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Morocco's unique situation in the climate change arena

An analysis of climate forecasts and their link to agriculture

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Abstract: Alterations in rainfall patterns and increasing temperatures due to climate change will most likely translate into yield reductions in desirable crops. In this particular context, the object of this paper is to lay down findings and results for projected yield impacts in Morocco using a well-tested crop model, CliCrop, which estimates yield impacts based on water stress. Simulation results from the CliCrop model suggest declining yields, but not by much, and variability is projected to increase marginally. These results are in sharp contrast with the other yield forecasts, which show substantial yield declines for Morocco. It is important for future research to resolve these differences.

Keywords: Morocco, climate change, CliCrop, agriculture, uncertainty
JEL classification: O13, Q54

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1 Introduction

The trend of agricultural productivity growth in the last decades has been tremendous in many ways, which helped to alleviate poverty and food insecurity in many areas (although there are still substantial differences across regions). This was primarily due to improved production systems and investments in crop and livestock breeding programmes. Nonetheless, climate change threatens to exacerbate the existing challenges faced by agriculture. The global population is estimated to reach nine billion by 2050, with the bulk of the increase occurring mostly in Africa and South Asia. Also, taking into account the accelerated demand for food and changes in dietary habits, the Food and Agriculture Organization (FAO) estimated that feeding the world population will require a 70 per cent increase in total agricultural production (FAO 2010).[1] Yet, the problem gets compounded as we take into consideration the threat of climate change to the stability and productivity of the agricultural sector. Numerous studies (Cline 2007; Fisher et al. 2005; IPCC 2007) have shown that the spectre of climate change is looming even bigger for regions already experiencing low and erratic productivity levels (e.g. Africa and South Asia). For instance, it has been estimated that a warming of 2 ˚C could result in a 4 to 5 per cent permanent reduction in an annual income per capita in Africa and South Asia (World Bank 2010).

In its latest report, the Intergovernmental Panel on Climate Change (IPCC) stated that the African continent is poised to be among the most vulnerable regions to climate change and climate variability, a situation that is aggravated by existing developmental challenges such as endemic poverty, complex governance, and institutional dimensions, as well as limited access to capital, infrastructure, and technology (IPCC 2007).[2] Chief among the concerns for the African continent is the modernization of the agricultural systems (at the level of both commercial and subsistence agriculture) deemed for many countries in the continent as a levy for economic growth.[3]

In recent years, there has been a great improvement in the science of climate change through advances in our understanding of the biophysical processes of climate, which enhanced our modelling capacity providing us with more robust climate projections at the global level. Nonetheless, more analysis is needed on the economics of climate change. There are many factors that explain this slower development of economic impact analysis, but chief among them is the dependency of economic impact assessments upon reliable climate projections that could be fed into economic models to measure impacts at the socio-economic level, and evaluate policy mitigation and/or adaptation strategies. The early literature of economic impact assessment of climate change has provided some useful insights on the issue, but remains limited in scope and depth as it focused on a highly aggregated unit of analysis (e.g. at the continental or sub-continental levels).

Nonetheless, the current trend of the empirical literature on the issue of economic impact assessment of climate change displays a shift towards engaging in 'case-by-case' analyses at the country and/or sub-country level, especially given the fact that consensus is growing among

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[1] In terms of undernourished people in the world, the post-economic crisis levels remain very high in comparison with their levels 40 years ago, and even higher than the level that existed when the hunger-reduction target was agreed at the World Food Summit in 1996 (FAO 2010).

[2] Overall, this finding has been robust for all of the SRES scenarios included in the analysis, although minor differences in terms of projections exist among the different scenarios mainly driven by the different assumptions underlining each scenario.

[3] For example, the contribution of agricultural gross domestic product (GDP) varies from one country to the other, but is still significant where the average in the continent is 21 per cent (ranging from 10 to 70 per cent) (Mendelsohn et al. 2007b)

policy makers on the need to act upon the challenges of climate change, and more importantly due to increased availability of climate projections at finer geographical scales that helps refine the analyses, and improves our ability to capture the intricate linkages that exist between climate change and the economy.

Therefore, and in recognition of this gap in the literature of economic impact analysis of climate change, we use a computable general equilibrium (CGE) model to analyse the impacts of climate change at a refined geographical scale, focusing on Morocco as a case study. First, we develop a set of yield projections under different climate scenarios using CliCrop, a crop model that estimates per cent changes in crop yields based on changes in temperatures (ΔT) and precipitations (ΔP) at the basin level. Subsequently, these exogenous changes are introduced in the regionally modified CGE model, which is based on the International Food Policy Research Institute's (IFPRI) standard CGE templates (Lofgren et al. 2002). This will allow us to map out region-specific economic impacts of climate-driven yield alterations. Finally, we will investigate the potential effects of adaptation policies in the agricultural sector being implemented at the regional level in Morocco.

The focus of this paper is on the data that will go into the country model. As such, we make use of 22 general circulation models (GCMs) and three climate scenarios. Our hypothesis is that there would be a side variation in the projections among these GCMs and climate scenarios. In fact, our hypothesis is that it would be difficult to formulate robust policies in the face of this uncertainty. As will become clear below, this turned out to be not the case. In fact, the projected yields for all GCMs and scenarios are not much lower than the mean of the past 15 years for Morocco, and the projected variability is even lower than in the past 15 years. One interpretation is that Morocco is already experiencing climate change. But whether it is that or something else, the bottom line from this data analysis is that the future 50 years do not appear very different from the recent past.

The paper will be organized as follows: Section 2 will briefly discuss some of the literature of CGE analysis related to economic impact assessment of climate change. In Section 3, we will present our methodological approach for developing the range of yield forecasts and data sources. Section 4 will summarize key findings and results, and we will wrap up in Section 5 with concluding remarks.

2 Climate change impact assessment and CGE analysis

The recent literature using CGE models to analyse climate change impacts and adaptation linkages has taken two directions. The first one is based on country-based CGE models that focus on domestic impacts, which allows for a more detailed analysis in terms of mapping out the latter impacts to the domestic economy. The second is based upon a multi-region structure at the global level (e.g. GTAP model), and where the focus is directed at analysing inter-regional impacts mainly driven through international trade linkages.

Horridge et al. (2005) use a bottom-up CGE model for Australia to analyse the impact of the 2002-03 drought. The model was coined TERM (The Enormous Regional Model), which was developed to deal with highly disaggregated regional data, and with the objective of analysing regional impacts of region-specific shocks. It uses data at a regional-sectorial disaggregation based on national I-O tables, together with regional data on production (for agriculture) and employment (in other sectors) for 45 regions and 38 sectors. Their findings suggest substantial negative impacts on agricultural output and income, which decreased on average by 30 per cent and 20 per cent, respectively. The most striking finding is that despite the small share of agriculture in Australian GDP (3.6 per cent), drought reduces GDP by 1.6 per cent and worsens the balance of trade.

Diao et al. (2008), in an extension of an earlier CGE application of Diao et al. (2005), use a country-based CGE model to analyse the impacts of conjunctive groundwater (GW) and surface water (SW) management in Morocco. The objective of the study was to assess the direct and indirect effects of GW regulation on agriculture and non-agricultural sectors under different scenarios such as (i) increased GW extraction costs, (ii) rural-urban transfers of SW, and (iii) reduced availability of water supplies due to drought. For instance, they found that a reduction of one standard deviation in SW supplies caused real output to fall by 11 per cent. Additionally, agricultural exports (mainly of irrigated crops) with the European Union (EU) experienced a decline of 13.6 per cent.

Berrittella et al. (2007) use a multi-region world CGE model, GTAP-W,[4] to analyse the effects of restricted water supply as it pertains to international trade linkages for agricultural products. Water resources usage in commodity production is captured through water intensity coefficients,[5] which describe the amount of water necessary for a sector to produce one unit of output. They contrast a market solution to the scarcity problem, where water owners have the ability to capitalize on their water rent, to a non-market solution, where supply restrictions imply productivity losses. They conclude that improvement to allocative efficiency can be achieved through supply constraints imposed on the resource, especially in the context of heavily distorted agricultural markets. They argue that welfare gains from curbing inefficient production may outweigh the welfare losses due to resource constraints.

Berrittella et al. (2008) use the same model, GTAP-W, to analyse the impacts of trade liberalization on water use at the global level. They particularly focus their analysis on the Doha Development Agenda launched in 2001, which sets forth a set of trade liberalization scenarios in both developed and developing countries. They found that trade liberalization induces reduction in water usage for regions with scarce supply and increases it for water abundant regions.

Calzadilla et al. (2008) use a CGE model to analyse the impacts of improved irrigation management under water scarcity. They use an updated version of GTAP-W (Berrittella et al. 2007), where a new production structure is introduced, which separates rainfed and irrigated crop production. Their findings suggest that improved irrigation efficiency in water-stressed regions produces positive effects on welfare and demand for water, whereas results are more mixed (mostly negative) for non-water scarce regions.

Laborde (2011) analyses the impacts of climate-induced yield changes on agriculture in South Asia, and investigates the potential for trade policy options to mitigate the latter. A modified version of the MIRAGE CGE model was used, where yield estimates were first obtained via the IMPACT model for 13 climate change scenarios (SRES). The latter are introduced as exogenous shocks in the modified MIRAGE CGE model, where baseline results are contrasted with the results from eight different trade policy landscapes for the region.

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[4] GTAP-W is a refined version of the GTAP model that accounts for water resources, and which is based on the work by Burniaux and Truong (2002).

[5] Calculations based on water requirement in terms of blue water (surface and ground water) and green water (moisture stored in soil strata). The data is taken from Chapagain and Hoekstra (2004) for agricultural production and from the AQUASTAT database (FAO 2013) for the water distribution services (i.e. household and industrial consumption). A major limitation with respect to the water intensity coefficients data for agriculture is that it does not differentiate between rainfed and irrigated agriculture.

Kuik et al. (2011) use the newly developed MOSAICC model by the FAO (2011), in partnership with European research institutes. The model allows for country-based climate change impact analysis via its modular platform. The latter include a climate data module, which aims at statistical downscaling climate data to be used in subsequent modules. Crop and hydrological modules are used to simulate crop growth and river basins hydrology under different climate change scenarios, using data from the previous module. An economic module, which is a country-based dynamic CGE model,[6] was employed for the economic analysis of climate change impacts through yield variations. The authors tested the model using Morocco, where data projections were used for the period 2001-30.

None of these models or analysis captures the inherent uncertainty in climate forecasts and the implications of this uncertainty for future crop yields. That is where we are headed with this research.

3 Background on Moroccan agriculture and methodological approach

3.1 Moroccan agriculture and climate change

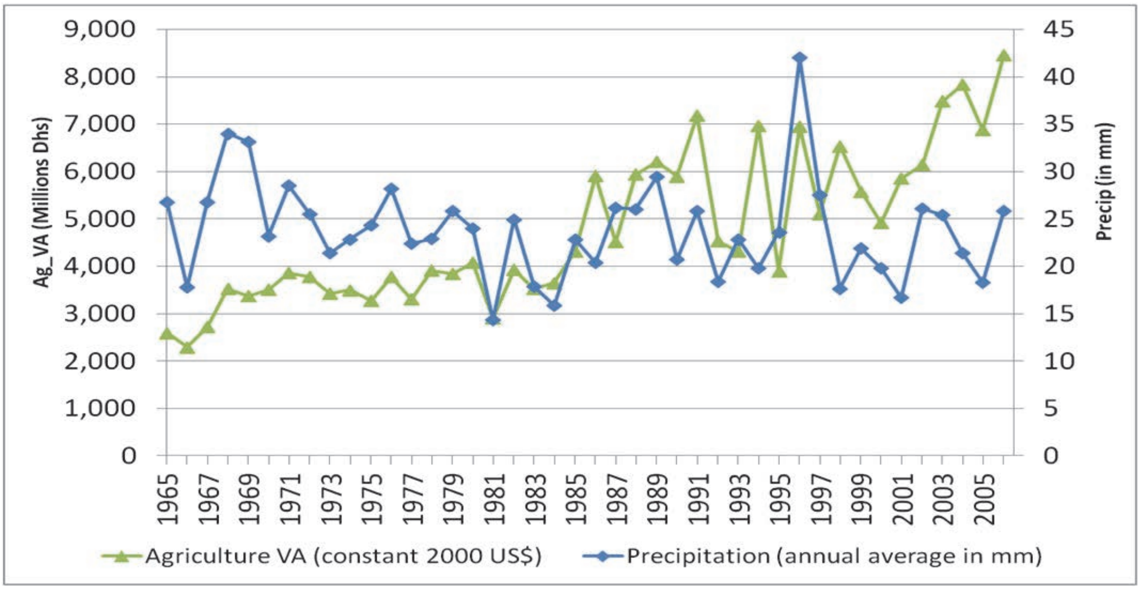
Morocco enjoys a very interesting geostrategic location with its 3,500 kilometers of coast line, spanning the Atlantic Ocean and the Mediterranean. Equally important is its diversity in terms of landscapes and ecosystems: the mountain chains of the North, and the Northeast to the Southwest, the plateaus of the East, the plains in the West and the Centre, and the desert in the South. In terms of climatology, the country enjoys a typical temperate Mediterranean climate, but with dry conditions in much of the country.[7] The country suffers from a cruel paradox in the form of advantageous precipitation patterns in the northern regions, but with very poor soil quality, vice-versa in the southern regions (Akesbi 2006).

The agricultural sector in Morocco is still highly dependable on climatic conditions as depicted by the high correlation observed between precipitations levels and agricultural value-added (Figure 1).

[6] The Dynamic CGE model was developed in partnership with the Free University of Amsterdam, and is inspired by the IFPRI DCGE model (Lofgren et al. 2002; Thurlow 2004).

[7] Half of the country's area is desert, whereas the rest is split among: cultivable agricultural area (9 million hectare), forests (6 million hectare), grassland (3 million hectare), and rangeland (21 million hectare).

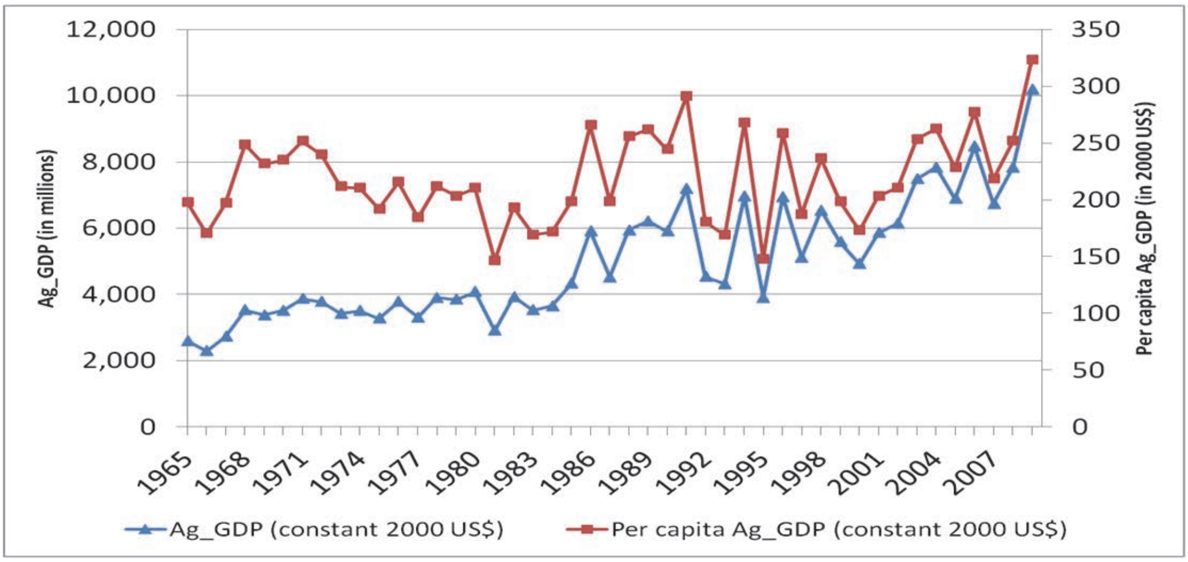
Figure 1: Evolution of agricultural value-added and precipitations in Morocco (1965-2006)



Source: Authors' adaptation based on World Bank (2010).

This is due in part to the general structure of production activities in the sector, which is highly skewed toward crop varieties with very low value-added; e.g., cereals, which are highly sensitive to climatic conditions and represent 55 per cent of total value-added of crop production and occupy 65 per cent of the agricultural area. Export crops, mainly citrus and vegetables, represent 15 per cent of value-added and respectively occupy 0.85 and 3 per cent of the total agricultural area (Akesbi et al. 2008). Although in terms of vegetative cover of agricultural land, citrus and vegetables occupy a very small share, their share in agricultural-added is substantially higher given the fact that those niches are usually more labour-, chemical-, and water-intensive compared with cereals. Post-independence agricultural reforms help to explain the present situation. Investigating the long-term trend in the sector's performance, we can identify three phases representing distinct growth patterns (Figure 2).

Figure 2: Evolution of agricultural GDP and per capita agricultural GDP in Morocco (1965-2009)



Source: Authors' adaptation based on World Bank (2010).

Phase I (1965-1985) is characterized by rather a weak performance of agricultural production, and even a slight decline of the per capita levels. The performance recorded during this period was contingent upon the performance of policies targeting the agricultural sector adopted in the early post-independence years. The first set of policies was oriented towards a reform of the status of property rights of land ownership through the nationalization of official and private colonial lands, and their redistribution by the state (Akesbi 2008). Moreover, and in parallel to the land reform efforts, a charter of agricultural investments was adopted in 1969,[8] with the objective of mobilizing the hydrologic potential of the country and providing incentives for the development of irrigated perimetres. This effort has been accompanied by a set of incentives to farmers to encourage investments in new technologies (e.g. machinery, fertilizers, seeds, etc.). Nonetheless, the state has intervened heavily and selectively to regulate markets and control prices for so-called 'strategic' commodities, which translated technically into controlling the flow of imports and exports.[9] Hence, the combined effect of these policies has led to an implicit taxation of the sector, especially when accompanied with the overvalued exchange rate at the time (Doukkali 2006).

Phase II (1985-91), displays a substantial increase in value of agricultural production, on average by 9.4 per cent/year, whereas the per capita levels increased by 6.7 per cent/year. The boost in agricultural productivity during this period came as result of favourable climatic conditions, but also due to the combined effect of the King's plan in 1985 to double the area cultivated in wheat, and the sustained liberalization effort in the agricultural sector and the exoneration of agricultural revenues from income tax. The result was an expansion of agricultural area and a reduction of small-scale farms, which came about due to increased investment and consolidation in the sector.[10]

Phase III (1991-2009) displayed a slowdown of growth in agricultural output at the aggregate and per capita levels. For instance, agricultural per capita output decreased by 14.39 per cent for the period 1991-2002. Nonetheless, the trend was reversed from 2002 onward when there was a significant improvement. In terms of the policy, this period is characterized by continued effort of liberalization in the agricultural sector. Overall, the level of production compared to pre-1991 levels was clearly higher. Nonetheless, agricultural growth still witnessed important fluctuations driven by the successive drought episodes that characterized the period, and which were particularly severe for crop production.

In conclusion, it appears that the agricultural sector in Morocco has been, and is still at the core of the state's economic strategy, given its strategic importance with respect to issues pertaining to employment, food security, poverty alleviation, etc. Despite the progress that has been achieved, there remain important challenges in taking advantage of the potential of the agricultural sector. The value-added problem is particularly acute with respect to the valuation of water usage in the sector.

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[8] The charter of agricultural investments, of its French name 'Code d'Investissements Agricoles (CIA)', was a set of laws passed in 1969 to primarily manage the public irrigation schemes at the time. It is presented as a contract between farmers and the state, defining rights and duties in public large-scale irrigation schemes. Historically, this policy has been coined as 'Politique des Barrages', which consisted of huge investments by the state in public irrigation infrastructure (i.e. building of grand dams) with the objective of reaching the milestone of one million hectare of irrigated agricultural land by 2000 (Doukkali 2006).

[9] Basically, in the post-independence era, the economic strategy adopted by Morocco was ambitious since it involved the combination of an 'import-substitution' led growth strategy coupled with promotion of exports, and in which the agricultural sector was the main engine (Akesbi 2006).

[10] This was depicted in the results of the General Agricultural Census in 1996, and which demonstrated an increase in the arable agricultural area by 21 per cent, whereas the number of small farms without land and with less than a hectare of land decreased by 85.6 per cent and 28.3 per cent, respectively (Doukkali 2006).

3.2 Analysis of yield projections results for Morocco

In this section, we will first describe the GCMs and SRES retained for the analysis. Second, we present a succinct description of the crop model used, CliCrop.

General circulation models and climate change scenarios

General circulation models characterize physical processes in the atmosphere, ocean, cryosphere, and land surface, and are the most advanced tools currently available for simulating the response of the global climate system to increasing greenhouse gas concentrations. While simpler models have also been used to provide globally- or regionally-averaged estimates of the climate response, only GCMs, possibly in conjunction with nested regional models, have the potential to provide geographically and physically consistent estimates of regional climate change, which are required in impact analysis. GCMs depict the climate using a three dimensional grid over the globe, typically having a horizontal resolution of between 250 and 600 km (IPCC 2007).

In most impact studies, the data from the GCMs is usually downscaled via statistical procedures to match finer resolutions pertaining to regional and/or country units of analysis. The Intergovernmental Panel on Climate Change (IPCC) on its latest report used 22 GCMs. The objective is to capture the wide range of uncertainties that is usually inherent in projecting climate fluctuations.

The IPCC has developed a new set of scenarios (or storylines) that describe the developments in many different social, economic, technological, environmental, and policy dimensions pertaining to future GHG emissions and their global impact of the climate. This work was initiated in 1997 in order to update the initial set of scenarios released in 1992, which were subjected to growing criticism amongst the scientific community (IPCC 2000). The newly developed set of scenarios under the SRES approach included four alternative scenario 'families' denoted by: A1, A2, B1, and B2. In a nutshell, these scenarios could be summarized as follows:

The A1 storyline and scenario family describes a future world of very rapid economic growth, low population growth, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building, and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system: fossil intensive (A1F1), non-fossil energy sources (A1T), or a balance across all energy sources (A1B).

The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which result in high population growth. Economic development is primarily regionally-oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.

The B1 storyline and scenario family describes a convergent world with the same low population growth as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.

The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with moderate population growth, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

For the present study, we retained three SRES climate scenarios, namely A1B, A2, and B1, and 22 GCMs. Table 1 summarizes the selected SRES scenarios and the GCM coverage.

Table 1: List of GCMs and climate scenarios (SRES) covered in CliCrop

GCM name	SRES Climate scenarios		
	A2	A1b	B1
bccr_bcm2_0	x	x	x
cccma_cgcm3_1	x	x	x
cccma_cgcm3_1_t63	x	x	x
cnrm_cm3	x	n.a.	x
csiro_mk3_0	x	x	x
csiro_mk3_5	x	x	x
gfdl_cm2_0	x	x	n.a.
gfdl_cm2_1	x	x	x
giss_aom	x	n.a.	x
giss_model_e_h	x	n.a.	n.a.
giss_model_e_r	x	x	x
iap_fgoals1_0_g	x	n.a.	x
inmcm3_0	x	x	x
ipsl_cm4	x	x	x
miroc3_2_hires	x	n.a.	x
miroc3_2_medres	x	x	x
mpi_echam5	x	x	x
mri_cgcm2_3_2a	x	x	x
ncar_ccsm3_0	x	x	x
ncar_pcm1	x	x	n.a.
ukmo_hadcm3	x	x	n.a.
ukmo_hadgem1	x	x	n.a.

Source: Authors' adaptation based on Fant (2009).

The CliCrop yield model

The development of CliCrop has as a main objective the maintenance of minimal input requirements as in CROPWAT, but with improved accuracy in yield estimation for both rainfed and irrigated agriculture. Four models were studied in details and used in the development of CliCrop: CROPWAT, SWAT, DSSAT, and LEAP. A major consideration leading to the development of CliCrop was the need for a modelling framework that provides robust yield estimates in the context of developing countries, where data limitations on model inputs are pervasive. Yield estimates, as produced by CliCrop, are based on the effect of changing daily precipitation patterns and temperatures, in contrast with available modelling methodologies that use monthly averages. The main inputs used by CliCrop are observed weather conditions (temperature and precipitation), soil parameters (field capacity, wilting point, saturated hydraulic conductivity, and saturation capacity), and crop specific parameters describing crops' growth behaviour (Fant 2009).

The historical daily climate data used was based on the database developed by Sheffield et al. (2006) for a 50-year period. The latter database is currently available at 1.0 degree, three-hourly resolution globally for the period 1948-2008. For the purpose of the analysis, and as mentioned previously, the climate variables captured in the dataset were aggregated to daily observations in order to enter CliCrop as inputs. Subsequently, the 1.0 degree results were aggregated to the regional units adopted in the analysis, and which refer to the regional disaggregation adopted for Morocco (Table 3). The objective of developing the database was to better capture the seasonal and inter-annual variability of climate variables that usually drives outcomes in terms of yield estimations in agronomic models.

Since CliCrop was based on its development on existing crop models, and specifically FAO's crop model CROPWAT, it borrows the same well-established and documented methodologies used in terms of calibrated parameters that enter the model as inputs. For instance, potential evapotranspiration (PET) is estimated based on mean daily temperature, daily temperature range, and latitude by using the modified Hargreaves equation (Hargreaves and Allen 2003). In what pertains to the crop parameters, CliCrop uses the same methodology used in CROPWAT, and which follows Allen et al. (1998) in terms of single and basal crop coefficients (Kc and Kcb), crop stage durations, yield coefficients, and other plant characteristics (e.g. root growth per day, initial root depth, etc.).

Compared to CROPWAT, which assumes no vertical differences in soil moisture, CliCrop introduces a dynamic soil profile module that captures the impacts of waterlogging on the dynamics of soil moisture. Therefore, data on soil profiles is required in order to calibrate the model correctly. To that purpose, CliCrop uses parameters (e.g. hydraulic conductivity, wilting point, field capacity, and saturation) estimated based on FAO's Soil Map of the World database, which contains clay and sand content, and the methods of the National Center for Atmospheric Research (NCAR) (Oleson et al. 2004).

Discussion of initial findings and results: case of durum wheat and barley

As previously mentioned, CliCrop produces yearly yield estimates covering 22 GCMs and three SRES scenarios (A1b, A2, and B1) for the period of 2011-50. Therefore, for each crop and each region included in the analysis, CliCrop produces a total of 3x22x40=2640 observations or yield estimates. The results can be treated subsequently as statistical distributions that can be analysed. The main objective as mentioned earlier is to capture the underlying uncertainty that revolves around the impacts of climate change on yield. The main (or null) hypothesis (H0) investigated is that the inherent uncertainty in the yield forecasts will overwhelm any adaptation policy to be tested in the subsequent modelling. Therefore, we set first to analyse the projected yields in order to derive statistical indicators to inform and characterize the inherent uncertainty in the forecasts.

In order to analyse the data, we have performed statistical tests in order to classify the GCMs' results for each crop based on case scenarios as follows: worst case (10th percentile), medium case (50th percentile or median), and best case (90th percentile). The results were obtained based on the statistical analysis of the distribution of five-year average (2046-50) across all GCMs and all SRES scenarios. Tables 2 and 3 summarize the results obtained for durum wheat and barley. The objective of the first step was to identify which of the 22 GCMs across all SRES climate scenarios for each crop correspond to the percentiles retained in the analysis. As we can notice from the results, the GCMs representing the 90th, 50th, and 10th percentiles differ for each crop under the different scenarios.

Table 2: Results of GCMs distribution by percentiles for durum wheat across SRES scenarios

Durum wheat				
SRES	GCM	Yield	Per cent	
B1	csiro_mk3_0	-5.47%	90.90%	p90
A2	miroc3_2_medres	-5.55%	89.00%	
A1b	cccma_cgcm3_1	-7.87%	50.90%	p50
A1b	miroc3_2_medres	-7.87%	49.00%	
A2	gfdl_cm2_1	-9.86%	10.90%	p10
A1b	inmcm3_0	-9.98%	9.00%	

Source: Authors' adaptation based on Fant (2009).

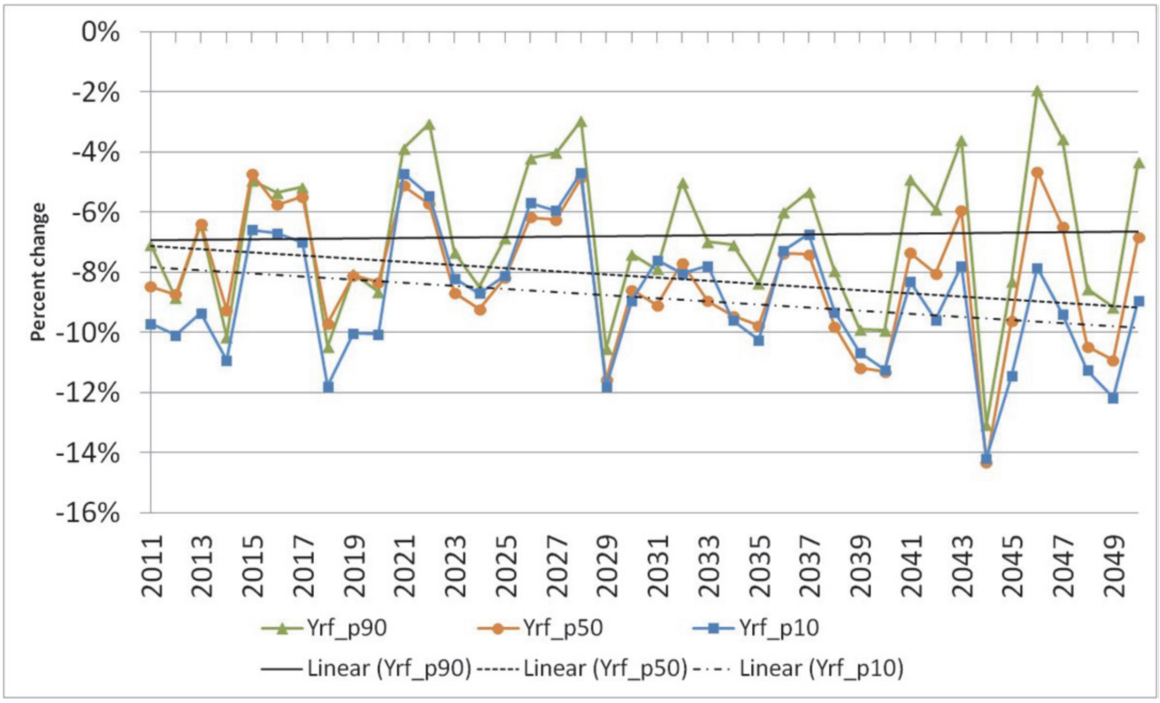
Table 3: Results of GCMs distribution by percentiles for barley across SRES scenarios

Barley				
SRES	GCM	Yield	Per cent	
B1	giss_aom	3.97%	90.90%	p90
A2	ncar_pcm1	3.83%	89.00%	
A2	cccma_cgcm3_1	0.54%	50.90%	p50
A1b	bccr_bcm2_0	0.50%	49.00%	
B1	cnrm_cm3	-4.72%	10.90%	p10
A1b	cnrm_cm3	-4.84%	9.00%	

Source: Authors' adaptation based on Fant (2009).

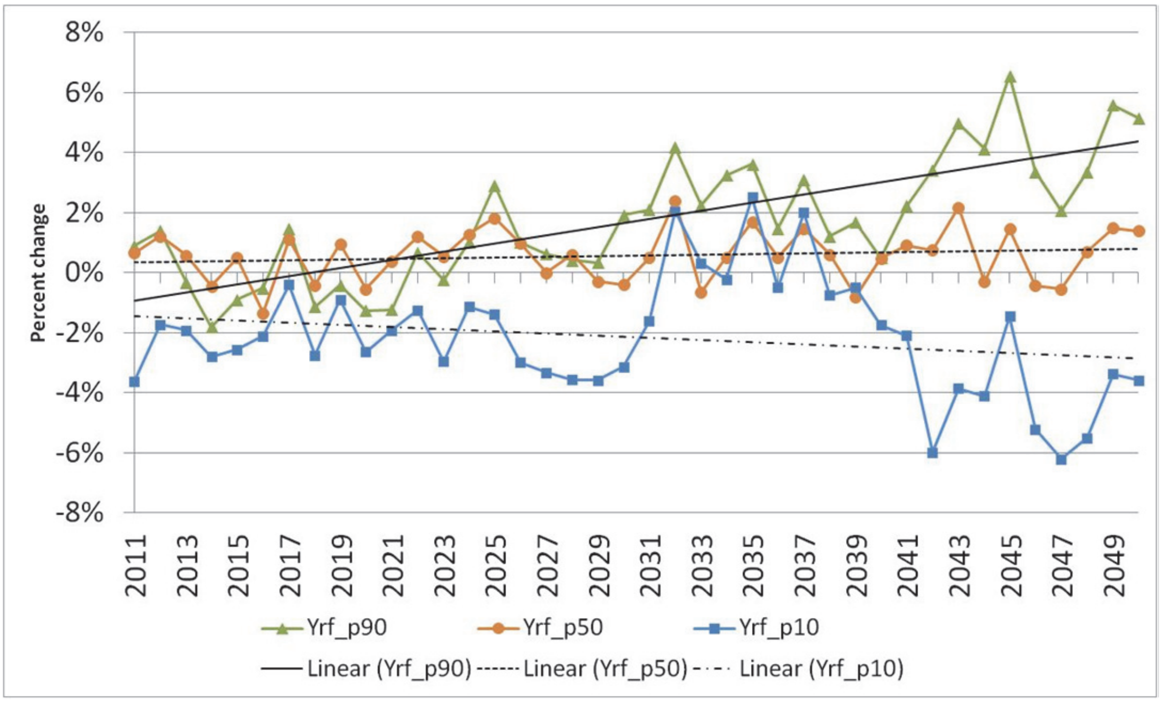
In the second step, we shift our focus to analyse the distribution of projected yields over time of the selected GCMs across all climate scenarios. Figures 3 and 4 summarize the results for durum wheat and barley, respectively.

Figure 3: Projected yield impacts (in %) for durum wheat by percentiles (2011-50)



Source: Authors' adaptation based on Fant (2009).

Figure 4: Projected yield impacts (in %) for barley by percentiles (2011-50)



Source: Authors' adaptation based on Fant (2009).

Overall, we notice that for wheat, and across all climate scenarios, the trend tends to be downward for the worst case (10th percentile) and medium scenarios, which means that yields are projected to continue decreasing through 2050; whereas for the best case scenario (90th percentile) scenario, the results show an unchanged progression in the predicted yield changes.

For barley, we notice that the projected yield changes represented by the 90th percentile-GCM are positive, and depict an increasing trend over time; whereas the situation is reversed for the 10th percentile-GCM since yields are projected to fall over time.

4 Contrasting CliCrop results in the light of historical trends with results from previous studies

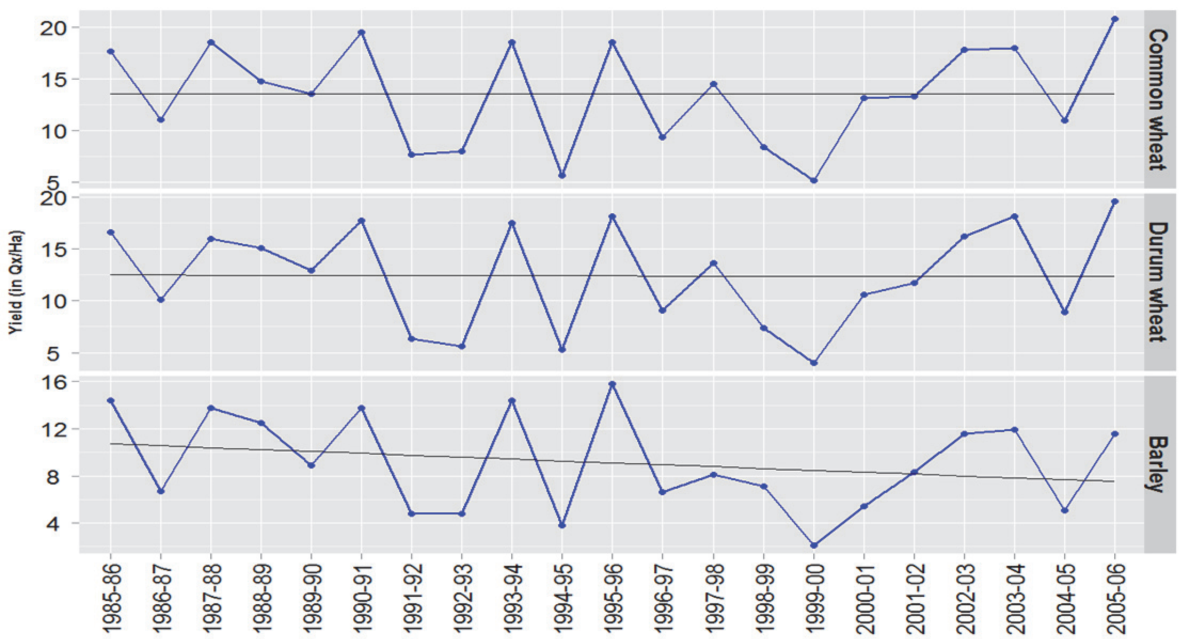
The first objective of this section is to contrast historical records on observed yields, spanning the last two decades (1985-2006), which we consider as our baseline, with the projected yields obtained from CliCrop.

The second objective is to contrast our results, obtained via CliCrop, with the projected impacts obtained by previous studies, and more specifically the study done by the World Bank (WB) and the Moroccan Ministry of Agriculture, Rural Development, and Fisheries (MPAM), in collaboration with the National Institute for Agricultural Research (INRA), the FAO, and the National Meteorology Authority (DMN) (Gommes et al. 2009). From this point forward, we will refer to the previous study as the WB/Morocco/FAO study for ease of reference.

4.1 Projected versus historical trends in yield impacts

Figure 5 presents the historical record of yields for common and durum wheat, and barley. For both wheat varieties, there is no evidence of any trend. But for barley, the historical record suggests falling yields. Although for common and durum wheat, the situation improved compared to the post-independence performance in the early-1960s until mid-1980s, the latter came about partly due to an expansionist public policy that encouraged conversion of favourable agricultural land into wheat cultivation, while at the same time driving out barley production to be reallocated into marginal agricultural lands. Nonetheless, a common feature that we observe for all three crops is the high level of volatility in the yields, which is primarily explained by the high correlation between rainfall and agricultural productivity for the latter crops.

Figure 5: Evolution of common wheat, durum wheat, and barley yields for the period 1960-2006 in Morocco



Source: Authors' adaptation based on FAO (2010).

Table 4 summarizes key statistical indicators for the three crops under consideration, and which will serve as our baseline. Table 5 provides summary statistics for the projected yields impacts (in per cent change) on durum wheat and barley for the period 2011-50 as simulated by CliCrop, and classified by the percentiles of the distribution over time. In Table 6, we apply the percentage change in projected yields to the historical base mean yields as a proxy for what yields might be expected from the climate forecasts. The result is that the yields are somewhat lower (less than ten per cent lower). The variability as measured by the coefficient of variation is somewhat higher for wheat, and generally about the same for barley. There is little difference among the different climate forecasts or scenarios.

Table 4: Summary statistics for historical time series on observed yields (1985-2006)

Indicator	Common wheat	Durum wheat	Barley
Mean	13.57	12.40	9.19
Median	13.45	12.45	8.60
Mode	18.60	18.20	14.40
Stand. deviation	4.76	4.83	4.03
Minimum	5.20	4.00	2.10
Maximum	20.80	19.60	15.80
Coefficient of variation	0.35	0.39	0.44

Source: Authors' adaptation based on FAO (2010).

Table 5: Summary statistics of projected yields impacts for durum wheat and barley by percentile

Indicator	Durum wheat			Barley		
	p90	p50	p10	P90	p50	p10
Mean	-6.8%	-8.1%	-8.8%	1.7%	0.6%	-2.2%
Median	-7.0%	-8.2%	-8.9%	1.5%	0.6%	-2.1%
Mode	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
Standard deviation	2.5%	2.2%	2.2%	2.0%	0.9%	2.0%
Minimum	-13.1%	-14.3%	-14.2%	-1.8%	-1.4%	-6.2%
Maximum	-1.9%	-4.6%	-4.7%	6.6%	2.4%	2.5%
Coefficient of variation	-0.37	-0.27	-0.25	1.19	1.54	-0.92

Source: Authors' adaptation based on Fant (2009).

Table 6: Summary statistics of projected yields impacts for durum wheat and barley by percentile

Indicator	Durum wheat			Barley		
	p90	p50	p10	p90	p50	p10
Mean	11.56	11.39	11.30	9.35	9.24	8.99
Median	11.57	11.42	11.34	8.73	8.65	8.42
Mode	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Standard deviation	4.95	4.94	4.94	4.11	4.06	4.11
Minimum	3.48	3.43	3.43	2.06	2.07	1.97
Maximum	19.22	18.69	18.68	16.84	16.18	16.20
Coefficient of variation	0.43	0.43	0.44	0.44	0.44	0.46

Source: Authors' calculations.

4.2 CliCrop results versus projected yield impacts in previous studies

In this section, we will contrast the results in terms of projected yield impacts obtained via CliCrop with the results from the WB/Morocco/FAO study.

The WB/Morocco/FAO study was done by considering 2 SRES scenarios, A2 and B2, and for which yield estimates have been produced as per cent change deviations by the horizon 2050. The framework adopted was based on FAO's Agro-Ecological Zones (AEZ), and for which the scenarios' data in terms of climate variables has been dowscaled from the global grid-boxes of 250 km x 250 km to a finer scale (10 km x 10 km) that is compatible with the agro-ecological zones established by the MAPM. Table 7 contrasts the results from CliCrop and the World Bank study using the average of the two scenarios at the national level.

Comparing the results from CliCrop and the WB/Morocco/FAO study, one observes large differences:

- For durum wheat, the WB/Morocco/FAO study shows a range of -16 to -31 per cent, whereas our CliCrop results indicate a range of -7 to -9 per cent. The respective 50 per cent values are -22 and -8 per cent, respectively. Thus, the WB/Morocco/FAO forecasts are for substantially larger yield reductions than the CliCrop forecasts.
- For barley, the differences are even greater. ClipCrop yield changes range from +2 to -7 per cent, whereas WB/Morocco/FAO forecasts range from -7 to -22 per cent. The respective 50 per cent values are +0.6 and -14 per cent.
- Variability is not provided by the WB/Morocco/FAO study, but the CliCrop variability results show barley resting about the same as the past 15 years, and wheat increasing somewhat compared to that period.

Table 7: Comparative results from CliCrop and the WB/Morocco/FAO study for projected yield impacts for durum wheat and barley

	Durum wheat			Barley		
	p90	p50	p10	p90	p50	p10
CliCrop	-6.8%	-8.1%	-8.8%	1.7%	0.6%	-2.2%
WB/Morocco/FAO	-16.2%	-22.2%	-31.1%	-7.4%	-14.3%	-22.4%

Source: Authors' adaptation based on Fant (2009) and Gommes et al. (2009).

5 Conclusion

The major conclusion from this data analysis is that there is still huge uncertainty in yield forecasts for Morocco. The WB/Morocco/FAO study uses yield shocks substantially larger than those estimated via the CliCrop model. The analyses of the results from the CliCrop simulations indicate that the yield shocks are relatively small and do not display substantial variabillity across SRES scenarios and GCM models. At the individual crop level, there is some increased variability for wheat, but little for barley.

To go to the next step, we will need to do sensitivity analysis on prospective yield shocks. There is no way at this point to know which forecasts are better, so all we can do is sensitively analyse the shocks. That is what we will do in the next step when we move to the actual modelling.

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