Crop Monitoring as an E-agricultural tool in Developing Countries

SEVENTH FRAMEWORK PROGRAMME

E-AGRI
E-Agriculture

CGMS PILOTING REPORT

Anhui - China

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Author(s):Allard de Wit, Bell Zhang, Yang Qing, Li Jia

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Author(s) : Allard de Wit, Bell Zhang, Yang Qing, Li Jia

Reviewer(s) :

Approver(s) :

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ACRONYMS & CLOSSARY

CGMS	-	Crop Growth Monitoring System
WOFOST	-	WOrld FOod STudies
AIFER	-	Anhui Institute For Economic Research
CAAS	-	Chinese Academy for Agricultural Sciences
FAO	-	Food and Agriculture Organisation of the United Nations
ISRIC	-	International Soil Reference Information Centre
IIASA	-	International Institute for Applied Systems Analysis
GSOD	-	Global Summary Of the Day
NOAA	-	National Oceanographic and Aeronautic Administration
CMA	-	Chinese Meteorological Agency
WMO	-	World Meteorological Organization
MARS	-	Monitoring Agricultural ReSources
CST	-	CGMS Statistical Toolbox
NUTS	-	Nomenclature des unités territoriales statistiques
AgMIP	-	Agricultural Model Intercomparison Project

EXECUTIVE SUMMARY

The goal of the e-Agri project was to support the uptake of European ICT technology in Anhui (China) to support crop monitoring and yield forecasting. From the perspective of ICT uptake and the objectives of the project, we must conclude that the objectives have been reached: people have been trained, CGMS has been setup and calibrated and the system is running operationally.

Nevertheless, from a thematic perspective we must conclude that the performance of CGMS for yield prediction is insufficient to be directly useful for wheat yield prediction in Anhui. The most important reason is that the yield variability in Anhui is probably driven by factors that are not included in the crop biophysical simulations of CGMS (disease, extreme weather).

Given the thematic difficulties described above and the operational difficulties related to weather data in China , a conclusion that may be drawn is that the CGMS approach is not the most “rewarding” or “efficient” approach in Anhui for yield forecasting purposes. Also given the good results that were obtained with satellite-based indicators in Anhui (Work Package 4), it should concluded that remote sensing is a more effective approach in Anhui compared to a modelling approach.

Nevertheless, as stated in the section 4.4, the combination of analysis of meteorological records and satellite observations is regarded to be a very useful tool by partner AIFER and they will further develop this part of CGMS for crop insurance purposes. Moreover, further developments in crop simulation modelling such as currently ongoing in AgMIP may lead to new model versions that have better explanatory power compared to the WOFOST version currently implementation in CGMS.

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 piloting phase of the CGMS implementation in Anhui province in China. First of all, gives an overview of the final implementation of the Crop Growth Monitoring System that has been set up at AIFER. Next, it describes the implementation of the different processing steps that are distinguished in the processing chain and the CGMS Viewer that has been set up to analyse results from the CGMS processing chain at AIFER.

Finally, a short analysis is made of the operations that have been carried out, difficulties encountered and the socio-economic impact is described briefly.

2. Implementation of CGMS Anhui

2.1. Spatial schematization

The spatial schemation of the CGMS Anhui was discussed in the Deliverable D23.1 " Anhui_CGMS_usability_report" and will be briefly described here as some changes have been implemented compared to the initial setup described.

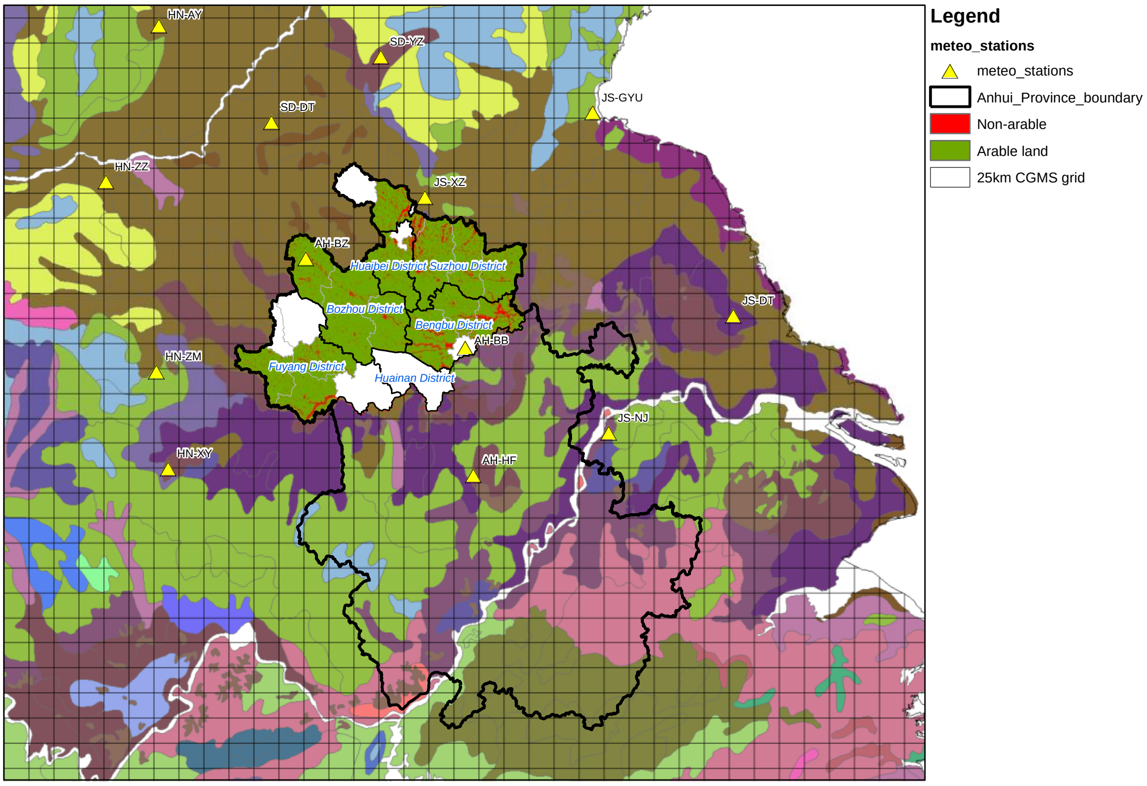

Figure 1. Spatial schematization of the CGMS-Anhui.

2.1.1. China CGMS grid

The CGMS implementation for huaibei plain in Anhui uses a grid with cells of 25x25 km which is defined in an Albers Conical Equal Area projection. This grid is defined for the whole of China and is also used by the Institute of Agricultural Resources and Regional Planning of the Chinese Academy of Agricultural Sciences. Also the grid numbers are identical which facilitates exchanging data at the level of the grid between CAAS and AIFER.

2.1.2. Soil map

Soil map is based on the SOIL and TERRAIN Database for Northern and Central EURASIA (SOTER) on a scale of 1:1,000,000. This database is prepared by FAO, ISRIC and IIASA in co-operation with the Dokuchaiev Institute of Soil Science, Moscow, Russia and the Institute of Soil Science, Academia Sinica, Nanjing, China.

The soil attributes defined in the SOTER map were used to estimate the soil hydraulic properties. This was done not within e-Agri, but was based on earlier work carried out in the framework of the MARS project with JRC. These soil hydraulic properties were used to for the CGMS-Anhui implementation as well.

2.1.3. Administrative regions

The Huaibei plan in Anhui has been subdivided administratively into 6 districts and 23 counties. During the transfer of the CGMS-Anhui to partner AIFER, it was found that the administrative division has changed which impacted the spatial schema. Finally, the latest administrative division (Table 1) was implemented in the CGMS-Anhui and the spatial schema was updated accordingly.

Table 1. Administrative regions implemented in CGMS-Anhui (2013 revision)

Code	Name_EN	Name_CN	Level	Belongs_To	Belongs_To_Name
34	Anhui province	安徽省	0	2	Lower Yangze
3403	Bengbu District	蚌埠市	1	34	Anhui province
340301	Bengbu city	市辖区	2	3403	Bengbu District
340321	Huaishan county	怀远县	2	3403	Bengbu District
340322	Wuhe county	五河县	2	3403	Bengbu District
340323	Guzhen county	固镇县	2	3403	Bengbu District
3404	Huainan District	淮南市	1	34	Anhui province
340401	Huainan city	市辖区	2	3404	Huainan District
340421	Fengtai county	凤台县	2	3404	Huainan District
3406	Huaibei District	淮北市	1	34	Anhui province
340601	Huaibei city	市辖区	2	3406	Huaibei District
340621	Suixi county	濉溪县	2	3406	Huaibei District
3412	Fuyang District	阜阳市	1	34	Anhui province
341201	Fuyang city	市辖区	2	3412	Fuyang District
341221	Linquan county	临泉县	2	3412	Fuyang District
341222	Taihe county	太和县	2	3412	Fuyang District
341225	Funan county	阜南县	2	3412	Fuyang District
341226	Yingshang county	颍上县	2	3412	Fuyang District

341282	Jieshou city	界首市	2	3412	Fuyang District
3413	Suzhou District	宿州市	1	34	Anhui province
341301	Suzhou city	市辖区	2	3413	Suzhou District
341321	Dangshan county	砀山县	2	3413	Suzhou District
341322	Xiaoxian	萧县	2	3413	Suzhou District
341323	Lingbi county	灵璧县	2	3413	Suzhou District
341324	Sixian	泗县	2	3413	Suzhou District
3416	Bozhou District	亳州市	1	34	Anhui province
341601	Bozhou city	市辖区	2	3416	Bozhou District
341621	Guoyang county	涡阳县	2	3416	Bozhou District
341622	Mengcheng county	蒙城县	2	3416	Bozhou District
341623	Lixin county	利辛县	2	3416	Bozhou District

2.1.4. Crop mask

A crop mask for the Huaibei Plain has been made available by AIFER with a spatial resolution of 100m (figure 3). The crop mask only makes a distinction between the land use classes “arable land” and “other land use”, moreover the crop mask is not crop specific. However, given that the distribution of crop types over the area is fairly homogeneous there is little difference between a general crop mask and a crop-specific mask. Therefore, the current crop mask was implemented in CGMS-Anhui.

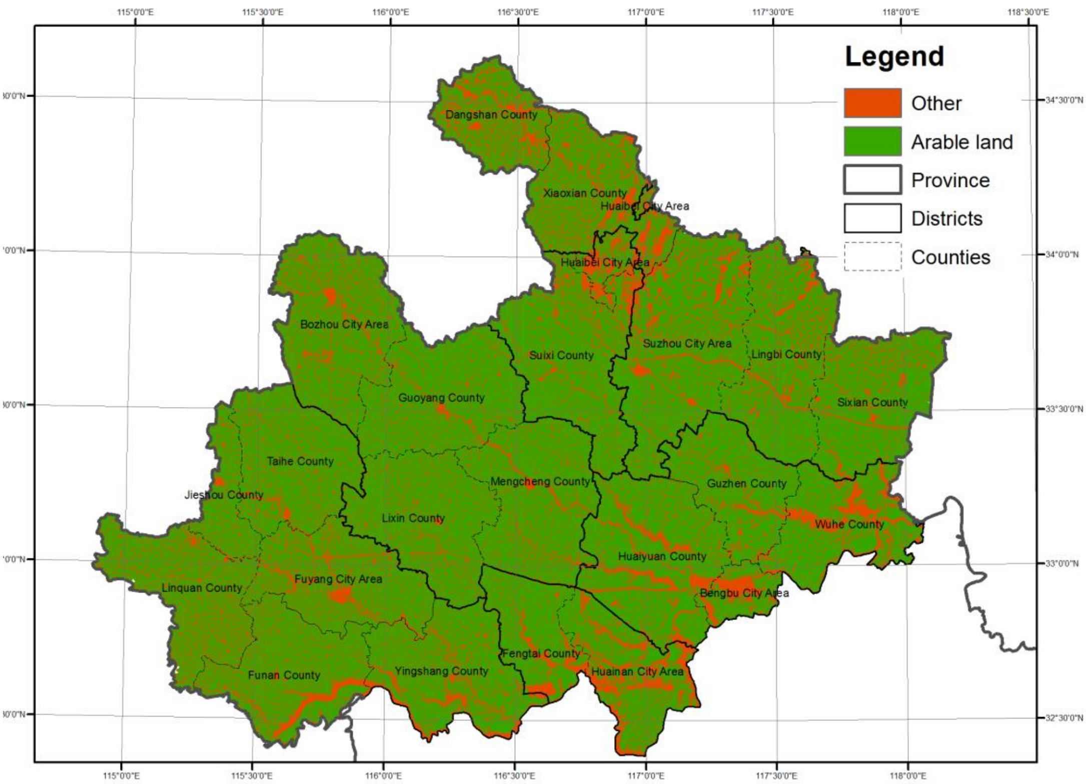

Figure 1. Crop mask for the Huaibei plain. Province boundaries in dark black lines, district boundaries for the Huaibei plain in thin black lines.

2.1.5. Meteorological data from weather stations

To reach an operational CGMS service for Anhui, daily weather data must be available within a few days. Meteorological observations from the Chinese Meteorological Agency (CMA) can only be received with a delay of three months, which is insufficient for near real-time monitoring. Therefore, the CGMS-Anhui has been linked with the Global Summary of the Day (GSOD) service from the National Oceanographic and Aeronautic Agency (NOAA) which provides acces to Chinese weather with a delay of 2 days, albeit for a limited number of stations (Figure 2). A comparison has been made between weather data from CMA and weather data from GSOD showing good correspondence between the two sources (Figure 3) although there are some small deviations for a number of days.

Comparison of available weather stations

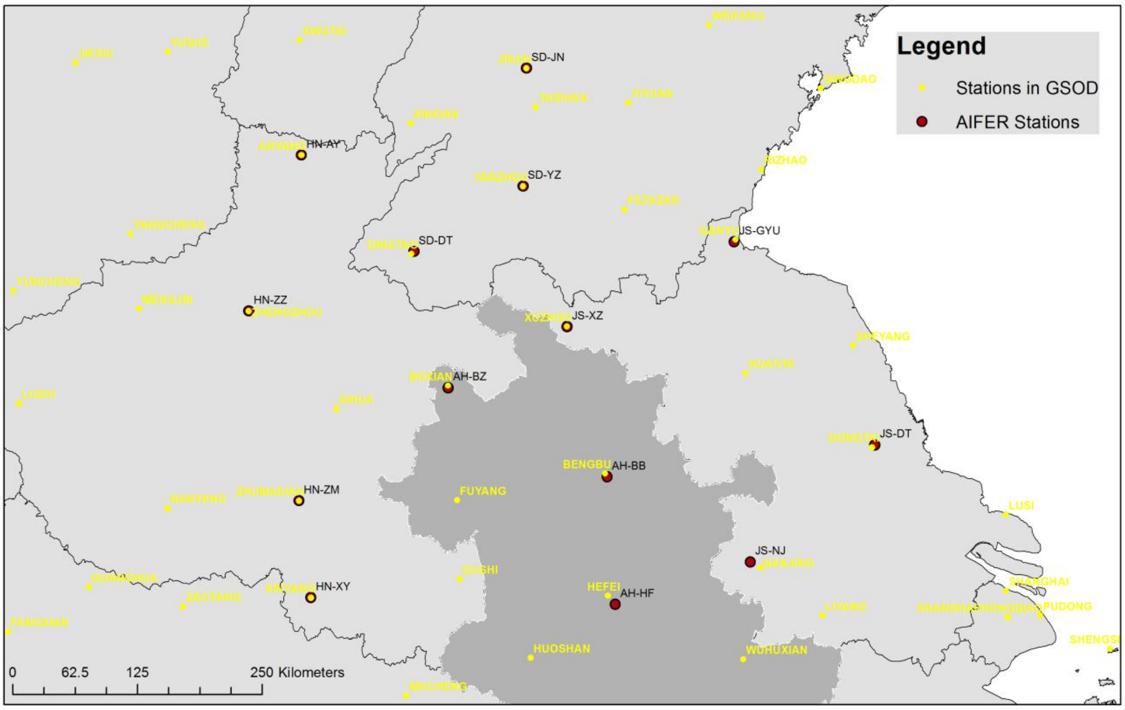

Figure 2. Comparison of available stations from partner AIFER through the Chinese Meteorological Agency and what is available from the GTS network of the World Meteorological Organization (WMO) through the GSOD service.

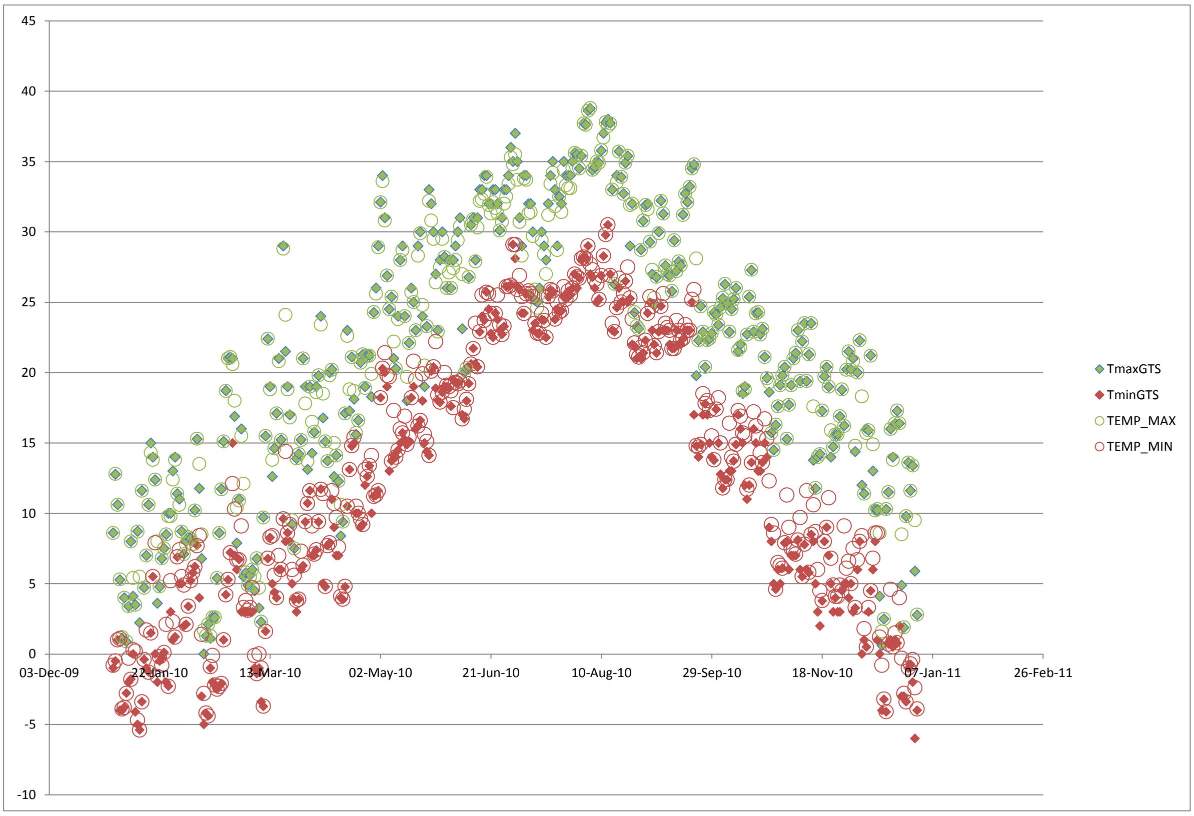

Figure 3. comparison of daily minimum and maximum temperature for a weather station from CMA (TEMP_MIN, TEMP_MAX) and the corresponding data retrieved from the NOAA GSOD service (TminGTS, TmaxGTS).

2.1.6. Crop calibration and crop calendar

The calibration of winter-wheat cultivars in Anhui has been carried out using data from the Fengqiu Comprehensive Agroecology Experiment Station and using time-series of phenological observations from 11 counties in northern Anhui. This work has been reported in Deliverable D21.1 and D21.2 and will not be repeated here.

For defining the crop calendar in CGMS-Anhui this above data sources have also been used. The observations of sowing and emergence indicated a trend of later sowing towards the south and therefore the Huaibei plain (including some area to the south and the north) has been stratified into three zones with different cultivar characteristics and average sowing dates (Figure 4). The north-western zone has been assigned a fixed sowing date of 28 October, the central zone a sowing date of 21 October and the southern zone a sowing date of 16 October.

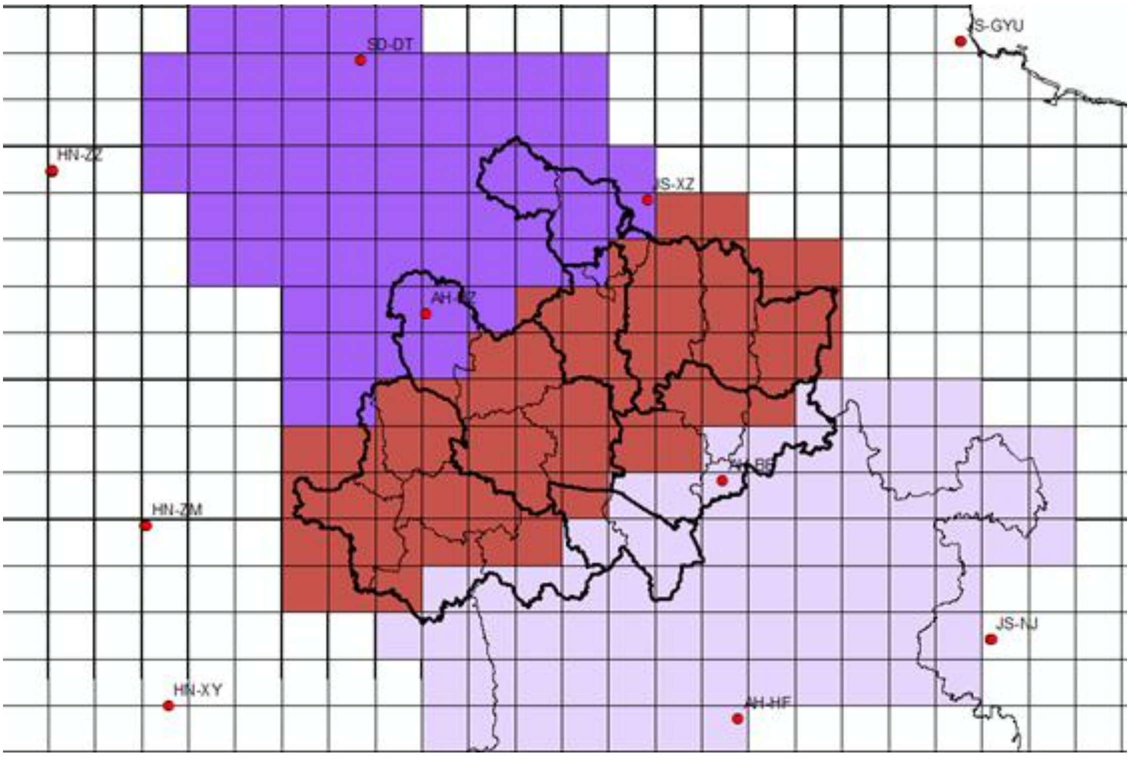

Figure 4. stratification of the Huaibei plain in three zones of equal cultivar and average sowing date.

3. Operations for running CGMS Anhui

3.1. Structure of the CGMS Anhui processing chain

The database, tools and processing chain that has been delivered by Alterra to partner AIFER has been split into a clear folder structure that reflects the different components of the CGMS Anhui and the processing chain for operating the system (Table 2). Most of the components in the folder are being described in separate deliverables or manuals. Therefore, the description here focuses on the operations of running CGMS Anhui on a day-to-day basis.

Table 2. Overall structure of the CGMS-Anhui setup

Top folder	Sub-folder	Description and further references (italics)
CGMS-Anhui	Calibration	Data and tools used for calibrating CGMS-Anhui *See deliverable D22.1 and D22.2*
	CGMS_DB	The CGMS Anhui database. *See section 3.2* *See http://www.marsop.info/marsopdoc/metamp*
	CGMSViewer_Standalone_ODBC	The CGMS Viewer for CGMS-Anhui.
	CST	The CGMS Statistical Toolbox: database & Installer *See CST documentation within CST package*
	Operations	Scripts and executables for CGMS Operations *See section 3.3*
	SpatialSchema	The spatial schematization of CGMS-Anhui *See chapter 2*
	WOFOST	Standalone WOFOST and the CGMS2WOFOST tool *See http://www.wageningenur.nl/wofost*

3.2. CGMS database

The CGMS-Anhui database has been implemented as a Microsoft Access database and is stored under the folder CGMS_DB. Initially, there were concerns regarding the size of the database which would quick become too large for an Access database which has a 2Gb size limit. Therefore, the use of a MySQL database has been investigated. Although the performance and operations with MySQL worked well at Alterra, the performance of MySQL was too low at AIFER for reasons that are not entirely understood. It may have to do with network connections that were too slow.

Therefore, the use of Microsoft Access was preferred and a solution for the size limit was found by migrating the largest table (the GRID_WEATHER table) to an external database file. The GRID_WEATHER table can be accessed from the main database through a "linked table" connection. A point of attention is that whenever the main database file is moved to another location, the path to the linked table must be updated as well.

3.3. Operations for updating CGMS-Anhui

The operations folder has three subfolders according to the three levels in CGMS processing. In each folder, the tools and configuration files have been stored which are needed to carry out the processing. Each processing step can be started with a batch file written in the MicroSoft command language. The downside is that no user interface tools are available to run the CGMS processing. The upside is that all operations can be fully automated easily and implemented in an automated processing chain that can run as an scheduled task under the Windows task scheduler. This way no supervision is needed for daily operations.

3.3.1. Level 1: weather processing

Several tools have been developed for weather data processing in the CGMS-Anhui processing chain for taking into account the complex situation with Chinese meteorological data. First of all, the level 1 procedures have been split into "daily" operations that should be run each day and "occasional" operations that should be run only in certain cases. The daily operations consist of two processing steps:

1. Invoking the python scripts that contact the NOAA Global Summary of the Day (GSOD) service and update the METDATA table with new meteorological data from GSOD. This process not only updates the most recent data days but includes the older updates when they come available.
2. Running of the CGMS executable to process the raw meteorological including estimating of data, calculation of additional variables (radiation, evapotranspiration) and interpolation of weather data to the 25x25 CGMS grid.

Finally, the 'daily' operations folder contains python scripts for loading weather data from files that are provided by the Chinese Meteorological Agency (CMA) including three different types: Archive weather data, daily weather data (but delayed) and radiation data. These scripts have not been used in E-Agri so far and will need some small modifications to work on the Access database of CGMS-Anhui. Nevertheless they can serve as a basis for future automated loading of CMA meteorological data.

The folder 'occasional' contains scipts and executable for tasks that should be carried out occasionally, for example when a new year of data is available. These set of tools available is the following:

- Scripts to update the LONG_TERM_AVERAGE_GRID_WEATHER table which should be carried out when new meteorological data has been loaded. The actual query is available in the CGMS-Anhui Access database itself, the script provides a description on how to start the process.
- The executable 'ReferenceWeather.exe' which is used to update the REFERENCE_WEATHER table in the CGMS database. This table contains the long term average meteorological data at station level and should be updated whenever a new meteorological year is available.
- Scripts for estimating the parameters in the Angstrom and Hargreaves models that are used for estimating the incoming global radiation. These models are needed because neither the GSOD service, nor the data from the Chinese Meteorological Agency provide real-time observations of solar radiation.

3.3.2. Level 2: Crop simulation

The folder "level2_cropsimulation" has been split into two seperate operations: "dekadal" operations that have to be carried out when level1 procedures have completed for 10-day period and "occasional" operations that have to be carried out at the end of each campaign year (e.g. cropping season).

The dekadal procedures are carried out by the CGMS executable and consist of two separate steps that have been implemented using Windows Command files:

1. Running of the crop simulations through the command '1_runcgms_cropsimulation.bat' which will trigger the CGMS executable and start processing according to the specifications in the configuration file 'CGMS_cropsimulation.ini'. The latter files still has to be adapted manually but this can be automated easily.
2. Running of the aggregation of simulation results from the lowest level (CROP_YIELD) towards the grid level (GRID_YIELD) which is needed for visualising results with the CGMS Viewer. This process is also done by the CGMS executable and started using the command file '2_runcgms_aggregation.bat' which reads its configuration from 'cgms_aggregation_gridyield.ini'. The latter needs to be adapted manually.

The only occasional procedure that has to be carried out is the recalculation of the LONG_TERM_AVERAGE_GRID_YIELD which is needed for the CGMS viewer. This is done using a query stored in the CGMS_DB itself. Under the 'occasional' folder there is only a text file describing the procedure.

3.3.3. Level 3: aggregation and data preparation for yield forecasting

The folder "level3_yieldforecast" only contains a folder for "dekadal" procedures. These procedures present the final step in the CGMS processing chain: the aggregation of results to the administrative regions and the preparation of results at administrative level for the yield forecasting procedures. These are implemented in two procedures in the Windows Command Language which execute the CGMS executable:

1. Aggregation of the crop simulation results to administrative level can be started from '1_runcgms_aggregation.bat'. This will read the configuration from the file 'cgms_aggregation.ini'. The settings in the .INI file need to be set manually, but this can be automated easily in the future.
2. Preparation of the results and inserting them into the CST database for analysis with the CGMS Statistical Toolbox (WP6) can be started with the script '2_runcgms_preparation.bat' which reads the configuration from the file 'cgms_preparation.ini'. The settings in the .INI file need to be set manually, but this can be automated easily in the future.

3.3.4. Maturity of the CGMS-Anhui processing chain

At the end of the E-Agri project a complete and (technically) tested processing chain has been developed for the Huaibei plain in Anhui. During the support visit to AIFER in November, the different processing steps have been explained by Alterra personell and a working CGMS chain has been installed at AIFER premises.

Nevertheless, partner AIFER will need to become more familair with the CGMS processing chain in order to effectively use it, understand the different processing steps, understand the underlying database structure and solve problems that may occur during processing of data. It is Alterra's experience, that this can be only obtained by working with the database and tools on a day-by-day basis in order to become acquinted with the different steps, understand the database structure and how the different tools work.

The current CGMS-Anhui processing chain still consist of many individual steps that have to be carried out manually. Automating these steps can be done relatively easily because all steps can be parameterized through the .INI files for the CGMS executable. Nevertheless, for a learning perspective it is advisable to operate the CGMS chain manually for some time. As the level of understanding and experience increases, more advanced options can be selected for automating the processing chain. This very much like the process as it went at Alterra with the European MARS project; in the beginning our CGMS processing chain was run manually, next it was scheduled using simple batch files using the Microsoft Command Language. Now, there are advanced daemons that schedule processes and update a web-based control board which monitors the timely execution of all processes.

3.4. CGMS viewer

The CGMS viewer that is currently used for the CGMS-Anhui is the so-called CGMS-Classic viewer which is a desktop application that can visualize data from the CGMS database. The CGMS viewer can visualize weather data and the crop simulation results at grid level. However, it cannot visualize results for administrative regions.

For the weather data at grid level, CGMS viewer can generate maps of the following weather variables at grid level:

- Basic meteorological variables: Temperature, radiation, rainfall, vapour pressure, windspeed and evapotranspiration. Moreover these variables can be taken as average values, sum of values or the minimum/maximum of these values.
- Summaries of meteorological variables with an agronomic interpretation: number of hot days, number of cold days, temperature sum, longest heat wave period.
- Advanced variables: climatic waterbalance (daily sum of precipitation and evapotranspiration)

All variables can be calculated for selected date ranges and can be expressed as absolute values or with reference to the previous year and the long-term average (absolute and percentual).

For the crop simulation results at grid level, CGMS viewer can generate maps of the following simulation results:

- General CGMS output variables: development stage, biomass, yield, leaf area index.
- CGMS output variables related to water requirements, soil moisture and water consumption.

All variables can be calculated for selected date ranges and can be expressed as absolute values or with reference to the previous year and the long-term average (absolute and percentual).

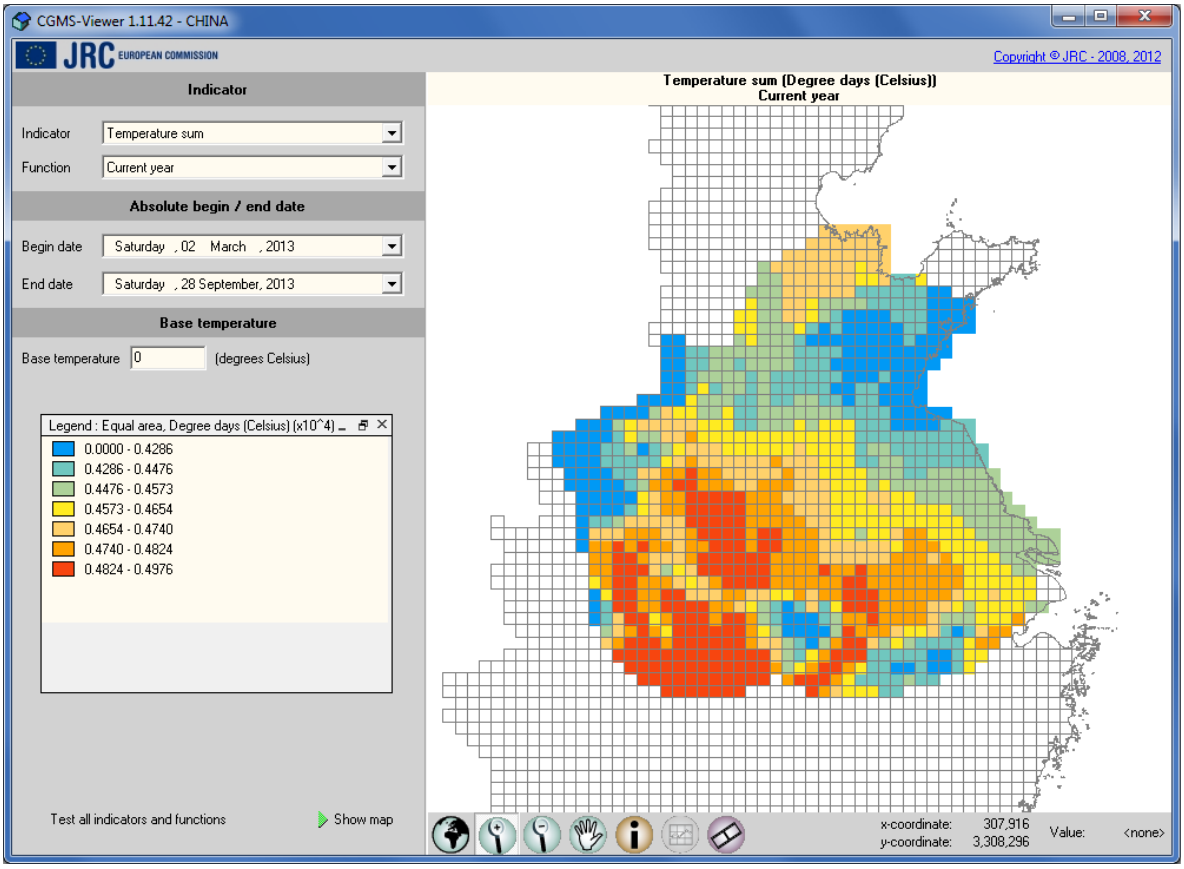

Figure 5. CGMS Viewer showing the temperature sum from 2 March 2013 up till 28 September derived from the CGMS-Anhui database.

3.5. CGMS Statistical Toolbox (CST)

The CGMS Statistical Toolbox has been provided as an integral part of the CGMS processing chain that is installed at AIFER. Aggregated results from the CGMS crop simulations are inserted in the relevant tables of CST and the system is easily extended to include other indicators that are relevant for crop yield forecasting. Also, the crop yield and area statistics for the different regions in Anhui have been updated up till 2012 by partner AIFER. Figure 6 shows a screenshot of the CGMS Statistical Toolbox for northern Anhui.

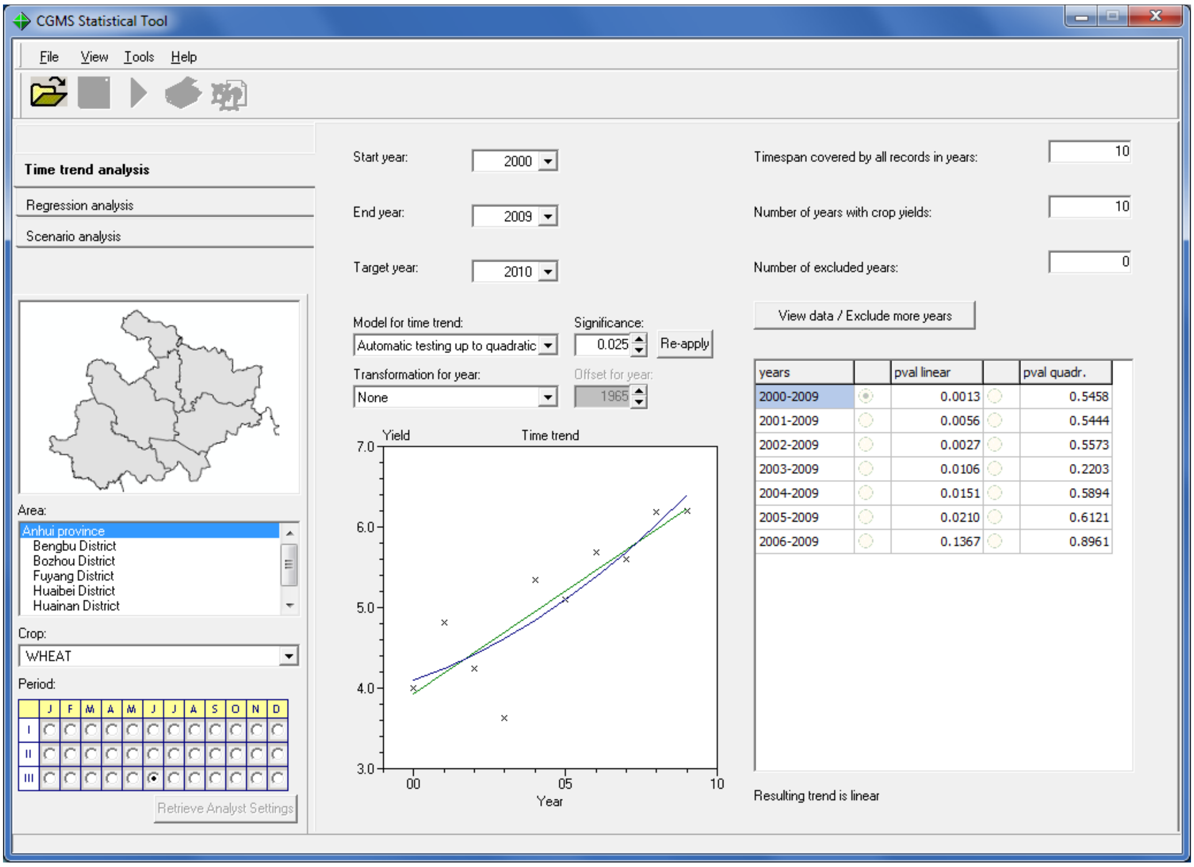

Figure 6. Setup of the CGMS Statistical Toolbox for the Huaibei plain in northern-Anhui.

4. Evaluation of CGMS Anhui

4.1. Operations carried out during the piloting period

With the help and guidance from Alterra, we have built CGMS-Anhui system which is operating in our institute now. The main achievements in association with this work are as below:

(1) Quasi real-time update of various weather data using the batch processing code made by Alterra. The weather data source is from NOAA GSOD. The weather database is updated to 2014 February.

(2) Update of the grid weather database, including the grid interpolation, every week using the processing code mentioned above.

(3) Undertaking grid-wise crop growth modeling, including potential biomass, potential yield under various environmental conditions. Up to now, the grid-wise crop modelling work is updated to the end of August of 2013.

(4) Realization of crop growth modeling at regional scale (i.e. NUTS level 2) by utilizing the grid weather data and the corrected NUTS information.

Modeling the crop growth status in six regions in the northern Anhui. The results of this modeling have been implemented in the CST system so that the yield prediction can be done later.

4.2. Difficulties encountered and solutions applied

We have been facing some difficulties and problems as below:

(1) Difficulties in obtaining real-time weather data. Due to constrain in the data policy of Chinese Meteorological Administration (CMA), there is a three months delay in accessing to CMA weather data portal. Such constrain has hindered the real-time operation of CGMS-Anhui. Alternatively, for the most recent three months, weather data from NOAA GSOD data portal are used in the CGMS-Anhui and then replaced once the CMA data are available.

(2) Difficulties in obtaining crop experimental data in the study area. We could not find crop growth experimental data over long period in Anhui province, which has brought difficulties in calibration of the crop growth model WOFOST in the CGMS-Anhui. Alternatively, we have used crop experimental data of multiple years

collected from Fengqiu experimental station. Fengqiu station is located in the Huaibei plain, about 150km away from the northern Anhui with similar crops, phenology, climate and terrain.

(3) Difficulties in migration of database. CGMS-Anhui database is built on ACCESS. Due to huge amount of data, we have encountered problems during experiments and modelling. Suggestion from Alterra is the migration of the whole database into MySQL or Oracle. However, I have noticed some data were lost during such migration. To solve the problem, further suggestion from Alterra is to separate the data table GRIDWEATHER from the CGMS-Anhui database and make use an external link to store the frigged weather data. The problem is solved now.

(4) Difficulties in integration and operational use of the CGMS-Anhui system. Our primary idea was to realize the visualization and real-time operation by utilizing WebGIS techniques. However, due to limited project time span and our lack of such skills, such objective has not yet been reached. It is worth to mention that Alterra has helped with offering a set of batch processing toolkits, which ensure us to realize quasi real-time operation of CGMS-Anhui.

4.3. Evaluation of forecasting performance at regional level

We have carried out yield predictions of winter wheat in the northern Anhui using the CST tool. The predicted 10-day crop growth status, e.g. yield per unit area, crop area, and total yield, by the CGMS-Anhui are compared with those from Statistical Yearbook of Anhui Province.

The prediction experiment using CGMS-Anhui is done for the period of 2000 to 2012 over six regions in the northern Anhui. Linear trend between the yield and years is found in the statistic data. The exceptional year is 2003, the statistic of yield in 2003 is much lower than other years. Multi-variable regression is made after removing the data from 2003. Yield in 2012 is then predicted using the multi-variable regression equation using CST.

It is found that none of the predictors describing growth status are relevant to the yields, only the linear relationship between yields and time (i.e. years) are found. Since we cannot get data of mid- or long-term weather prediction from meteorological bureau at the time being, the yield prediction using weather data are not yet carried out.

4.4. Socio-economic impact

Through the e-Agri project, we have built the capacity on knowledge of using e-agricultural tools and remote sensing techniques for agriculture monitoring. In particular, young staffs are trained with broader international view and advanced knowledge and techniques. Such capacity building will improve our competence in crop growth monitoring, promote our ability to cope with climate change and benefit our capability on early warning for food security.

Based on the knowledge and techniques that we gained from the e-Agri project, we have identified a Memorandum of Understanding for cooperation with Guoyuan Insurance Company in Anhui, VITO and Swiss Re-insurance Company (Swiss RE) for crop growth monitoring in the northern Anhui. The objective of the project is to predict and assess the risk of crop production through the monitoring of crop growth and the evaluation of disaster damage using CGMS-Anhui system by comparison with the historical records and use of remote sensing observations.

The outcome of the project will provide scientific evidence and support to insurance company for better loss assessment and decision-making of claims compensation. Furthermore, the outcome of the project can be used to build crop yield loss early warning system and help the local government to make policies and scientific-sound decisions on agricultural management, agricultural disaster early warning and mitigation, and provide a basis for regional differentiation in agricultural insurance premium in Anhui province. Moreover, the project can provide information service to farms in different stages of crop growth for their better management.

5. Conclusions and outlook

The goal of the e-Agri project was to support the uptake of European ICT technology in developing countries to support crop monitoring and yield forecasting. One of the focus areas in the workpackage 2 was on the monitoring and forecasting of winter-wheat yield and production in the Huaibei plain in Anhui, China.

From the perspective of ICT uptake and the objectives of the project, we must conclude that the objectives have been reached: people at AIFER have been trained, data on winter-wheat growth have been collected, CGMS has been set up and calibrated for the Huaibei plain. Moreover, the system can run operationally (despite the difficulties with meteorological data) and persons at AIFER have been trained in the operations and maintenance of CGMS.

Nevertheless, from a thematic perspective we must conclude that the performance of CGMS for yield prediction is insufficient to be directly useful for wheat yield prediction in Anhui. There may be several causes for the poor performance. First of all (and most important), yield variability in Anhui is probably driven by factors that are not included in the crop biophysical simulations of CGMS. This point was already argued in the deliverable D23.2 (strategy report) and seems to be confirmed by the final results of the system. Second, calibration of CGMS for winter-wheat is still insufficient. Indications that calibration plays a role is that CGMS currently underestimates the wheat yield level in the Anhui plain. Finally, related to the previous issue is that the meteorological input data may still be insufficiently accurate particularly for the global radation. Calibration of CGMS was carried out using archive radiation data coming from numerical weather prediction models from ECMWF. However, ECMWF data is not operationally available to AIFER and therefore they rely on the empirical models embedded in CGMS. Although the parameters of these radation models were calibrated biases may still be present.

Given the thematic difficulties described above and the operational difficulties related to weather data in China , a conclusion that may be drawn is that the CGMS approach is not the most “rewarding” or “efficient” approach in Anhui for yield forecasting purposes. Also given the good results that were obtained with satellite-based indicators in Anhui (Work Package 4), it should concluded that remote sensing is a more effective approach in Anhui compared to a modelling approach. This is also related to the typical agricultural patterns in China where the agricultural landscape is often dominated by a few main crops which can be effectively monitored with satellite data because landscape fragmentation plays a limited role.

Nevertheless, as stated in the section 4.4, the combination of analysis of meteorological records and satellite observations is regarded to be a very useful tool by partner AIFER and they will further develop this part of CGMS for crop insurance purposes. Moreover, further developments in crop simulation modelling such as currently ongoing in AgMIP may lead to new model versions that have better explanatory power compared to the WOFOST version currently implementation in CGMS.