Crop Monitoring as an
E-agricultural tool in
Developing Countries

CGMS PILOTING REPORT

Morocco

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ACRONYMS & CLOSSARY

CGMS	-	Crop Growth Monitoring System
DMN	-	Direction de la Météorologie Nationale
DSS	-	Direction de la Statistique
DSSF	-	Down-welling Short-wave Surface Flux (from MSG satellite)
EMU	-	Elementary Mapping Unit
IDW	-	Inverse Distance Weighting
INRA	-	Institut national de la recherche agronomique
MSG	-	Meteosat Second Generation
NDVI	-	Normalized Difference Vegetation Index
NUTS	-	Nomenclature des unités territoriales statistiques
OGC	-	Open GIS Consortium
SMU	-	Soil Mapping Unit
WMO	-	World Meteorological Organization
WOFOST	-	WOrld FOod STudies

1. Introduction

The overall goal of the E-Agri proposal to support to the uptake of European ICT research results in developing economies. The objective can be realized by setting up an advanced European E-agriculture service in two developing economies, Morocco and China, by means of crop monitoring and yield forecasting. In the work package 2 of the E-Agri project, the focus is on the implementation of the European Crop Growth Monitoring System (CGMS) for wheat monitoring and yield forecasting in two target regions: Morocco and the Huaibei region in Anhui province in China.

This deliverable describes the results from the CGMS implementation in Morocco. The first two and a halve years of the project have focused on adaptation, technology transfer and capacitity building. During the last 6 months of the project, the Moroccan CGMS system has been in a piloting phase during which the operations were carried out, the system results were provided to the different partners, could be visualized in the CGMS-Maroc viewer and analysed with the CST.

The deliverable describes the CGMS setup for Morocco and the results from the CGMS piloting phase in Morocco. Moreover, it provides an indication/outlook of the socio-economic impact of CGMS-Maroc and some suggestions for further developmoment in the future.

2. Implementation of CGMS for Morocco

The CGMS-Maroc is an institutionally distributed system which involves the Moroccan institutes DMN, INRA and DSS. The part of the CGMS-Maroc that implements the database, weather data processing, crop simulation and prepration for statistical yield forecasting is implemented at the premises of DMN 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. This section provides a short overview of the entire processing chain.

2.1. Spatial schematization

The spatial schema of CGMS-Maroc consists of several layers (Figure 1):

1. The basis for the spatial schematization of the CGMS-Maroc is a uniform grid with cells of 9.14x9.14 km size covering the entire Morroccan territory.
2. The 1:1,000,000 soil map of Europe which was combined with a more detailed soil map that was available only for the agriculture zone in the northern part of Morocco. Moreover, the soil hydraulic properties were estimated for the spatial units in the Moroccan soil map.
3. The land cover mask derived from the GlobCover project. From this map, the classes related to arable land were derived in order to calculate the percentage of arable land per CGSM grid.
4. The administrative regions for Marocco consisting of four levels: districts, provinces, agrozones and whole country

All layers of information were combined and loaded into the CGMS database and the database for the CGMS Statistical Toolbox.

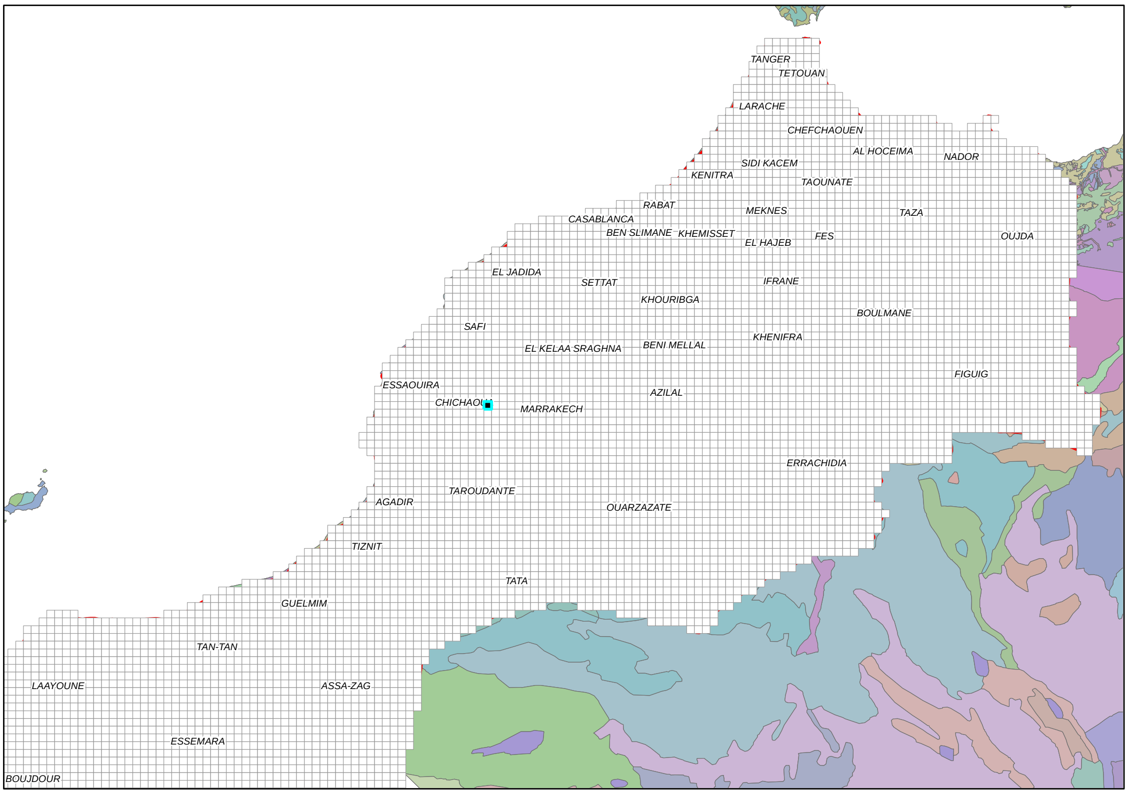

Figure 1. Overview of the CGMS-Maroc spatial schema for the Northern part of Morocco, including the province boundaries (red), the soil map (coloured polygons) and the CGMS grid (grey rectangular boxes). Labels are province names.

2.2. Weather data processing

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.

2.2.1. Data aqcuisition

The stations used in CGMS MOROCCO are those which are qualified as synoptic in WMO classification. The inserted stations are described in WEATHER_STATION table.

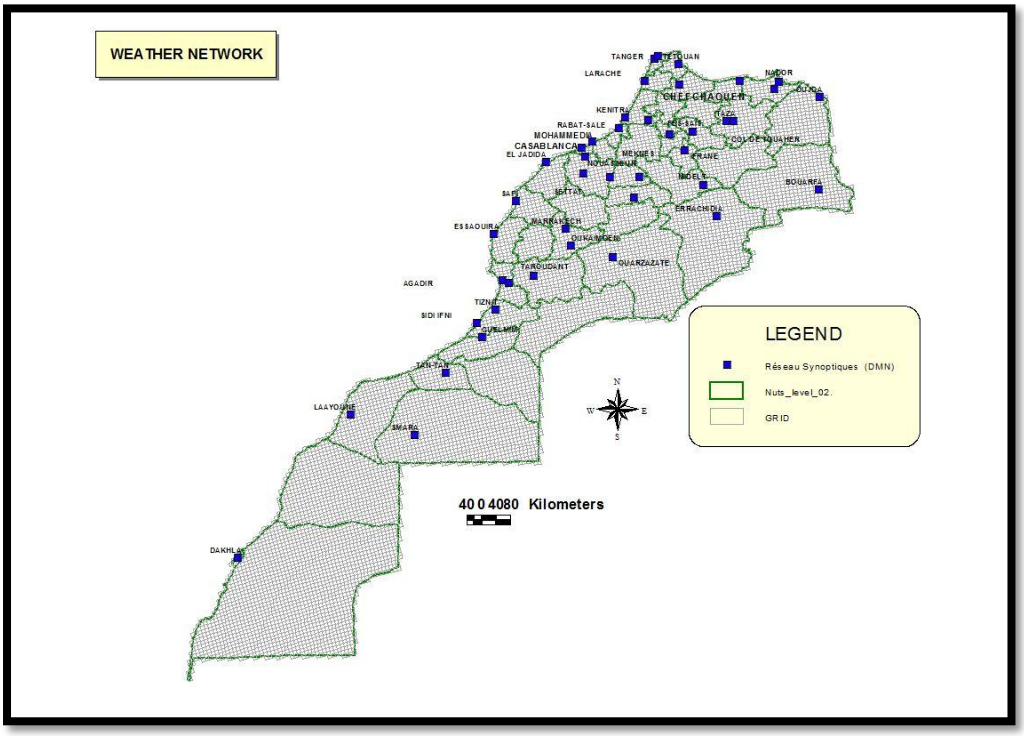

Figure 2:The synoptic stations network of DMN

With regards to meteorological time series length, the inserted daily data begins from 1987 and not before. In some cases, new stations replaced the oldest one such as NADOR-AROUI (60340002) instead of Nador (60340001)….etc. The geographical distribution of DMN network tends to cover all agricultural areas (Figure 2). Indeed , there is at least one synoptic station by province.

ID_STATION	STATION_NAME	BEGIN
60155001	CASABLANCA-ANFA	01/03/1911
60127001	TAZA	01/01/1918
60250001	AGADIR INEZGANNE	01/03/1921

60150001	MEKNES	01/01/1924
60230001	MARRAKECH	01/01/1930
60195001	MIDELT	01/01/1931
60100001	TANGER-PORT	01/01/1931
60265001	OUARZAZATE	01/02/1931
60318001	TETOUAN	01/01/1935
60115001	OUJDA	01/01/1941
60220001	ESSAOUIRA	01/01/1941
60165001	EL JADIDA	01/11/1944
60135001	RABAT-SALE	01/05/1947
60190001	KASBA-TADLA	01/03/1949
60101001	TANGER-AERO	01/01/1950
60120001	KENITRA	01/01/1951
60185001	SAFI	01/07/1954
60160001	IFRANE	01/06/1956
60107001	AL-HOUCEIMA	01/01/1960
60191001	BENI MELLAL	01/01/1960
60200001	BOUARFA	01/01/1960
60141001	FES-SAIS	01/01/1961
60105001	LARACHE	01/02/1962
60096001	DAKHLA	01/07/1963
60060001	SIDI IFNI	01/01/1969
60156001	NOUASSEUR	01/01/1970
60210001	ERRACHIDIA	01/01/1973
60285001	TAN-TAN	01/11/1974
60033001	LAAYOUNE	01/01/1976
60340001	NADOR	01/01/1976
60252001	AGADIR AL MASSIRA	01/01/1978
60136001	SIDI SLIMANE	01/07/1979
60270001	TIZNIT	01/11/1982
60178001	KHOURIBGA	01/02/1984
60335001	SMARA	01/01/1987
60146001	MOHAMMEDIA	01/10/1989
60280001	GUELMIM	01/05/1990
60253001	TAROUDANT	01/01/1992
60106001	CHEFCHAOUEN	01/08/1994
60237001	OUKAIMDEN	01/08/1996

60177001	SETTAT	01/10/1999
60125001	COL DE TOUAHER	01/01/2002
60101002	TANGER-VILLE	01/01/2002
60340002	NADOR-AROUI	01/02/2002

Table 1: the opening date of synoptic stations of DMN

2.2.2. Extracting daily measured Weather parameters

From 1987 to 2012, meteorological data are received from climatogical database managed by DMN. The historical data are assumed to be checked for quality and consistency. The time series are inserted in the table METDATA which comprises the available parameters of minimum and maximum temperature, the rainfall, cloud cover and sunshine duration, daily mean vapor pressure and daily global radiation at surface.

For real time processing and from 01/01/2013 up to now, METDATA is alimented by a mixture of SYNOP and METAG meteorological messages. These messages are decoded and then processed for extracting the needed meteorological parameters.

Variable	DESCRIPTION	UNIT
DAY	Date	DATE
MAXIMUM_TEMPERATURE	Daily Maximum air temperature	°C
MINIMUM_TEMPERATURE	Daily Minimum air temperature	°C
VAPOUR_PRESSURE	Daily mean vapor pressure	HPA
WINDSPEED	Daily mean wind speed at 10 m height	m/s
RAINFALL	Daily rainfall	mm
SUNSHINE	daily sunshine duration	H
CLOUD_DAYTIME_TOTAL	daily mean of total cloud cover	oktas
RAD_MEA	daily global radiation at surface	KJ.m-2.d-1

Table 2 The minimum data set required for CGMS

2.2.3. Estimating daily mean vapour pressure

The availability analysis of the daily mean actual vapor pressure in historical weather time series reveals an important shortage. This variable is needed for calculating the reference evapotranspiration by Penman-Monteith. To overcome this problem, an estimate based on the minimum temperature was used. This method assumes that Minimum temperature in close to dew point temperature which is not always the case especially for stations inside morocco and far from sea influence. For this purpose we add a correction by linear regression between Ea calculated from T_{min} and the available observed one. When this correction is not reliable, we extrapolate the coefficients from the closest reliable stations by IDW.

It's worth noting that this estimate is applied for historical time series from 01/01/1987 to 31/12/2012. For real time processing, actual vapor pressure is calculated using a formula based on T_{dew}.

2.2.4. Estimating global radiation

A major problem is the scarcity of measured global radiation. In cases where no direct observations are available it must be derived from sunshine duration, cloud cover and/or temperature. The global radiation calculation uses one of three formulae (Ångström, Supit, and Hargreaves). As an alternative, the global radiation is extracted from the DSSF product for each weather station in CGMS during the available MSG time-series. The DSSF radiation estimates provide station-specific calibration for the global radiation models included in CGMS (e.g. Angstrom, Supit, and Hargreaves).

With regard to the constants for the radiation models (Angstrom, Supit and Hargreaves Constants), usually the problem is that estimates of global radiation are not widely available. To overcome this problem, we extract the global radiation estimates from the Meteosat Second & First Generation archives for the synoptic stations. These data is a mixture of the global radiation estimates from MeteoSat 2nd generation (2005 – 2010) and 1st generation (1983-2005). A validation of the MSG global radiation estimates has demonstrated that the radiation estimates are accurate.

For this purpose, two python scripts were developed by Alterra and applied by DMN for finding the Angstrom and Hargreaves coefficients. The scripts require a table "RADIATION_CALIBRATION_DATA" with the following structure:

- Wmo_no: the weather station number
- Day: the date of the observation
- Sunshine: the observed sunshine duration
- Temp_min: the observed minimum temperature
- Temp_max: the observed maximum temperature
- Radiation_global: the observed global radiation

Outputs are written to a database table and are used for estimating global radiation.

WMO_NO	ANGSTROM_A	ANGSTROM_B	HARGREAVES_A	HARGREAVES_B
60033001	0.412	0.356	0.035	8.384
60060001	0.358	0.441	0.021	13.131

60096001	0.412	0.356	0.035	8.384
60100001	0.317	0.467	0.053	3.429
60101001	0.317	0.467	0.053	3.429
60101002	0.317	0.467	0.053	3.429
60105001	0.287	0.509	0.045	5.056
60106001	0.174	0.639	0.047	2.096
60107001	0.289	0.533	0.05	4.284
60115001	0.336	0.45	0.048	2.573
60120001	0.285	0.504	0.045	4.604
60125001	0.65	0.098	0.038	6.681
60127001	0.288	0.599	0.046	4.53
60135001	0.289	0.499	0.044	5.238
60136001	0.081	0.68	0.032	4.571
60141001	0.274	0.513	0.046	2.91
60146001	0.305	0.485	0.035	9.282
60150001	0.286	0.506	0.047	3.288
60155001	0.305	0.485	0.036	8.14
60156001	0.355	0.453	0.044	4.162
60160001	0.209	0.586	0.049	2.785
60165001	0.305	0.485	0.036	8.14
60177001	0.264	0.525	0.045	3.795
60178001	0.287	0.494	0.047	4.061
60185001	0.351	0.43	0.047	5.08
60190001	0.304	0.483	0.046	3.089
60191001	0.285	0.508	0.043	3.89
60195001	0.334	0.455	0.038	6.642
60200001	0.403	0.413	0.046	4.835
60210001	0.355	0.43	0.042	5.767
60220001	0.351	0.43	0.047	5.08
60230001	0.291	0.508	0.042	5.113
60237001	0.288	0.599	0.046	4.53
60250001	0.345	0.445	0.032	9.689
60252001	0.384	0.403	0.051	2.84
60253001	0.369	0.43	0.036	7.236
60265001	0.355	0.43	0.042	5.767
60270001	0.374	0.41	0.037	8.237
60280001	0.412	0.356	0.035	8.384

60285001	0.412	0.356	0.035	8.384
60318001	0.242	0.552	0.039	5.599
60335001	0.412	0.356	0.035	8.384
60340001	0.123	0.649	0.041	1.059
60340002	0.123	0.649	0.041	1.059

2.2.5. Calculation of Evapotranspiration

Daily meteorological station data received from the Moroccan Climatological Database or from Synop/Metag messages does not contain potential evapotranspiration. This parameter is calculated by the CGMS with the well-known Penman formula (Penman, 1948). For E0, ES0, and ET0 albedo values of 0.05, 0.15 and 0.20 are used respectively. The evaporative demand is determined by vapor pressure, wind speed and surface roughness. For crop canopies (ET0) a surface roughness value of 1.0 is used and for a free water surface and for the wet bare soil (E0, ES0) value 0.5 is taken. The calculated E0, ES0, and ET0 are stored in table CALCULATED_WEATHER.

2.2.6. Interpolation

The daily meteorological data is interpolated towards the centers of the regular climatic Grid. The interpolation is executed in two steps: first the selection of suitable meteorological stations to determine representative meteorological conditions for a specific climatic grid cell. Second, a simple average is calculated for most of the meteorological parameters, with a correction for the altitude difference between the station and grid cell centre in case of temperature and vapor pressure. As an exception rainfall data are taken directly from the most suitable station. The results are stored in the table GRID_WEATHER and actually it contains daily grids from 01/01/1987 up today.

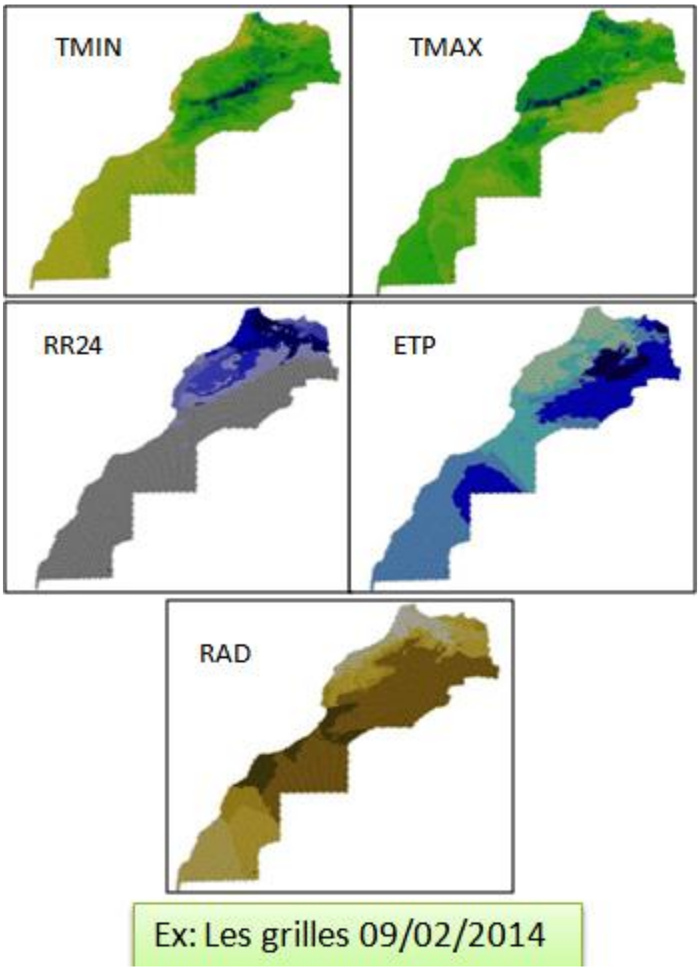

Figure 3: An example of interpolated climate grids for minimum and maximum temperature (TMIN/TMAX), daily rainfall (RR24), reference evapotranspiration (ETP) and global radiation (RAD).

2.2.7. Operational implementation

The operational implementation follows these steps:

1. Metdata is updated daily by processing Synop and Metag Messages at 11h00.
2. A FORTRAN executable checks automatically the last day from the table GRID_WEATHER and compares it with the last available day in METDATA. If the date in GRID_WEATHER is earlier than the date in METDATA, the program updates SYSCON table with the related current_year.

3. The program generates automatically the configuration file for running CGMS in batch mode. The configuration file contains the last day.METDATA as the begin and end date of interpolation, the calculated weather option is also activated for global radiation and PET calculation.
4. The program runs CGMS in batch mode, then the table GRID_WEATHER is updated by the real time values at 13h00.

2.3. Crop simulations (CGMS level 2)

2.3.1. Details of CGMS level 2

The crop monitoring component produces simulated crop indicators like biomass and yields to show the effect of recent weather on crop growth. The work is divided into four activities (see). 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 schematisation.
- Running of crop simulations for individual map units.
- Spatial aggregation. of results

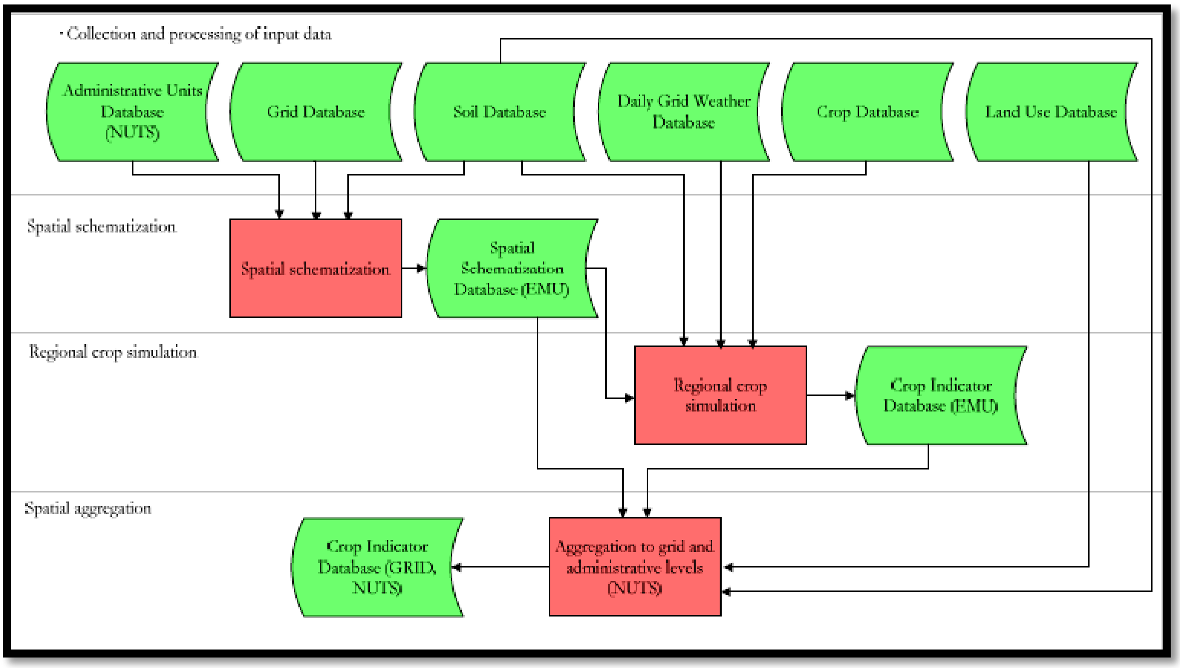

Figure 4 overview of the crop monitoring components in CGMS MOROCCO

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 (Figure 4 and Figure 6).

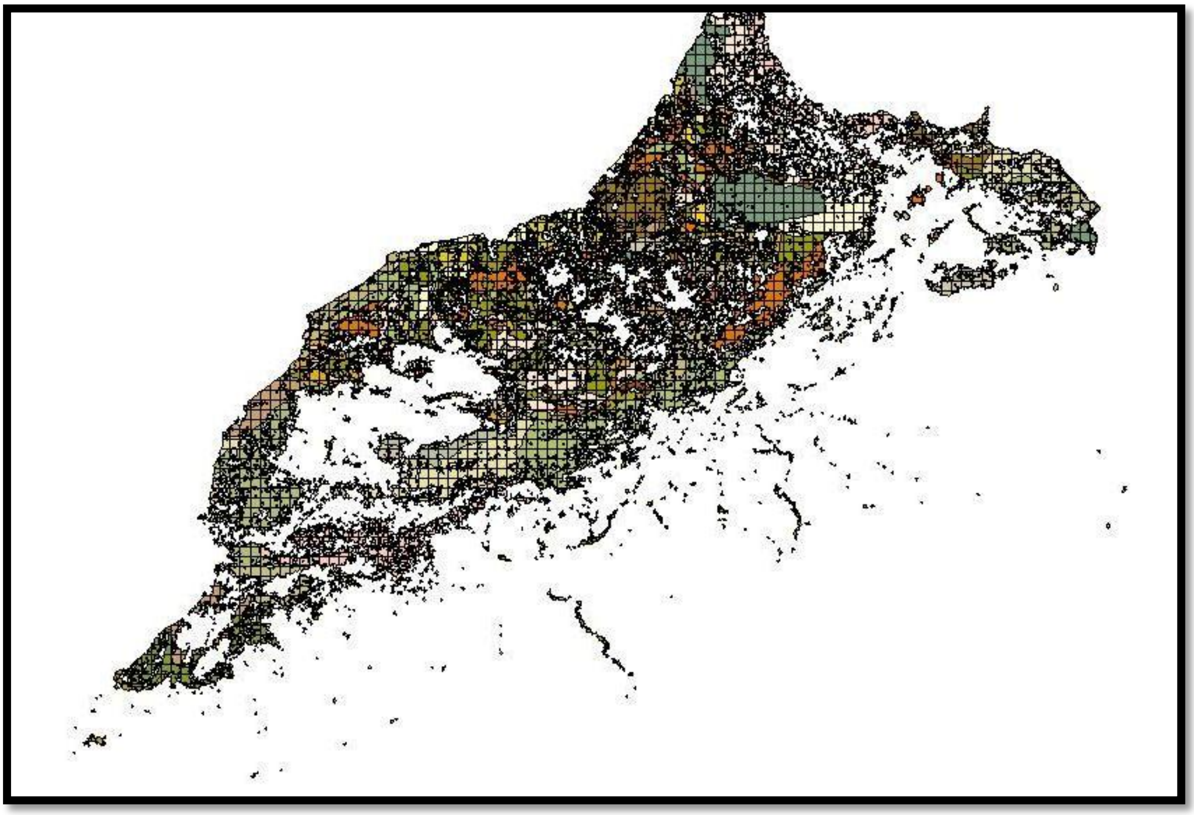

Figure 5: The Elementary Mapping Units used in CGMS MOROCCO when building inputs for Level 2

The results of the processing of crop monitoring component are written in CROP_YIELD table and it contains the following columns (Figure 7):

Varaiable	Unit	Description
CROP_NO	#	crop number
GRID_NO	#	grid number
SMU_NO	#	soil mapping unit number
DAY	DATE	date
POTENTIAL_YIELD_BIOMASS	kg.ha-1	potential dry weight biomass
POTENTIAL_YIELD_STORAGE	kg.ha-1	potential dry weight storage organs
WATER_LIM_YIELD_BIOMASS	kg.ha-1	water limited dry weight biomass
WATER_LIM_YIELD_STORAGE	kg.ha-1	water limited dry weight storage organs
POTENTIAL_LEAF_AREA_INDEX	m2.m2	potential leaf area index: leaf area divided by surface area
WATER_LIM_LEAF_AREA_INDEX	m2.m2	water limited leaf area index: leaf area divided by surface area
DEVELOPMENT_STAGE	#	development stage of crop 0-200)

RELATIVE_SOIL_MOISTURE	percentage	percentage of (field capacity minus wilting point)
TOTAL_WATER_CONSUMPTION	cm	sum of water limited transpiration
TOTAL_WATER_REQUIREMENT	cm	sum of potential transpiration
FSM	#	volumetric soil moisture content in rooted zone
FSMUR	#	volumetric soil moisture content in not rooted zone
LEAVES_DIED_BY_COLD	#	fraction of leaves died by cold wrt total biomass
RUNOFF	cm	run off
SOIL_EVAPORATION	cm	soil evaporation
LOSS_TO_SUBSOIL	cm	amount of water drained to the sub soil and therefore lost for the crop

Table 3. The outputs of Level 2

Simulated crop indicators of the EMU's are spatially aggregated to the smallest administrative polygons. The aggregation from EMU to administrative region at level 3 is based on the weight of each EMU within this region of interest. The weight is the area fraction of the EMU which is covered by the selected crop in relation to the total area of all EMU's within the district (Figure 6). The distinct unique combination of climatic grid cell, SMU, administrative region at level 3 and crop plus related area are stored in table EMU_PLUS_NUTS_LANDCOVER. In CGMS MOROCCO, level 3 which represents the districts geographical layer (communes) is choosen and the results are written in the table NUTS_YIELD (Figure 8).

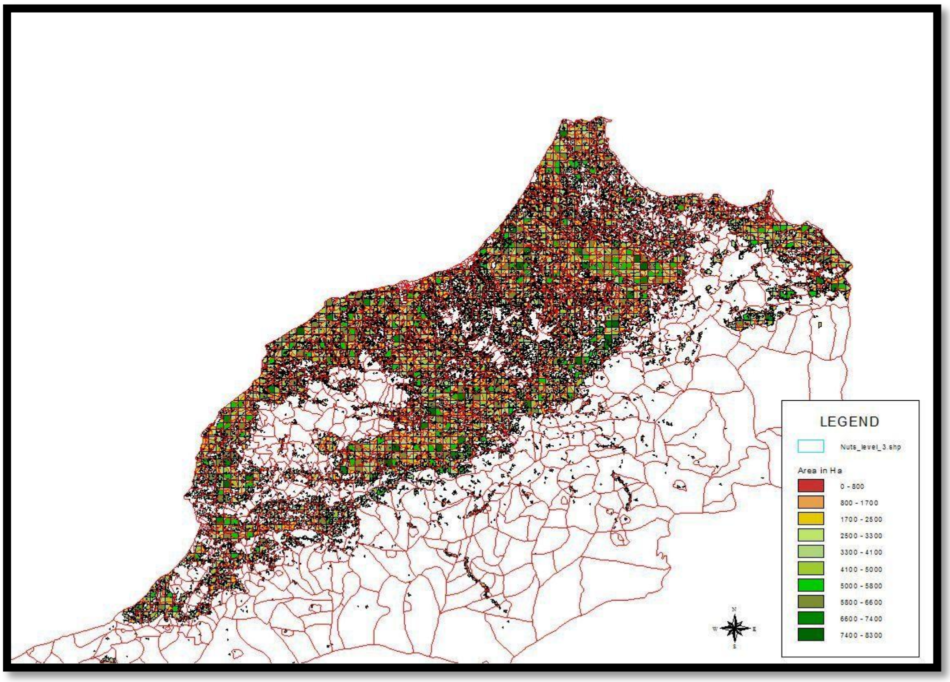

Figure 6 Area in Hectares computed and stored in EMU_PLUS_NUTS_LANDCOVER

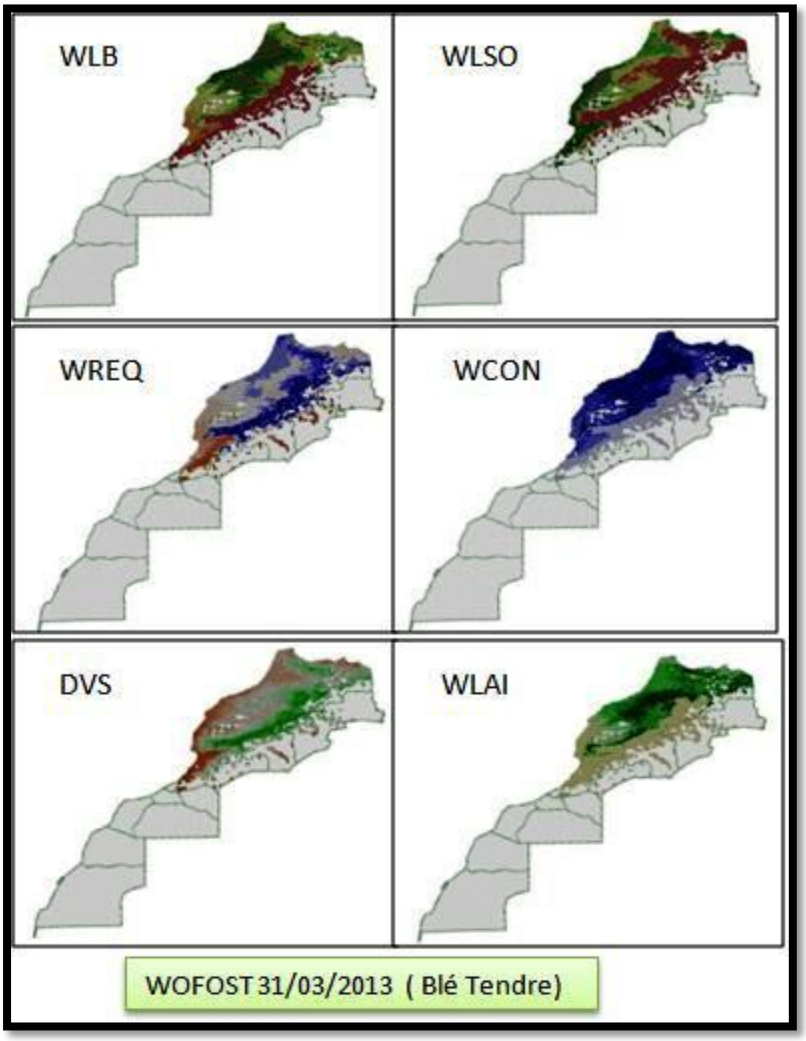

Figure 7 example of WOFOST outputs from CGMS MOROCCO level 2: WATER_LIM_YIELD_BIOMASS, WATER_LIM_YIELD_STORAGE, TOTAL_WATER_REQUIREMENT, TOTAL_WATER_CONSUMPTION, DEVELOPMENT_STAGE, WATER_LIM_LEAF_AREA_INDEX

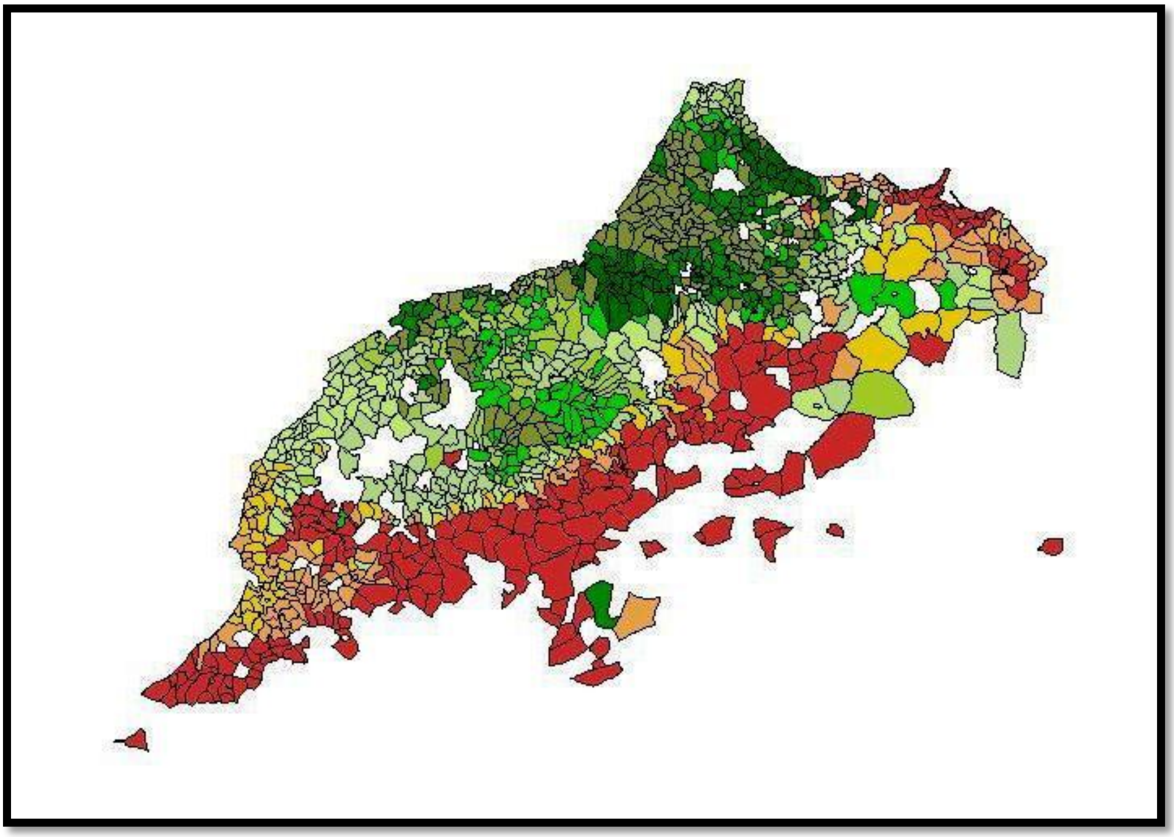

Figure 8 Example of WOFOST outputs (WATER_LIM_YIELD_STORAGE) at the end of 2013 campaign aggregated to nuts level 3 for Soft Wheat.

2.3.2. Operational implementation

The implementation of the crop simulations has been largely established according the results described in deliverable “D22.2 Morocco StrategyReport”. This included the calibration of the crop parameters related to phenology for soft-wheat and durum-wheat. Other crop parameters were so far left to their default values, but they could be updated using results from WP3 where a new calibration was carried out using newly collected data for soft-wheat and durum-wheat in Morocco. Also, the crop calendar was defined with a fixed sowing date on the 1st of December and letting the model run up till maturity.

The estimation of the initial soil water was finally implemented by starting the simulation on the 1st of June with a completely dry soil profile. This approach allows 6 months to accumulate water in the soil profile before the crop simulation starts on the 1st of December. It was demonstrated that the predictive capabilities of the system strongly improved using this simple approach.

The operational implementation of the CGMS level 2 is currently still a manual process where an operator is needed to run the CGMS executable, start the aggregation of crop simulation results to grid and regional level and finally export the aggregated results to the CGMS-Maroc viewer. As this process has to be performed on decadal time-steps, this is not problematic. Nevertheless, an automated procedure can be implemented easily by updating the CGMS configuration file and running the CGMS executable using a scheduled procedure.

2.4. Preparation of CGMS results for yield forecasting

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. At DMN 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 9.

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.

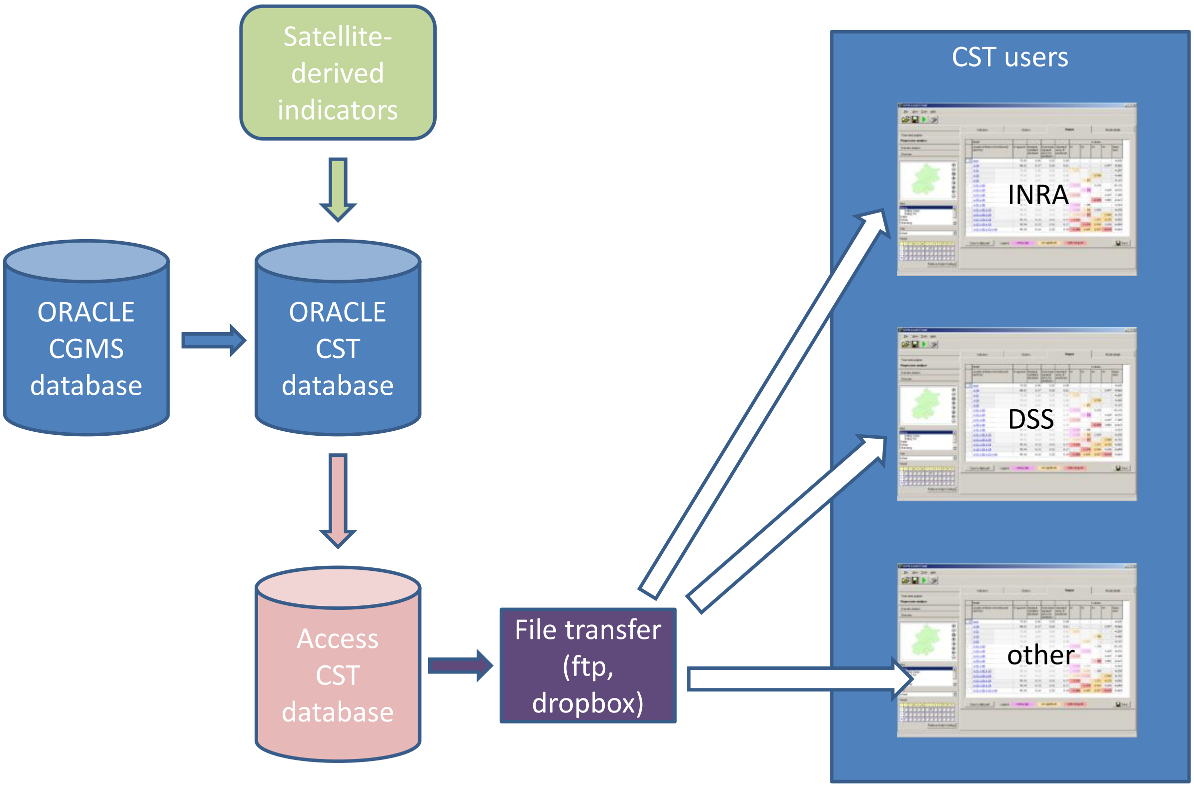

Figure 9. Flow of information from CGMS to the CGMS statistical toolbox and its end users.

3. CGMS-Maroc viewer

A Web viewer, called CGMS-MAROC and available at www.cgms-maroc.ma (Figure 10), has been developed by the project in order to visualize data and make preliminary analyses of status of the cropping season. It is managed autonomously by a consortium composed of three national institutions involved by the project in Morocco (INRA, DMN, DSS) and which are bound by a mutual official agreement.

3.1. Design and implementation

The choice of a client-server WebMapping has been adopted and implemented. The server architecture was built around MapServer as mapping server, Apache as the web server associated with the interpreter PHP script that allows the server to read the scripts, Postgresql / PostGIS as database server and finally Dracones as framework and development environment for the web interface. This set forms a development environment based on free tools for interfacing web mapping applications. These tools meet the standards defined by the OGC (Open Geospatial Consortium), and allows to integrate basic navigation features and to adapt develop more advanced and personalized features.

The general functionalities have been inspired from "MARSOP3" Web viewer (http://www.marsop.info/marsop3/) developed by Alterra. The Moroccan Web viewer is hosted on a server located at INRA and supplied by daily climatic data (rainfall, maximum and minimum temperature, reference evapotranspiration) coming from all synoptic stations of DMN, by main outputs derived from WOFOST crop model, as well as by satellite imagery products (NDVI and DMP, coming from both SPOT-VEGETATION and MODIS) delivered every 10 days by VITO. All data are aggregated at common uniform grid cells of 9.14x9.14 km size. The size of the grids was decided as a compromise between needed accuracy for crop monitoring and forecasting and the error generated when interpolating weather data coming from the 43 available synoptic stations. It is intended to reduce the size of the grid when new synoptic stations will be available for CGMS-MAROC.

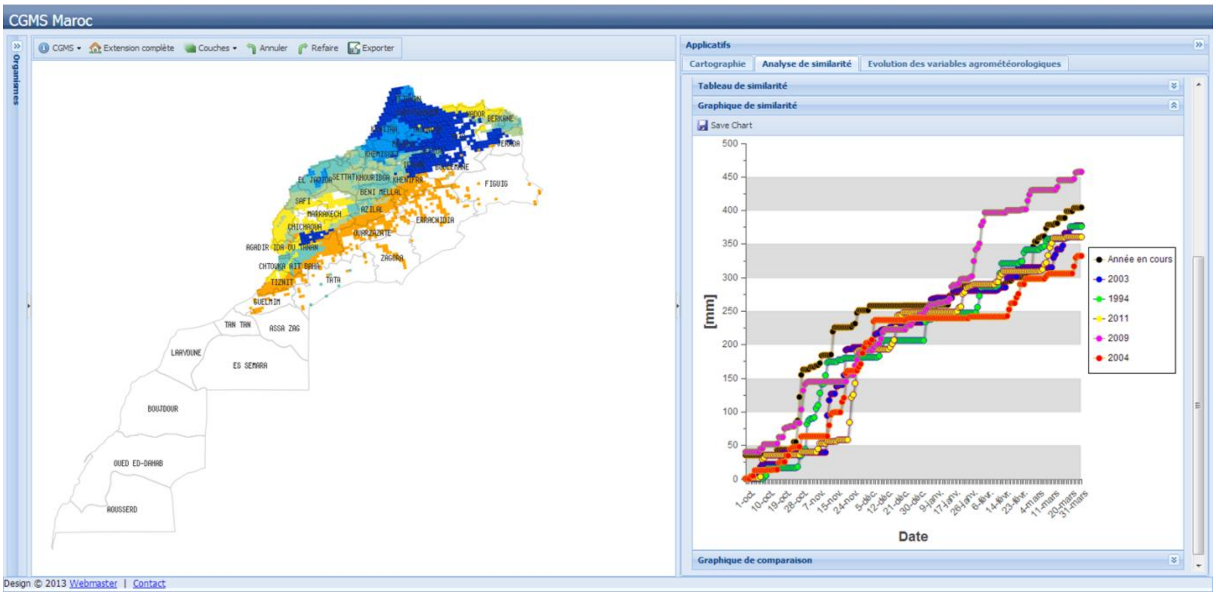

Figure 10: The Web viewer of CGMS-MAROC (www.cgms-maroc.ma) for bio-climatic monitoring of cereals, and preliminary statistical analysis of the cropping season. On the left side window is displayed the cumulated rainfall over the season on croplands (9.14x9.14 km grid). On the right window is shown, the similarity analysis using cumulated rainfall, in the administrative Commune of Ben Ahmed (Province of Settat).

Similarity analysis capabilities have been implemented in this Web interface, allowing preliminary analysis of the cropping season and rapid cereal forecasts, at all administrative levels (Figure 10). Similarity analysis is an effective, fast, and easy means for forecasting cereal yields. It consists in identifying, among past cropping seasons, those that are agro-climatically similar to the one concerned with crop yield forecasting. It is a statistical analysis method that assumes that a cropping season of similar agro-climatic conditions to past ones would result in similar crop yields, all other factors assumed to be equal. Similarity analysis could be performed at national, provincial and even sub-provincial lev0el (administrative commune).

For these data analyses, all spatial data (NDVI, weather and simulations) are aggregated from the grids to administrative levels (Commune, Province, Country) only over the agricultural areas of Morocco, thanks to the crop mask. Spatial aggregation consists in averaging data values (rainfall, NDVI, temperature, etc.) at administrative levels, based on weights that are equal to the percentage of each grid area that is covered by croplands (Figure 11). Thus, the analyses are performed only on data that are prevailing over croplands.

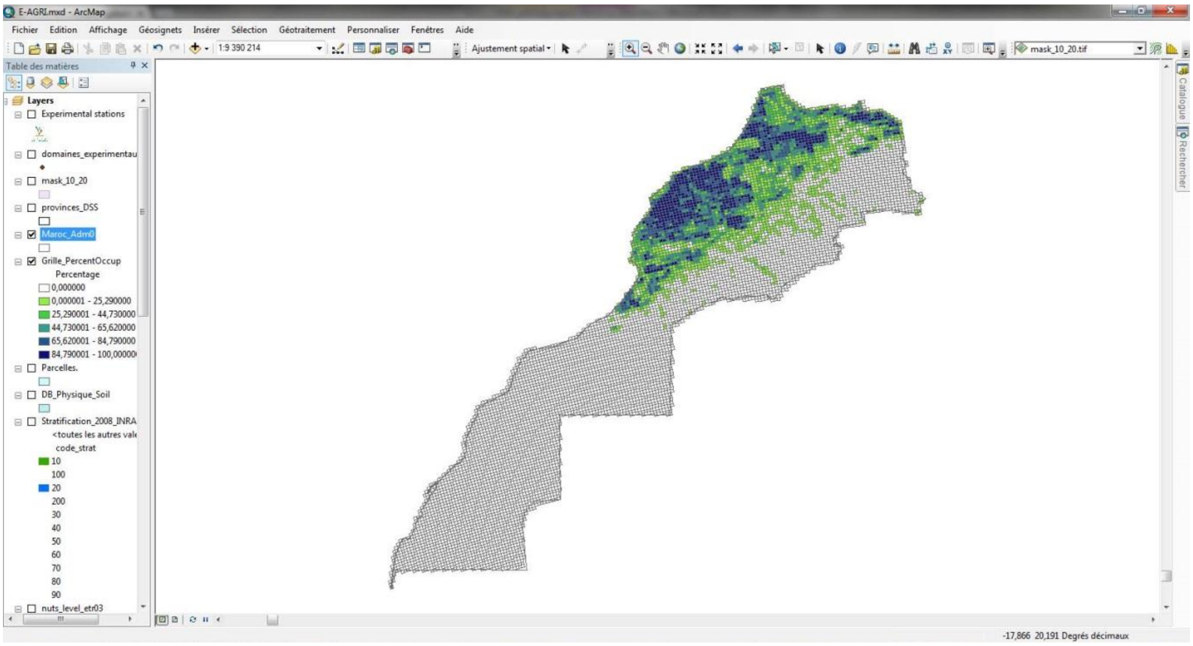

Figure 11: The 9.14x9.14 km grid used to spatially aggregate data in CGMS-MAROC. Spatial aggregation consists of data values consists in averaging data values (rainfall, NDVI, temperature, etc.) at spatial administrative levels, based on weights that are equal to the percentage of each grid area that is covered by croplands (displayed by a range of colors: blue=high percentage; green=low percentage; blank=no croplands).

3.2. Users of the CGMS-Maroc viewer

Users of CGMS-MAROC are mainly the crop forecasters and statisticians of the Ministry of agriculture (DSS), supported by INRA and DMN. For this purpose they use all capabilities offered by the Web viewer of CGMS-MAROC as well as by the CGMS Statistical Tool Box (CST) developed by Alterra and adapted to Morocco. However, a public version of the Web viewer is available at www.cgms-maroc.ma with limited capabilities, and can be used for season monitoring. A new project on crop insurance has been launched on index based crop insurance in Morocco, since start of January 2014. The objective of this project (2014-2016) is to adapt CGMS-MAROC so that it can be used to forecast cereal yields at Commune administrative level in main cereal areas of Morocco. If results are promising, then the system is planned to be operationally used by commercial insurance companies with support of the Ministry of Agriculture.

4. Evaluation of CGMS Morocco

4.1. Evaluation of forecasting performance at national level

CGMS-MAROC has been tested for two cropping seasons, 2011-2012 and 2012-2013. Forecasted cereals yields were very close to final official yields (Figure 12). Cereal production was calculated using forecasted yields and official cereal area delivered by the Ministry of agriculture. Cereal (soft wheat, durum wheat and barley) production was estimated at **4.72 million tons**, at April 10th 2012, against 5.07 million tons from official statistics. During 2012-2013, Cereal production was estimated at **8.83 million tons**, at April 6th 2013, while the official statistics are still not available up to date.

4.2. Socio-economic impact

In Morocco, food security is based on cereal production which is sensitive to climatic risks. Domestic production of cereals is highly exposed to climate risk as it is mainly localized in the arid and semi-arid areas of the country, characterized by limited soil and water resources.

Cereal imports were consistent since 1980, representing nearly half (48.7%) of the cereal production and most of imported food products and import cost. Annual cereal imports amounts to 2.6 million tons on average for the period of 1980-1981 till 2010-2011, most of it composed of soft wheat which accounts for 77%, followed by durum wheat (12%) and barley (11%). Cereal imports are in constant progression since early 1990s, fluctuating over time and ranging from 10% of average cereal production (during season of 1994-1995) following the good harvest of 1993-1994 to 244% during 2000-2001 following the dry season of 1999-2000. However, cereals are imported even during record productive seasons like during 2008-2009 (10.2 million tons of production), where significant quantity was imported during the next season (2.56 million tons), that is 25% of the 2008-2009 total cereal production.

Total cereal supply, as the sum of production and import, without accounting for stocks, which may represents total needs for food and feed, increases over years with a rate of 0.16 million ton per year since the 1990s. This high dependence on imported cereals is associated with risks of short supplies and high prices in the international market which may result from the variation in global production, embargos on imports and speculation.

Crop monitoring and forecasting is an essential component of the climate risk management in agriculture. CGMS-MAROC allows to instantly forecast grain yields two to three months before harvest. Forecasting the production of crops early before harvest allows decision makers to be prepared in advance for eventual consequences of abnormal deviations of the climate, particularly for strategic commodity crops to food security like cereals.

Currently the Moroccan ministry of agriculture has not yet carried out a quantitative socio-economic evaluation regarding cost-savings made by the CGMS-Maroc system that was implemented in e-Agri. Nevertheless, given the depency of Moroccan agriculture on cereal imports (as outlined above), the potential savings from strategic commodity trading can be substantial.

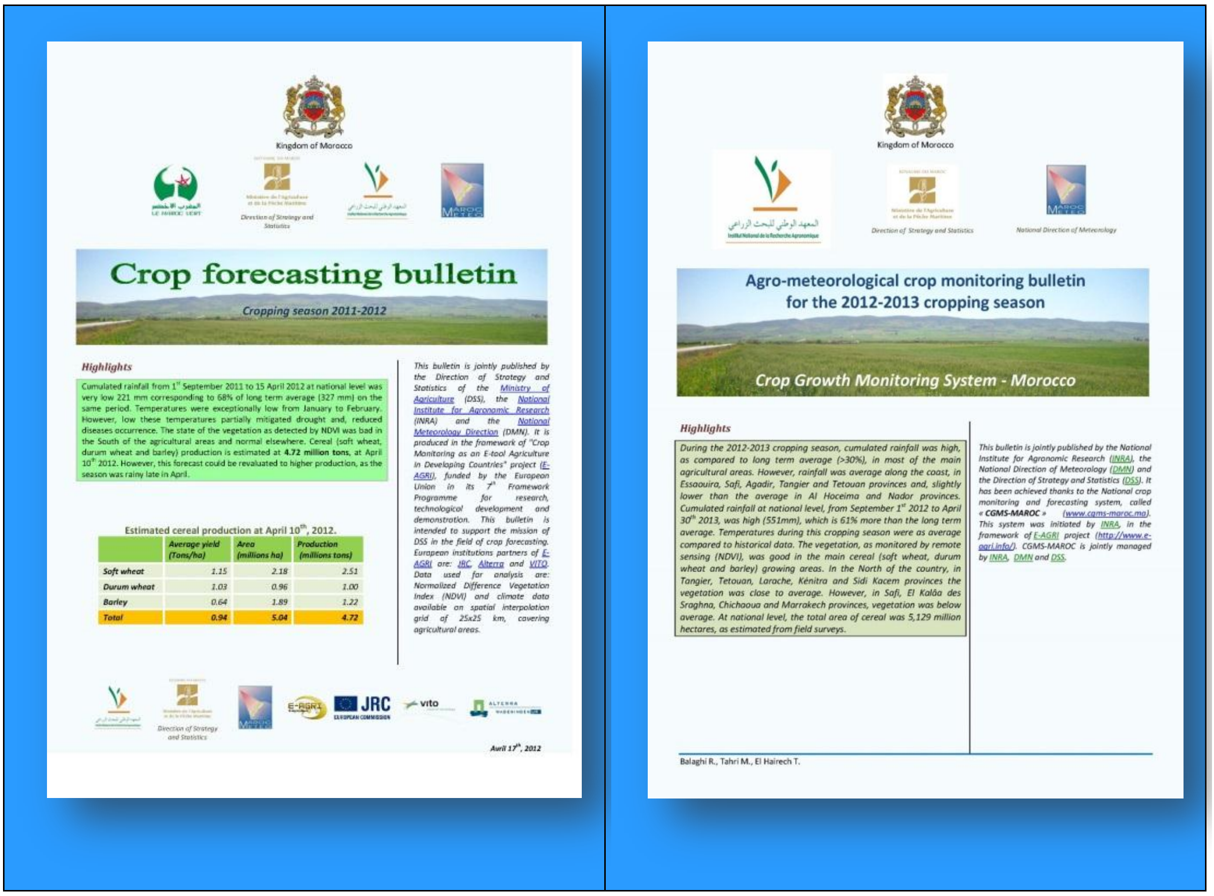

*Figure 12: The two crop monitoring and forecasting bulletins published in April 2012 and 2013 (freely available at **www.cgms-maroc.ma**).*

5. Conclusions

In general it must be concluded that the transfer of the CGMS technology has been very successful in Morocco which was demonstrated during the piloting phase. In three years time, a complete processing chain has been set up, capacity has been built by several partners (applying CGMS, handling of databases, CST, producing of bulletins, viewer development) and two forecast bulletins have already been produced and published to the ministry of Agriculture.

From a thematic point of view, it was demonstrated that the CGMS could be strongly improved for Moroccan conditions by making relatively simple changes to the CGMS configuration and parameterization. These changes have been implemented in the CGMS-Maroc. Moreover, further refinements could be implemented by using results from WP3 where more detailed crop calibrations were carried out.

At the base of this successful implementation and capacity building lies the agreement that has been made between the three institutes involved: The agriculture institute (INRA), the national meteorological centre (DMS) and statistical bureau (DSS). This agreement ensured that data can be shared between institutes and provided a common understanding to work jointly on a common goal. This is underlined by the fact that considerable work has been undertaken by DMN, while DMN was not formally part of the e-Agri consortium and did not receive funding from the European Commission.

6. Outlook and further development

CGMS-MAROC can be improved and used in agricultural early warning, by incorporating modules for forecasting short-term weather events (rain, drought, heat waves and cold) and biotic hazards (diseases, insects). These products can be generated directly from local weather stations, national networks of weather stations or numerical models of spatial interpolation of climate data. This implies a consorted effort in local data collection, transmission, processing and dissemination of agrometeorological information to farmers and agricultural advisors.

The scope of agricultural warning is large, which may include in addition to the plant protection, fertilization management, supplemental irrigation, and the choice of sowing date. This is a field of research and development to develop in Morocco, which can have significant positive impact on agriculture and the environment. It is in this context that the National Health Security Office of Food Products (in French Office National de Sécurité Sanitaire des Aliments, ONSSA) and DMN included in their priorities the development of a national program on agricultural warning.

CGMS-MAROC can be adapted for forecasting cereal yields in countries with similar climate to that of Morocco, such as the Mediterranean countries. In these countries, behavior of cereals crops to weather and crop management are similar. Moreover, the system can also be adapted to other purposes, through additional improvements, like drought insurance, agricultural warning, mapping potential of land and land use, seasonal forecasting of crop yields and impact of climate change on agricultural productivity.