates: 16 April 2013, 02 May 2013, 18 May 2013, 19 June 2013, 05 July 2013, 06 August 2013
- Spatial resolutions: 30 m
- Processing level: L1
- Challenges, if any, in ordering and acquiring the data: No challenges.
- Challenges, if any, in processing and using the data: No challenges.

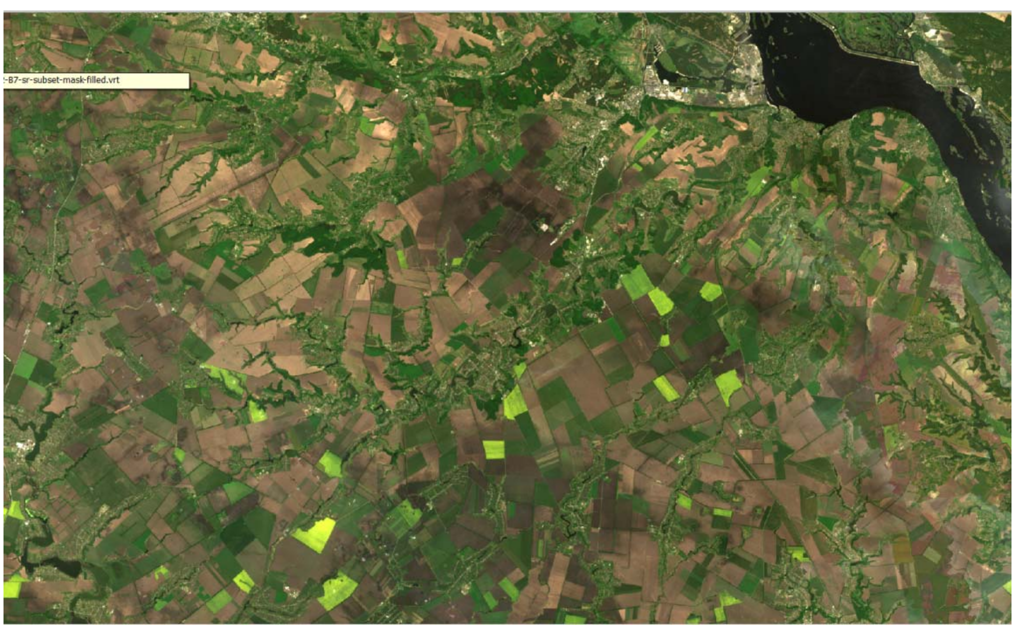
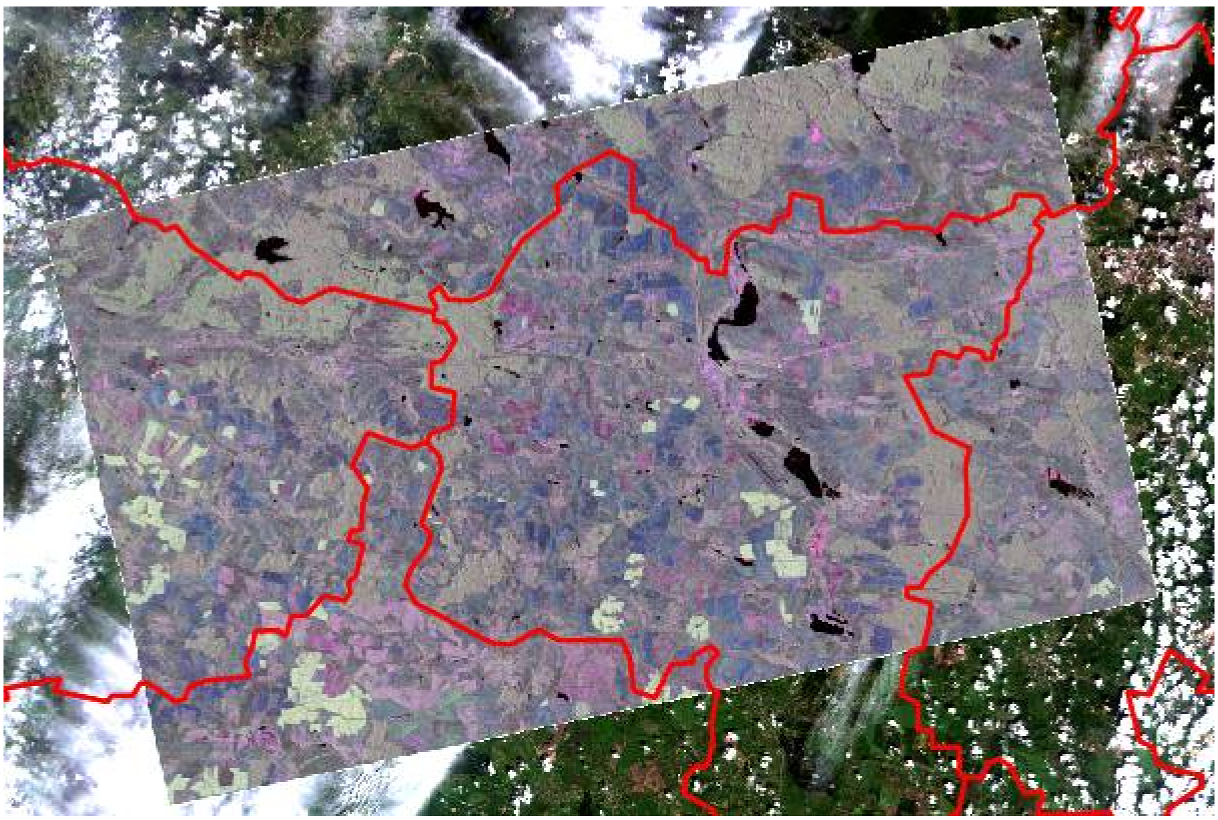


Figure 124: Landsat-8 Image Acquired on 18 May 2013

RADARSAT-2

- Space agency or Supplier: Canadian Space Agency (CSA) within the SOAR-JECAM project no. 5102 “SAR parameters optimization for crop classification”
- SAR
- Number of scenes: 14
- Range of dates: 20 May 2013, 25 May 2013, 04 June 2013, 13 June 2013, 18 June 2013, 28 June 2013, 12 July 2013, 22 July 2013, 05 August 2013, 15 August 2013, 29 August 2013, 08 September 2013, 22 August 2013, 02 October 2013
- Beam modes/ incidence angles/ spatial resolutions: FQ20W (39.5), FQ8W (27.5), 8 m
- Processing level: SLC
- Challenges, if any, in ordering and acquiring the data: No challenges.
- Challenges, if any, in processing and using the data: No challenges.

**Figure 125: RADARSAT-2 Image Acquired on 20 May 2013 (Lviv region)**



SPOT-4

- Space agency or Supplier: ESA (within Take-5 initiative, as ESA Champion user)
- Optical
- Number of scenes: 17
- Range of dates: 06 February 2013 – 16 June 2013
- Beam modes/ incidence angles/ spatial resolutions: 20 m

- Processing level: L1, L2
- Challenges, if any, in ordering and acquiring the data: No challenges.
- Challenges, if any, in processing and using the data: No challenges.

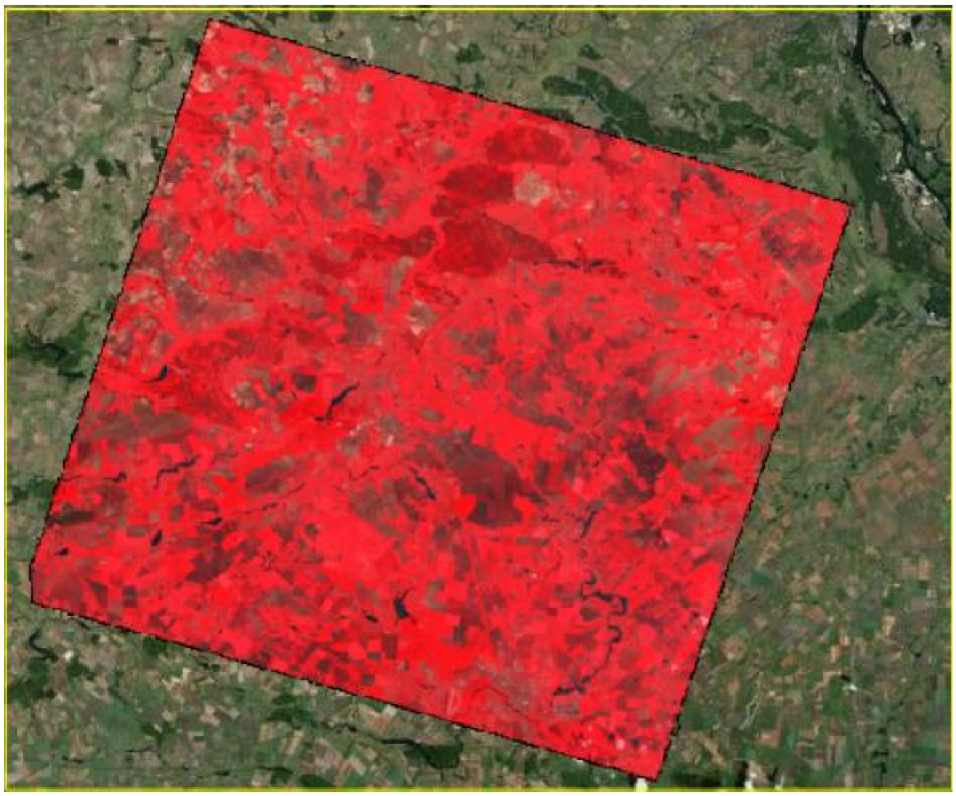


**Figure 126: SPOT-4 Image Acquired on 06 June 2013**

RapidEye

- Space agency or Supplier: ESA (within Take-5 initiative, as ESA Champion user)
- Optical
- Number of scenes: 29
- Range of dates: 06 February 2013 – 16 June 2013
- Beam modes/ incidence angles/ spatial resolutions: 5 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 127: RapidEye Image Acquired on 02 May 2013**

**Winter wheat yield forecasting**

Winter wheat forecasting was done in operational mode using MODIS data, in particular MOD13Q1 product. We used the technique that was developed and validated in 2012-2013 (Kogan et al., 2013).

In situ Data

Two types of ground data were collected:

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

**Along the roads**

About 390 fields were observed with major crop classes (Figure 128): maize (30%), wheat (20%), soybeans (20%), sunflower (10%), rapeseed (2.5%), Barley (2%). The observations were made in June when all crops were present.

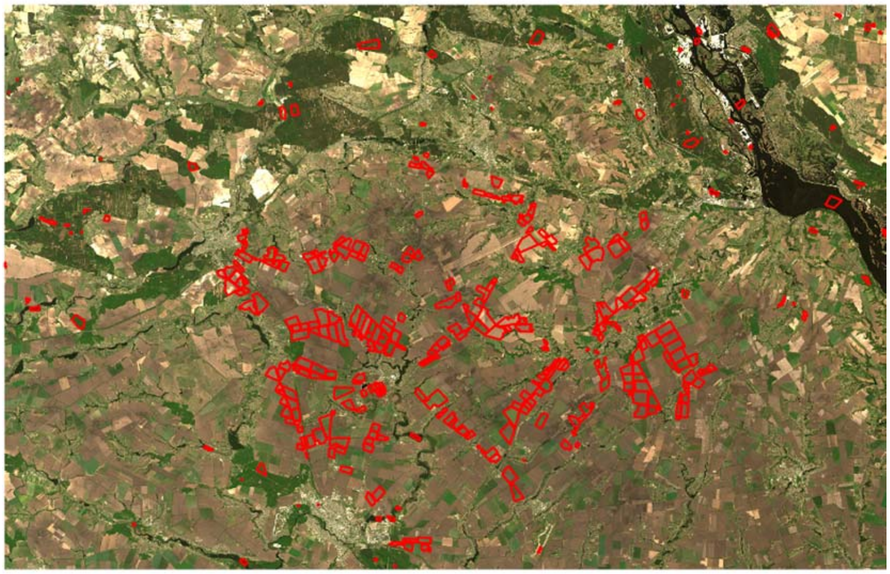


Figure 128: Along the Roads Observation Overlaid on Landsat-8 Image Acquired on 02 May 2013

**Observations of biophysical parameters**

Three field campaigns to characterize the vegetation biophysical parameters at the Pshenichne test site were carried out:

- First campaign: 14th to 17th of May 2013.
- Second campaign: 12th to 15th of June 2013.
- Third campaign: 14th to 17th of July 2013.

Digital Hemispheric Photographs (DHP) images were acquired with a NIKON D70 camera (Figure 129). Hemispherical photos allow the calculation of LAI and FCOVER measuring gap fraction through an extreme wide-angle camera lens (i.e. 180º) (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.

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

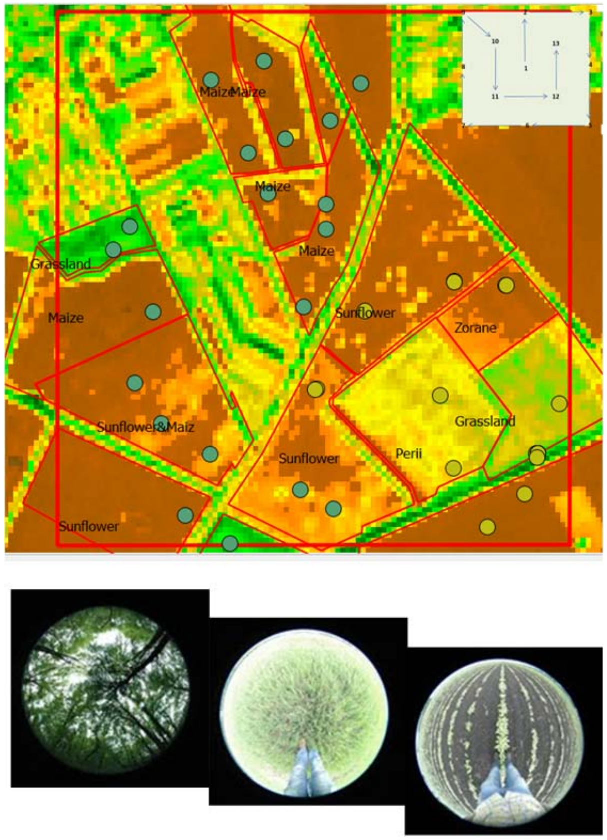



**Figure 129: In situ Observations with DHP Images**

Collaboration

We participate in the following collaborative projects:

1. EU FP7 project “Stimulating Innovation for Global Monitoring of Agriculture and its Impact on the Environment in support of GEOGLAM” (SIGMA). Participation as project partner
2. EU FP7 project “Implementation of Multi-scale Agricultural Indicators Exploiting Sentinels” (ImagineS). Providing ground observations for validation of EO products.
3. ESA Sentinel-2 for Agriculture. Participation as a “Champion User” in Take5 Initiative: SPOT-4 and RapidEye observed JECAM Ukraine every 5 days to simulate Sentinel-2.

Results

**Biophysical Parameter Retrieval**

Satellite data were used for producing biophysical parameter maps. Figure 130 shows the corresponding maps.

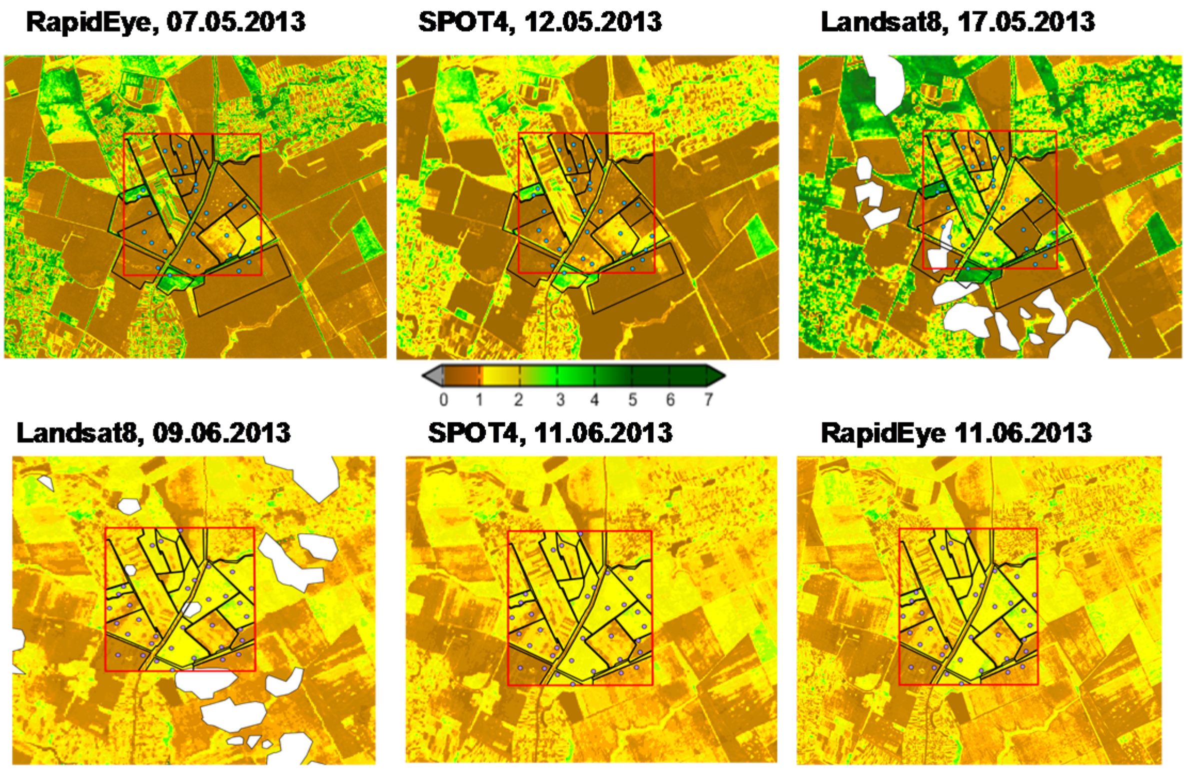



Figure 130: LAI Maps Derived from Landsat-8, SPOT-4 and RapidEye

Two approaches were tested:

- NDVI regression based model that was built by Space Research Institute NASU-SSAU (Ukraine): for Landsat-8, SPOT-4 and RapidEye
- Transfer function that exploits all spectral bands built by Earth Observation Laboratory (EOLAB, Spain) within the FP7 Imagines project: SPOT-5.

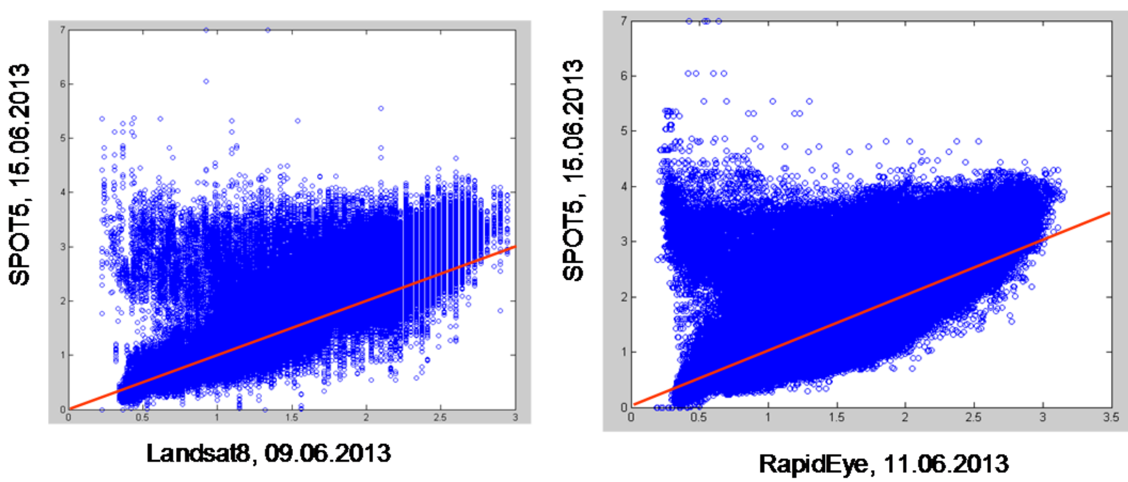



Figure 131: Cross-validation of LAI Produced by Different Methods and Satellite Imagery

Figure 131 shows inter-comparison between SPOT-5, Landsat-8 and RapidEye. We can see that LAI from the NDVI-based maps underestimate LAI from the transfer function from SPOT-5. The overestimated values using SPOT-5 images correspond to the road (highway) and village (which composed of mixed artificial and very small farming fields; there is also a river and a pond with high-dense vegetation near the village).

**Crop mapping**

A time-series of Landsat-8 images was used to provide crop classification. The images were acquired on the six dates given earlier. The following pre-processing steps were carried out:

1. Conversion to top-of-atmosphere (TOA) reflectance.
2. Atmospheric corrections (from TOA to surface reflectance (SR)) using the SMAC model (http://www.cesbio.ups-tlse.fr/multitemp/?p=2956). Parameters of the atmosphere (aerosol optical depth) were acquired from the Aeronet network (a station in Kyiv). Atmospheric correction is important for multi-temporal classification. A Comparison of atmospheric correction effects is shown in Figure 132. This is a true color composition of Landsat-8 bands 4-3-2. TOA and SR reflectance are scaled from 0 to 0.15.

Figure 132: TOA (left) and SR (right) for Landsat-8 Acquired on 08 August 2014

3. Detection of clouds and shadows using multi-temporal cloud detection (MTCD) algorithm (Hagolle et al., 2010).
4. Filling in missing data due to cloud and shadow areas (restoration) using self-organizing Kohonen maps (SOMs). Reconstruction error depends on the spectral band and ranges from 0.014 to 0.067. Figure 133 shows the results of the restoration.

Ground data were divided into disjoint training (50%) and testing (50%) sets on a field basis. So pixels from the same field were used either for training or testing purposes. Class nomenclature is presented in Table 24. Spring and winter crops were integrated because of poor discrimination.

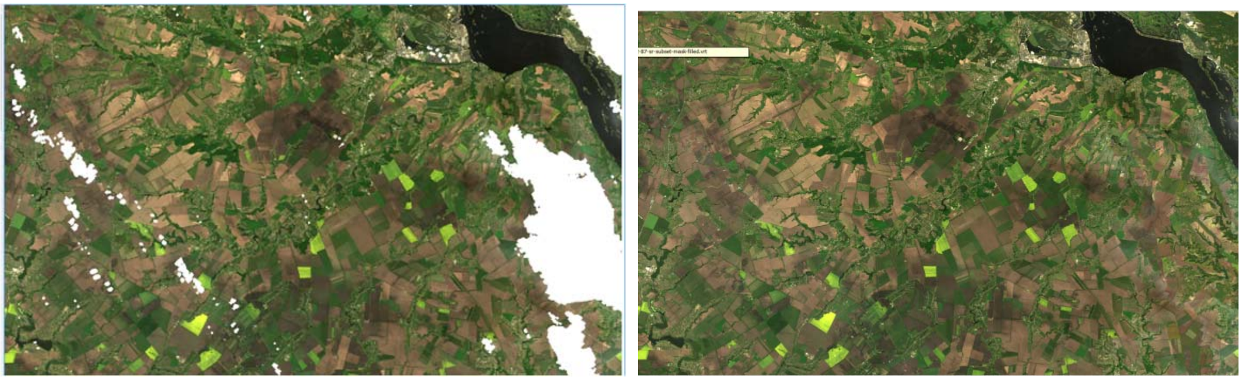


**Figure 133: Filling in Missing Data Due to Clouds and Shadows (white areas on left image) Using SOMs (right)**

| Class no. | LUCAS | Description |
|---|---|---|
| 1 | Axx | Artificial |
| 2 | B11, B12, B14 | Winter and spring crops (wheat, barley) |
| 3 | B32 | Winter rapeseed |
| 4 | B16 | Maize |
| 5 | B22 | Sugar beet |
| 6 | B31 | Sunflower |
| 7 | B33 | Soybeans |
| 8 | B19, B39, B40 | Other cereals, other annual crops, temporary grass |
| 9 | Cxx, B60 | Forest, fruit trees |
| 10 | Exx | Grassland |
| 11 | Fxx | Bare land |
| 12 | Gxx | Water |

**Table 24: Class Nomenclature for Crop Mapping**

A neural network approach was used for classification of images. The confusion matrix of test data sets is shown in Table 25. The overall accuracy of the testing set is 85.98% and Cohen's kappa is 0.8294. The following conclusions can be drawn:

- Crops with both producer's accuracy (PA) and user's accuracy (UA) more than 85%:
  - Winter wheat + spring barley (93.3% and 91.3%)
  - rape seed (93.2% and 93.4%)
  - maize (89.7% and 86.7%)
  - sugar beet (93.7% and 91.6%).
- Discrimination of other classes is less accurate:
  - Sunflower (PA=85.4%, UA=83.6%). The main confusion is with soybeans.
  - Soybeans (PA=65.6%, UA=78.7%). The main confusion is with the following classes: maize and sunflowers. There is some confusion (commission) with spring crops.
- Non-agriculture classes are well discriminated with exception of grassland: PA=91.3% and UA=78.2%. The main confusion is with the following classes: forest, other cereals and winter wheat.

The resulting classification map is shown in Figure 134.

Bayes Confusion Matrix (85.98%)

Predicted (rows) / True (columns)

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 182 | 0 | 0 | 8 | 0 | 1 | 0 | 0 | 0 | 4 | 1 | 0 | 92.9 |
| 2 | 0 | 18775 | 8 | 684 | 1 | 17 | 407 | 586 | 0 | 39 | 47 | 0 | 91.3 |
| 3 | 0 | 80 | 3778 | 18 | 0 | 60 | 106 | 0 | 0 | 4 | 1 | 0 | 93.4 |
| 4 | 0 | 0 | 0 | 33662 | 2 | 332 | 4705 | 79 | 1 | 52 | 0 | 0 | 86.7 |
| 5 | 0 | 1 | 0 | 221 | 3466 | 82 | 14 | 1 | 0 | 0 | 0 | 0 | 91.6 |
| 6 | 0 | 8 | 0 | 585 | 41 | 13455 | 1861 | 63 | 0 | 84 | 0 | 2 | 83.6 |
| 7 | 0 | 36 | 0 | 2181 | 191 | 1212 | 13812 | 63 | 2 | 45 | 0 | 0 | 78.7 |
| 8 | 0 | 540 | 265 | 65 | 0 | 524 | 129 | 6003 | 0 | 18 | 0 | 0 | 79.6 |
| 9 | 0 | 27 | 0 | 59 | 0 | 29 | 8 | 93 | 4182 | 140 | 0 | 0 | 92.2 |
| 10 | 1 | 659 | 1 | 40 | 0 | 22 | 13 | 249 | 147 | 4102 | 13 | 0 | 78.2 |
| 11 | 1 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 403 | 0 | 97.6 |
| 12 | 0 | 1 | 0 | 3 | 0 | 19 | 0 | 0 | 0 | 0 | 0 | 2522 | 99.1 |
| 0 | 98.9 | 93.3 | 93.2 | 89.7 | 93.7 | 85.4 | 65.6 | 84.1 | 96.5 | 91.3 | 86.7 | 99.9 | 85.98 |

**Table 25: Confusion Matrix of Test Data within Crop Classification using a Time-series of Landsat-8 Images**

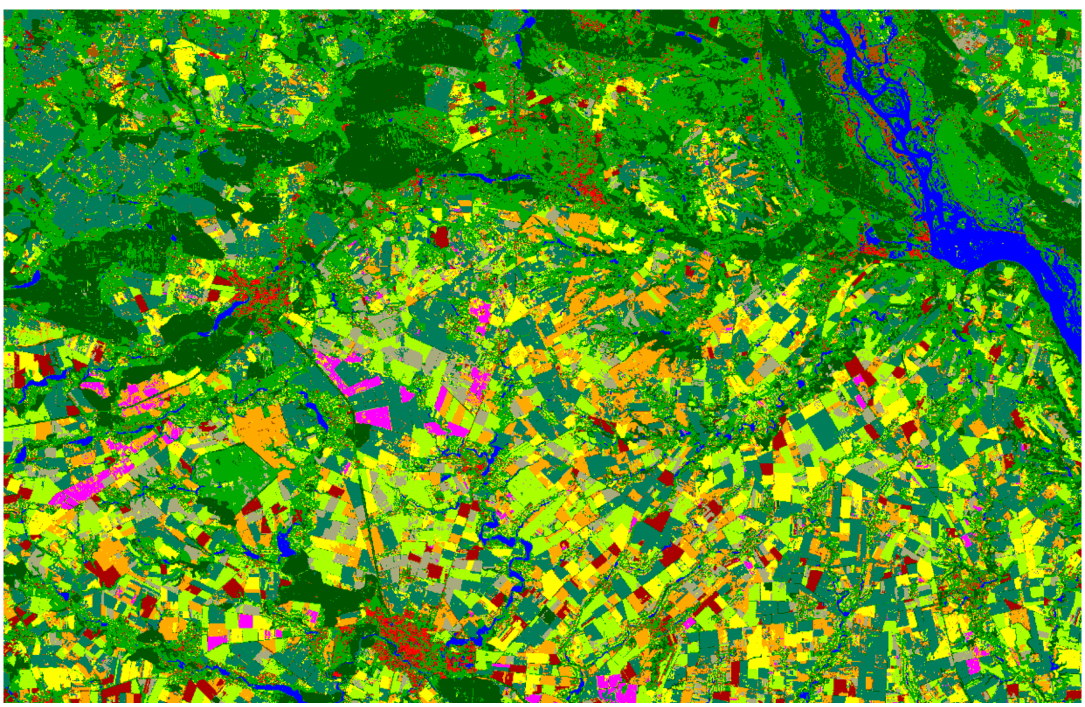


**Figure 134: Crop Map Based on Classification of Time-series of Landsat-8 Images**

**Winter Wheat Yield Forecasting**

Operational forecasting of winter wheat yield was carried out in 2013. Every 16 days forecasts of winter wheat yield are provided upon arrival of new EO data and products. Due to the spring dry kill effects, many areas of winter wheat in the southern regions of Ukraine were damaged in May of 2013. These regions could be identified from EO data. Figure 135 - Figure 137 below show forecasts of winter wheat yield as of 8 May and 23 May 2013, and changes in forecasts between 8 May and 23 May 2013. For the southern regions, changes are of an order of 0.9 t/ha.

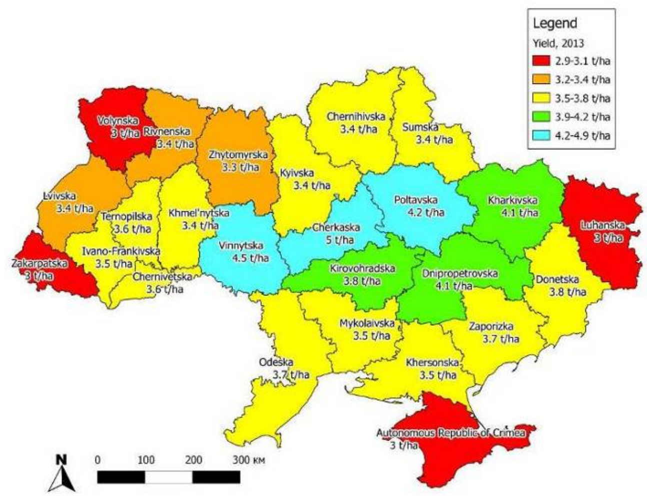



**Figure 135: Winter Wheat Yield Forecasts for Ukraine for 2013 as of 08 May 2013**

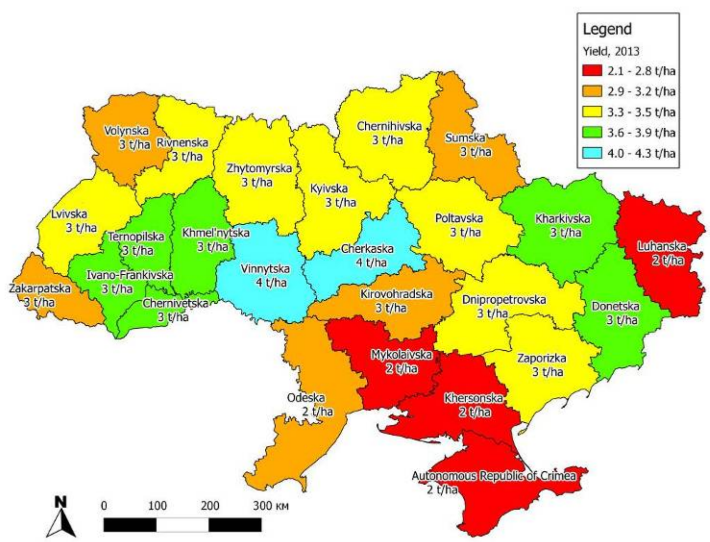



**Figure 136: Winter Wheat Yield Forecasts for Ukraine for 2013 as of 23 May 2013**

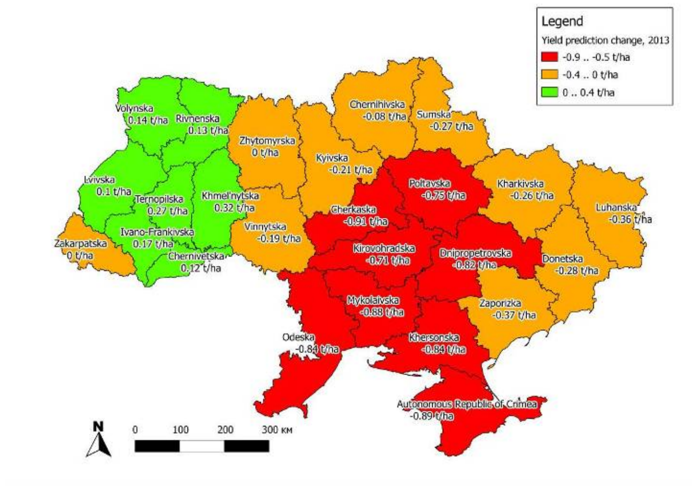



**Figure 137: Changes in winter wheat yield forecasts between 23.05.13 and 08.05.13**

Obtained forecasts (that were produced 2 months before harvest) were compared to official statistics, released in January 2014. The results are shown in Figure 138. The RMSE error (at oblast level) was 0.58 t/ha.

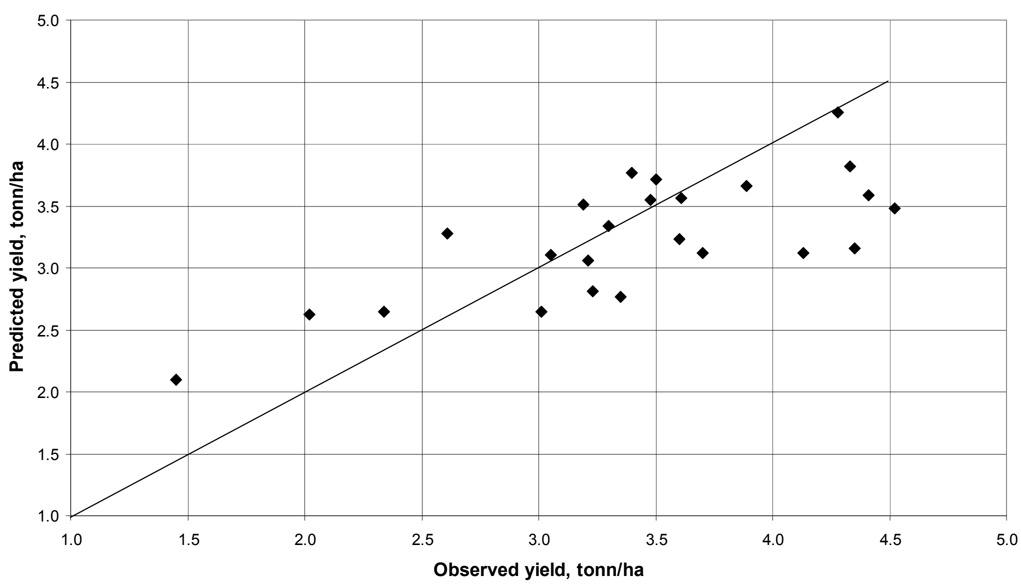



**Figure 138: Comparison of Predicted Winter Wheat Yield (made May 2013) with Official Statistics (released January 2014)**

**To what extent have the project objectives been met?**

Crop mapping with optical and SAR images and biophysical parameters retrieval are ongoing activities that will continue in 2014. Winter wheat forecasting using MODIS images was already put into operation.

**Can this approach be called 'best practice'?**

We think that both approaches (crop mapping and winter wheat forecasting) could be considered as best practice. Moreover, crop yield forecasting methodology was presented in the form of recommended practices and introduced to the UN-SPIDER (within disaster risk management activities).

Experience with the COVE Planning Tool

We did not use this tool, but are interested in using it.

Plans for Next Growing Season

More research in 2014 will be done on the assessment of integration of SAR and optical images for crop mapping in Ukraine. Special attention will be paid to sequential crop mapping, i.e. producing crop maps as satellite images become available. New test sites in Lviv and Crimea will be incorporated. We anticipate ordering the same type/quantity of EO data next year.

Publications

**Papers in peer reviewed journals**

1. Gallego F.J., Kussul N., Skakun S., Kravchenko O., Shelestov A., and Kussul O., (2014) "Efficiency assessment of using satellite data for crop area estimation in Ukraine", International Journal of Applied Earth Observation and Geoinformation, Vol. 29, pp. 22–30. (http://dx.doi.org/10.1016/j.jag.2013.12.013)
2. Kogan, F., Kussul, N., Adamenko, T., Skakun, S., Kravchenko, O., Kryvobok, O., Shelestov, A., Kolotii, A., Kussul, O. & Lavrenyuk, A., (2013) "Winter wheat yield forecasting in Ukraine based on Earth observation, meteorological data and biophysical models", International Journal of Applied Earth Observation and Geoinformation, vol. 23, pp. 192-203. (http://dx.doi.org/10.1016/j.jag.2013.01.002)
3. Shelestov, A.Yu., Kravchenko, A.N., Skakun, S.V., Voloshin, S.V., Kussul, N.N., (2013). "Geospatial information system for agricultural monitoring", Cybernetics and Systems Analysis, Volume 49, Issue 1, pp 124-132. (http://dx.doi.org/10.1007/s10559-013-9492-5)
4. Kussul N., Skakun S., Kravchenko O., Shelestov A., Gallego F. J., Kussul O., (2013) "Application of satellite optical and SAR images for crop mapping and area estimation in Ukraine", International Journal "Information Technologies & Knowledge", Vol.7, No. 3, pp. 203-210
5. Kussul N., Skakun S., Shelestov A., Kravchenko O., Kussul O. (2013) "Crop clasification in Ukraine using satellite optical and SAR images", Models&Analyses, N 2, pp. 118-128.

**Presentations**

1. Kussul N., EO for agriculture monitoring in Ukraine within international initiatives GLAM and JECAM, presented at GEO European Projects' Workshop-7, 15-16 May 2013, Barcelona, Spain.

2. Kussul N., Agricultural monitoring satellite-based data fusion: experience and developments of Space Research Institute, Ukraine, presented at Regional workshop "Satellite Monitoring of Agricultural Lands in Northern Eurasia“, October 28-31, 2013, Moscow, Russia.
3. Shelestov A., Ukrainian JECAM test site, presented at Regional workshop "Satellite Monitoring of Agricultural Lands in Northern Eurasia“, October 28-31, 2013, Moscow, Russia.
4. Kussul O., et al., Assessment of Relative Efficiency of using MODIS Data to Winter Wheat Yield Forecasting in Ukraine, presented at IGARSS 2013, July 25, 2013, Melbourne, Australia.
5. Kussul N., et al., Agricultural Satellite Monitoring and Crop Yield Forecasting in Ukraine, presented at Crop Yield Forecasting in South East Europe Workshop, 30-31 May, 2013, Skopje, Macedonia.
**6.** Kussul N., et al., Natural Disasters Risk Assessment at UN-SPIDER Regional Support Office in Ukraine, presented at CEOS WGISS-36, May 16-19, 2013, Frascati, Italy, ESA/ESRIN.

## 24. Uruguay

Team Leader and Members: Andres Berger, Deborah Gaso, Veronica Ciganda

Project Objectives

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

- Crop Condition/Stress:
  - Estimate the impact of management and identification of management zones within a field.
- Soil Moisture:
  - Estimate soil water holding capacity and crop evapotranspiration.
- Yield Prediction and Forecasting:
  - Estimate yield pre harvest through crop modeling, in a small area (less than100 ha).

Site Description

There are three sites: Colonia, Soriano, San Jose.

- Location: Colonia (Latitude: 34° 22' 42'' S - Longitude: 57° 37' 45'' O); Soriano (Latitude: 33° 34' 45'' S - Longitude: 58° 10' 82'' O) and San Jose (Latitude: 33° 51' 53'' S - Longitude: 56° 33' 39'' O).
- Topography: maximum slope 5%, average 2%.
- Soils: depth between 0.4 to 1 m.
- Drainage class/irrigation: not irrigated, well drained with occasional poor drained zones.
- Crop calendar: Wheat (winter) / soybean (summer) (southern hemisphere).
- Field size: around 100 ha each site.
- Climate and weather: Mild temperate
- Agricultural methods used: Zero tillage.

EO Data Received/Used

We are interested in receiving RapidEye and DMC images, so far we were not able to work out the procedures to access them through JECAM. We are using Landsat 7-8 imagery and UAV images.

In situ Data

All sites have a soybean-wheat crop sequence. Typical fields are cultivated with 2 crops (summer and winter) a year. In each of the sites we measured biophysical parameters every 15 days:

- crop biomass,
- crop cover,
- leaf area index,
- fraction of intercepted radiation,

- Identification of phenological events,
- Identification of management practice.

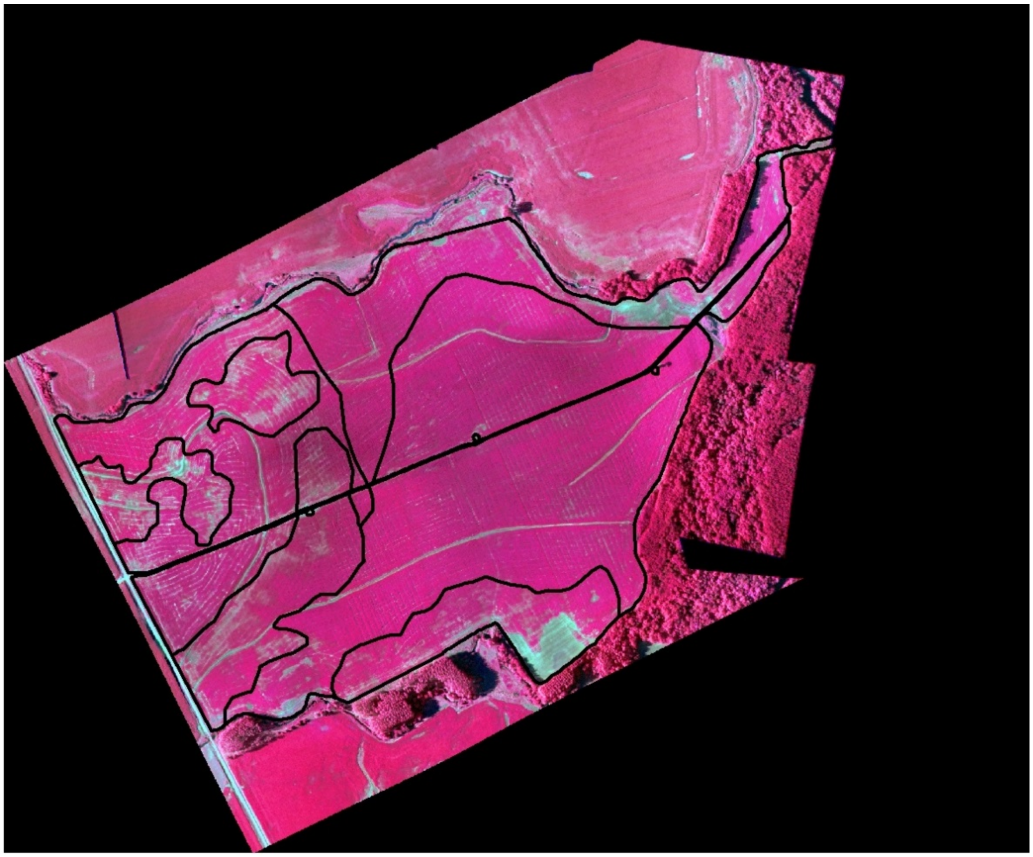


**Figure 139: Soybean Fields and Surroundings**

Collaboration

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

Results

During 2012 and 2013, some measurements were collected for the three sites in Uruguay. Some results are presented in Figure 142 and Figure 143. The project objectives have been met about 80%. This approach can be called 'best practice'.

Experience with the COVE Planning Tool

We have not used the COVE acquisition planning tool provided by NASA, but would be interested in on-line training.

**Figure 140: In situ Sensors at Site #1**

**Figure 141: In situ Sensors at Site #2**

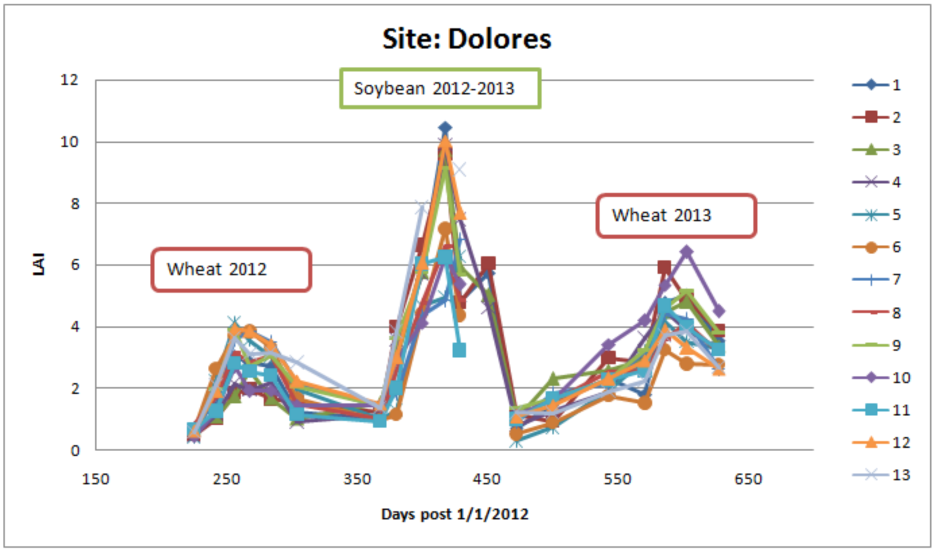



Figure 142 : LAI at Dolores Site

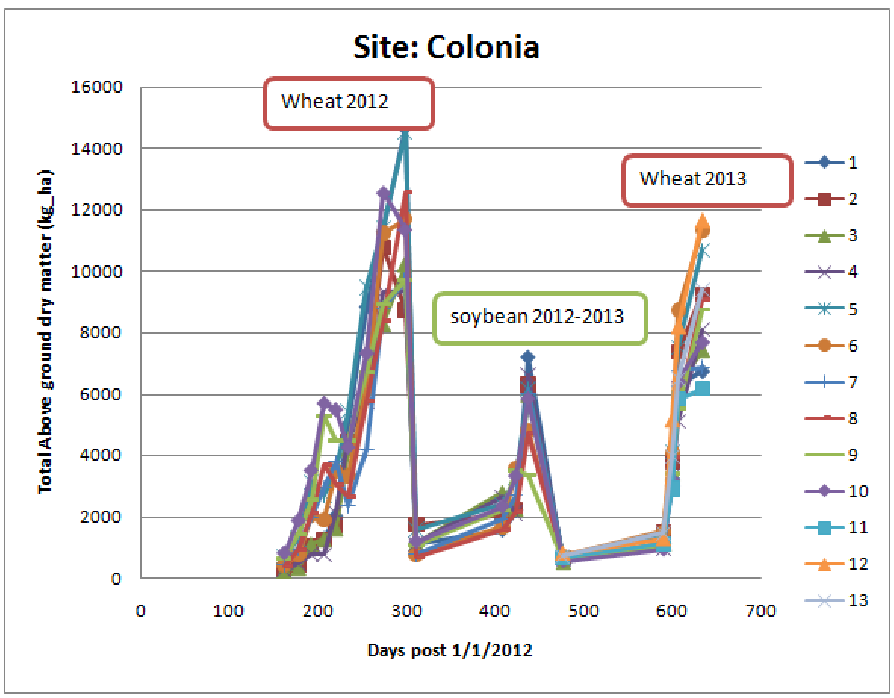



Figure 143: Total Above Ground Dry Matter at Colonia Site

## Plans for Next Growing Season

The project is continuing with similar objectives.  The main change is greater emphasis in modelling with assimilation of a reduced number of scenes.  We would like to incorporate more sensors to increase the temporal sampling of the sites.

## Publications

None listed.

# 25. U.S.A.

## 25.1 Iowa

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

Project Objectives

The original project objectives for our site have not changed.

- Crop identification and Crop Area Estimation
  - Crop area estimation was conducted via the USDA Farm Service Agency and National Agricultural Statistical Service programs for the South Fork. This is an operational product.
- Crop Condition/Stress
  - As part of a remote sensing project, the evaporative stress index (ESI) is being computed on a 10 km resolution for the continental U.S. This is available from http://hrsl.arsusda.gov/drought/. This is operational.
- Soil Moisture
  - Four soil moisture, stations were in place for the past year, but plans have been developed to expand this network to approximately twenty stations for the upcoming soil moisture calibration/validation program of the NASA SMAP mission. This is still in development.
- 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. This is still in development.

Site Description

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

EO Data Received/Used

AWIFS data was received for four dates in April to Sept 2013.

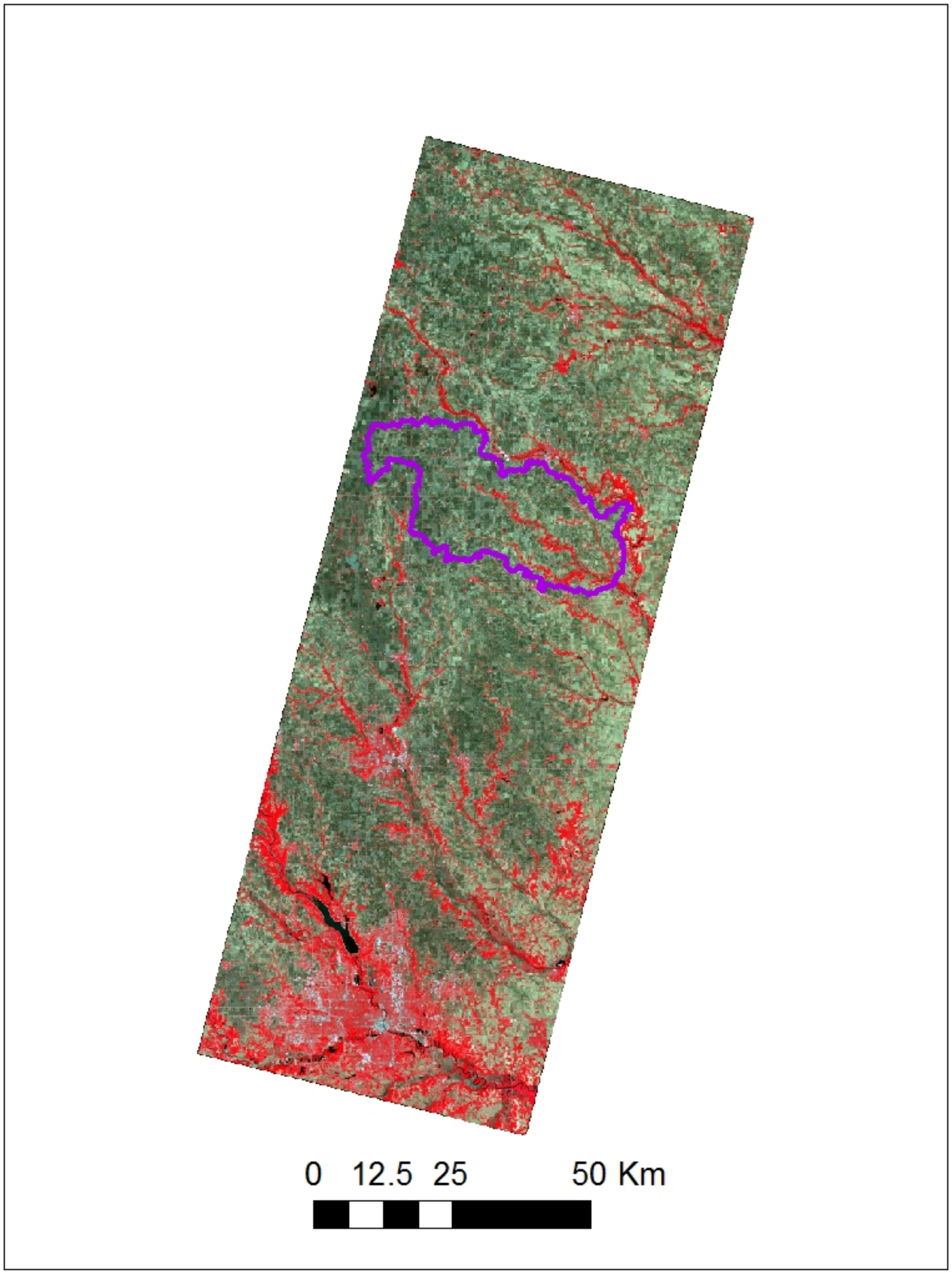



Figure 144: SPOT Image from 16 May 2012 with the South Fork Watershed Outline in Purple

<u>In situ Data</u>

There are currently 20 in situ soil moisture stations collecting soil moisture, soil temperature and precipitation data in the South Fork Region, shown in Figure 145. Fifteen USDA stations are labelled SF01-SF15. NASA operated stations are labelled NA01-NA05. In addition, during the spring and fall, in situ crop residue studies were conducted to estimate residue amounts via field measures and roadside surveys.

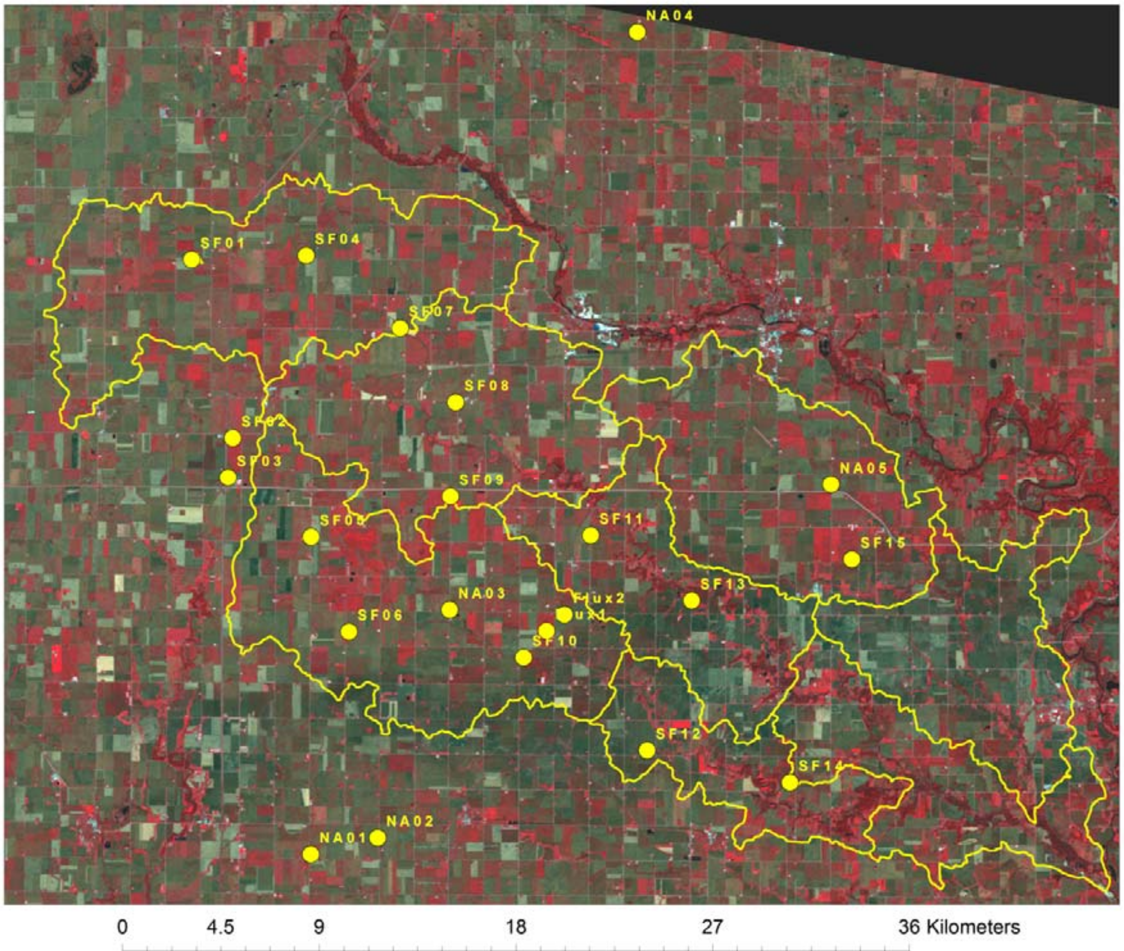



**Figure 145: In Situ Soil Moisture and Precipitation Network Installed over the South Fork Experimental Watershed**

Collaboration

Mr. Sujay Dutta of IRS has received data on land cover type for the past 10 years for comparison to AWIFS data per the agreement with JECAM.

NASA Global Precipitation Measurement Mission in association with University of Iowa and USDA-Agricultural Research Service conducted an intensive precipitation experiment during spring of 2013 entitled Iowa Flood Study (IFloodS). See Figure 146 for photos of the installations. (There are soil moisture sensors installed at 5, 10, 20, and 50 cm. Two precipitation gauges record liquid precipitation hourly and per second for high resolution monitoring required by IFloodS.) This merged intensive in situ precipitation and soil moisture instrumentation with temporarily deployed experimental ground based radar is used to study precipitation estimation. A website detailing the experiment is found at http://iowafloodcenter.org/projects/ifloods/.

**Figure 146: Photos of the In situ Network Installations for USDA-ARS**

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.

Experience with the COVE Planning Tool

We have not been able to exploit the COVE Planning Tool at this time. An online training course would be of interest to us.

Plans for Next Growing Season

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

Publications

No papers have been published yet on this site.

## 25.2 Oklahoma

No report received.

# 26. JECAM Support to Important Multi and Bi lateral Work

There is already significant bi-lateral collaboration between JECAM sites planned and underway. In addition, the site network is being used to support research external to JECAM. Examples include:

- ESA Sentinel-2 Simulation over JECAM sites (Take 5)
- ESA Sentinel 2 Agri
- IMAGINES project
- NASA Soil Moisture Active Passive mission validation exercise (SMAPVEX)
- EC FP7 SIGMA Project.

SMAPVEX

SMAP will provide global soil moisture data using active radar and passive microwave sensors. The Agriculture and Agri-Food Canada (AAFC) Red River JECAM site was used by AAFC, NASA and U.S. Department of Agriculture (USDA) for an international SMAP validation experiment in 2012. SMAPVEX has helped NASA to validate their models for soil moisture retrieval and will be used to adapt AAFC models to use SMAP data. This work involved 75 scientists. In Canada, AAFC, Environment Canada, the Manitoba provincial agriculture ministry (MAFRI) and 3 universities participated. The U.S. team includes NASA, Jet Propulsion Lab, USDA and 10 universities. The campaign lasted 6 weeks and resulted in 45,000 soil moisture measurements; NASA flew 2 aircraft 17 times. Plans are underway to repeat the exercise in 2015, once the SMAP mission is active.

ESA Sentinel-2 Simulation over JECAM sites (Take 5)

Six JECAM sites were asked to participate. Five were able to support the mission with ground data. ESA acquired Spot-4 and RapidEye over the sites from February through May. The SPOT-4 orbit was lowered 3km to mimic the Sentinel-2 Constellation 5 day repeat cycle. Simulated multi-temporal datasets have been made available.

European Commission FP7 SIGMA Project

SIGMA is making use of the JECAM network to provide field sites for many of the work packages. Further, SIGMA has brought several new sites to JECAM, helping to broaden JECAM to over 30 sites. The intention is to collect minimum datasets of in-situ and satellite data over these sites and make them widely available for collaborative research purposes. It is anticipated that the JECAM site network will make a significant contribution to GEOGLAM through the FP7 SIGMA project.

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. Support will include exploring the development of minimum datasets of in-situ and satellite data for a core number of sites and taking part in the NASA "cloud" prototype to enhance data sharing and multi-party data licensing.