Crop Monitoring as an E-agriculture tool in developing countries

E-AGRI – an FP7 project (270351)

PROJECT FINAL REPORT

Grant Agreement number:	**270351**
Project acronym:	**E-AGRI**
Project title:	**Crop Monitoring as an E-agriculture tool in developing countries**
Funding Scheme:	**Collaborative project – International collaboration project (STREP/SICA)**
Period covered:	**2011-02-01 to 2014-01-31**
Name, title and organisation of the project's coordinator	**Dr. Qinghan Dong** **VLAAMS INSTELLING VOOR TECHNOLOGISH ONDERZOEK** **Tel: +32-14-336856** **Fax: +32-14-322795** **E-mail: qinghan.dong@vito.be**
Project website:	**http://www.e-agri.info**

Table of content

1. Final Publishable Summary Report

1.1. Executive Summary

This project aimed to address one of the targets stated in the Objective ICT-2009.1 of FP7 work programme, namely the support to the uptake of European ICT research results in developing economies. The objective were realized by setting up an advanced European E-agriculture service in two developing economies, Morocco and China, by means of crop monitoring. The activities of capacity building were carried out in the third developing country, Kenya, to raise the interest of local stakeholders on European E-agricultural practices and to pave the way for a technological transfer in the future.

At the end of the implementation, the most demonstrative achievements include:

- *Establishment of a comprehensive and advanced crop monitoring system for Morocco (CGMS-MAROC)*: the original European CGMS was fully reshuffled and re-parameterized to a system fully adapted to the local environmental and cropping conditions. The analyses for local monitoring and yield forecasting can now be carried out via a web based system (www.cgms-maroc.ma) by different end-users in a parallel way.
- Release of the multi-model platform BioMA to the Chinese partner in Jiangsu province to simulate crop growth and subsequently crop yield prediction. This first reported multi-model approach demonstrated its capacity to consider and simulate several yield impact drivers simultaneously such as diseases or climate change.
- E-AGRI project contains also a component of crop growth monitoring using earth observation information. The bio-physical variables derived from satellite imagery are particularly apt to provide highly accurate yield estimates for the targeted regions, especially in the early growth season. Moreover, due to the high availability of satellite data, this approach has found further application potential in the domains of agricultural insurance, food security early warning, or climate change on agricultural productivity. These domains are most of interest and actively promoted by various national and international instances such as FAO, WFP or World Bank.
- The local experts in two targeted regions have been able to knowledge crop mapping using remote sensing data. Furthermore an accurate and cost-efficient area sampling approach to assess the crop acreage was developed, which fits particularly well to the cropping patterns on the Huaibei Plain.

The implementation of E-AGRI project will assist the developing countries in their challenge of agricultural policy making. It helps to achieve the food security, increase farmer incomes and protect local farmer interest, in the context of agricultural liberalization and sustainable development. On the other hand, the feedback from this project enhances the applicability of European crop monitoring technology on a global scale, thus ultimately strengthens its capacity in global monitoring of food security. The networking developed within this project allows the partners to team up for new projects or activities and explore new horizons. Finally the project is believed to have contributed, through its capacity building component, to the Millennium Development Goals.

1.2. Project context and objectives:

Agriculture is one of the most important domains to which the European Union (EU) exercises the direct competence via its **Common Agricultural Policy** (CAP). In order to support the implementation of the CAP which represents more than 40-50% of the annual budget of the Union during the last decade and to assess the **agricultural production within EU and other critical regions**, the Directorate General Agriculture has funded the **MARS Programme** (Monitoring Agriculture with Remote Sensing).

Following the implementation of the different phases of programme (MARS operation I-III), under the leadership of the Joint Research Centre of the European Commission, the European partner institutions have been able to developed series of technologies based on the remote sensing, geographic information system and agro-meteorological modelling for assessing the crop yield as well as for estimating the crop acreage. The technologies have essentially been developed in three domains:

1. Crop monitoring using space based information to monitor the crop growth status and predict the crop yield. The approach takes advantage of the earth observation information provided by the satellite sensors, which are able to observe vegetation at daily base and derive different vegetation indices.
2. Crop monitoring can also be carried out by agro-meteorological modelling. The system CGMS was developed following this approach. It has been used to providing accurate and timely crop yield forecasts and crop production biomass for the 28 member state territory and other strategic areas of the world. The System contributes to the evaluation of global productions in support to CAP management decision. On the hand, A multi-component based platform BioMA has been developed to model several yield impact drivers at same time and in one system.
3. In terms of crop area estimates, test pilot approaches using area frame sampling and remote sensing has been developed in Europe.

The project was proposed to address one of the target outcome stated in the work programme ICT-2009-9.1: support to the uptake of European ICT research results in developing economies. The E-AGRI consortium was convinced that the general objective could be contributed through a transfer and adaptation of the European MARS Crop Yield Forecasting System and its multi-component extensions.

The project entailed a research and development (RTD) component and a demonstration (DEMO) component. The RD tasks aimed to adapt European technologies to local agri-environmental conditions and to develop and integrate additional peripheral components. The DEMO activities measured locally the effectiveness of the transferred technologies through an establishment of users' networks and disseminate the RTD results through different channels. These activities were proposed to be implemented in two developing countries Morocco and the Huaibei Plain in China, where a large portion of its population were still living in rural areas. These two target regions were proposed because of their **relatively advanced base on technological knowledge, their local economical affordability and their local exploitation opportunities.**

Finally a capacity building activity were organized in the third developing country, Kenya, to pave the way for a further technological transfer.

The project had the following specific objectives:

- ***Objective of DEMONSTRATION* : to transfer and adaptation of European agricultural monitoring technology in two developing countries.**
- ***Objective of DISSEMINATION*: to establish networks of users on the crop monitoring technology across three continents in the world (Europe , Africa and Asia (China)).**
- ***Objective of providing ADDED VALUES for EU*: to obtain the feedback and thus to improve for European expertise and know-how (ADDED VALUES for EU)**
- ***Objective of COLLABORATION*: to create synergy with other European crop monitoring actions (MARS-Stat-Food, GMFS…)**

1.3. Main scientific and technological results

The implementation and achievement of the project should allow the local partner organizations to build up their own knowledge and experience on using European crop monitoring technologies. Practically, at the end of the implementation, the local partners have acquired the know-how, on the pre-operational level, on the key crop monitoring components (for example, CGMS or BioMA platform) that are transferred by the European partners. That means, once local input data and institutional support are available, the operation of these crop monitoring systems will be sustained.

The success of the project, at the end of implementation, is reflected by the infrastructure set-up of locally adapted technologies and the knowledge and capability set-up for operating this infrastructure. In this regard, implementation of some key technologies went well beyond the frame set out in the Description of Work:

- the CGMS set up in Morocco is the best illustration of the progress. Thanks to the common effort from the European and local partners, particularly to the collaboration contributed by other two Moroccan organisations outside of E-AGRI consortium, the CGMS-MAROC has been set up and brought to operation, integrating both agro-meteorological and remote sensing indicators. The system has been further built up in the web viewer environmental allowing parallel and simultaneous analysis of crop growth status from different terminals
- the BIOMA platform has been further completed with a module for assessing the disease impact on the crops, which was not planned initially
- crop yield forecasting using remote sensing indicators has been further developed on the Huaibei Plain to include an indicators for yield technological trends, so that the forecasting performed with the same level of accuracy in Europe
- a new area frame sampling approach has been developed together with the Joint Research Centre with increased cost effectiveness and accuracy

1.3.1. Set-up and operationalization of CGMS (case study of Morocco)

The CGMS-MAROC is an institutionally distributed system which involves the Moroccan institutes DMN, INRA and DSS. The CGMS-MAROC consists of modelling at three Levels. All three levels including weather data processing (Level 1), crop simulation (Level 2) and statistical analysis for yield forecasting (Level 3) are implemented at the premises of local partners and consists of an ORACLE database, the CGMS executable for weather data processing and crop simulation as well several other tools that support the processing chain.

Daily meteorological station data are used in two ways in CGMS. First as indicators for weather monitoring. Second, as input for the crop growth model WOFOST. The weather monitoring component is the core of CGMS-MAROC and it's the aim of the CGMS Level 1. It consists of the following steps:

1. Acquisition, quality checking and processing of raw daily meteorological station data from the DMN network;
2. Computing and estimating the actual vapor pressure;
3. Estimating global radiation according to CGMS hierarchical technique: Angstrom and Hargreaves;
4. Calculation of advanced parameters: Reference evapotranspiration (PET) according to Penman-Monteith formula, evaporation of water surface and evaporation of wet bare soil
5. Spatial interpolation to the regular Moroccan climatic grid.

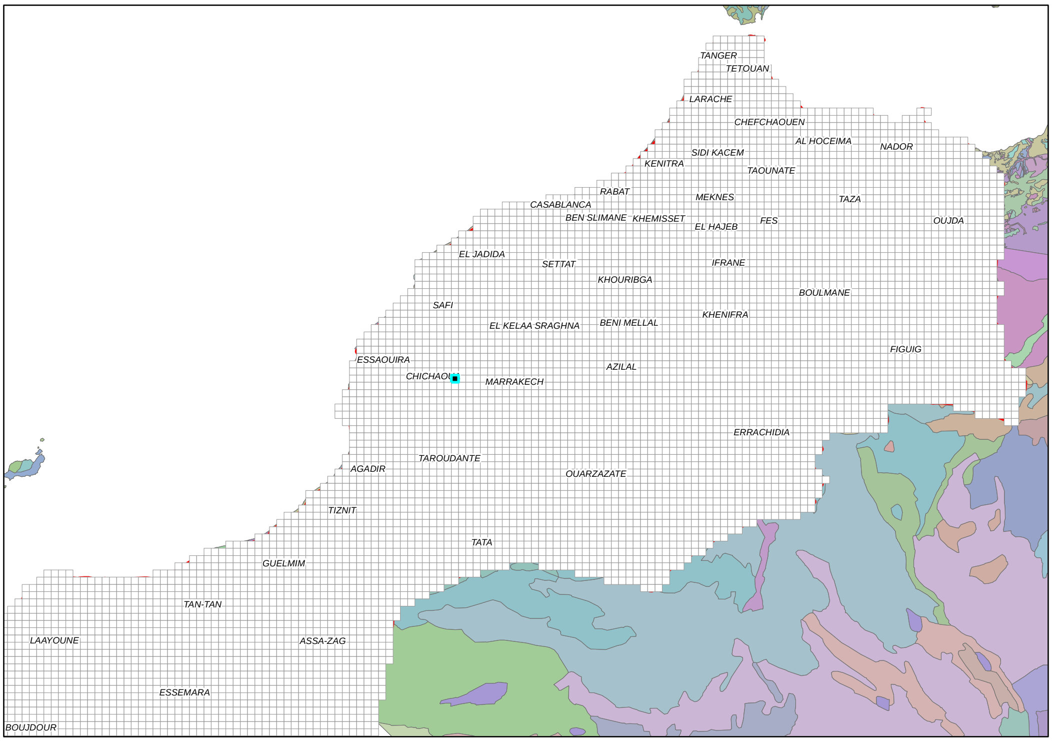


Figure 1. Overview of the CGMS-MAROC spatial schema for the Northern part of Morocco, including the province boundaries (red), the soil map (colour polygons) and the CGMS grid (grey rectangular boxes). Labels are province names.

The crop monitoring component produces simulated crop indicators like biomass and yields to show the effect of recent weather on crop growth. This Level 2 work is divided into four activities. Only the last two are part of the operational services, while the first two are pre-processing tasks:

- Collection and processing of input data.
- Spatial schematization.
- Running of crop simulations for individual map units.

- Spatial aggregation. of results

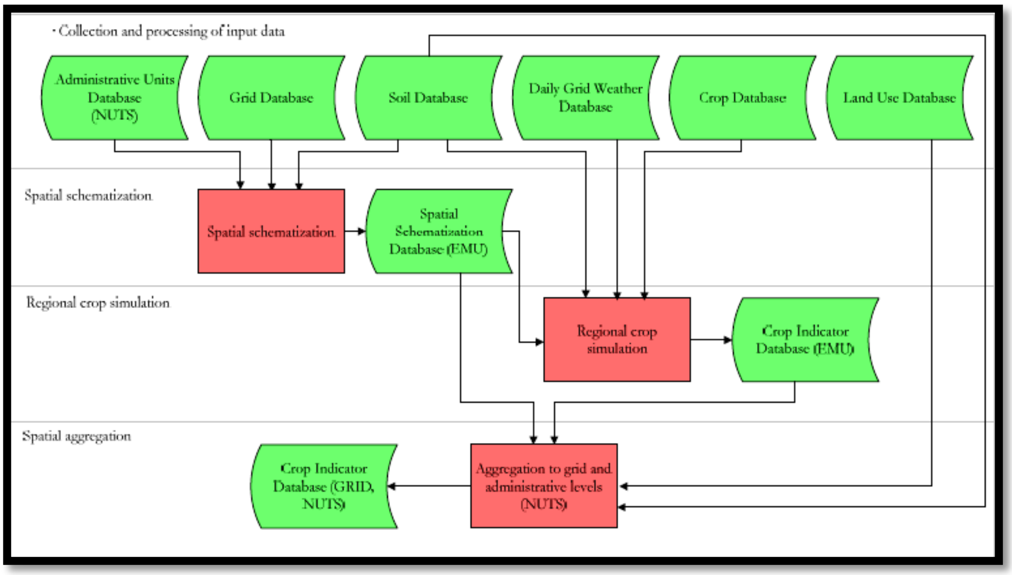


Figure 2 overview of the crop monitoring components in CGMS MOROCCO

The crop monitoring component in CGMS MOROCCO is based on WOFOST simulations. This model is a point model. To apply this model at a larger scale, areas where meteorological data, soil characteristics and crop parameters can be assumed homogeneous have to be identified. It is assumed that the simulated crop growth is representative for those areas. To build these areas, two geographic layers (climatic grid cell and SMU) are intersected which results in so called Elementary Mapping Unit's (EMU). Furthermore, a crop mask shapefile is used for excluding the non arable areas and to keep only intersection between Climate grids, SMUs and arable lands. The EMUs are then the smallest units of simulation by WOFOST.

Simulated crop indicators of the EMU's are spatially aggregated to the smallest administrative polygons

The aggregated crop simulation results at regional level are on the of indicators which are used for crop yield forecasting by the CGMS statistical toolbox (Level 3). At the local partner institution, a second database schema has been implemented which holds the database schema necessary for storing the data for the CGMS Statistical and results from the application. The entire flow of information is depicted in Figure 3.

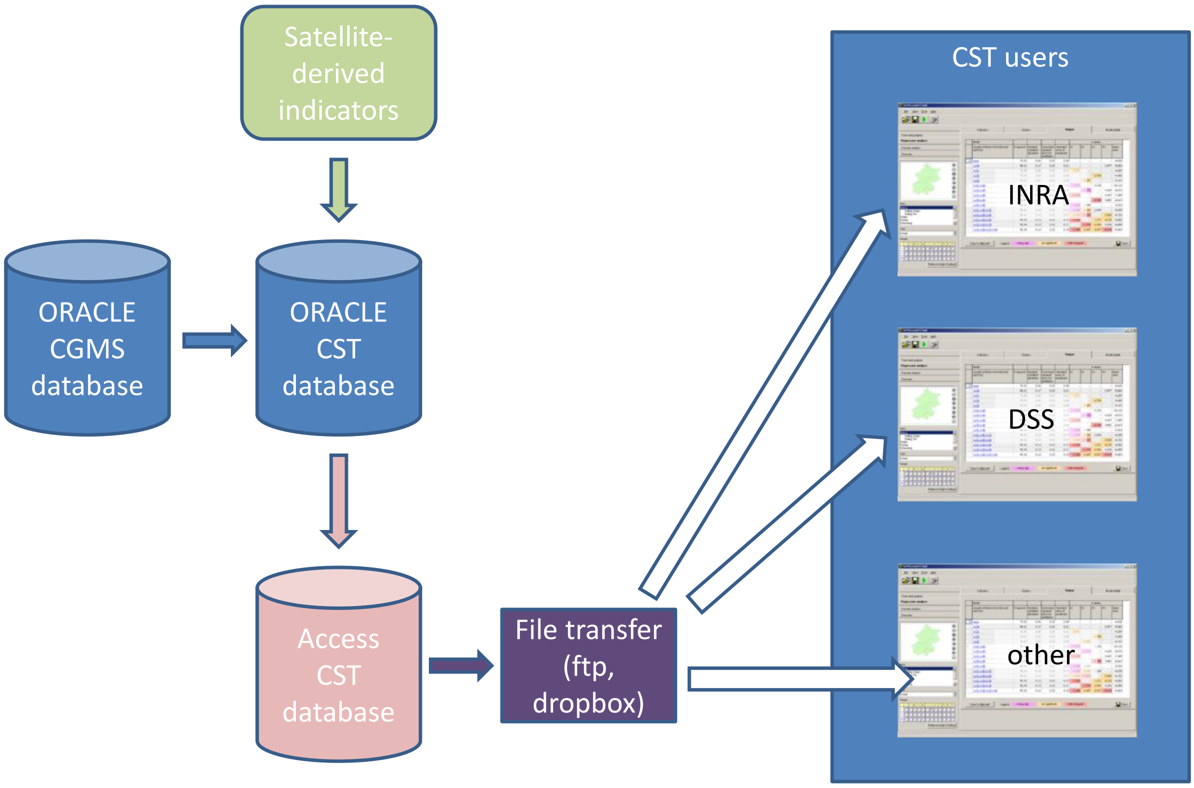


Figure 3. Flow of information from CGMS to the CGMS statistical toolbox and its end users.

Results from the CGMS level 2 are send to the CST database schema which can accomplished through several select-insert statements as this is the same database. At the same time, additional indicators are added which are derived from the weather data directly and from satellite processing chains at VITO. The entire CST database in ORACLE is then replicated in an Microsoft Access database which can be easily done due to the strong data reductions are a result of averaging.

Finally, this Microsoft access database can be packaged (zipped) and put on a medium for file-sharing such as DROPBOX or an ftp server that can be accessed by CST users. The Access database can be picked from the file sharing medium, unzipped onto the right CST folder structure and the end user can analyse the latest indicators for yield forecasting.

At the end, a Web viewer, called CGMS-MAROC and available at www.cgms-maroc.ma (Figure 4), has been developed by the project in order to visualize data and make preliminary analyses of status of the cropping season.

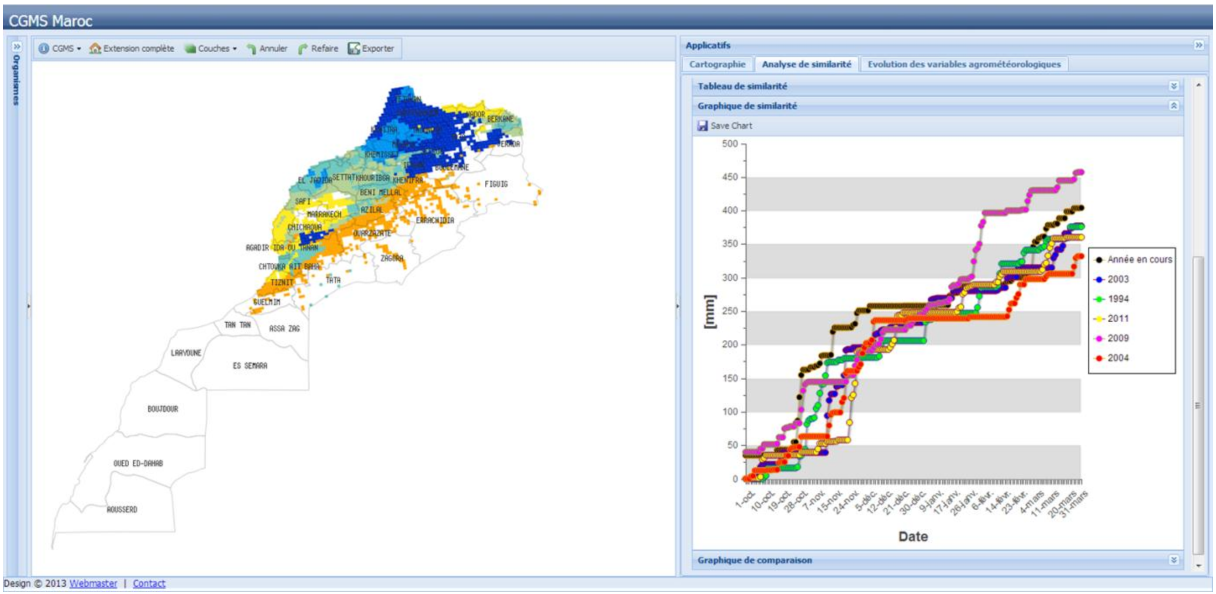


Figure 4: The Web viewer of CGMS-MAROC (www.cgms-maroc.ma) for bio-climatic monitoring of cereals, and preliminary statistical analysis of the cropping season. On the left side window is displayed the cumulated rainfall over the season on croplands (9.14x9.14 km grid). On the right window is shown, the similarity analysis using cumulated rainfall, in the administrative Commune of Ben Ahmed (Province of Settat).

1.3.2. Multi-model platform BioMA for rice monitoring on Jianghuai Plain

BioMA is a platform developed for analysing and running - on explicit spatial units - modelling solutions based on biophysical models. The platform is composed of different integrated tools easily allowing the user to create specific configurations, in this case for comparing (i) the outputs simulated by different crop models, (ii) as well as their capability of forecasting yields, without the need for opening and modifying the underlying databases.

The user can especially visualize and compare the outputs and forecasting results derived from the modification of management options or from the simulation of crop limitations (i.e., water stress, biotic and abiotic damages).

In this work, BioMA was applied to simulate rice growth and development in Jiangsu province (China) in the period 1990-2010. The biophysical models CropSyst, WARM and WOFOST, previously calibrated (during this project) for the specific conditions explored, were used and compared for the spatial simulations, whereas - to assess the advanced functionalities of the platform -only WARM's outputs were post-processed to obtain the yield forecasting. The evaluation of the multi-model approach for yield forecasts were performed. CropSyst, WARM and WOFOST differently reacted to the modification of management and to the simulation of the plant-pathogens interaction. Indeed, the values and patterns followed by the output variables strictly depend on the approach used by each simulation model to reproduce crop growth and development. The variability of official yields explained by the statistical post-processing of simulated data changed when management options were modified and increased if the diseases limited outputs were inserted as indicators in the regression analysis. In the specific case, the coefficient of determination increased for about 5% using the disease-limited indicators.

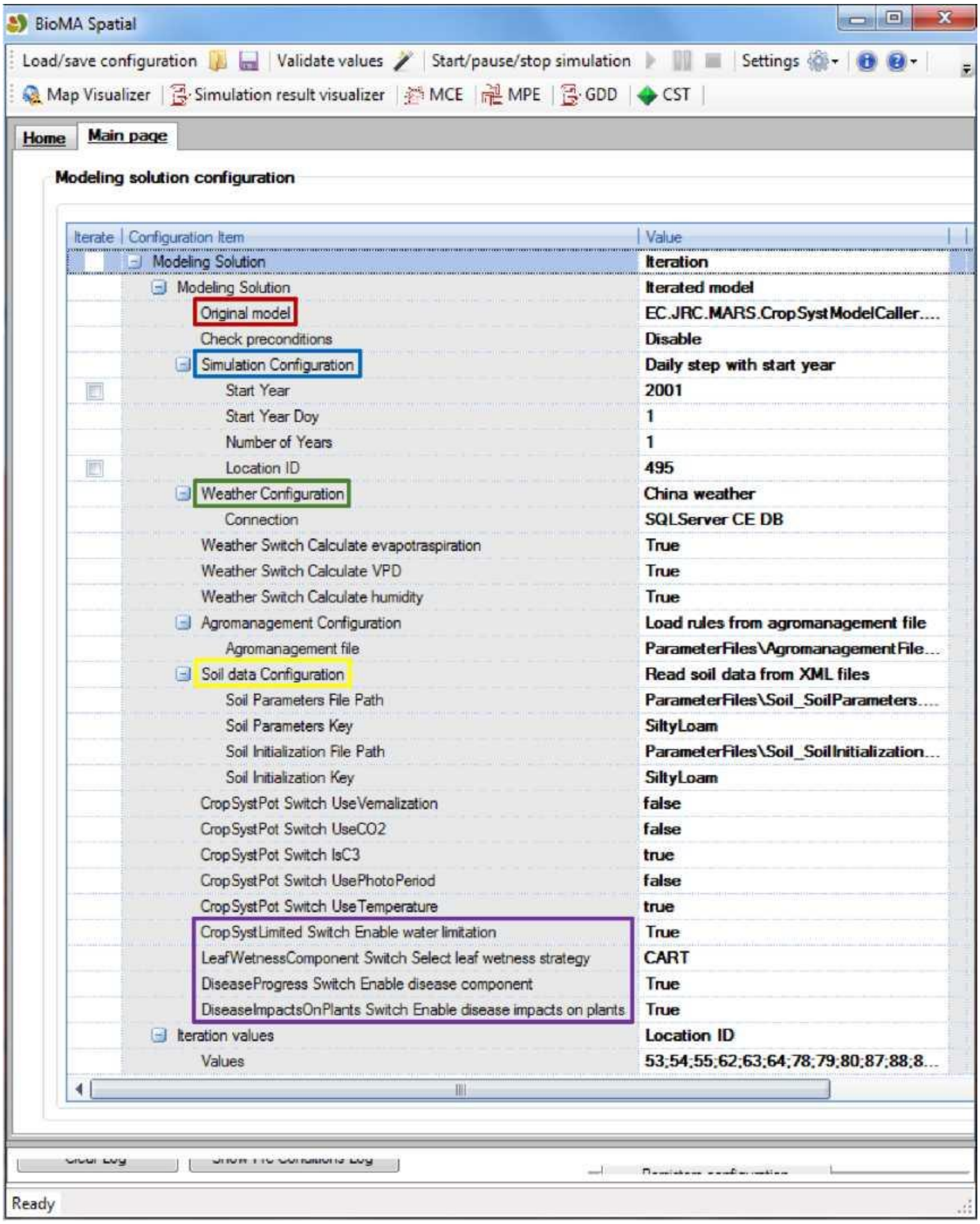


Figure 5: Components of the modelling solution configuration

According to the authors, this is the first time a multi-model approach was developed and evaluated for in-season monitoring and forecasting purposes. Results demonstrated the usefulness of this approach, with different models achieving the best agreement metrics according to the climate conditions explored and to the time when the forecasting events were triggered. All the crop models showed, however, satisfactory performances, thus demonstrating (i) the soundness of the approaches used to reproduce crop growth and development and (ii) the reliability of the parameterizations, in turns deriving from the high quality activities performed during the project for experimental data collection and calibration.

This work also demonstrated the usefulness of simulating disease impact on crop yields, since disease-limited indicators were always selected by the CGMS statistical post processor, regardless from the crop model used and the time series considered.

1.3.3. Crop yield prediction using remote sensing

Crop yields can be assessed by using the low-resolution imagery registered by synoptic observation systems, such as NOAA-AVHRR (active since early 80's) or SPOT-VEGETATION (available since 1998). Such an assessment can usually be achieved by examining so-called vegetation indices retrieved from these systems, as a measure for plant growth and development. Since the appearance of the oldest and simplest vegetation variable NDVI (Normalized Difference Vegetation Index), other model based indices such as, Fraction of Absorbed Photosynthetically Active Radiation (fAPAR) or Dry Mass Productivity (DMP) are widely used. The statistical variables (maximum, minimum or mean etc.) derived from these vegetation times series enabled to detect anomalies in growth conditions. On the other hand, these biophysical variables are also widely used as predictors in crop yield forecasting models. The project analyzed all biophysical, technological and meteorological factors that affect wheat yield on the Huaibei plain and establish the yield prediction models for each of the prefectures using these driving factors as explanatory variables.

For the use operational use, we built and tested models, which are relevant for yield estimation at an early stage of crop growth season. For this test purposes, a database containing the mean values of all relevant predictors was built for whole Plain. Table 6 displays the potential regression models for early season yield forecasting with different prediction periods, from autumn to nearly harvest.

The cumulative variable NDVI in the emergence-tiller phenological stage and the variable CFI (Chemical Fertiliser Input) are revealed most crucial. It is understandable that the absolute errors of forecasting increase while the forecasts were conducted in earlier stages of growth.

In conclusion, for the whole Huaibei Plain the cumulative value of NDVI from second dekad of October to the second dekad of November is the most explanatory variable for wheat yield forecasting on the Huaibei Plain.

Table 1: The best-fit regression models for wheat yield prediction at the prefecture level on Huaibei Plain using NDVI, CFI and meteorological variables as predictors

Prefecture	Models				R^2	Absolute Error (ton)
	Constant	ΣNDVI	CFI	Meteorology		
Bengbu	-3.875	+6.183*O2N2		-0.019*RHV+ 0.471*TJ-0.093*RW - 0.326* SW	0.990	0.062
Bozhou	-5.040	+7.376*N1	+0.031*CFI		0.851	0.291
Fuyang	-12.189	+3.374*O2N1	+0.029*CFI	+0.282*SS	0.907	0.183
Huaibei	-2.588	+0.730*J3M3	+0.071*CFI	-0.40*RJ	0.963	0.283
Huainan	2.691		+0.050*CFI	-0.053*RJ-0.135*SH	0.964	0.167
Suzhou	-2.623	+12.762*M3		-0.065RJ+0.055*RTG	0.936	0.213

Table 2: **different scenarios for early yield forecasting**

Prediction periods	**Models**				**R^2**	**Absolute Error**
	Constant	ΣNDVI	CFI	Meteorology		
May 3rd	-6.879	+2.865*O2N2	0.314*CFI	+0.022*Sm	0.965	0.129
March 1st	-5.996	+2.526*O2N2	+0.355*CFI	-0.22*Rg	0.960	0.159
February 1st	-6.327	+3.683*O2N2	+0.299*CFI	-0.017*Tw	0.901	0.185
November 2nd	-5.959	+3.578*O2N2	+0.302*CFI		0.927	0.238

In the study region of Morocco, the forecasting models using NDVI at provincial, agro-ecological zone and national levels show most consistency. Figure 6 shows the classification and spatial distribution of the provinces according to their forecast consistency in terms of cereal yields.

Figure 7 illustrates that at provincial level, the consistency of the forecasting, represented by the coefficient of determination, improves, although slightly when we use the average of NDVI value between the months of February and April..

As the conclusions of this chapter, Compared to the approaches using weather data coming from ground stations, indicators derived from remote sensing, such as NDVI, have the advantage of being available throughout the extent of the country, without discontinuity at high spatial and temporal resolutions (in "raster" form, known as pixel), which is well suited for crop yield forecasting. Forecasts can be performed operationally at the levels of the provinces, agro-ecological zones and national level. Forecasted yield for each province can even be aggregated to national level, proportionally to their respective cropped areas, for providing yield forecast for the entire country. This approach requires more computational workload but with better accuracy. The coefficients of determination (R^2) of these models were high, ranging between 72 and 98%, except in the arid southern provinces of the country, which contribute little to the total national production. These regression models were relatively stable, since their coefficients of determination in cross-validation (Rp^2) were still between 59 and 94%. Furthermore, forecasts were relatively accurate and can be conducted early in the growth season, for example, two months prior to harvests.

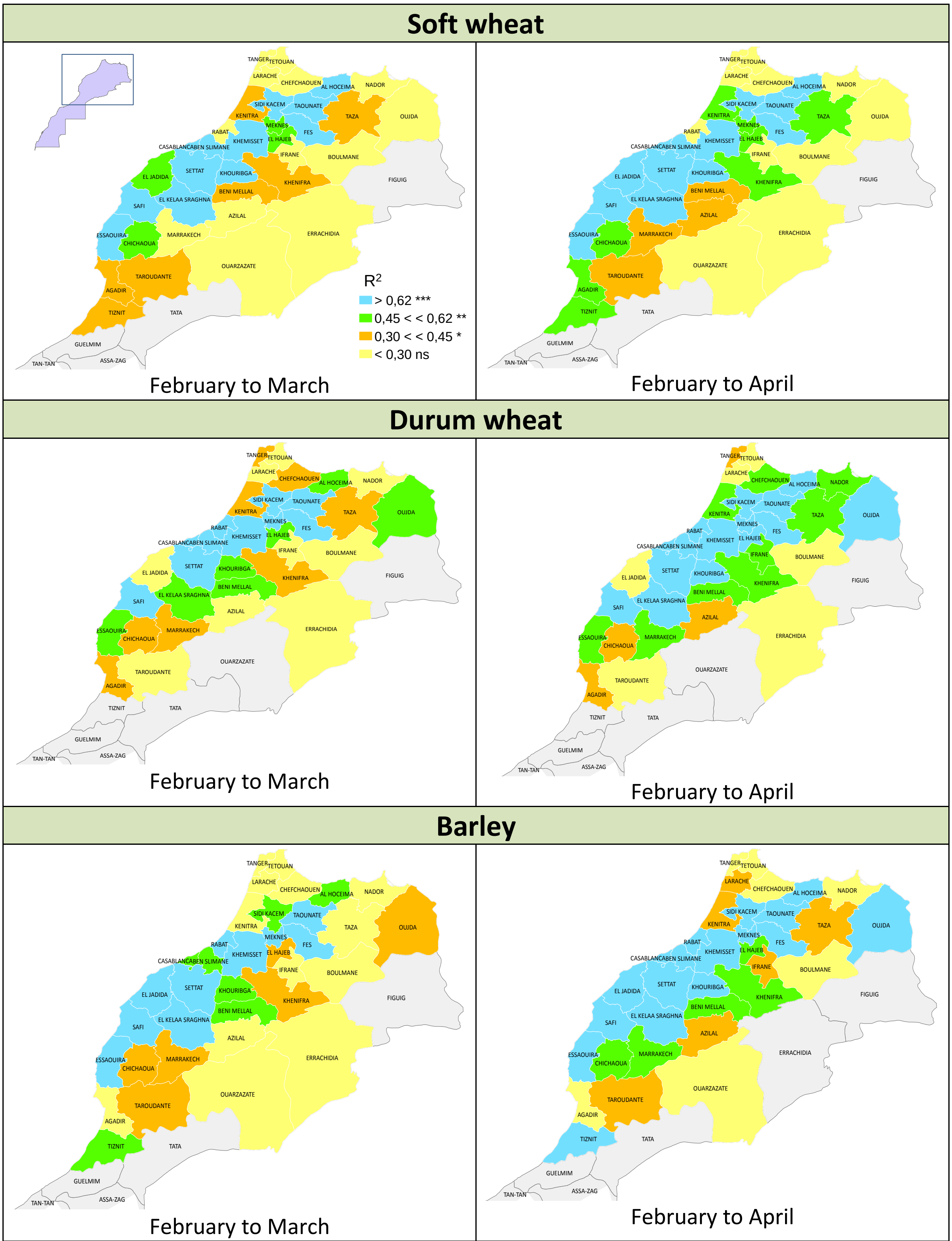


Figure 6: Mapping of four classes of coefficient of determination (R^2) of the linear regression models between yields of soft wheat, durum wheat and barley, and average dekad NDVI (SPOT-VGT) from February till March and from February till April.

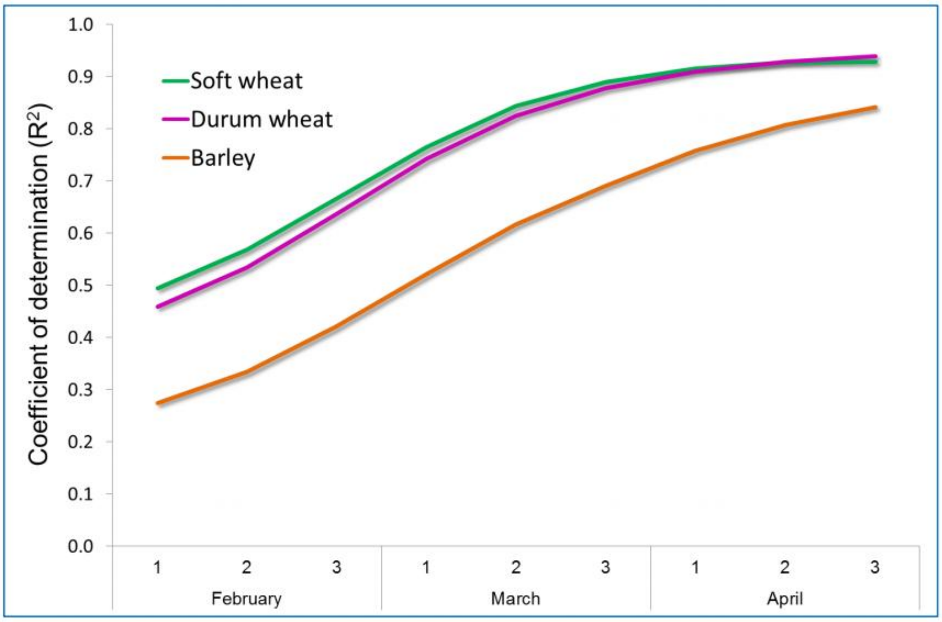


Figure 7: Coefficient of determination (R^2) of regression models between yields of the three main cereals (soft and durum wheat, and barley) in Morocco, and average NDVI (SPOT VGT), at the national level (data from 1999 to 2011), by step of one dekad, since the 1st dekad of February.

1.3.4. Crop area estimation

The two stage method for area frame sampling, recommended by FAO was applied for two study areas in Morocco.

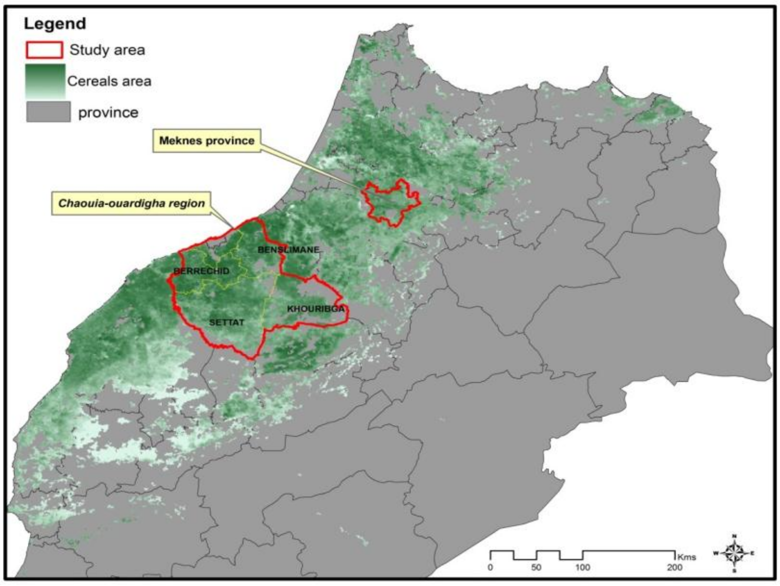


Figure 8: The two selected test areas (boundaries in red), for area assessment based on Remote Sensing. The two areas cover a significant part of the agricultural lands of Morocco (in green).

The basic stratification employed involves: (1) dividing the land into land-use strata such as rainfed cultivated land, urban areas and rangeland etc.., and (2) further dividing each land-use stratum into substrata by grouping areas that are agriculturally similar. In this study, the stratification consisted in delineating the land cover classes, called "Strata". Ten strata where defined by DSS for Morocco. These 10 strata were digitized using GIS, based on aerial photography, topographic maps, ortho-rectified SPOT 5 images.

The zoning is the procedure for delineating the Primary Sampling Units (PSU) and the Secondary Sampling Units (SSU). The zoning is a three steps procedure:

- First step: It consists in dividing each stratum in regular rectangles, called Primary Sampling Units (PSU). The size of the rectangles is defined of each stratum.
- Second step: It consists in correcting the borders of the PSU so that they match with natural boundaries (roads, rivers, lakes, etc.).
- Third step: It consists in dividing the PSU in regular squares, also called "segments" or Secondary Sampling Units (SSU).

The selection of primary sampling units was performed according to a random probability method proportional to size. The secondary sampling units were performed using a simple random sampling. Once the primary units were selected, a subdivision of these units or sub-units segment was performed.

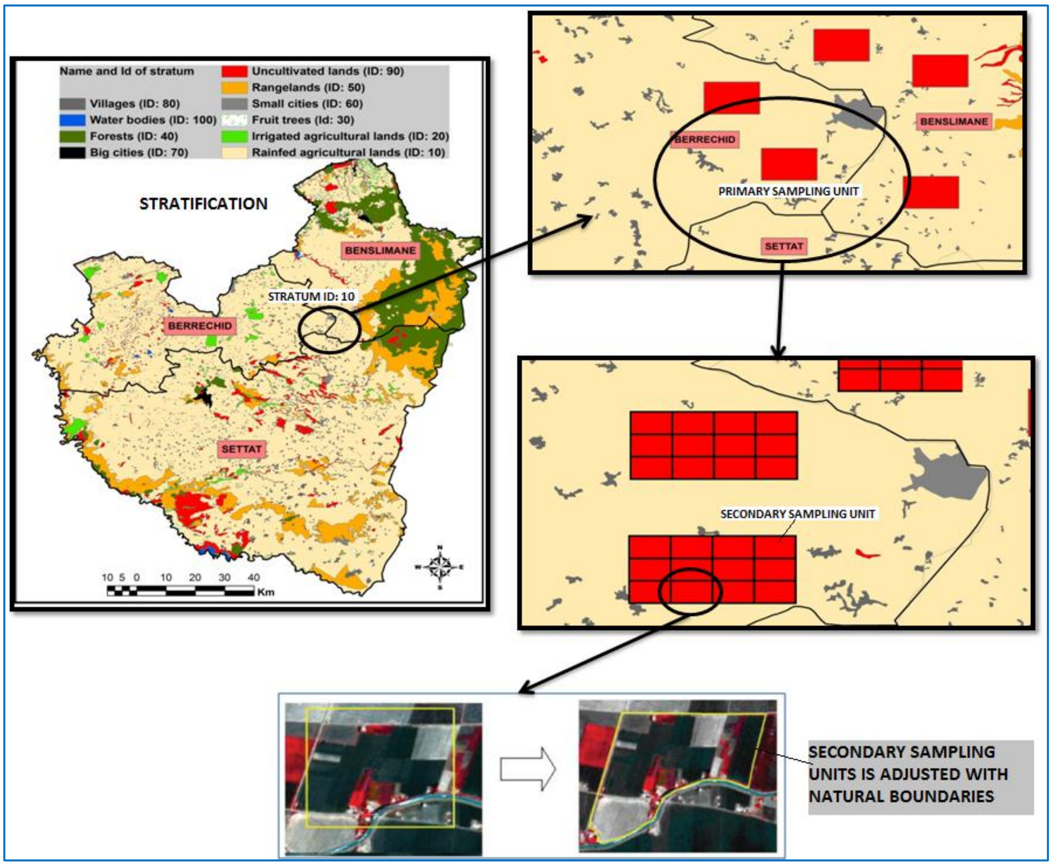


Figure 9: Example of the scheme of area frame sampling, in the Chaouia-Ouardigha region.

Table 3: Area estimates (Hectare) for cereals (soft wheat, durum wheat and barley) in the studied provinces during season of 2012-2013. Y (h): area of stratum h; Y_T: total area observed in the sample; Y_{cer}: Surface observed on cereals in the sample; CE: Extrapolation coefficient

2013	Y (h)	Y_T	CE	Y_{barley}	$Y_{durum\ wheat}$	$Y_{soft\ wheat}$	Barley	Durum wheat	Soft wheat	All cereals
BENSLIMANE	133570	2482	54	288	15504	873	**46962**	**179**	**9620**	**72086**
BERRECHID	222120	2166	103	636	65197	644	**66060**	**281**	**28797**	**160053**
KHOURIBGA	270288	2247	120	265	31829	350	**42137**	**1075**	**129345**	**203311**
SETTAT	498917	3896	128	1285	164632	783	**100268**	**916**	**117348**	**382248**
MEKNES	104086	1109	94	10	978	564	**52924**	**39**	**3653**	**57555**

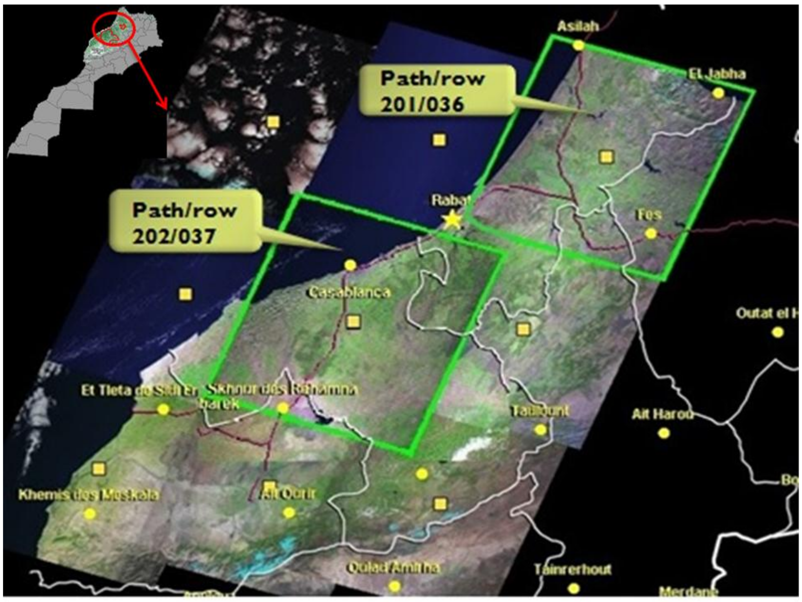


Figure 10: Example of Landsat7-ETM scenes, registered for the two "frames" covering the "study areas": the 202/037 scene covers Chaouia-Ouardigha region and the 201/036 covers the Meknes provinces. Source: GLOVIS website.

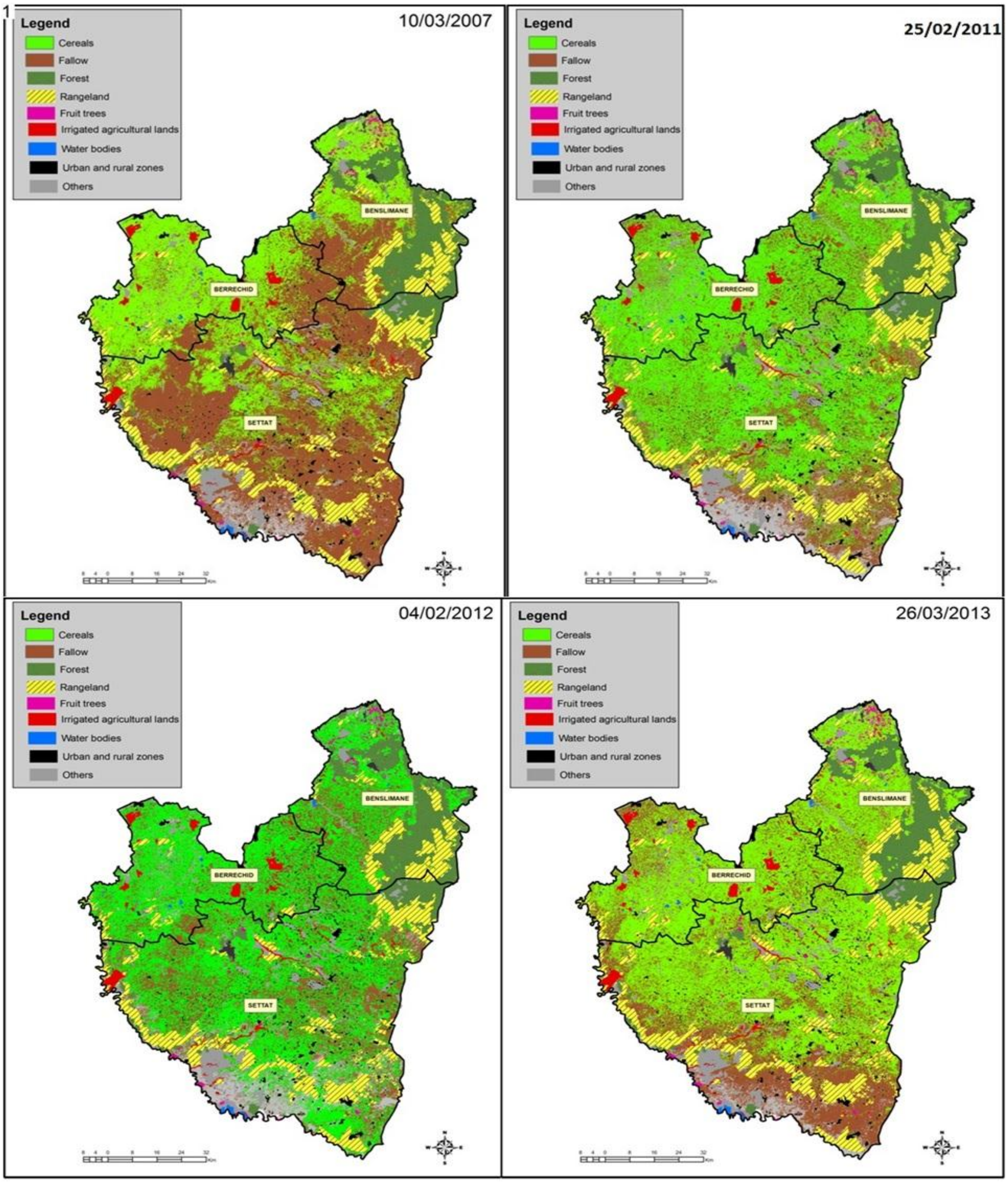
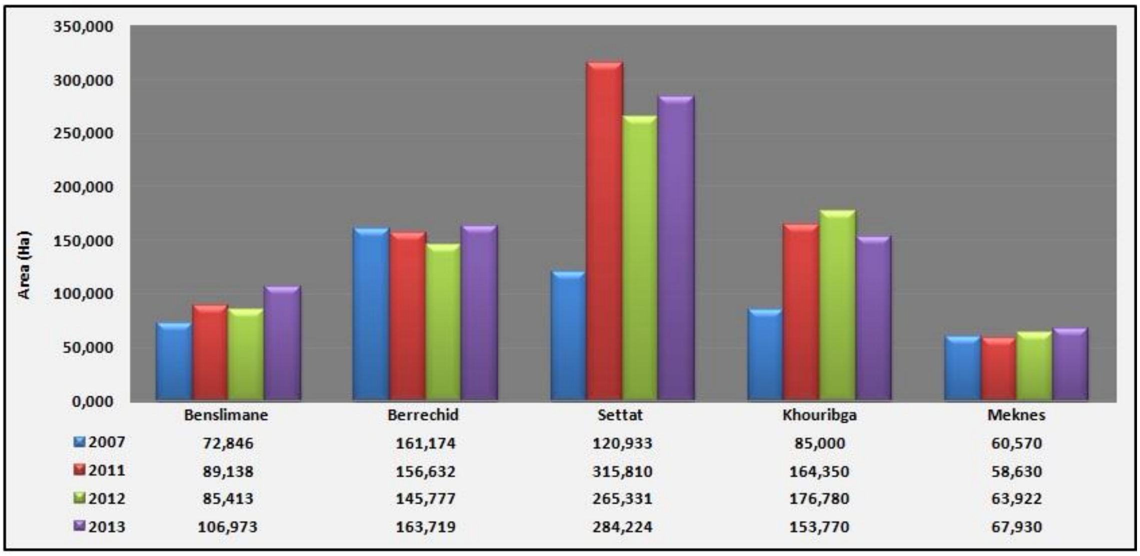


Figure 11: Land cover map of Settat, Berrechid and Benslimane provinces showing the spatial distribution of cereals (green color) during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013.



	Benslimane	Berrechid	Settat	Khouribga	Meknes
2007	72,846	161,174	120,933	85,000	60,570
2011	89,138	156,632	315,810	164,350	58,630
2012	85,413	145,777	265,331	176,780	63,922
2013	106,973	163,719	284,224	153,770	67,930

Figure 12: Area estimates based on remote sensing classification, for the three cereals (soft wheat, durum wheat and barley) in the studied provinces (Settat, Benslimane, Berrechid, Khouribga and Meknes), during seasons of 2006-2007, 2010-2011, 2011-2012 and 2012-2013.

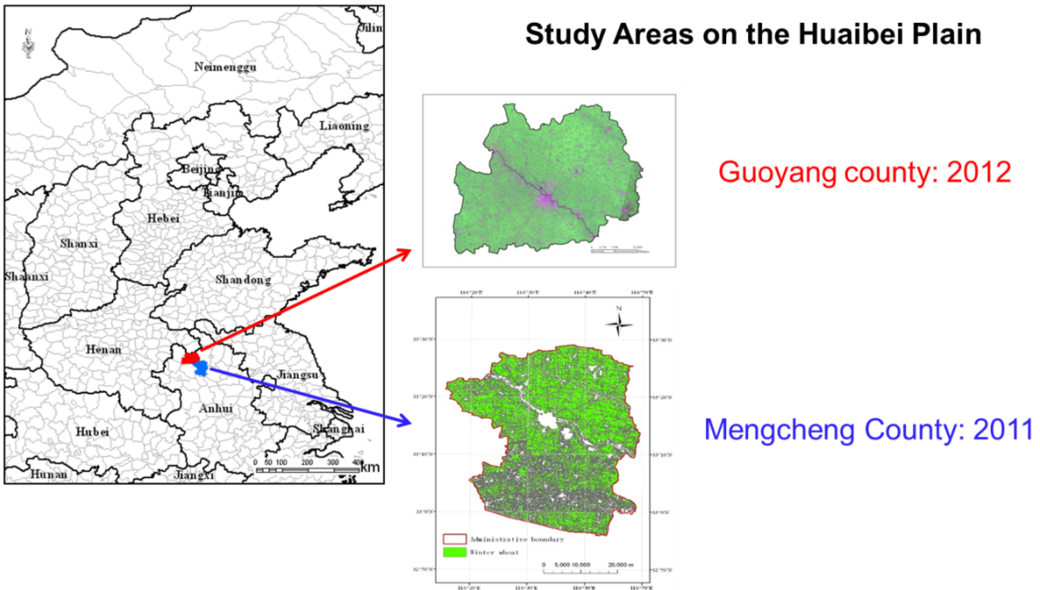


Figure 13: The study area on Huaibei Plain where the area frame sampling was conducted. The Plain composed of 6 prefectures is located on the North of the Anhui Province and on the south edge of the North China Plain. Agriculture there is well diversified due to the prevailed climate. The main products are wheat in the winter-spring season and soybean, maize and cotton in the summer crop season. Sampling was conducted in Mengcheng and Guoyang counties of Bozhou prefecture.

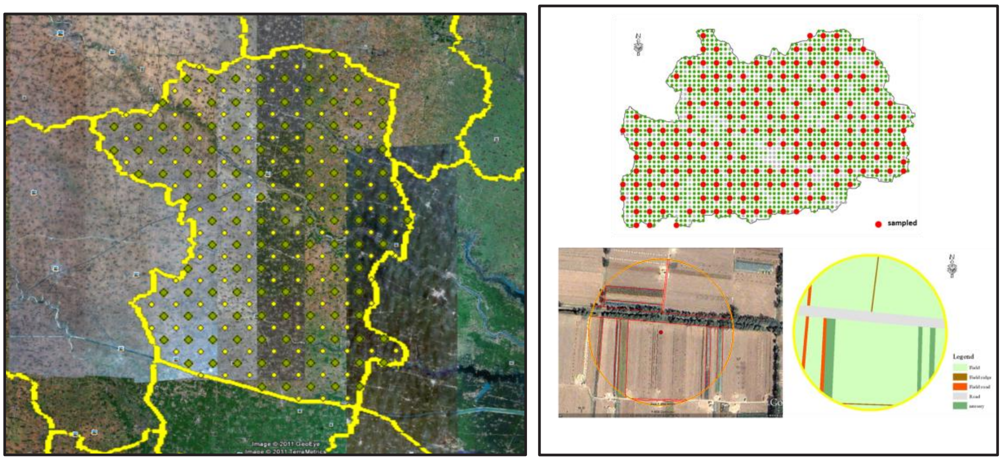


Figure 14: In this study to estimate the maize area, the point frame sampling approach is adapted to the strip-like cropping pattern on the North China Plain.

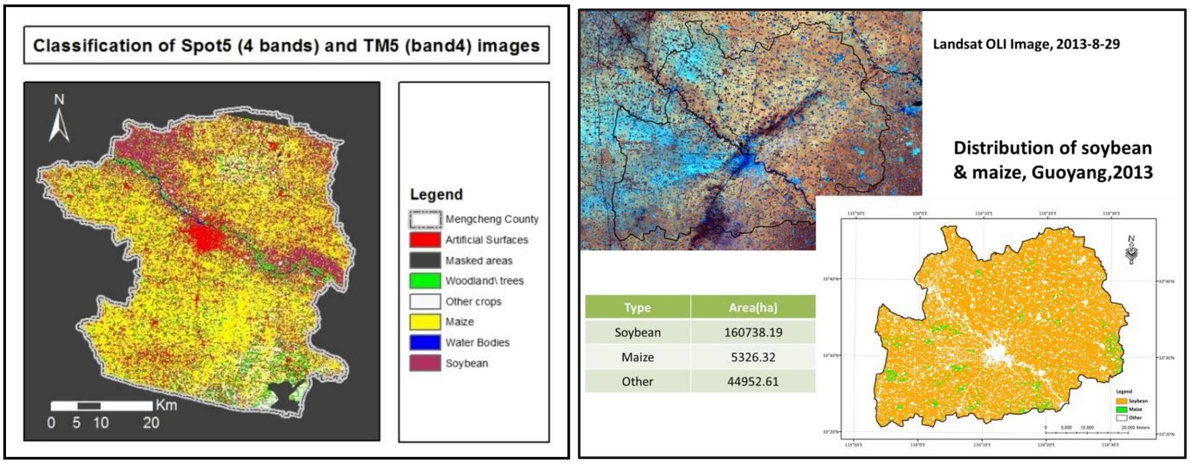


Figure 15: the use of remote sensing images for improving agricultural statistics derived from ground survey for the Mengcheng and Guoyang Counties on the North China Plain. The contribution of remote sensing was made on two levels: (1) it helped in area frame stratification (2) image classification was incorporated as an auxiliary variable in the analysis of regression estimator

Table 4: crop area proportions derived from: ground survey, image classification and regression estimator

	Maize	Soybean	Other crops
Area mean from ground survey (83 segments) and (SD)	76.8% (2.7%)	19.8% (2.5%)	3.0% (1.3%)
Regression slope (b) and coefficient of determination (R^2_{py})	0.71 (0.62)	0.74 (0.63)	0.56 (0.50)
Area mean from image classification in terms of arable land points	59.0%	28.6%	7.9%
Area mean within the 83 (arable) segments	64.7%	28.6%	5.5%
Regression estimator and (SD) in the arable stratum	72.8% (1.7%)	19.8% (1.5%)	4.4% (0.9%)
Relative efficiency of RS & equivalent sampling size	2.6 218	2.7 223	2.0 167
Number of ha in the county (assuming 157057 ha arable area)	114,287 ha (2,602 ha)	31,067 ha (2,418 ha)	6,882 ha (1,398 ha)

The contribution of remote sensing was made on two levels: (1) it helped in area frame stratification, therefore in optimising the sampling design prior to the ground survey; (2) remote sensing, by means of image classification, was incorporated as an auxiliary variable in the analysis of regression estimator, and therefore improved the precision of estimates by reducing the error of variance.

1.3.5. CGMS statistical tools

An important component in any regional crop yield forecasting system is the screening and analysis of regional statistical data on crop yield, area and production. Moreover, for yield forecasting purposes it is necessary to understand the inter-annual variability of crop yield and to determine if this variability can be explained by one or more indicators. These indicators can then be used to predict crop yield early in the growing season. Such indicators are often derived from weather data, from satellite information or from crop simulation models. Based on a previous frame developed within the context of the MARS system, an improvement for E-AGRI project application was conducted that combines these analyses within a single (relatively) easy to use application: the CGMS Statistical Tool (CST). The CST allows 1) to select a region and crop type, 2) select a time period in the year, 3) make a time-series analysis on the available statistical data, 4) carry out a regression or scenario analysis and 5) finally predict crop yield for the target year.

It should be noted that in principle all these analyses can be carried out using modern office tools like Microsoft Excel and there is no “magic” in terms of statistics involved. Nevertheless, carrying out such exercises in Excel is time-consuming, error-prone and cumbersome. Therefore, the CST streamlines the process of analysis and allows to store and document the settings used to make a certain forecast. The following figure (Figure 16) illustrates the functionality in time series and trends analysis.

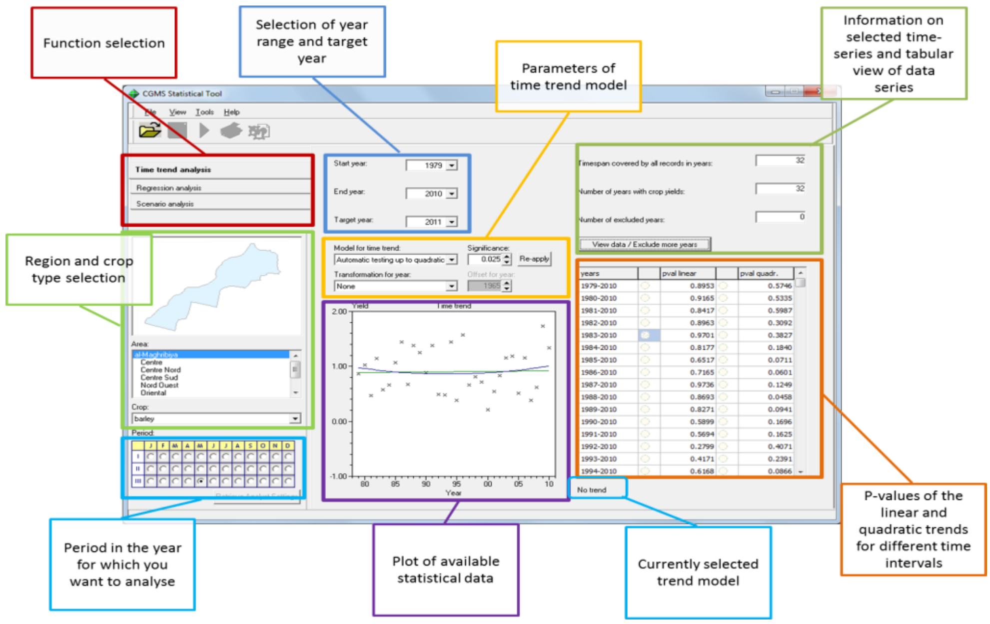


Figure 16. The Time-trend analysis window for the CST Morocco implementation.

The document describes installation procedures related to the CST can be found at: http://e-agri.wikispaces.com/CGMSStatTool

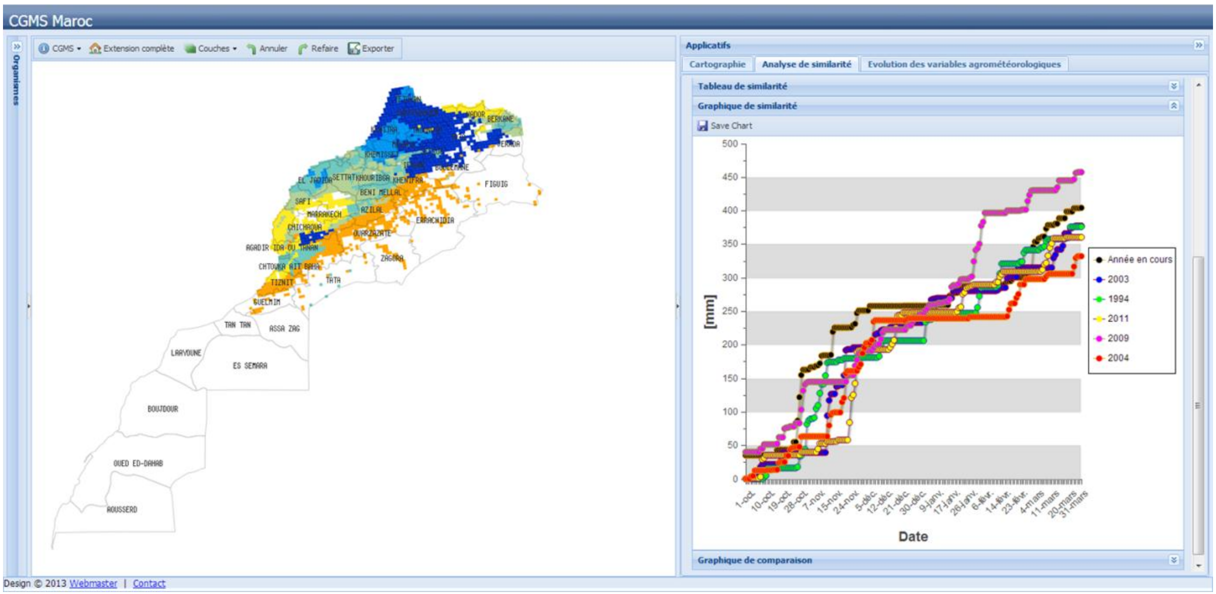


Figure 17: The Web viewer of CGMS-MAROC (http://www.cgms-maroc.ma) for bio-climatic monitoring of cereals, and preliminary statistical analysis of the cropping season. On the left side window is displayed the cumulated rainfall over the season on croplands (9.14x9.14 km grid). On the right window is shown, the similarity analysis using cumulated rainfall, in the administrative Commune of Ben Ahmed (Province of Settat).

1.3.6. Capacity building and networking

Series of workshops and training session were organized to strengthen the knowledge and capability of operation of local partners. The following table summarises the periods and places of these events.

Table 5: the main capacity building events organized within E-AGRI project

Event	Organizers	Place	Period
Rabat workshop on Yield forecasting using remote sensing	INRA / VITO	Rabat, Morocco	Oktober 2011
Hefei workshop on CGMS setup	AIFER / SDLO / VITO	Hefei, China	November 2011
Kenitra workshop on statistic tool box	SDLO / INRA	Kenitra	February 2012
Training on satellite image classification	VITO	Mol	June 2012
Training on crop yield forecasting using remote sensing	INRA	Rabat, Morocco	September 2012
CGMS training	SDLO	Wageningen, The Netherlands	September 2012
Training on vegetation indices computing	VITO	Mol, Belgium	October 2012
Kenya, National Workshop	MEMR / SDLO / VITO	Nairobi, Kenya	October, 2012
First BioMA workshop	UMIL / JAAS	Nanjing, China	December v2012
Seminar on crop area estimation	CAAS/VITO/JRC	Beijing, China	February 2013
Second BioMA training workshop	UMIL/INRA	Rabat, Morocco	March 2013
Training on image classification	VITO	Mol, Belgium	June, 2012
E-AGRI/AGRICAB Hands-on workshop on image classification using high resolution data over Kenya	VITO/MEMR	Nairobi, Kenya	November 2013
Training session “CGMS-Anhui Set-up”	SDLO/AIFER	Hefei, China	November 2013
Third BioMA training	UMIL	Milan, Italy	December 2013

1.4. Potential impact

The potential impact of the project can been seen at different levels. In the domain of a sustained local institutional set up, the local experts are able to advise adequately the agriculture policy makers on the issue of food security and the agro-commodity trading. The local partners publish periodically the yield forecast bulletins ((Figure 18), or attend the policy advising meetings. In longer term, the outcome of the project can help to promote initiatives for improving governance systems and policies especially in the area of adaptation and proactivity dealing with climate change and climate risks. More specifically, the success of the adaptation of agriculture to climate risks depends on national institutions which are responsible for food security, directly or indirectly.

Other impact of project towards policy makers can be illustrated by the invited lectures for DG AGRI of the European Commission and for experts of FAO of United Nations.

On the other hand, the feedback of European technological transfer has improved the applicability and robustness of these technologies. The adaptation brought to the CGMS application in Morocco, helped to make progress the GLOBCAST system operation by the DG AGRI of the European Commission. In the case of the rice monitoring, although this staple food is consumed by half of world population, the rice production monitoring is not closely followed by European institutions. The results generated from this project can be readily disseminated and fill the gap at the European level.

Finally the establishment of a crop monitoring system in North African will with no doubt strengthen the European capability of intervention in the domains of warning and food security.

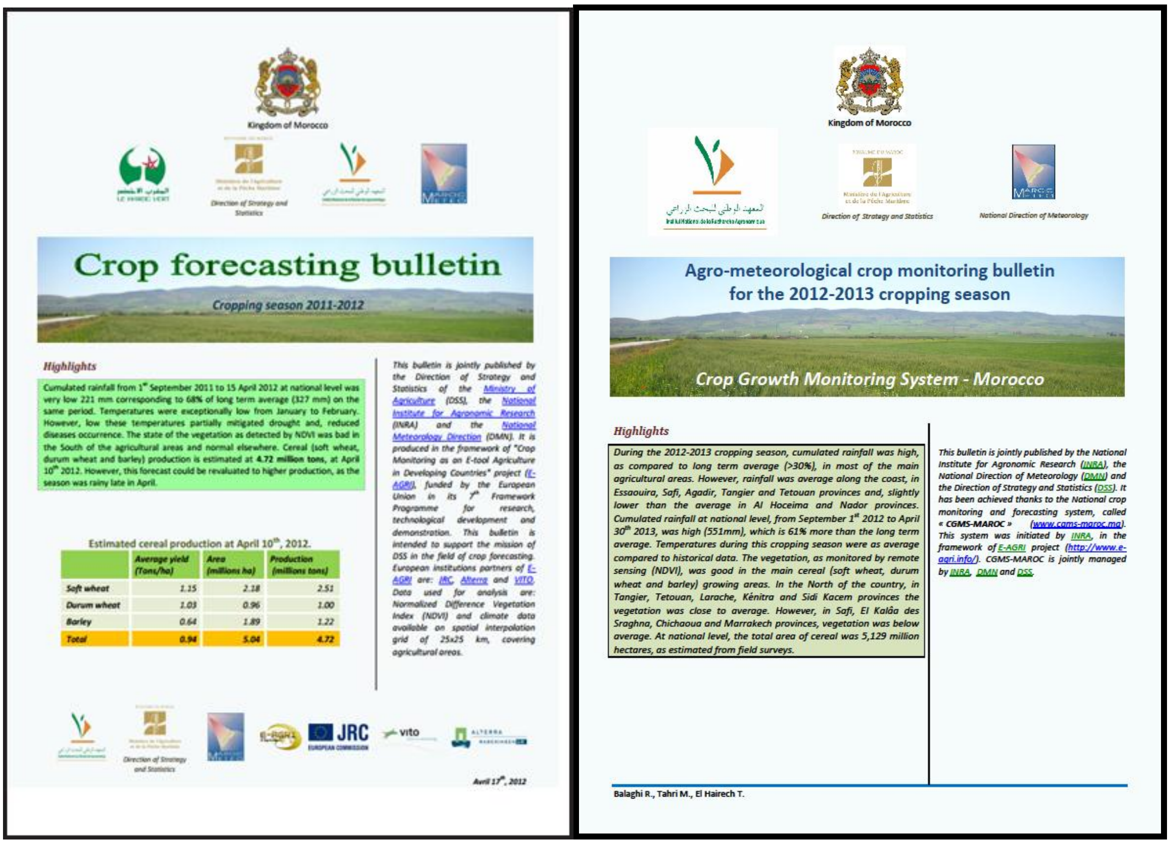


Figure 18: 2011-2012 & 2012-2013 crop yield forecasting bulletins for Morocco based on E-AGRI methodologies.

1.5. Project promotional media

1.5.1. Project's web-sites

The project general site (http://www.e-agri.info) has been recently updated including the major deliverables and new links to the other related project or activity websites including CGMS-MAROC:

Figure 19. Renewed project web site (www.e-agri.info).

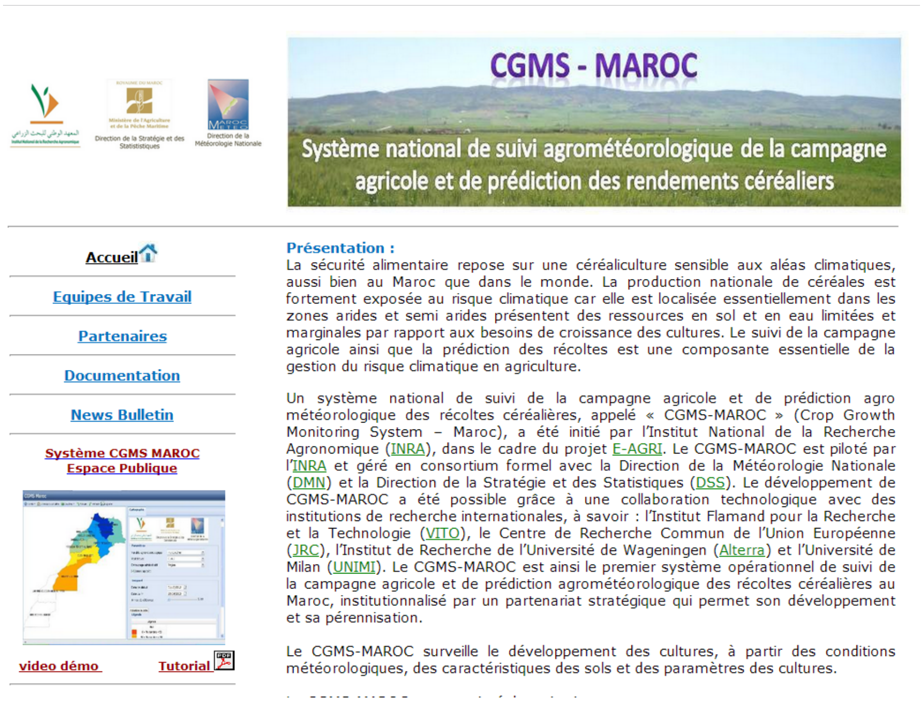
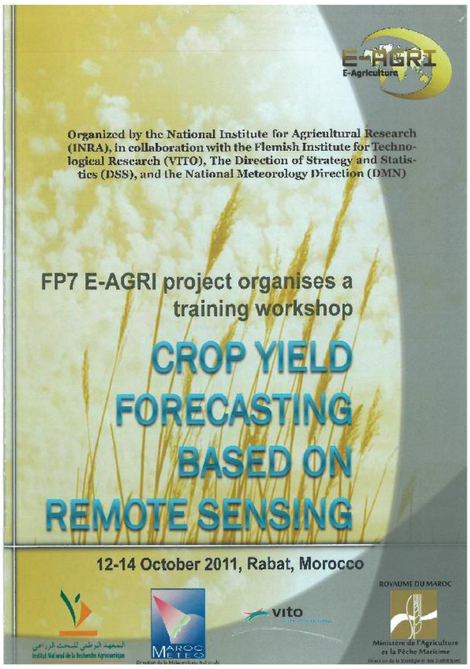


Figure 20. CGMS-Maroc web site (www.cgms-maroc.ma).

1.5.2. Project logo

1.5.3. Project folders



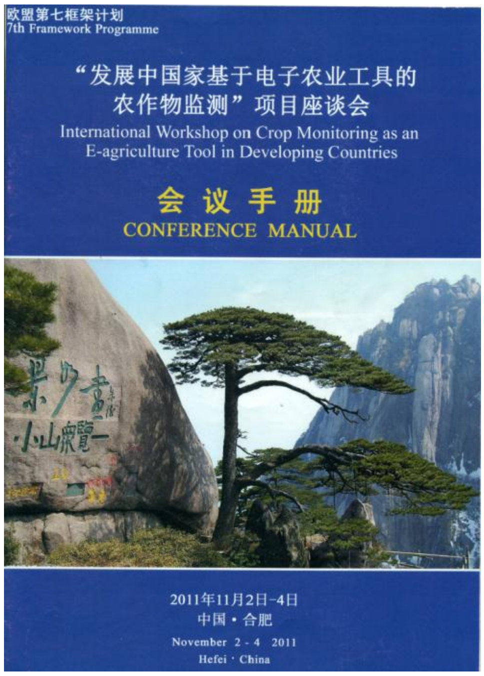


Figure 21: Project folder and Worksop announcement flyers

1.5.4. Project's promotional work in the media

In the scientific community:

Figure 22: project results dissemination &mong the scientific community

In the journals:


aufait

ACTUALITÉS ECONOMIE SPORT OPINIONS CULTURE & LOISIRS MA VIE

MAROC MAGHREB AFRIQUE MOYEN-ORIENT MONDE SCIENCES & ENVIRONNEMENT MÉDIAS

Accueil → Economie → Agricultures-et-peches

Dernière mise à jour : 11/10/2011 à 09:02

Atelier sur les prévisions des rendements des cultures par techniques de télédétection spatiale, du 12 au 14 octobre à Rabat

Un atelier de formation sur les prévisions des rendements des cultures par les techniques de télédétection spatiale sera organisé du 12 au 14 octobre à Rabat par l'Institut national de la recherche agronomique (INRA).

Premier événement du Projet E-AGRI financé par la Commission européenne dans le cadre de son 7ème Programme "Framework Programme (FP7)", cet atelier constitue une occasion pour familiariser et standardiser l'utilisation des techniques de télédétection pour les prévisions des rendements des cultures, indique un communiqué de l'INRA.

L'atelier, initié en collaboration avec l'institut VITO-Belgique et la Direction de la stratégie et des statistiques et la Direction de la météorologie nationale, sera animé par une pléiade de spécialistes et d'experts du Maroc, d'Europe et de Chine.

Les zones tests du Maroc et ceux de la Province de Ahuri (Chine) seront utilisées comme cas d'études lors de cette rencontre.

Le Projet E-AGRI vise la diffusion et la promotion des technologies de prévision des récoltes développées par les institutions européennes au Maroc, en Europe et en Asie.

MAP

Maghress

Atelier de formation

Un atelier de formation sur les prévisions des rendements des cultures par les techniques de télédétection spatiale sera organisé du 12 au 14 octobre à Rabat par l'Institut national de la recherche agronomique (INRA).

Libération

Atelier de formation

Figure 23: Press for general audience announcing the Rabat workshop

Multimedia links:

https://www.youtube.com/watch?v=mwU2rxuiYlM

http://www.youtube.com/watch?v=uuiDwPhhNPM&feature=youtube_gdata

In the official websites:

http://www.agriculture.gov.ma/pages/statistiques-agricoles

2. Use and dissemination of foreground

A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES

NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Open access[2] provided to this publication?
1	*New multi-model approach gives good estimations of wheat yield under semi-arid climate in Morocco*	*Simone Bregaglio*	*Agronomy for Sustainable Development*	*accepted*	*Springer*	*Berlin*	*2014*	*Still not available*		no
2	*Wheat modelling in Morocco unexpectedly reveals predominance of photosynthesis versus leaf area expansion plant traits*	*Roberto Confalonieri*	*Agronomy for Sustainable Development*	*No 33, August 2012*	*Springer*	*Berlin*	*2013*	*pp. 393 - 403*		no
3	*Quantifying plasticity in simulation models*	*Roberto Confalonieri*	*Ecological Modelling*	*No 225, January 2012*	*Elsevier B.V.*	*Amsterdam*	*2012*	*pp. 159 - 166*		no

[1] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[2] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

4	*A multi-approach software library for estimating crop suitability to environment*	*Roberto Confalonieri*	*Computers and Electronics in Agriculture*	*No 90, January 2013*	*Elsevier B.V.*	*Amsterdam*	*2013*	*pp. 170 - 175*		
5	*A simplified and improved version of WOFOST model*	*Tommaso Stella*	*Environmental Modelling & Software*	*Re-submitted after minor revision*	*Elsevier B.V.*	*Amsterdam*	*2014*	*Still not available*		*No*
6	*Evaluation of WARM for rice growth simulation and different establishment techniques in Jiangsu (China)*	*Valentina Pagani*	*European Journal of Agronomy*	*Submitted*	*Elsevier B.V.*	*Amsterdam*	*2014*	*Still not available*		*no*

A2: LIST OF DISSEMINATION ACTIVITIES

NO.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Countries addressed
	Workshop	*Qinghan Dong / Raid Balaghi*	*Crop yield forecasting using remote sensing*	*12-14 October 2011*	*Rabat, Morocco*	*Researchers and technical experts*	*80*	Morocco and China
	Workshop	*Allard de Wit / Qinghan Dong/Ma Zhongmo*	*CGMS set up*	*02-04 November, 2011*	*Hefei, China*	*Students, Researchers and technical experts*	*60*	*China and Morocco*

[3] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[4] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

	Workshop	*Steven Hoek*	*CGMS statistical tool box*	*15-17 February 2012*	*Kenitra, Morocco*	*Researchers*	*20*	*Morocco*
	Lecture	*Qinghan Dong*	*Application of e-agricultural tools in developing countries*	*3 March, 2012*	*Anhui Agricultural University, Hefei, China*	*Students and researchers*	*70*	*China*
	Workshop	*Carolien Toté*	*Application of European ICT in agriculture*	*25 October 2012*	*Nairobi, Kenya*	*Policymakers and their technical advisers*	*64*	*Kenya*
1	*Workshop*	*Roberto Confalonieri*	*FP7 E-AGRI "2nd progress meeting and BioMA workshop"*	*10-12 December 2012*	*Nanjing, China*	*Scientists and technicians*	*About 30 persons*	*China, Morocco*
2	*Workshop*	*Riad Balaghi*	*FP7 E-AGRI "WP34 workshop and 2nd BioMA training"*	*19-21 March 2013*	*Rabat, Morocco*	*Scientists and technicians*	*About 30 persons*	*Morocco*
3	*Training*	*Roberto Confalonieri*	*FP7 E-AGRI "3rd BioMA training"*	*9-13 December 2013*	*Milan, Italy*	*Scientists*	*2 persons*	*Morocco*
4	*Presentation/Training to the Chinese Academy for Agricultural Science*	*Roberto Confalonieri*	*FP7 E-AGRI "Multi-model forecasting systems using BioMA"*	*5-8 December 2012*	*Beijing, China*	*Scientists and technicians*	*About 15 persons*	*China*
	Seminar	*Chen Zhongxin*	*Crop area estimation in China*	*27 February 2013*	*Beijing, China*	*Scientists and technicians*	*About 30*	*China*
	Symposium	*Qinghan Dong*	*2013 ESA DRAGON 3 symposium held in from*	*3-7 June 2013*	*Palermo, Italy*	*Scientific Community*	*About 200*	*International*
	Lecture	*Qinghan Dong*	*Presenting the project E-AGRI in the DG AGRI of the European Commission*	*July 2, 2013.*	*Brussels, Belgium*	*European agricultural policy makers and advisers*	*About 50*	*International*

	Conference	*Qinghan Dong*	*Second International Conference on Agro-Geo-informatics organized by US department of Agriculture and the University of George Mason*	*August 12-16, 2013*	*Fairfax, US*	*Scientific Community*	*About 150*	*International*
	The Global Food security conference	*Allard de Wit*	*CGMA–MAROC*	*29 September - 2 October 2013*	*Noordwijk, the Netherlands*	*Scientific Community*	*About 100*	*International*
	Presentation for the FAO experts	*Qinghan Dong*	*E-AGRI project and its impact*	*11 October 2013*	*Antwerp, Belgium*	*Scientific Community*	*10*	*International*
5	*Conference: "4th AgMIP Annual Global Workshop"*	*Valentina Pagani*	*Multi-model simulations for rice yield forecasts in Jiangsu (China)*	*28-30 October 2013*	*New York*	*Scientific Community*	*Hundreds of scientists*	*Tens of countries*
6	*Visit to the International Rice Research Institute*	*Roberto Confalonieri*	*Crop modelling for rice yield forecasts: discussing systems for rice yield forecasts based on WOFOST-derived crop models and assimilation of remote sensing data*	*8-11 October 2013*	*International Rice Research Institute, Los Baños, Laguna, Philippines*	*Scientists and technicians*	*About 30*	*Asian countries where rice is grown*
	Workshop	*Roel Van Hoolst*	*E-AGRI/AGRICAB Hands-on training on image classification using high resolution satellite imagery over Kenya", ,*	*25-29 November 2013*	*Nairobi, Kenya*	*Technical experts*	*About 50*	*Kenya*
	Conference	*Riad Balaghi*	*E-AGRI Morocco dissemination Event*	*26-03-2014*	*Rabat, Morocco*	*Policymakers and their technical advisers*	*About 200*	*Morocco*