Crop Monitoring as an
E-agricultural tool in
Developing Countries

ASSESSMENT REPORT ON BIOMA APPLICATION IN MOROCCO

Reference: *E-AGRI_D35.1_Assessment report on BioMA application in Morocco*
Author(s):Valentina Pagani, Davide Fumagalli, Fabien Ramos, Simone Bregaglio, Caterina Francone, Roberto Confalonieri
Version: 1.0
Date: 7/01/2014

DOCUMENT CONTROL

Signatures

Author(s) : Valentina Pagani
Davide Fumagalli
Fabien Ramos
Simone Bregaglio
Caterina Francone
..Roberto Confalonieri

Reviewer(s) :

Approver(s) :

Issuing authority :

Change record

Release	Date	Pages	Description	Editor(s)/Reviewer(s)
1.0	08/01/2014	26	D35.1 - Report	

TABLE OF CONTENT

LIST OF FIGURES

EXECUTIVE SUMMARY

BioMA is a platform developed to run multi-model simulations on explicit spatial units and to forecast crop yields at different spatial levels. BioMA, unlike the existing forecasting systems, is characterized by a user friendly environment, allowing the user to upload new configurations and change different simulation options without the need for opening and modifying any database. Thanks to the integration of simulation, mapping and statistical tools, BioMA allows to compare results of specific configurations at two levels: a) the pattern and values of model outputs in each spatial unit; b) the results of forecasting yields.

In this work, BioMA was applied to simulate soft and durum wheat growth and development in Morocco from 1987 to 2012. The biophysical models CropSyst and WOFOST, previously calibrated (during this project) for the specific conditions explored, were used and compared for spatially distributed simulations, whereas – to assess the advanced functionalities of the platform – only WOFOST's outputs were post-processed to obtain the yield forecasting at national and regional level. Indeed, the evaluation and comparison of the BioMA models for wheat yield forecast in Morocco are reported in specific E-AGRI deliverables (e.g., D35.2).

CropSyst and WOFOST differently reacted to specific environmental conditions, to the change of management practices and to soil water stress dynamics and biotic factors (fungal pathogens). The simulated values and patterns of the model outputs strictly depend on the approaches used by the two models to simulate crop growth and development. The main driver for wheat production in Morocco is the scarcity of water. Indeed, the simulated yields almost halved compared to the values obtained under potential conditions.

Considering all the indicators (i.e., potential and water/diseases limited) simulated by WOFOST, the varibility of official yields explained after the statistical post-processing varied from region to region, ranging from 52% to 83%. The impact of changes in modelling options within the simulation environment is also discussed.

1. Introduction

Crop monitoring systems allow to timely forecast crop productions, sustaining the agricultural policies and limiting the negative impact of speculations on the market. Different forecasting systems were developed during the last decades, based on crop simulation models and remote sensing. All these systems are affected by some limitations, especially due to the unsuitability of the modelling solutions (e.g., key processes not simulated) and the uncertainty of model inputs (e.g., information on crop distributions). Moreover the existing systems do not allow the user to easily create specific configurations and to obtain a yield forecasting without modify the related databases.

BioMA (Biophysical Model Applications) is a software platform characterized by a user friendly environment, that allows running multi-model simulations and obtaining yield forecasts at different spatial levels, without opening and modifying any database. A detailed description of all the software components implemented in Bioma is shown in the web site *http://bioma.jrc.ec.europa.eu/*. The statitical post-processing of official yields and simulated indicators is performed using the software CST, developed for the JRC's MARS (Monitoring Agriculture with Remote Sensing) project, and now integrated in the BioMA simulation environment.

2. Materials and methods

2.1. The BioMA platform

The BioMA platform allows the user to easily customize modelling solutions, loading the data sources and modifying parameters values. In addition to the simulation tool, BioMA is also integrated with maps and data visualizers, i.e., tools for mapping and plotting the different outputs of the simulations.

Moreover, the platform is also connected to the CST statistical tool, a system developed for statically processing simulated and historical yields to produce the forecast for the current year.

This structure easily allows comparing results obtained from the different crop models implemented in BioMA via the CropML software library. The platform also allows to change agronomic practices (via the AgroManagement component) and to analyse results; moreover, it allows to run simulations accounting for different factors limiting crop growth, like water availability and fungal pathogens.

A detailed description of the main options which can be modified by the user inside the simulation environment is shown in E-AGRI report 33.1, that considers the assessment of BioMA for rice monitoring in China. A summary of the main functionalities of BioMA, especially referring to soft and durum wheat growth and development in Morocco, is shown in the following sections of this report.

2.1.1. The simulation and mapping tools

The simulation tool allows the user to build a new configuration, selecting the crop model, the period of simulation, the weather files, the management options and the biotic limitations affecting crop growth and development (red box, Figure 1). In order to simulate wheat growth and development, only two of the biophysical models implemented in the component CropML were used: CropSyst and WOFOST.

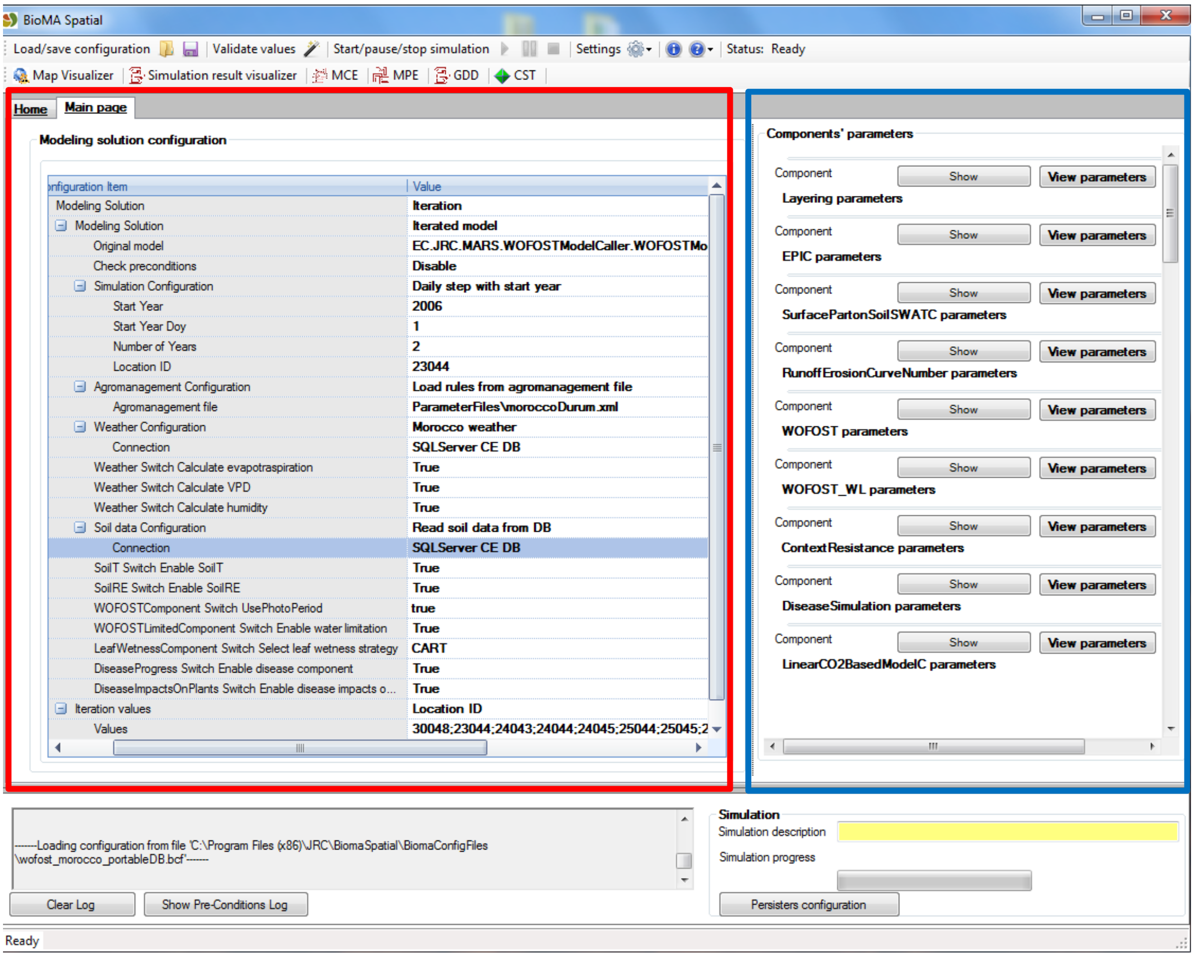

Figure 1 Graphical user interface of the simulation tool of BioMA

During previous project activities (see E-AGRI deliverables D34.1 and D34.3) wheat varieties cultivated in Morocco were divided in three groups (durum wheat, soft wheat – high productivity and soft wheat – low productivity), and specific parameter sets were developed for both CropSyst and WOFOST (see E-AGRI D34.3). The user can select the specific crop group and consequently the parameters key from the application "AgroManagement Configuration Generator" (Figure 2).

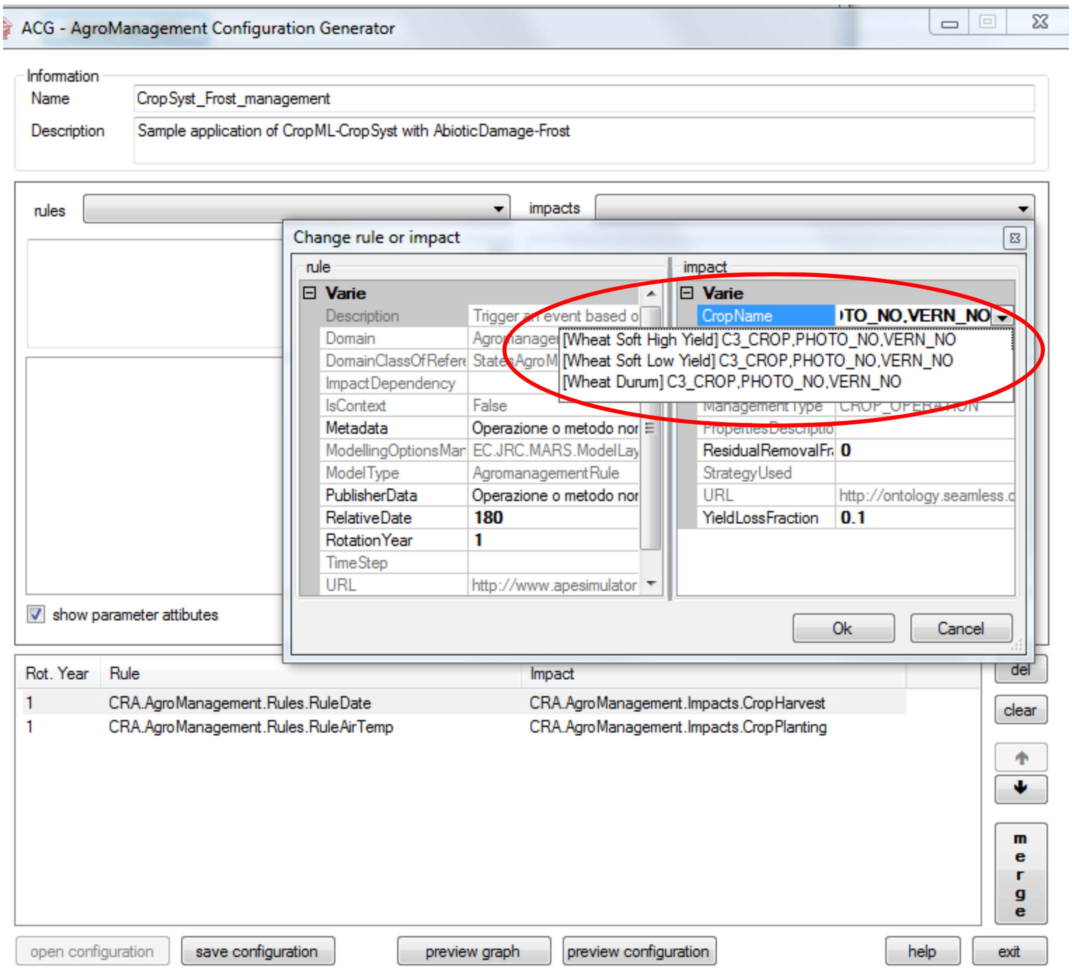

Figure 2 Choice of the crop parameters key from the 'Agromanagement Configuration Generator'

Wheat in Morocco is mainly not irrigated, thus rainfall is the only water source and it affects the processes involved with plant development and growth. BioMA includes three components involved with the simulation of soil dynamics, and each one offers a wide range of alternative approaches:

- UNIMI.SoilW for simulating water dynamics in the soil;
- UNIMI.SoilT for simulating soil temperature, which the user can activate using a switch button (blue box in Figure 3);
- UNIMI.SoilRE for soil runoff and erosion simulation, which the user can activate using a switch button (blue box in Figure 3).

Physical and chemical properties of the local soils are stored in a database connected with BioMA (red box in Figure 3).

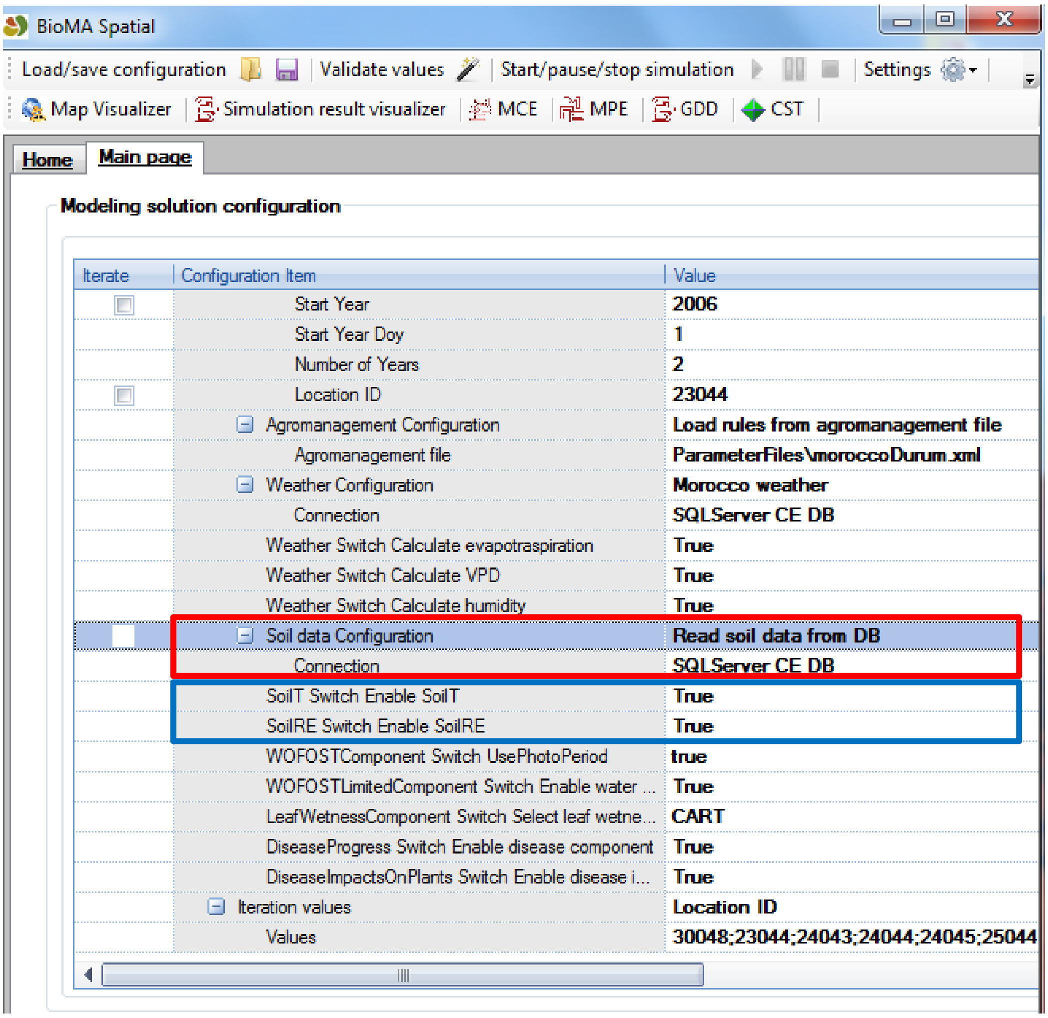

Figure 3 Components used for the simulation of water dynamics in the soil

The defined modeling solution configuration is currently applied to each of the 25 km × 25 km cells of a grid corresponding to the MARS grid weather. The size of each cell derives from the resolution of the weather data, which is 1 degree latitude × 1 degreee longitude. The itaration button, which is the last in the 'modeling solution configuration' box, allows to select the cells where the simulation will be performed, through the component 'Location selector'.

Figure 4 shows the 25 km × 25 km grid for Morocco, with the green cells representing the elementary units covered by wheat according to the available crop mask.

The user can then upload and modify the parameter files related to the models implemented in the BioMA components (blue box in Figure 1), and finally he/she can select the database where outputs will be stored, validate the inputs, and launch the simulations.

The ‘map and data visualizer’ tool allows the user to visualize the spatially distributed variables simulated by the models (e.g., aboveground biomass, leaf area index, yield and development stage).

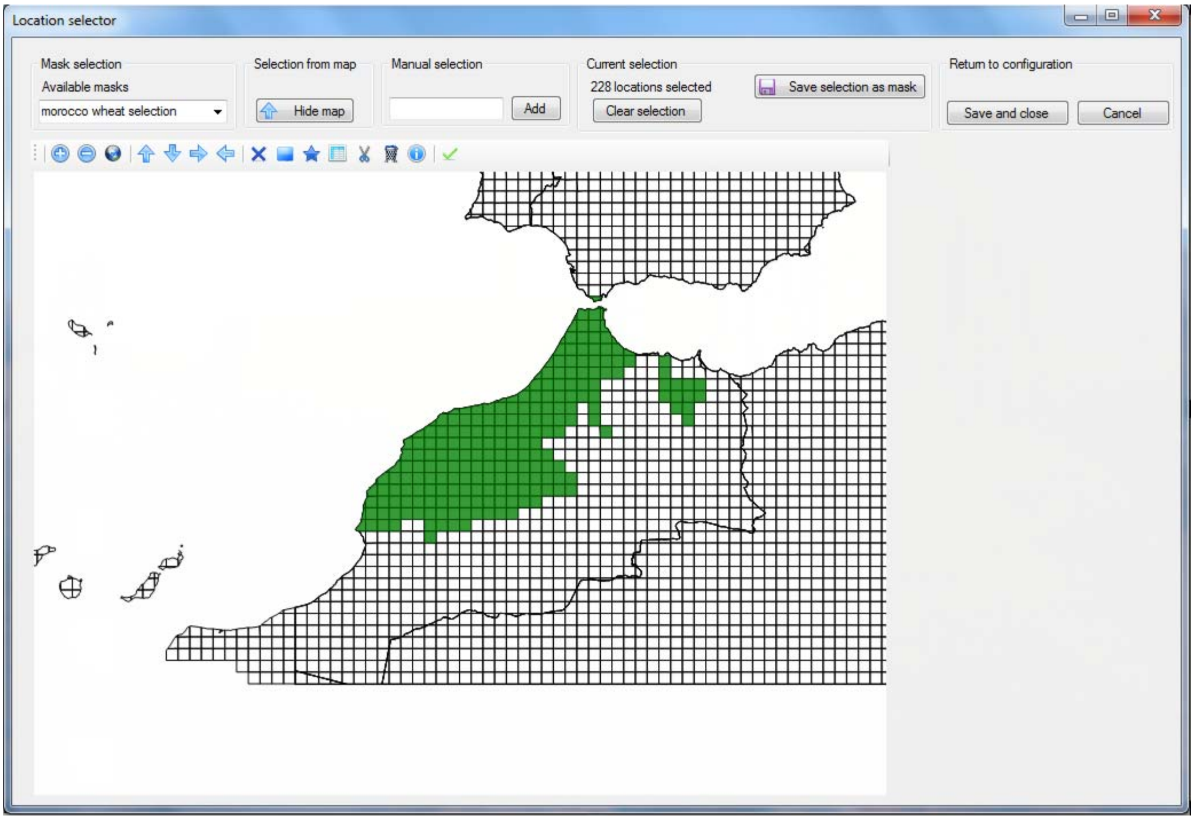

Figure 4 The component ‘Location Selector’

2.1.2. The statistical tool

The outputs simulated in each grid cell are stored in a database each ten days. After the simulations, these variables are automatically aggregated at national and regional level, according to the percentage of crop presence in each elementary simulation unit. Statistics on official yields and cultivated area are stored in the same database. The following steps for obtaining yield forecasts using the CGMS statistical tool are detailed in E-AGRI report 32.1.

Official statistics were available separately for durum and soft wheat at national and regional levels; this allowed to perform yield forecasts for the two species at both the administrative levels. These options can be selected by the user from the first page of the CST tool (red box in Figure 5).

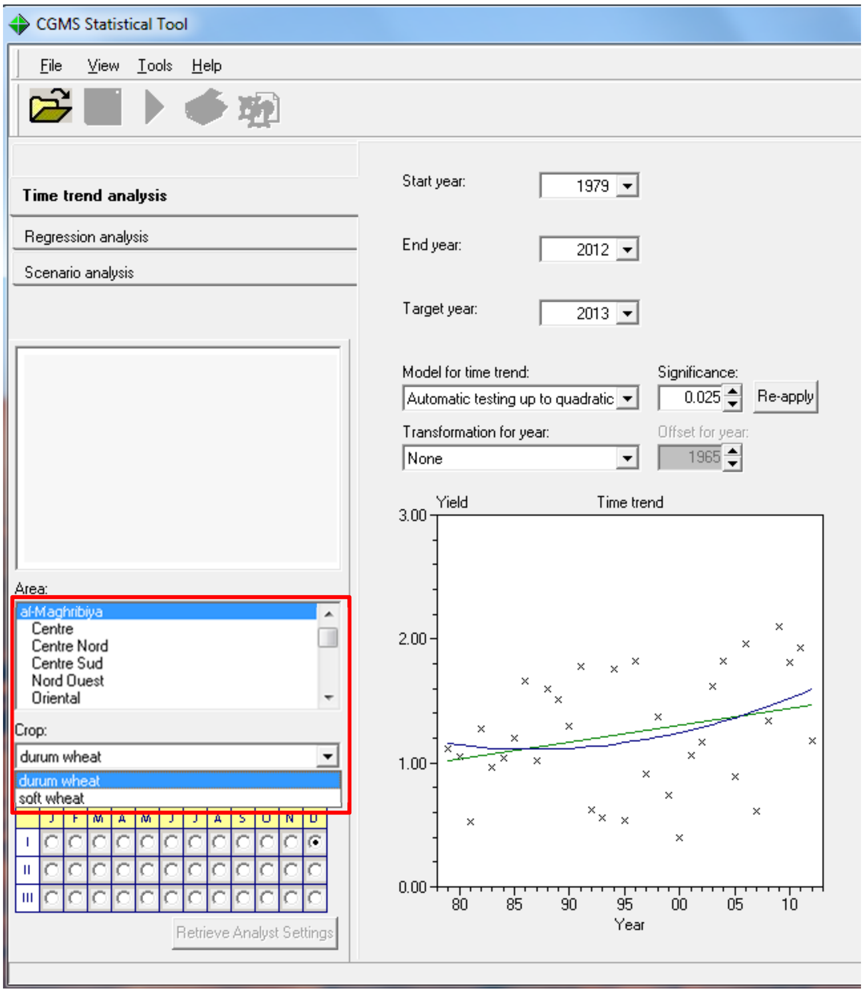

Figure 5 Choice of the spatial level (i.e. nation or regions) and the wheat group in the CST tool

2.2. Spatially distributed simulation tests

In this report, the BioMA platform was applied to durum and soft (high and low potential cultivars) wheat in Morocco, using the models CropSyst and WOFOST.

The options implemented in BioMA for spatially monitoring crop growth, described in section 2.1.1, were modified and applied. The results obtained for the season 2000-2001 are shown as example. In particular, the following tests were applied:

a) Application of the simulation tool to the three groups of wheat cultivars using CropSyst and WOFOST under potential conditions. The rule-impact management selected was that based on a specific date for planting and harvesting. The sowing date was set to 30th November and the harvest one at the end of June. The simulations were performed in all the 228 25 km ×25 km grid cells where wheat is cultivated according to the available crop mask.

b) Management options. The sowing rule was changed and set to an automatic rule based on air temperature: if the daily mean air temperature is higher than 14°C for 4 consecutive days between the 305 and the 350 day of the year, then the planting event is triggered. If the rule is not triggered during the selected time window, the crop will be sowed at the end of this period. The values of parameters of this management option were chosen according to the typical sowing period in Morocco and to the daily mean air temperatures recorded in the same time window. The results obtained using the soft wheat – low productivity parameters set are shown as example.

c) Simulation of water stress and of plant-pathogens interaction. We evaluated the effect of water stress, which is the main factor affecting wheat productivity in Morocco, and the integrated effect of water stress and diseases. In particular, we analysed here the interaction between wheat and the rust fungus *Puccinia recondita*. The results obtained using the soft wheat – low productivity parameters set are shown as example. The sowing date was the same applied in test a), thus isolating and studying the effects of limiting factors from those resulting from changes in management.

2.3. Yield forecasting tests

As an example, the complete workflow needed to reach the forecasted yield was carried out using the simulation model WOFOST (the multi-model approach is reported in E-AGRI D35.2). Official yields for both durum and soft wheat at national and regional levels (Figure 6) were provided by the 'Institut National de la Recherche Agronomique'.

Figure 6 Regions of Morocco

In this test, durum wheat official yields and simulated indicators from 1998 to 2010 were used within CST to find the best regression models, which were applied to forecast wheat yield for 2011. Yield forecasts considering all the indicators simulated by the model (i.e., potential and water-diseases limited variables) were performed at national and regional level and the results obtained were analyzed and compared. The planting date was fixed at November 30th and the harvest date at the end of June. Then, two other tests were performed, using only national official statistics of durum wheat, to demonstrate that the modifications on the simulation tool largely affect the results of yield forecasting:

a) results obtained setting a fixed sowing date (i.e. November 30th) and using a different rule to trigger the sowing event (i.e., that based on air temperature used in the spatially distributed test b) were compared. Both potential and limited indicators were included in the regression model;
b) results obtained considering only potential indicators in the regression model were compared to results obtained from the first test, to study the improvement derived from the simulation of water and diseases stress.

3. Results and discussion

3.1. Spatially distributed simulations tests

The outputs obtained from the three tests are shown in Figures from 7 to 11. The maps were created using the mapping tool integrated in BioMA.

a) Maximum aboveground biomass (AGB) and leaf area index (LAI) simulated by CropSyst and WOFOST under potential conditions using the parameters set for durum and soft (high and low productivity) wheat are shown in Figure 7 and Figure 8, respectively. This first test shows that the values of the two variables and the spatial patterns simulated by the two models using the three parameters sets were different, indirectly demonstrating the usefulness of differentiating the parameter sets for the different groups of cultivars. CropSyst and WOFOST showed comparable performances during calibration; however, the response to the various climatic and environmental conditions explored in the Country revealed a different behavior for the two models. This is due to the specific approaches used by each model in reproducing the processes related to crop growth and development. The AGB values simulated by CropSyst followed a north-south gradient, which is the typical gradient of temperature and solar radiation in Morocco. The biomass ranged from 15 t ha^{-1} to values higher than 21 t ha^{-1} simulated in the southern regions, with pick LAI values ranging between 6 m^2 m^{-2} and 7 m^2 m^{-2} in most of the grid cells. The gradient followed by the AGB simulated by WOFOST is characterized by a lower production in the southern cells, where the daily maximum temperatures averaged on the wheat growing period (i.e., from December to May) reached the highest values (Figure 9a). This different response is explained by the crop growth limitation to high temperatures and the maintenance respirations uniquely considered by WOFOST.

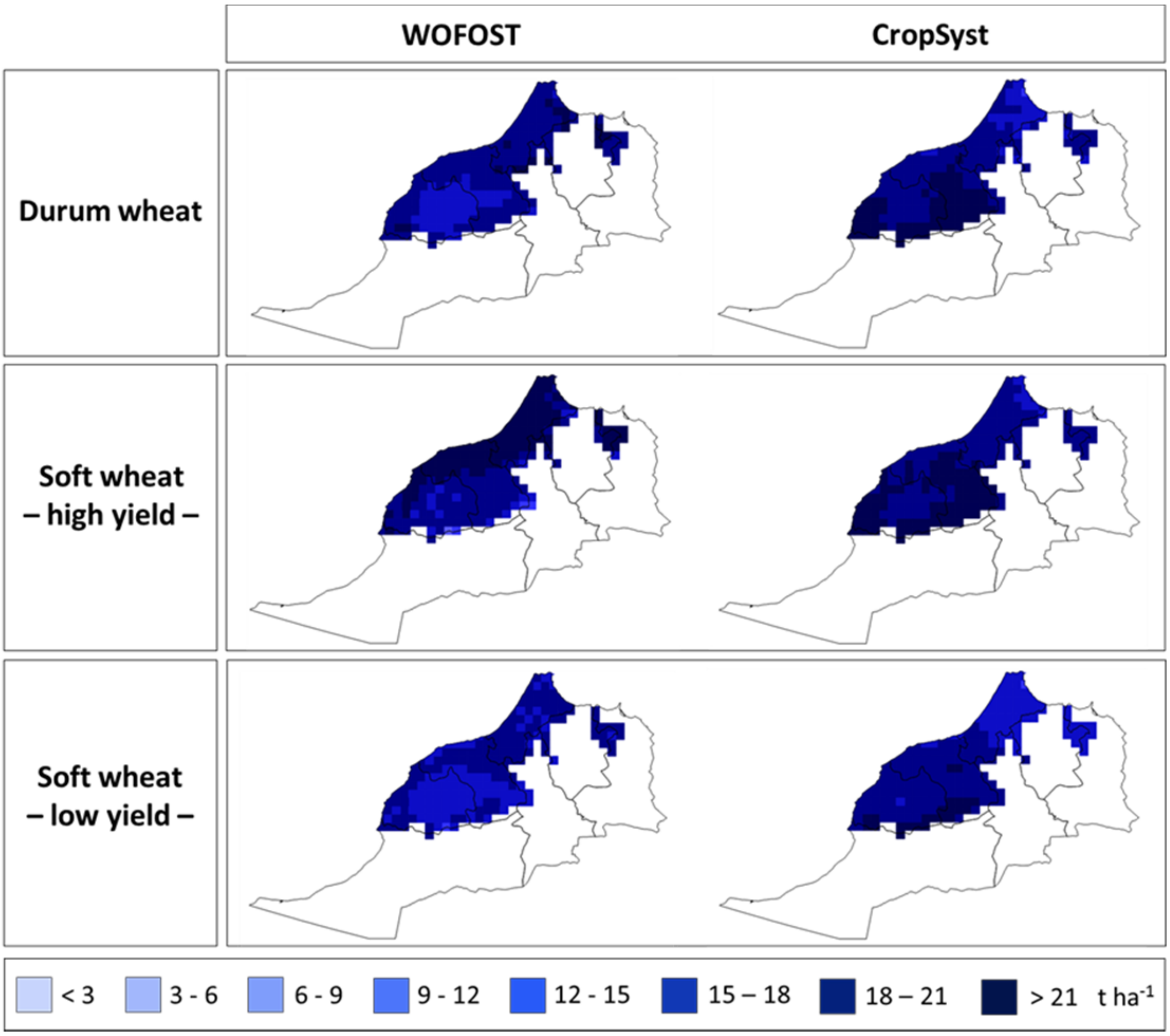

Figure 7 *Final aboveground biomass simulated by WOFOST and CropSyst in potential conditions using the durum, soft – high productivity and soft – low productivity parameters set*

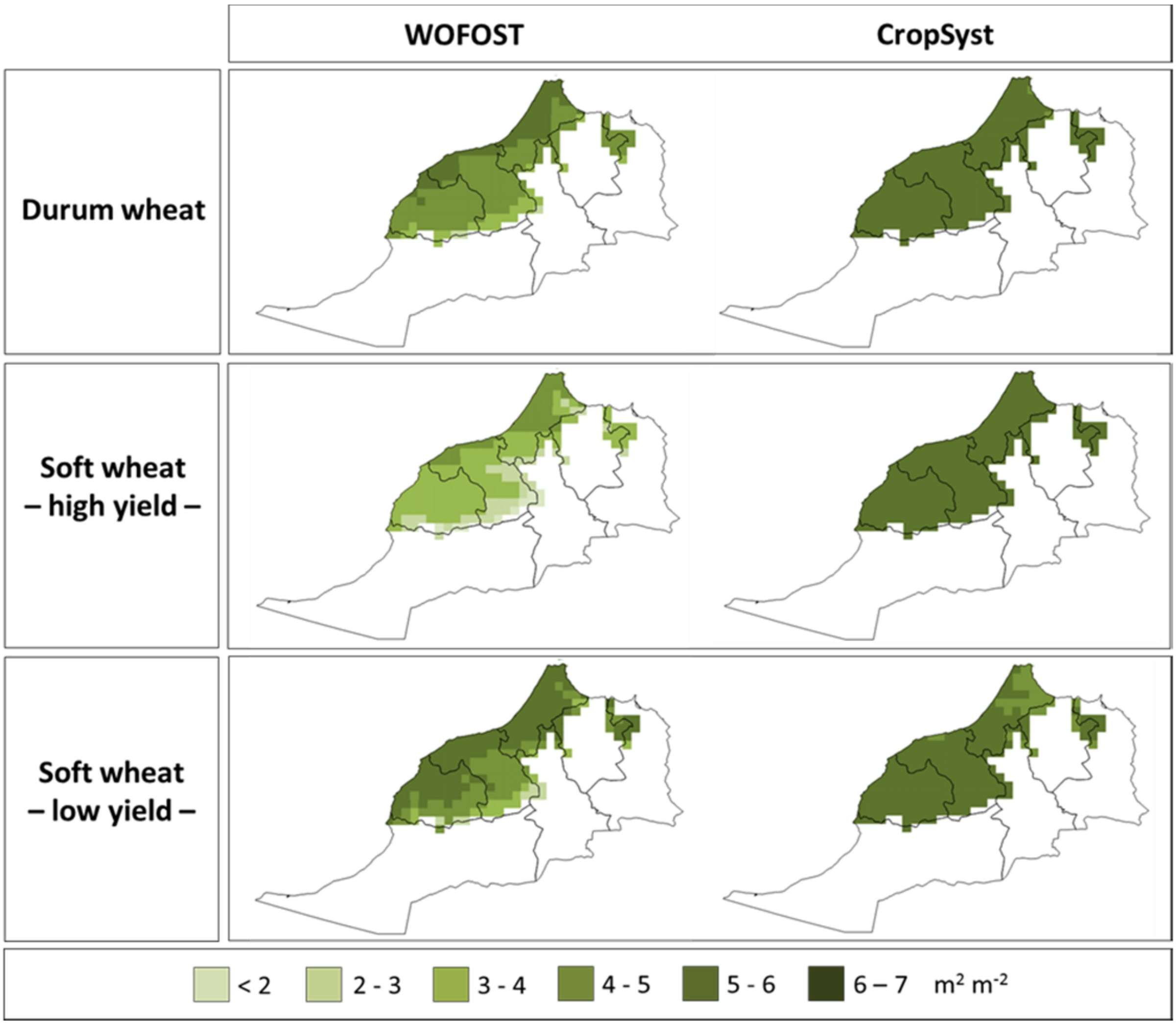

Figure 8 *Maximum leaf area index simulated by WOFOST and CropSyst in potential conditions using the durum, soft – high productivity and soft – low productivity parameters set*

b) Figures 10 and 11 show the effects of the changes in sowing date on AGB and LAI of soft wheat – low potential. The final AGB and LAI simulated by CropSyst and WOFOST maintained almost the same pattern shown in test a). However, it is possible to observe a general decrease in biomass accumulation, probably due to the anticipation of the sowing date in most of the grid cells, caused by the sudden occurrence of the conditions set in the management rule (i.e., 14 °C for 4 consecutive days from the beginning of November to the end of December). The crop was sown in November instead of December, thus the higher monthly temperatures caused a reduction of the crop cycle length.

c) Figures 10 and 11 show the effects of the water stress on AGB and LAI of soft wheat – low potential cultivars. AGB and LAI simulated both by CropSyst and WOFOST follow a north-south gradient opposite to that observed under potential conditions. This spatial pattern is explained by the concentration of rainfall in the northern part of Morocco (Figure 9b). This is an evidence that the abundance of rain where wheat is not irrigated represents the major driving variable to assure good yields at the end of the season. The reduction of crop productivity simulated by the two models under water limited conditions is different: the AGB values simulated by CropSyst ranged from less than 3 t ha^{-1} to 6-9 t ha^{-1}, whereas WOFOST simulated more diversified values, that reached 18 t ha^{-1} in the northern cells.

The simultaneous simulation of water stress and the interaction between crop and *Puccinia recondita* caused a slight decrease in final biomass. Figure 10 shows that the main impact was simulated by Cropsyst in the southern cells, where higher values of temperatures were reached during the growing period.

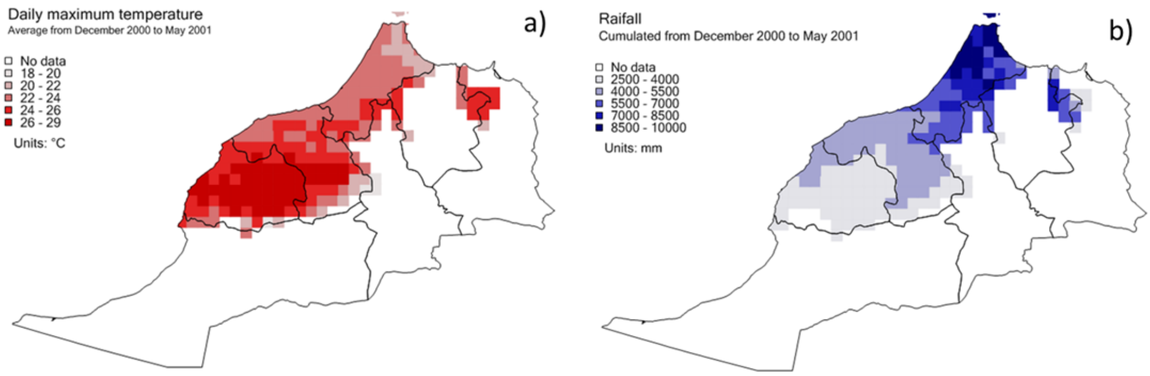

Figure 9 a) daily maximum temperature averaged from December 2000 to May 2001; b) rainfall cumulated from December 2000 to May 2001

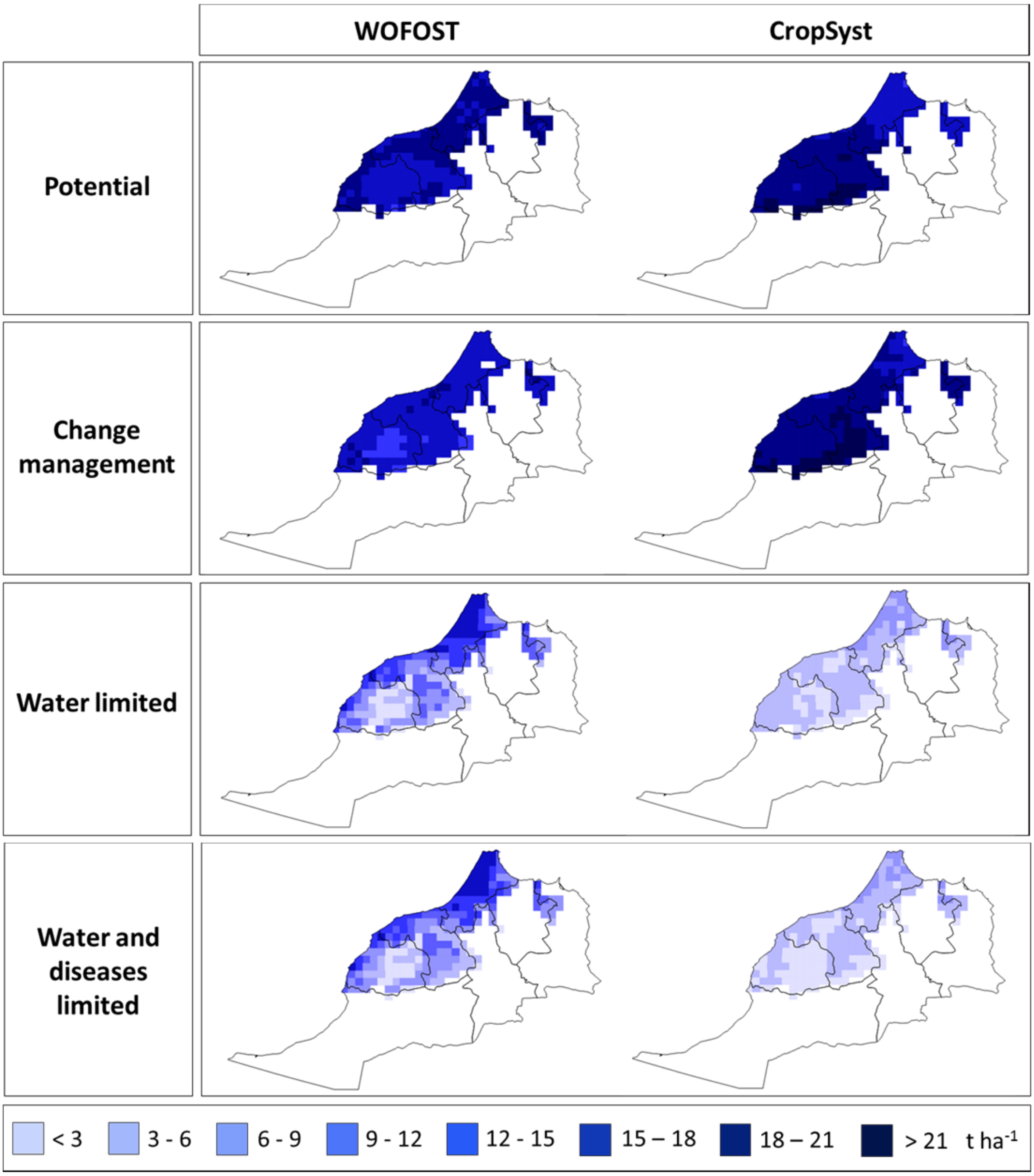

Figure 10 *Final aboveground biomass simulated by WOFOST and CropSyst in potential, water limited, water and diseases limited conditions and after the change of management options using the soft – low productivity parameters set*

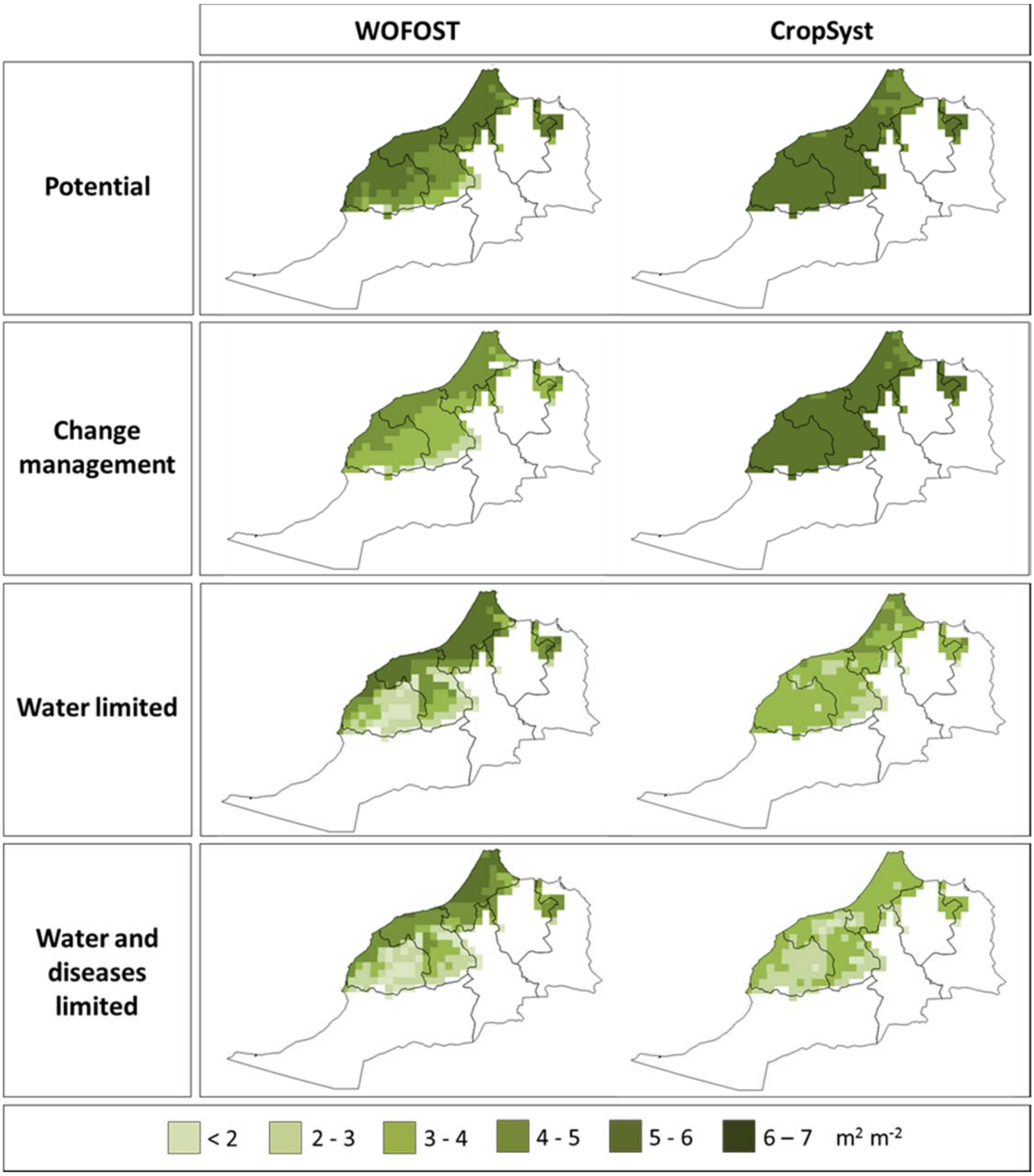

Figure 11 Maximum leaf area index simulated by WOFOST and CropSyst in potential, water limited, water and diseases limited conditions and after the change of management options using the soft – low productivity parameters set

3.2. Yield forecasts tests

The first step is to define the type of time trend in durum wheat official yield statistics in the period of interest at national and regional level. As shown in Figure 12, official yields at national level follow a linear trend, confirmed by the automatic test applied by the statistical tool. At regional level, there is no trend in official yields in most of the cases.

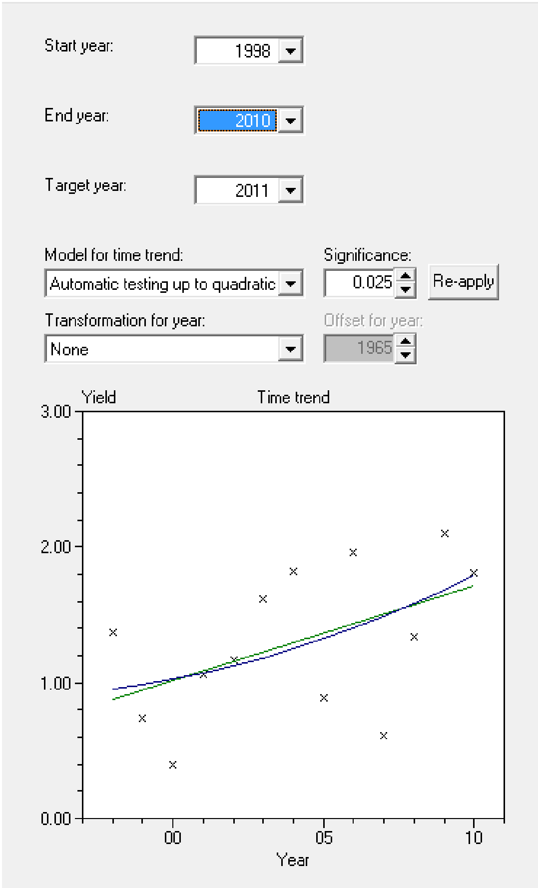

Figure 12 Time trend followed by durum wheat official yields from 1998 to 2010

It was decided to trigger the forecasting event at maturity which, according to the simulated crop development, occurres at the end of May in most of the grid cells.
In the first test, the simulated indicators used to find the best regression models were:

- Potential aboveground biomass
- Potential development stage
- Potential leaf area index

- Water/diseases limited aboveground biomass
- Water/diseases limited leaf area index
- Number of infections

The comparison between official and estimated yields obtained from the application of the best regression models is shown in Figure 13. The selected indicators were water/diseases limited aboveground biomass and number of infections. This can be explained by the relevant influence of water stress and diseases on wheat growth and final yields in Morocco.

At national level, the best regression model is able to explain 83.03 % of the inter-annual variability in official yields and the selected indicators were limited aboveground biomass, number of infections, potential and limited leaf area index. Green circles in Figure 13 show that forecasted yields overestimated and underestimated official yields in 2007 and 2009, respectively.

At regional level the best forecasting results were obtained in the Oriental region, where 83.82 % of variability was explained and, as shown in Figure 13, the general trend of official yields is well reproduced in all the studied years. In the other regions, the percentage of variability explained ranged from 52 % to 82 %. In Figure 13 the years charactherized by a marked overestimation or unerestimation of official yields in each region are eclosed by red circles.

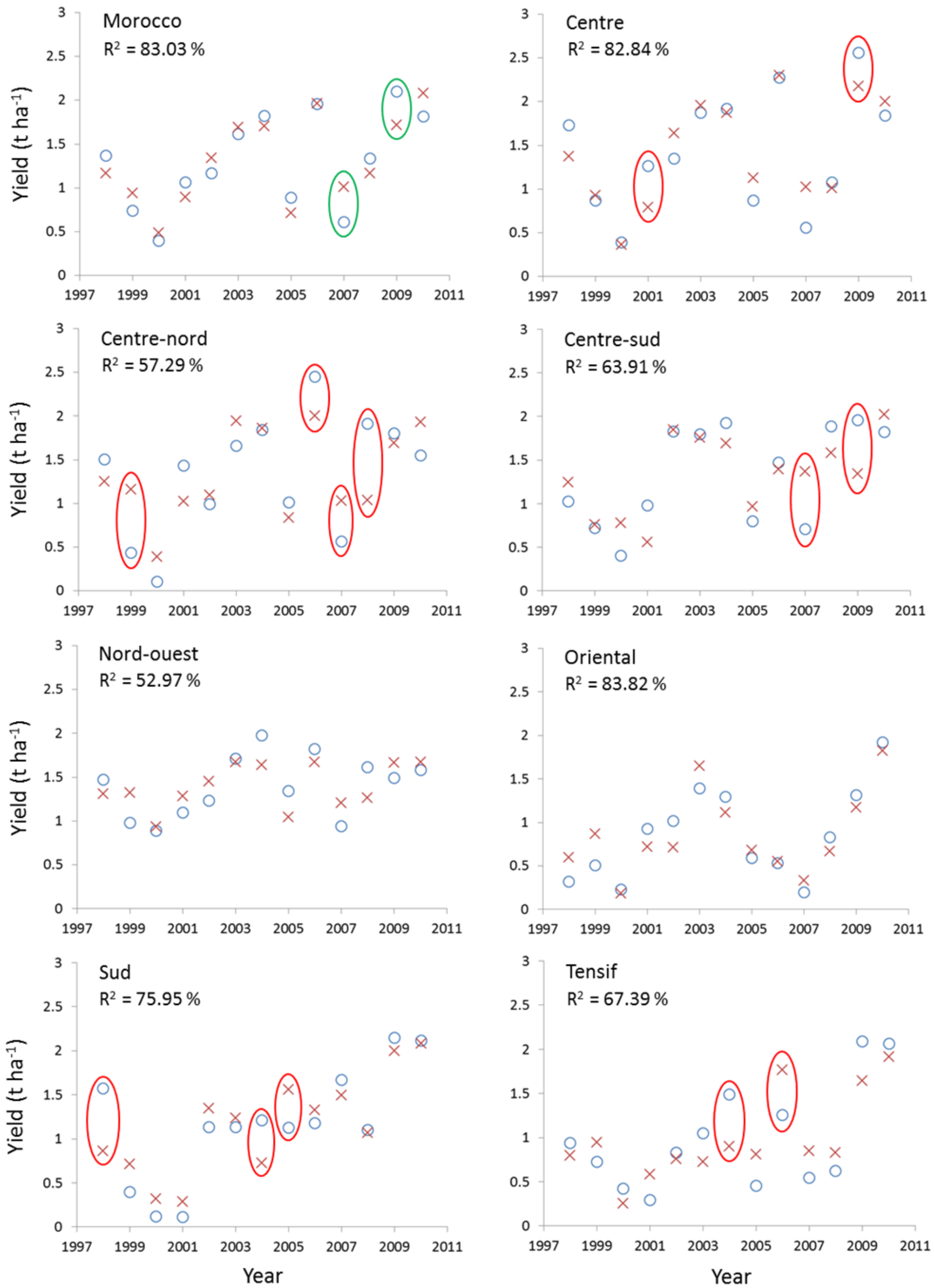

Figure 13 Comparison between official yields (blue circles) and estimated yields (red crosses) from 1998 to 2010 at national and regional level

The results of the other two tests are shown below:

a) Figure 14 shows the comparison between results obtained at national level (i) using a fixed sowing date and (ii) changing the sowing rule. The change of management led to a little increase in the amount of inter-annual variability in yields explained by the model. The coefficient of determination of the regression model is 83.48 % and the simulated indicators chosen were potential aboveground biomass, number of infections, limited LAI and potential development stage. It can be observed an overestimation of the official yields in 2007, similar to that obtained with a fixed sowing date, and an underestimation in 2008 (green circles). This improvement is due to the good accuracy in the period from 2000 to 2003, underlined in Figure 14 with a blue circle.

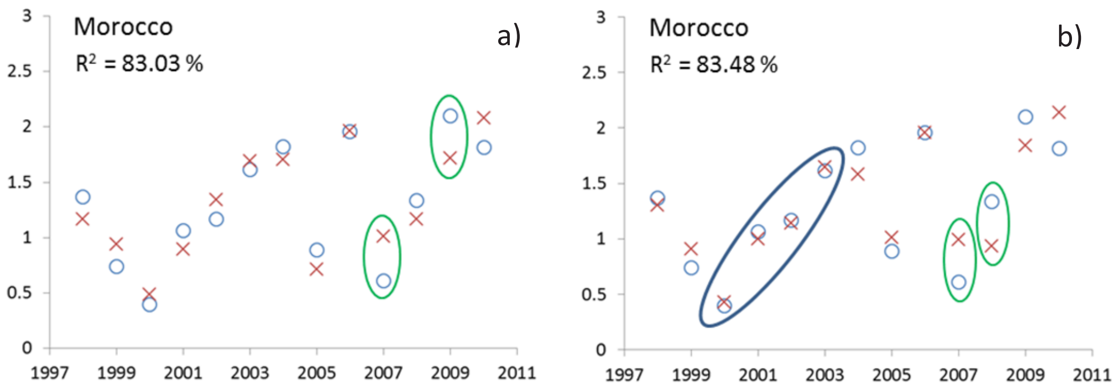

Figure 14 Comparison between official yields (blue circles) and estimated yields (red crosses) from 1998 to 2010 at national level using a) a fixed sowing date b) a planting rule based on air temperature

b) Figure 15 shows the comparison of the results obtained considering (i) both limited and potential indicators and (ii) only potential ones. Only three variables were here considered as potential indicators, i.e. aboveground biomass, leaf area index and development stage. The best regression model considers the three simulated indicators as independent variables and it is able to explain 42.52 % of the inter-annual variability in official yields, which is almost half of the percentage explained used both limited and potential indicators. It can be observed a worsening of forecast reliability between 2004 and 2007, underlined with a green box in Figure 15b, with marked overestimation and underestimation in 2005/2007 and 2004/2006, respectively.

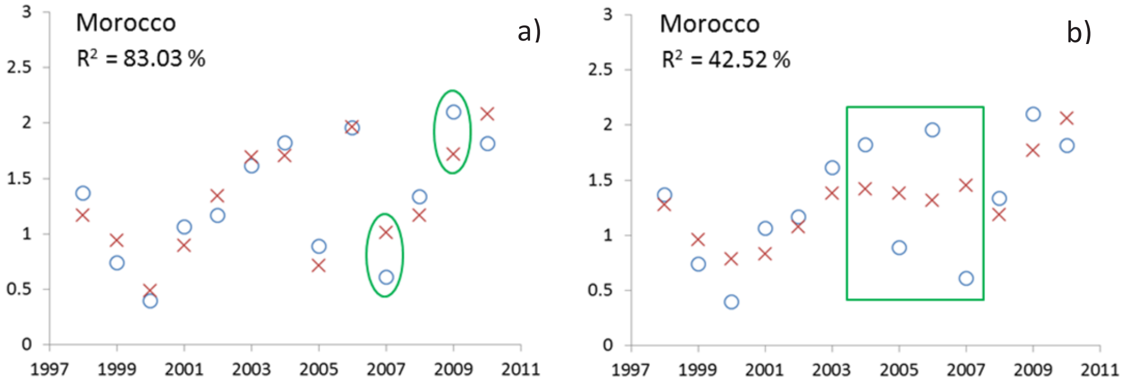

Figure 15 Comparison between official yields (blue circles) and estimated yields (red crosses) from 1998 to 2010 at national level considering a) both potential and water/diseases limited indicators; b) only potential indicators

4. Conclusions

BioMA demonstrated its suitability to perform monitoring and forecasting activities for durum and soft wheat in Morocco.

The high usability of the simulation environment, together with the integrated utilities for customizing the modelling solutions, for displaying and analyzing results, and for running the CST application, provide users with a powerful and extensible monitoring platform.

The evaluation of BioMA for multi-model approach to monitor wheat growth in Morocco is reported in E-AGRI deliverable D35.2.