CYCAS-MED project: analysis at regional and local scale of climate change impacts on cereals yield in Morocco[1]

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Abstract: The project CYCAS-MED: *Crop yield and climate change impacts on agriculture: adaptation strategies to desertification processes in the Mediterranean areas*, aimed at the development of tools and methodologies for the assessment of the response of three major crops in Morocco to climatic change. Results for durum wheat are here presented.

Keywords: climate change, cereals, crop growth models, land suitability, weather yield function

1. Introduction

The rising trend of global atmospheric carbon dioxide is expected to induce a change in climate. Despite the uncertainty regarding the magnitude of this climate change, assessments of its impacts on agricultural production are needed for both scientific and policy-making purposes. The complexity of climate-crop production interactions makes simulation a very useful and practical approach available for making the needed assessments (de Jong *et al*. 2003).
The CYCAS-MED project aimed at assessing the magnitude of the response of three major crops in Morocco (barley, soft wheat and durum wheat) to climate change. Weather daily data have been analyzed to outline the climate of Morocco. This analysis allowed the calibration of a stochastic weather generator that, in turn, has been used to provide future climate scenarios. At the regional scale, the relationship between weather and crop yield has been investigated by linear regression and, according to this relationship, the mean crop yield under different climate scenarios has been obtained. Moreover, the Land Suitability approach for rainfed wheat as been applied to analyse land use modifications. At the farm level, a further analysis has been carried out by applying the crop simulation model CERES-Wheat (Ritchie and Otter-Nacke, 1985).

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2. Materials and Methods

Data. Daily data on rainfall and temperature at 30 meteorological stations have been provided by the partner Insitut National de la Recherche Agronomique (Morocco) and refer to the period from 1973-2006. Annual crop yield data for 15 provinces come from The Ministry of Agriculture, Rural Development and Fisheries of Morocco.

Regional scale analysis: impact on annual production. The FAO methodology developed for Africa and based on the Crop Specific Soil Water Balance (CSSWB), and its implementation by the software AgroMetShell (AMS; Gommes 1993) have been used for operational crop yield forecasting. This model requires daily weather data only and is specific for regions lacking of more agronomical information. The output of AMS consists of several indexes: *water excess*, *water deficit* and *actual evapotranspiration* computed at several phenological phases, *water satisfaction index* (WSI) and *total water requirement*. The relationship between annual crop yield and these output variables (*weather yield function*) has been estimated by linear regression analysis. The stochastic weather generator M&Rfi (Dubrovský *et* al. 2004) has been calibrated on daily weather data and used to generate synthetic time series of current and future weather. Two different scenarios have been considered: SRES B1 (low impact) and SRES A2 (high impact; IPCC, 2000) and projections of climate at 2050 derived from the coupled atmosphere-ocean general circulation model HadCM3. The estimated regression equations have been used to compute the expected crop yield for each time series from current and future climate.

Regional scale analysis: impact on land use modification. Evaluating land suitability means defining the requirements of the different land-use types for each land units of a certain region. A land suitability classification for rainfed wheat growing in the province of Settat has been made. Land is classified as suitable, using 3 different classes of suitability, or not suitable.

Farm scale analysis. The crop simulation model CERES-Wheat (Ritchie and Otter-Nacke, 1985) included in DSSAT v. 4.0 (Jones *et al.*, 2003) has been used to predict grain yield of a local variety grown at six experimental farms for which all the pedological, climatic, genetic and agronomic information necessary for model calibration and evaluation are available.

3. Results

Climate analysis. An accurate analysis of the climate in Morocco is prevented by short and strongly discontinuous time series, especially for rainfall. Data from four stations only allow analyzing the inter-annual variability of temperatures. These data show a homogeneous increase of temperatures (Mann-Kendall test) and of the index Tn90, describing the number of warm nights (Frich *et al*. 2002). The other climatic indexes considered in this study do not show similar results (see Bodini *et al*. 2011).

Regional scale analysis: impact on annual production. The goodness-of-fit of the linear regression model was high ($R^2 > 0.85$), a part for a few cases. Regression analysis of annual crop yield on the AMS output variables highlights that WSI is always significant, as expected. However, a second significant variable is sometimes obtained, varying with place and cereal, whose meaning has to be further investigated. See Bodini *et al*. (2011) for detailed results.

The weather generator M&Rfi was able to well reproduce temperature data, however it strongly underestimated precipitation variability. However, as AMS allows a trade-off between amount of rainfall and length of the growing season, this underestimation do not seem to affect crop yield estimation. According to the weather yield functions estimated from the available data, mean future yield for each time series from the two scenarios have been computed and compared to those obtained from simulations representing the current climate. For durum wheat (Figure 2), crop yield will decrease everywhere, and in some places, like Marrakech (MAR) crop yield could halve. Similar results are obtained for the other cereals (see Bodini *et al*. 2011).

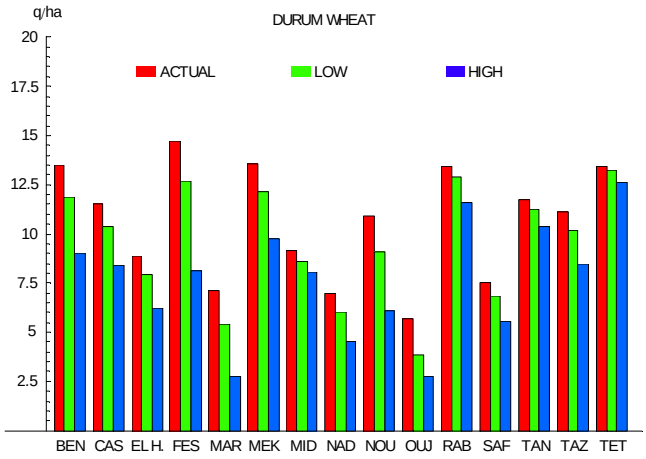

Figure 2 Mean expected annual crop yield for durum wheat at 2050, according to current climate (actual), scenario SRES B1 (low impact) and scenario SRES A2 (high impact). The plotted values are mean from 1000 simulations.

Regional scale analysis: impact on land use modification. Land Suitability analysis shows that the class of highest suitability (S1) for rainfed wheat became half at 2050 (high impact scenarios), and completely disappears at the 2100 projection, whereas S2 class reduces from 10% to 40%. In synthesis, a general reduction of major portions of territory suitability is evident, and the marginal suitability class (S3) increases in importance, doubling (2050 low and high, 2100 low) or tripling its incidence (high scenario 2100), as shown in Figure 3.

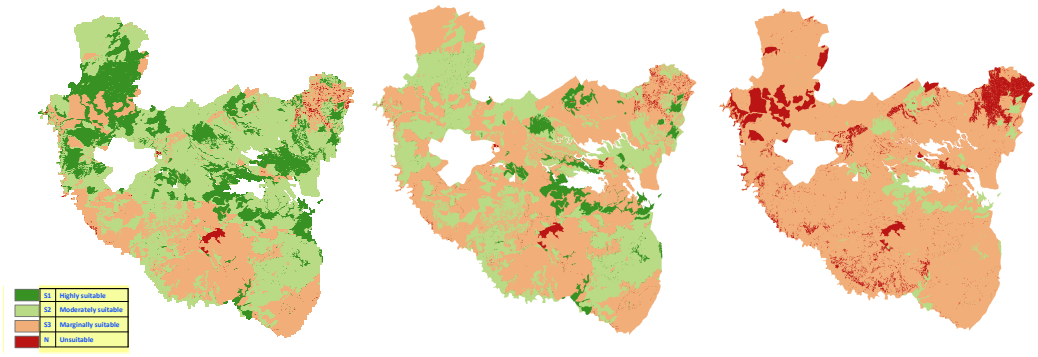

Figure 3 Map of Land Suitability for rainfed wheat in Settat province for actual climate (left), high impact scenario at 2050 (centre), and high impact scenario at 2100 (right).

Farm scale analysis. The application of the crop model at different locations shows a general tendency to a reduction of wheat yield moving from actual conditions to higher impact future scenarios. See Cesaraccio *et al*. (2011) for more details about this analysis.

4. Concluding remarks

The analysis of the impacts of future climate change scenarios highlights a significant reduction of the suitable areas for agriculture in Morocco and a significant reduction of rainfed cereals yield regardless of emission scenarios.
Adaptation strategies for responding to changes in climate regimes need to be investigated to adapt agricultural systems to the new conditions. From this perspective, tools and methods used in this project can be used to investigate other crops performances under changed conditions. Future work will concern the improvement of the WG and the investigation of other crop performances under climate change scenarios.

References

Bodini A., Cesaraccio C., Duce P., Entrade E., Zara P. (2011) Impatto dei cambiamen-ti climatici sulle produzioni agricole: strategie di adattamento ai processi di desertifi-cazione nelle aree mediterranee (CYCAS-MED). Report finale - Parte A, Technical Report IMATI-MI 11-1, Milano. Available on-line at the web site http://www.mi.imati.cnr.it/iami/abstracts/11-01.html

Cesaraccio C., Duce P., Zara P., Ferrara R., Pintus G., Bodini A., Dubrovský M. (2011) Impatto dei cambiamenti climatici sulle produzioni agricole: strategie di adattamento ai processi di desertificazione nelle aree mediterranee (CYCAS-MED), Report finale - Parte B. Technical Report IMATI-MI 11-2, Milano. Available on-line at the web site http://www.mi.imati.cnr.it/iami/abstracts/11-02.html

de Jong R, Li K.Y., Bootsma A., Huffman T., Roloff G., Gameda S. (2003) *Crop Yield and Variability under Climate Change and Adaptative Crop Management Scenarios*, Report, Climate Change Action Fund.

Dubrovský M., Buchtele .J, Zalud Z. (2004) High-Frequency and Low-Frequency Variability in Stochastic Daily W eather Generator and Its Effect on Agricultural and Hydrologic Modelling, *Climatic Change*, 63, 145-179.

Frich P., Alexander L.V., Della-Marta P., Gleason B., Haylock M., Klein Tank A., Peterson T. (2002) Global changes in climatic extremes during the 2nd half of the 20th century, *Climate Research*, 19, 193-212.

Gommes R. (1993) FAOINDEX, Version 2.1. Agrometeorology Group. FAO Rome.

IPCC (2000) *Emissions Scenarios. A Special Report of Working Group II of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge.

Jones J.W., Hoogenboom G., Porter C., Boote K., Batchelor W., Hunt L.A., Singh U., Gijsman A., Ritchie, J. (2003) The DSSAT cropping system model, *European Journal of Agronomy*, 18, 235-265.

Ritchie J.T., Otter-Nacke S. (1985) Description and performance of CERES-Wheat: use-oriented wheat yield model, in: *ARS wheat yield project*, ARS-38 National Technical Information Service, Springfield, VA, 159-175.