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Climatic constraints play a predominant role in the performance of national agricultures and their capacity to support economic growth and assure food security for the population. With the climate changes and projected inter and intra annual fluctuations, management of the agricultural sector takes a particular dimension including management of risks inherent in the sector and searching for sustainable growth for the sector. Agricultural policies must permit a continual adaption of the processes of agricultural production and a reduction of negative effects of climate change in order to assure food security for the population.

In the face of climate change, the adaptation strategies can generate important development opportunities. Also, governments have need for pertinent evaluations of the impacts of climate change.

Considering the importance of this problem; to permit an exchange of ideas among professional staff, researchers, and specialists in the domain of development; to contribute to a richer understanding of methods and analytical tools ; and to contribute to better preparation of decision making in this domain – the Moroccan Association of Agricultural Economics (AMAEco) in collaboration with the International Association of Agricultural Economics (IAAE) and the World Institute For Development Economics Research of the United Nations University (UNU-WIDER) are organizing an international conference 6-7 December in Rabat, Morocco under the theme:

« Impacts of climate change on agriculture »

Rabat, Morocco December 6-7, 2011

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3. **Adaption strategies for agriculture in the face of climate change: systems of production, risks in agriculture, and policies for food security**
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A CGE Analysis of Economy-wide Impacts of Climate Change on Agriculture in Morocco

Ismail Ouraich and Wallace E. Tyner[1]

Abstract:

Climate change is one of the major risks facing developing countries in Africa for which agriculture is a predominant part in the economy. Alterations in rainfall patterns and increasing temperatures will most likely translate into yield reductions in desirable crops (Gommes et al. 2009). The early literature of economic impact assessment of climate change has provided some useful insights on the issue, but remained limited in scope and depth as it focused on 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 display 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 policymakers 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. This calls for adequate policy responses at the country and regional levels. The present research will focus its attention on Morocco. In this context, the objectives of the analysis is to quantify the economic-wide impacts of climate-driven yield alterations under 3 SRES scenarios (A1b, A2 and B1) using a modified version of IFPRI's CGE model, which was upgraded to account for the sub-regional disaggregation adopted in the analysis (Dudu and Cakmak, 2011). This part of the analysis will focus on country-specific economy-wide impacts driven by productivity shocks on yields for each region. Yield estimates are produced via CliCrop, which simulates yield changes by water basin based.

Key words: CGE models, agricultural policy, adaptation, climate change, SRES scenarios.

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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 differentials across regions). This was primarily due to improved production systems and investments in crop and livestock breeding programs. Nonetheless, climate change threatens to exacerbate the existing challenges faced by agriculture. The global population is estimated to reach 9 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 FAO estimated that feeding world population will require a 70 percent increase in total agricultural production (FAO, 2010)[2]. 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., 2002; IPCC, 2007) have shown that the specter 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 percent permanent reduction in annual income per capita in Africa and South Asia[3].

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, and limited access to capital, infrastructure and technology (IPCC, 2007)[4]. 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[5]. Reforming the agricultural sector in Africa is a necessity to tackle problems pertaining to food security[6], water scarcity, access and management, health and malnutrition, etc. Indeed, many countries in the continent already experience challenging climatic conditions that impact negatively the prospects for agriculture. For example, it has been projected in some countries that yield reductions could reach as high as 50% by 2020, with small-scale farmers being the most affected (IPCC, 2007)[7]. In terms of socio-economic impacts in the continent, acute yield reductions as mentioned above could have severe consequences in terms of economic growth and poverty alleviation, given the fact that many African countries rely substantially (to varying degrees) on the agricultural sector as a source of national income through exports of cash crops and also as a major provider for job opportunities, especially in rural areas.

[2] 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).

[3] The World Bank, *'World Development Report (WDR)'*, 2010.

[4] 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.

[5] For example, the contribution of agricultural GDP varies from one country to the other, but is still significant where the average in the continent is 21% (ranging from 10 to 70%) (Mendelson et al., 2000b)

[6] In 2006, food prices escalated into a surge of food price inflation around the world, with Africa being particularly hard hit which experienced food riots. In the wake of the Financial Crisis of 2007-08, the FAO food price index rose by 27% in 2007, and this increase persisted and even accelerated during the first half of 2008 (FAO, 2009).

[7] It should be noted that these projections are quite differentiated from one country to the other, driven by the difference climatic scenarios and their underlining assumptions, as well as by the economic structures characterizing each country in the African continent.

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 modeling 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 remained limited in scope and depth as it focused on 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 display 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 policymakers 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 climate change economic impact analysis, we use a computable general equilibrium model to analyze the impacts of climate change at a refined geographical scale, and 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 percent changes in crop yields based on changes in temperatures (? T) and precipitations (?P) at the basin level. Subsequently, these exogenous changes are introduced in the regionally modified computable general equilibrium model, which is based off IFPRI's CGE templates (Logfren 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 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 bpresent our methodological approach 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 computable general equilibrium models to analyze 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 analyzing inter-regional impacts mainly driven through international trade linkages.

Horridge et al. (2005) use a bottom-up CGE model for Australia to analyze the impact of the 2002-2003 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 analyzing 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% and 20% respectively. The most striking finding is that despite the small share of agriculture in Australian GDP (3.6%), drought reduces GDP by 1.6% and worsens the balance of trade.

Diao et al. (2008), in an extension of an earlier CGE application of Diao et al. (2005), used a country-based CGE model to analyze 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 GW regulation on agriculture and nonagricultural 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%. Additionally, agricultural exports (mainly of irrigated crops) with the European Union (EU) experienced a decline of 13.6%.

Berrittella et al. (2007) used a multi-region world CGE model, GTAP-W[8]; to analyze 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[9], which describe the amount of water necessary for sector j to produce one unit of output. They contrasted 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) used the same model, GTAP-W, to analyze the impacts of trade liberalization on water use at the global level. They particularly focused their analysis on the Doha Development Agenda launched in 2001, and 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) used a CGE model to analyze the impacts of improved irrigation management under water scarcity. They used 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) analyzes 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 SRES scenarios. The latter are introduced as exogenous shocks in the modified

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

[9] Calculated 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 AQUASTAT database 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 differentiates between rainfed and irrigated agriculture.

MIRAGE CGE model, where baseline results are contrasted with the results from 8 different trade policy landscapes for the region.

Kuik et al. (2011) used the newly developed MOSAICC model[10] by the Food and Agriculture Organization (FAO), 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 of 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[11], 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 2001-2030.

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 seashores, spanning the Atlantic Ocean and the Mediterranean. And 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[12]. The country suffers from a cruel paradox in the form of advantageous precipitation patterns in the northern regions, but with very poor soil quality, and 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, Appendices). 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% of total value-added of crop production and occupy 65% of agricultural area. Export crops, mainly citrus and vegetables, represent 15% of value added and respectively occupy 0.85 and 3% of total agricultural area[13]. Although in terms of vegetative cover of agricultural land, citrus and vegetables occupy a very small share, yet their share in agricultural-added is substantially high given the fact that those niches are usually more labor, chemical, and water intensive compared with cereals. Post-independence agricultural reforms that Morocco has engaged in helps explain the present situation, where upon investigating the long term trend in the sector's performance; we can identify three phases representing distinct growth patterns (Figure 2, Appendices): Phase I (1965-1970s until 1985) 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

[10] MOSAICC - Modelling System for Agricultural Impacts of Climate Change (http://www.fao.org/climatechange/mosaicc/en/)

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

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

[13] Conseil General du Développement Agricole (CGDA), 2004.

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[14]. Moreover, and in parallel to the land reform efforts, a charter of agricultural investments was adopted in 1969[15] with the objective of mobilizing the hydrologic potential of the country and providing incentives for the development of irrigated perimeters. 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[16]. 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 (1985-1991), displays a substantial increase in value of agricultural production, on average by 9.4%/year; whereas the per capita levels increased by 6.7%/year. The boost in agricultural productivity during this period came as result of favorable 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[17]. 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% for the period 1991-2002. Nonetheless, the trend is 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 subjected to 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 the face of fully 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. There is a strong consensus among policymakers that the growing hydrologic constraints in the country, owing among other things to climate change and its impacts on

[14] Akesbi, N., Benatya, D., and El Aoufi, N., *"L'agriculture marocaine a l'épreuve de la libéralisation"*, Ed. Economie Critique, 2008.

[15] 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 1 million Ha of irrigated agricultural land by 2000 (Doukkali, 2005).

[16] 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; RDH50, 2006).

[17] 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%, whereas the number of small farms without land and with less than a hectare of land decreased by 85.6% and 28.3% respectively (Doukkali, 2006; RDH50, 2006).

precipitation patterns, will be one of the major challenges in subsequent decades due to increased scarcity of water resources and demand driven by demographic pressure.

3.2. Methodology and materials: Country-based CGE model

The economic model to be used in this study is inspired by the IFPRI CGE model (Logfren et al., 2002). The model was developed to include a number of features critical to analyses focusing on developing countries such as including household consumption of non-marketed (or "subsistence") commodities, and multi input-output production structure that allows for any activity to produce multiple commodities and any commodity to be produced by multiple activities. The IFPRI CGE modeling infrastructure allows for a regionalized disaggregation that would support the regional structure chosen for this analysis, and which is based on the regional disaggregation of Moroccan territory at the administrative regional scale (Table 1).

Table 1: Administrative regions in Morocco

TR1*	Guelmim-Es Semara, Laayoune-Boujdour-Sakia El Hamra and Oued Eddahab-Lagouira	**TR8**	Rabat-Sale-Zemmour-Zaer
TR2	Souss-Massa-Draa	**TR9**	Doukkala-Abda
TR3	Gharb-Cherarda-Bni Hsan	**TR10**	Tadla-Azilal
TR4	Chaouia-Ouardigha	**TR11**	Meknes-Tafilalet
TR5	Marrakech-Tensift-El Haouz	**TR12**	Fes-Boulemane
TR6	L'Oriental	**TR13**	Taza-Taounate-Al Hoceima
TR7	Grand Casablanca	**TR14**	Tanger-Tetouan

N.B:
*R1 represents the aggregation of three regions due to data limitations.
Source: Authors' adaptation

The data to be used in the model is taken from the compilation of a national social accounting matrix for 2003 based on the work of Dr. Rachid Doukkali of IAV/Hassan II in Rabat, Morocco, and which identifies 60 activities and 68 commodities. The institutional block in the data is represented by 10 households'[18], the government and the rest of the world accounts. Tables 2 and 3 (Appendices) summarize the list of activities and commodities adopted in the analysis, and which, after some data manip ulations, collapse the dimensions of the model to 32 production activities producing 32 commodities.

Production is modeled under the assumption of profit maximization subject to a production technology (Figure 1, Appendices). The model specification allows for flexibility in terms of production technology to be used. At the top level, the technology is specified as constant elasticity of substitution (CES) function or, alternatively, a Leontief function of the quantities of value-added and aggregate intermediate input. For the purpose of our analysis, we use the default specification of a Leontief technology since we assumed that each activity at the aggregate level uses bundles of value-added and aggregated intermediate inputs to produce one or more commodities according to fixed yield coefficients. The profit-maximizing decision process assumed for each activity implies that factors are used up to the point where marginal revenue product of each factor is equal to its wage (or factor price). In the model, an economywide wage variable is free to vary to assure that the sum of demands from all activities equals the quantity of factor endowments, which is assumed to be fixed at the observed level.

Household consumption is modeled via a Linear Expenditure System (LES), which results from the household's utility maximization problem using a "Stone-Geary" utility function subject to a consumption expenditure constraint. Household consumption covers marketed commodities, purchased at market prices, and home commodities, which are valued at activity specific-specific producer prices. Government collects taxes (fixed at *ad valorem* rates) and receives transfers from other

[18] Urban households and rural households identified at the level of five income decile.

institutions, which constitute its revenue. Government consumption expenditures are assumed to be fixed in real terms, transfers to domestic institutions are CPI-indexed.

At the level of commodity markets (Figure 2, Appendices), total domestic supply comes from total aggregate output across activities, which is obtained via a CES function that accounts for the imperfect substitutability of different outputs due to, for instance, differences in quality, and distance between locations of activities. In order for market clearance to occur, an activity-specific price serves to clear the implicit market for each disaggregated commodity. In the next stage, aggregated domestic supply is allocated between exports and domestic sales via a constant elasticity of transformation (CET) function.

Domestic demand is made up of the sum of demands from households, government, investments and intermediate inputs. The latter demands are, to the extent that a commodity is imported, for a composite commodity made up of imports and domestic output.

3.3. *Regionalization data and Scenarios analysis*

As previously mentioned, the model regional disaggregation is based on the administrative and economic regional disaggregation of Morocco (Table 1).

In order to regionalize the data in the social accounting matrix (SAM), regional statistics on production were used as a basis. For example, for agricultural crop production (12 activities), we used statistics from the Agricultural Survey of Major Crop Production for the agricultural campaign 2002-2003, which corresponds to the base year of our SAM. Regionalization shares are based on production levels in each region (cf. Table 5), and which are provided for all production activities retained in the model. For the livestock sectors (4 activities), regional statistics on livestock headcount for 2004 of cattle and sheep were used to regionalize production activities for bovine and ovine meat production (HCP, 2005); whereas for poultry meat production, regional statistics pertaining to 2005[19] were used as a basis for regionalization. Table 6 summarizes the regionalization procedure and data used for all production activities and institutions as represented in the SAM.

One of the main features of the model is the interregional trade structure adopted in order to account for the flows of commodity accounts to activity accounts at the regional level. The latter interregional trade flows are computed as a residual, assuming no transaction costs. This is achieved in the model by calculating the difference between a region's production and consumption. The resulting residual, if a surplus, is then distributed to other regions based on their demands. We assume that for regions with surpluses, the latter consume only their own products, and export the rest to regions with commodity deficits. As for the importing regions, imports are subtracted from the region's production to keep the balance between consumption and production (Dudu and Cakmak, 2011).

In what pertains to the scenarios identified for the analysis, we have identified 6 scenarios as described in Table 7. These scenarios are defined based on the climate-driven yield shocks to be introduced for selected crops, and refer to each SRES used in the analysis (A1b, A2, and B1). The objective is two folds: a) to capture the uncertainty underlying the projections in yield responses to climate change across SRES scenarios, and b) capturing the underlying uncertainty within each climate scenario. This is achieved, for the first case, by taking the average of yield response across 22

[19] Data was provided by Dr. Abdellah MDAFRI, Head of the Central Zone Division, Project Management Department, Agricultural Development Agency (ADA), Morocco.

GCMs by 2050; whereas for the second case, uncertainty within a particular SRES scenario is captured by taking the 10th, 50th (i.e. average) and 90th percentiles of the yield distributions as estimated by each of the 22 GCMs by 2050.

Yield estimates were obtained via the CliCrop crop model. Tables 8 and 9 summarize respectively the SRES and GCMs, as well as crop coverage for CliCrop. Yield estimates, as produced by CliCrop, are based on the effect of changing daily precipitation patterns and temperatures, in contrast with available modeling methodologies that uses monthly averages. The main inputs used by CliCrop are weather (temperature and precipitation), soil parameters (field capacity, wilting point, saturated hydraulic conductivity, and saturation capacity), and crop specific parameters describing crops' growth behavior. The development of Clicrop was based primarily on FOA's CROPWAT model, and a number of other well established crop models[20]. The main objective is to maintain minimal input requirements as in CROPWAT, but with improved accuracy in yield estimation for both rainfed and irrigated agriculture. A major consideration leading to the development of CliCrop was the need for a modeling framework that provide robust yield estimates in the context of developing countries, where data limitations on model inputs are pervasive. Table 10 provides a comparative summary of CliCrop and crop models used in its development (add reference to the paper here).

[20] Four models were studied in details and used in the development of CliCrop: CROPWAT, SWAT, DSSAT and LEAP. (need to add reference to CliCrop paper)

Table 8: List of GCMs and climate scenarios (SRES) covered in CliCrop

GCM name	SRES Climate Scenarios		
	A2[21]	A1b[22]	B1[23]
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: Strzepek, K., and Fant, C., '*CliCrop Methods*', 2009.

[21] Describes a very heterogeneous world. The underlying theme is that of strengthening regional cultural identities, with an emphasis on family values and local traditions, high population growth, and less concern for rapid economic development.

[22] Describes a future world of very rapid economic growth, low population growth and rapid introduction of new and more efficient technology. Major underlying themes are economic and cultural convergence and capacity building, with a substantial reduction in regional differences in per capita income. In this world, people pursue personal wealth rather than environmental quality.

[23] Describes a convergent world with the same global population as in the A1 storyline but with rapid changes in economic structures toward a service and information economy, with reductions in materials intensity, and the introduction of clean and resource-efficient technologies.

Table 9: List of crops covered in CliCrop

List of crops	
1.) Cassava and other Roots and Tubers	16.) Spring Wheat
2.) Cotton	17.) Winter Wheat (with frost)
3.) Grains	18.) Winter Wheat (without frost)
4.) Groundnuts	19.) Tobacco
5.) Maize (Grain)	20.) Vegetables
6.) Maize (Sweet)	21.) Citrus, 70% canopy but no ground cover
7.) Millet	22.) Banana, first year
8.) Potato	23.) Banana, second year
9.) Pulses	24.) Walnut
10.) Rice	25.) Pistachios
11.) Sorghum	26.) Coffee
12.) Soybeans	27.) Olives
13.) Sugar Beets	28.) Barley
14.) Sugar Cane (Raton)	29.) Tea
15.) Sweet Potatoes and Yams	30.) Rubber

Source: Strzepek, K., and Fant, C., *'CliCrop Methods'*, 2009.

4. Productivity shocks, results and discussions

In this section, first we will discuss the projected yield estimates of CliCrop, under the different SRES scenarios (A1b, A2 and B1) and crop categories (durum wheat, soft wheat, barley, Sugar crops, tomatoes, olives, citrus and other vegetables) selected for the analysis. Subsequently, we will provide an analysis of the economic impacts of climate-driven yield changes under the different scenarios used.

4.1. Climate-driven productivity shocks

Figures 6-13 summarize the nation-wide and regional average yield impacts as projected by CliCrop across 22 GCMs, under the different climate change scenarios, for all selected crops. It is worth mentioning that for all selected crop categories, yield estimates account for CO_2 fertilization effects as the latter are significant.

First, we notice that at the national level, projected yields depict variation across crops and climate scenarios. For instance, wheat (durum and soft), sugar crops (sugar beet and sugar cane), and citrus are the most negatively affected crops, where respectively, yields decline by -5 to -8% for wheat (durum and soft), -4 to -5% for sugar crops, and -3 to -6% for citrus. Whereas tomatoes, olives and other vegetables (and to a certain extent barley) tend to benefit from climate change, where yields are projected to increase by +3 to +10% for tomatoes and other vegetables, +3 to +11% for olives, and +0.2 to +1% for barley.

For SRES A2, the distribution of yield projections at the national level as estimated by each of the 22 GCMs for the year 2050, and captured by the 10^{th}, 50^{th} and 90^{th} percentiles displays substantial variation (Figures 14-21). For example, whereas wheat (durum and soft) and sugar crops yields are projected to decrease by -4 to -10% and -3 to -6%, barley, tomatoes, other vegetables, olives and citrus display sign reversals in the direction of projected yield impacts across GCMs. For instance, the projected yield impact for barley ranges from -4 to +6%; for tomatoes and other vegetables, yields are expected to range between -6 to +20%; for citrus, the latter range between -13 to +2%; and for olives, projected yields vary between -7 to +19%.

Nonetheless, using national averages does not inform us on the regional heterogeneity in the results, and which depict some interesting results. For instance, projected yields for wheat (durum and soft) are expected to fall for all regions and all SRES scenarios. Among the hardest hit regions, the Sahara region[24] and Taza-Taounate, which together account for respectively for 16% and 7% of total durum and soft wheat production, will experience respectively -12% and -10% decrease in yields on

[24] The Sahara region represents the aggregation of Guelmim-Es Semera, Laayoune-Boujdour-Sakia El Hamra and Oued Eddahab-Lagouira.

average across all SRES. The latter are followed by Tanger-Tetouan, Fes-Boulemane, and Rabat-Sale, which represent together 16% and 18% of total durum and soft wheat production, and which are expected to incur a -9% decrease in yields. For barley, the results show substantial variation across regions. For example, yields are expected to increase by +12% to +25% in the regions of Taza-Taounate, Grand Casablanca, and the Sahara regions; whereas yields decreases of -5% to -14% are expected in the Tafilalet, Tadla, Doukkala, l'Oriental, El Haouz, and Chaouia regions, and which account for 72% of total production. For sugar crops (sugar beet and sugar cane), the results show substantial decreases in projected yields, where the latter are more pronounced in the l'Oriental and Doukkala regions (-13% and -12% respectively), followed by the Gharb and Tanger-Tetouan regions (-5% and -6%). The latter regions account for 77% of total production, whereas in the Tadla region, yields are expected to increase by 3% by 2050. For tomatoes, the yield projections in most regions depict positive results. For instance, yields in the Souss, Gharb and Doukkala regions (which account for 78% of total production) are projected to increase by +13%, +9%, and +9% respectively by 2050. Only minor yield decreases are projected in the l'Oriental and Taza-Taounate regions (-1% and -4%), where the latter represent only 3% of total production. For olives, the results show that most regions will experience yield increases. The latter will be substantial for certain regions and range between +9% to +17% in the Souss, Gharb, Chaouia, Tensift-El Haouz, Doukkala, and Tafilalet regions, and which represent 47% of total production. The only negative impacts recorded are in Fes-Boulemane and Taza-Taounate regions, where yields are respectively projected to decline by -3% and -2%. For citrus, the results show a negative impact on yields in almost all regions. The yield decrease ranges between -3% to -9% in the Souss, Gharb, l'Oriental, and Tadla regions, and which account for 91% of total production. For other vegetables, yields are projected to increase in most regions, ranging from +7% to +20% in the Souss, Gharb, Tensift-El Haouz, Rabat-Sale, Doukkala, Tadla, Tafilalet, Fes-Boulemane, and Tanger-Tetouan regions, and which represent 78% of total production.

In conclusion, the results depict the wide range of variability that exists in terms of projected yield impacts at the national level, across and within SRES, but also across regions. Capturing this variability, and accounting for its economic impacts is key to understand the potential inter-regional linkages in terms of climate change.

4.2. Findings and results

The present analysis identifies 6 scenarios, as defined in Table 7. The model closure rules follow conventional neoclassical assumptions.

For imports and exports, we assume that Morocco is a small-country facing infinitely elastic supplies and demands at world prices.

Full employment of factors is assumed, where capital and land are activity-specific; whereas labor is mobile across regions and sectors. The numeraire is assumed to be the Consumer Price Index (CPI).

At the macro level, government savings, i.e. the difference between government's revenues and expenditures, is a fixed share of GDP. In order to reach the targeted level of government savings, the tax rate is allowed to adjust uniformly across all sectors. We assume fixed foreign savings, and allow for a flexible exchange rate in order to clear the balance of the rest of the world.

The simulation results suggest that the effect of climate change on the economy is quite heterogeneous across scenarios analysis, where we notice declines and increases in the sign of key indicators as summarized in Tables 10 and 11 (Appendices). Under all scenarios, the GDP results are driven by the performance in the agricultural sector, and sectors closely related to it (e.g. livestock and food processing). We notice that despite the negative productivity shocks that characterizes our scenarios analysis; their actual impacts on the economy at the national level are quite minimal. For example, we notice that the impact on aggregate real GDP under the cross SRES ranges from -0.15% (A1b_2050), +0.01% for (A2_2050), to +0.32% (B1_2050). For aggregate agricultural output, the impacts range from -0.61% for scenario A1b_2050, -0.03% for A2_2050, and +1.16% for the more optimistic scenario B1_2050. The same pattern is recorded with the results from the second set of scenario analysis that introduces the distribution of productivity shocks as estimated under SRES A2. We notice that for the first scenario (A2_10th percentile)[25], total GDP decreases by -0.77% and total agricultural output by -3%. Under the average scenario (A2_average), total agricultural output decreases by -0.03%; whereas a reversal of signs occurs for total GDP with the latter increasing slightly by +0.01%. As for the third case, results for total GDP suggest an increase by +0.77% and by +3% for total agricultural output.

Household (rural and urban) income displays similar trends, where the results showcase quite a heterogeneous response across scenarios (Table 13). The impact on income is primarily driven by the impacts on factor returns. This in turn affects regional consumption patterns as summarized in Table 14.

Agricultural output at the activity level depicts substantial effects of climate change on production levels. Table 15 summarizes the changes observed under each scenario, and for each activity at the national level. For crop production activities, the results display substantial decreases in durum wheat, soft wheat and citrus production levels for all SRES scenarios. For instance, the latter were respectively -5% for durum and soft wheat, and -11% for citrus under scenario A1b_2050. Tomatoes, other vegetables and olives on the other hand showcase a significant boost in production, where we record that output increased by +19%, +11% and +6% under scenario B1_2050.

The food processing sectors, given their dependence on agricultural performance, depict substantial changes across scenarios. Durum and soft wheat mill processing experience a decline in output and which is substantial for all scenarios, with respectively -2% and -3% decrease under scenario A1b_2050.

5. Conclusion

The agricultural sector in Morocco consists of a heterogeneous distribution of production activity across regions. This diversity in the regional structure of agriculture brings about complicated linkages in terms of projected impacts of climate change across regions, which in turn trickles down to affect the rest of the economy.

In this paper, we attempt to shed light on interregional linkages under different climate-driven agricultural productivity shocks using a regional adaptation of a CGE model. In Morocco, climate change intervenes by substantially changing the regional production patterns and hence, introduces changes in prices of commodities. As showcased in the results, agriculture, and to a certain degree, food processing sectors production levels are substantially affected by climate change.

Nonetheless, the present analysis is an exploration into the analysis of the regional

[25] The percentile distribution for yield estimates under SRES A2 is obtained by using the actual derived values for the efficiency parameter to be introduced in the model as a shock, and which is defined as: ????? ? ? ? ?, where ? is the actual predicted yield change as estimated via CliCrop. The latter could be negative or positive. Therefore, the scenarios derived from the percentile distribution of the parameter *'yield'* are interpreted as follows: 'A2_10th percentile' represents the worst case scenario, 'A2_average' as its name indicates is the middle road scenario, and 'A2_90th percentile' is the best case scenario.

implications of climate change. The results presented are preliminary and need further refinement.

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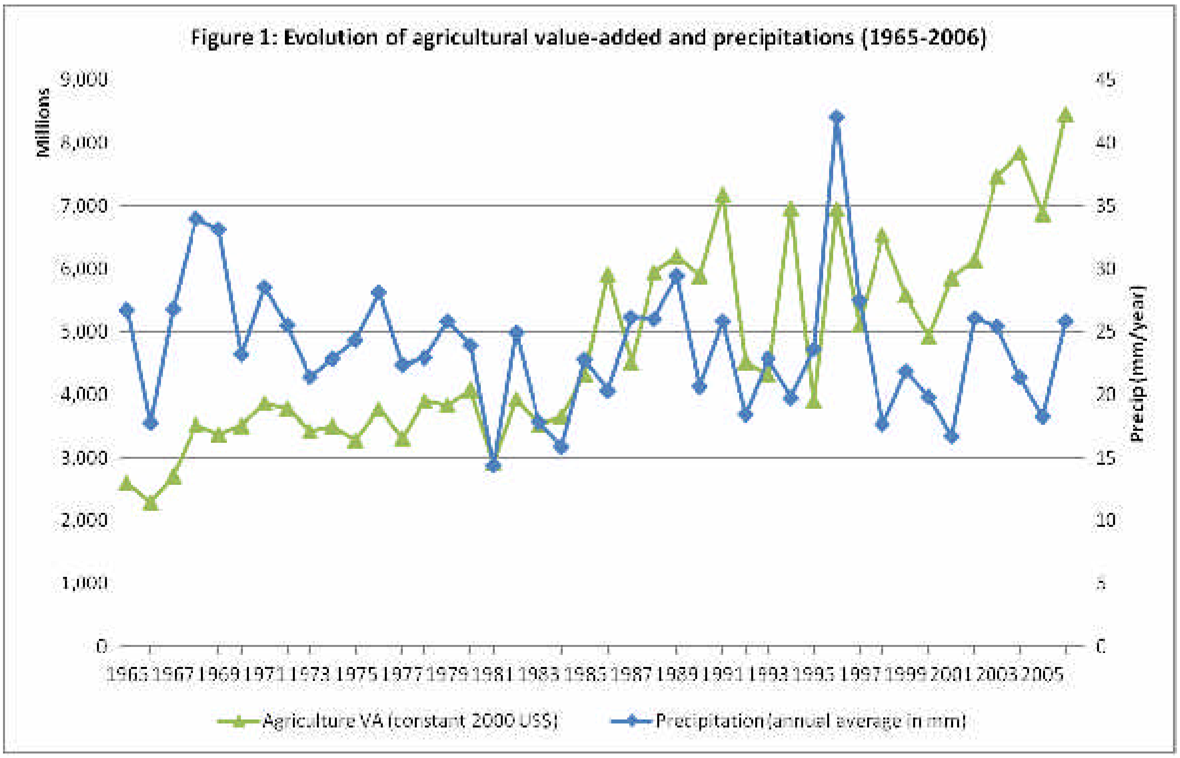
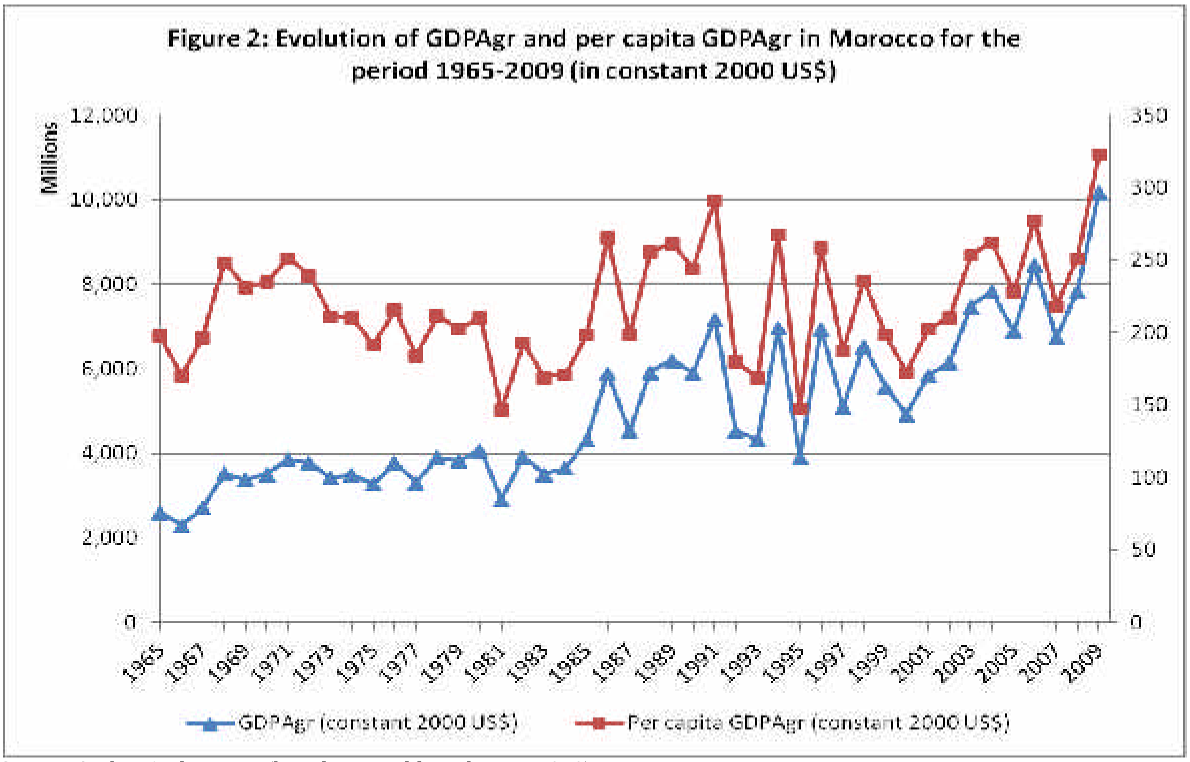
APPENDICES



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



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

Table 2: List of Activities

hdwht-a	Hard wheat	**forst-a**	Forestry
sfwht-a	Soft wheat	**fshry-a**	Fishery
barly-a	Barley	**dairy-a**	Dairy
sgrcr-a	Sugar crops (incl. sugarbeet and sugarcane)	**sugar-a**	Sugar processing
tomat-a	Tomatoes	**milhw-a**	Hard wheat mill
xvegts-a	Other vegetables (incl. potatoes and onions)	**milsw-a**	Soft wheat mill
xvgin-a	Other industrial vegetables	**oilpr-a**	Processed oil
forags-a	Forage crops (incl. Alfalfa)	**olvwh-a**	Whole olives
olive-a	Olives	**olvol-a**	Olive oil
agrms-a	Citrus	**xfdpr-a**	Other food processing
xfruts-a	Other fruit (incl. grapes, dates, and almonds)	**chmcl-a**	Chemical industries
xcrops-a	Other crops nested (incl. other grains, grain legumes, other ind. Crops)	**refol-a**	Refined petroleum
bovin-a	Bovine meat	**wtrel-a**	Water and electricity utilities
ovine-a	Sheep and other red meats	**xinds-a**	Other industries
avine-a	Poultry	**srvpr-a**	Private services
xmeat-a	Other meat production	**srvpb-a**	Public services
(green)	Agriculture (incl. crop production and livestock), forestry and fishery		
(red)	Manufacturing and industry (incl. food processing)		
(blue)	Services		

Source: Authors' adaptation

Table 3: List of commodities

hdwht-c	Hard wheat	**forst-c**	Forestry
sfwht-c	Soft wheat	**fshry-c**	Fishery
barly-c	Barley	**dairy-c**	Dairy
sgrcr-c	Sugar crops (incl. sugarbeet and sugarcane)	**sugar-c**	Sugar processing
tomat-c	Tomatoes	**milhw-c**	Hard wheat mill
xvegts-c	Other vegetables (incl. potatoes and onions)	**milsw-c**	Soft wheat mill
xvgin-c	Other industrial vegetables	**oilpr-c**	Processed oil
forags-c	Forage crops (incl. Alfalfa)	**olvwh-c**	Whole olives
olive-c	Olives	**olvol-c**	Olive oil
agrms-c	Citrus	**xfdpr-c**	Other food processing
xfruts-c	Other fruit (incl. grapes, dates, and almonds)	**chmcl-c**	Chemical industries
xcrops-c	Other crops nested (incl. other grains, grain legumes, other ind. Crops)	**refol-c**	Refined petroleum
meatrbov-c	Bovine meat	**wtrel-c**	Water and electricity utilities
meatrov-c	Sheep and other red meats	**xinds-c**	Other industries
meatw-c	White meats	**srvpr-c**	Private services
xmeat-c	Other meat production	**srvpb-c**	Public services
(green)	Agriculture (incl. crop production and livestock), forestry and fishery		
(red)	Manufacturing and industry (incl. food processing)		
(blue)	Services		

Source: Authors' adaptation

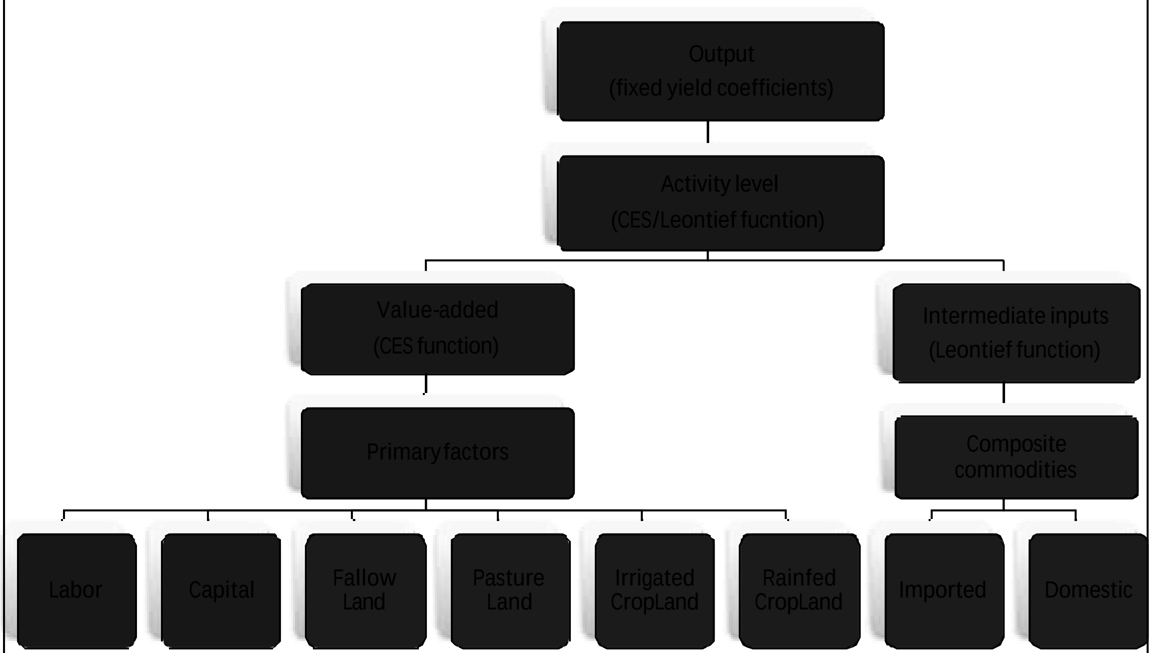


Figure 3: Production technology (adapted from Lofgren et al., 2002)

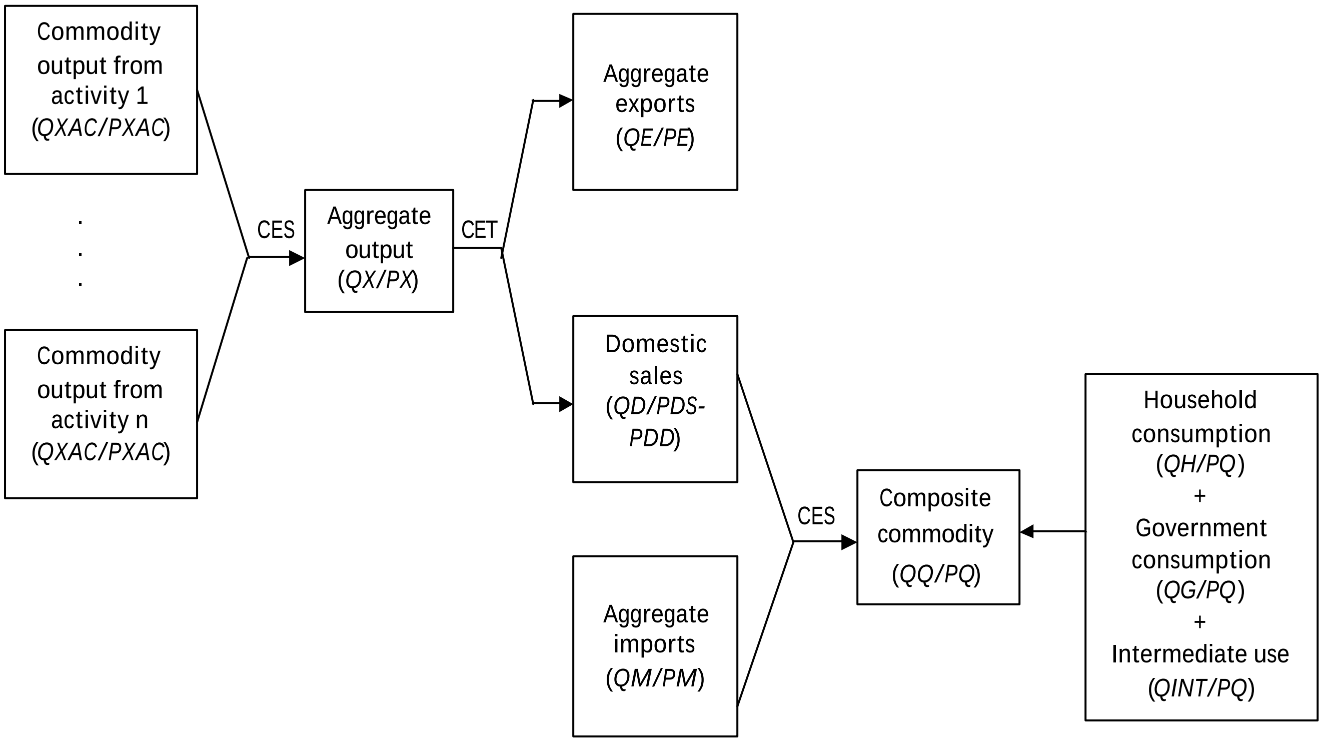


Figure 4: Flows of marketed commodities (Logfren et al., 2002)

Table 5: Sample data of regional crop production statistics for hard wheat

HARD WHEAT (in million Qx)	**DPA**	**ORMVA**
REGION 1: Guelmim-Es Semara, Laayoune-Boujdour-Sakia El Hamra and Oued Eddahab-Lagouira	1.7	1.3
REGION 2: Souss-Massa-Draa	0.0	102.9
REGION 3: Gharb-Cherarda-Bni Hsan	343.8	535.9
REGION 4: Chaouia-Ouardigha	3,375.5	0.0
REGION 5: Marrakech-Tensift-El Haouz	738.3	601.3
REGION 6: L'Oriental	471.7	108.1
REGION 7: Grand Casablanca	34.6	0.0
REGION 8: Rabat-Sale-Zemmour-Zaer	874.3	0.0
REGION 9: Doukkala-Abda	995.6	2,011.6
REGION 10: Tadla-Azilal	657.4	432.6
REGION 11: Meknes-Tafilalet	1,351.8	321.6
REGION 12: Fes-Boulemane	852.7	0.0
REGION 13: Taza-Taounate-Al Hoceima	2,827.4	0.0
REGION 14: Tanger-Tetouan	846.2	175.9
TOTAL	**13,371.0**	**4,291.2**

Source: author's adaptation

Table 6: Summary of regionalization procedure and data sources for the national accounting matrix (SAM)

Accounts	Description	Regionalization data source
Production activities		
hdwht-a	Hard wheat	For all crop productions, disaggregation at the administrative regional level was done based on the production statistics in the PV of Agriculture for the agricultural campaign 2002-2003
sfwht-a	Soft wheat	
barly-a	Barley	
xgrns-a gnleg-a	Other grains Grain legumes	
sgrbt-a	Sugar beets	
sgrcn-a	Sugar cane	
xcshc-a	Other industrial crops incl oil seeds	
tomat-a	Tomatoes	
potat-a	Potatoes	
onion-a	Onions	
xvegts-a	Other vegetables	
xvgin-a	Other industrial vegetables	
alfaf-a	Alfafa	
forag-a	Forage crops	
olive-a	Olives	
agrms-a	Citrus	
grape-a	Grapes	
almnd-a	Almonds	
dates-a	Dates	
xfruts-a	Other fruit	
xcrop-a	Other crops nested	
bovin-a	Bovine meat	- For ‘bovin-a’ and ‘ovine-a’ activities, the regionalization was based on data on livestock headcount of cattle and sheep for 2004 (source: HCP, 2005, *‘Le Maroc des regions* ‘)
ovine-a	Sheep and other red meats	- For ‘xmeat-a’, there was no data at the regional level. We have adopted a regionalization based on the average regional shares for cattle and sheep for 2004.
avine-a	Poultry	- For ‘avine-a’ activities, we regionalized the data based on regional statistics of poultry meat

		production for 2005.
xmeat-a	Other meat production	
forst-a	Forestry	- We used regional data on forest cover as provided in the "Atlas de l'Agriculture 2008". The data pertains to the General Agricultural Survey of 1996.
fshry-a	Fishery	- We used statistics of value of catchment at the regional level. The data was obtained from the Statistical Report of the Office National des Peches, 2003.
dairy-a	Dairy	- We used data on milk production available at the regional level (ADA, 2005).
sgrrw-a	Raw sugar	- We used the production data of 'sgrbt-a' and 'sgrcn-a' in order to approximate the regional disaggregation of sugar production activities. This was based on the assumption that most of the sugar production units are located within the perimeters producing sugar beet and sugar cane.
sgrrf-a	Refined sugar	
milhw-a	Hard wheat mill	- For 'milhw-a' and 'milsw-a', we used data at the regional level pertaining to processing capacity of hard wheat and soft wheat (ONICL, 2010).
milsw-a	Soft wheat mill	
oilrw-a oilrf-a	Raw oil Refined oil	- For 'oilrw-a' and 'oilrf-a', we used data pertaining to food processing industry's production level in 2003 (in millions Dhs) at the regional level to approximate regionalization shares (HCP, 2010).
olvwh-a	Whole olives	- The regionalization of 'olvwh-a' and 'olvol-a' is based on the regional production shares of olives and which were obtained from the PV of Agriculture for the agricultural campaign 2002-2003.
olvol-a	Olive oil	
xfdpr-a	Other food processing	- For 'xfdpr-a', we used data pertaining to food processing industry's production level in 2003 (in millions Dhs) at the regional level to approximate regionalization shares (HCP, 2010).
refol-a	Refined petroleum	- For 'refol-a', most of the refinery capacity is located in two regions, Grand Casablanca and Gharb with respectively 90% and 10% of production capacity.
wtrel-a	Water and electricity utilities	- The regionalization of 'wtrel-a' was based on regional production statistics of municipal water (in m3) and net electricity production (in million KWh) for 2003 (HCP, 2010). Since this activity bundles together water and electricity production, we used value of production for each one of them in order to compute regionalization shares that are consistent: 1) For water, regional production was valued based on the average price of bulk water supply tariff (WB, 2004); 2) For electricity, we used a weighted price average based on electricity supply tariffs (ONE, 2004).
xinds-a	Other industries	- The regionalization shares for 'xinds-a' and 'chmcl-a' have been approximated by regional data of production level (in million Dhs) for textile and leather industries, mechanical and metal industries, electronic industries and chemical industries for 2003 (HCP, 2010).
chmcl-a	Chemical industries	
srvpr-a	Private services	- For the service sectors, regionalization was based on regional employment data in the sector for

srvpb-a	Public services	2003, but which does not distinguish between private and public services sectors. We kept the latter in the same proportions as in the original data in the SAM.
Commodity accounts The disaggregation of the commodity accounts at the regional level follows the structure adopted in the production activities accounts, where each commodity account is regionalized based on the regionalization of the production activity producing it.		
Institutional accounts		
uh	Urban households	- The regionalization of households' consumption was based on regional expenditure data from the Survey on household consumption and expenditures for 2001 -2002 (HCP, 2010).
rh	Rural households	
gov	Government consumption	- The regionalization of the government accounts was based on regional data on government expenditure (in million Dhs) for the 2010 government budget (Ministere de l'Economie et des Finances, 2011).
row	Trade accounts	- For export accounts, the regionalization follows from the regional shares of the production activities since we assume that each region is participating according to its level of production for any given commodity. - For imports, regionalization was based on regional demand from institutions (i.e. households and government), regional intermediate demand, and regional savings -investments.
TX	Tax accounts	- Regionalization of tax revenues was based on regional per capita expenditure of households, differentiated by urban and rural. We assume that tax revenues accrue from commodity taxes levied on consumption.
	Government transfers	- Regionalization was based on regional population census data for 2004.

Source: Author's adaptation

Table 7: Description of scenarios analysis

Scenario	Description	Objective
A1b_2050	This is a scenario that describes yield changes with respect to the 'base' as projected by the climate change scenario A1b by 2050.	The purpose of including yield estimates as projected under 3 different SRES scenarios is to account for uncertainty across climate change scenarios.
A2_2050	This is a scenario that describes yield changes with respect to the 'base' as projected by the climate change scenario A2 by 2050.	
B1_2050	This is a scenario that describes yield changes with respect with respect to the 'base' as projected by the climate change scenario B1 by 2050.	
A2_10th percentile	This is a scenario that describes the 10th percentile of the distribution of yield changes with respect to the 'base' as projected by the climate change scenario A2 by 2050.	The objective is the capture of the underlying uncertainty that characterizes the yield estimates under SRES A2, and which provide insights on the distribution of impacts across 22 GCMs.
A2_average	This is a scenario that describes the average yield changes with respect to the 'base' as projected by the climate change scenario A2 by 2050.	
A2_90th percentile	This is a scenario that describes the 90th percentile of the distribution of yield changes with respect to the 'base' as projected by the climate change scenario A1b by 2050.	

Source: Authors' adaptation

Figure 6: National and regional projected yield impacts for Durum wheat for all SRES by 2050

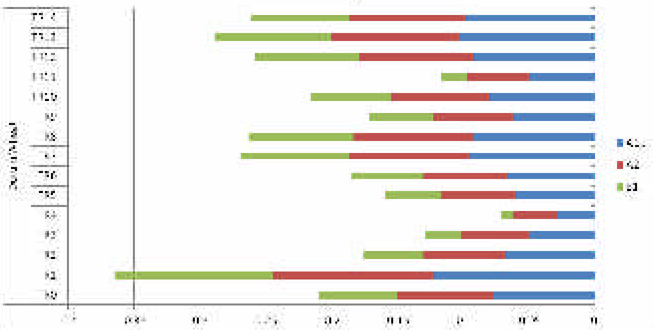


Figure 7: National and regional projected yield impacts for Soft wheat for all SRES by 2050

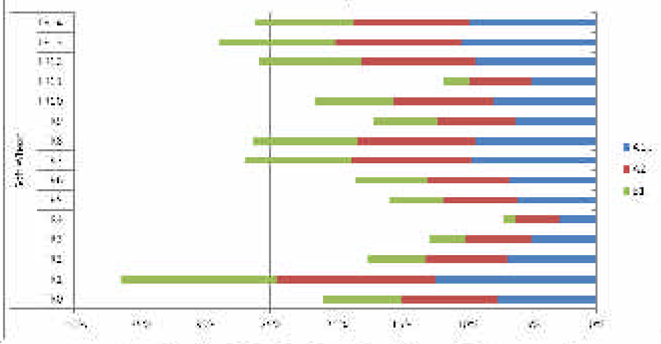


Figure 8: National and regional projected yield impacts for Barley for all SRES by 2050

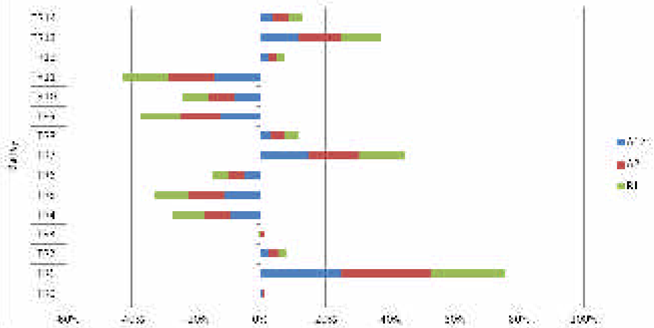


Figure 9: National and regional projected yield impacts for Sugar crops for all SRES by 2050

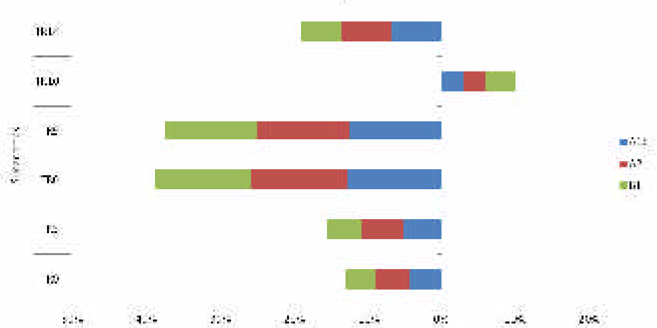


Figure 10: National and regional projected yield impacts for Tomatoes for all SRES by 2050

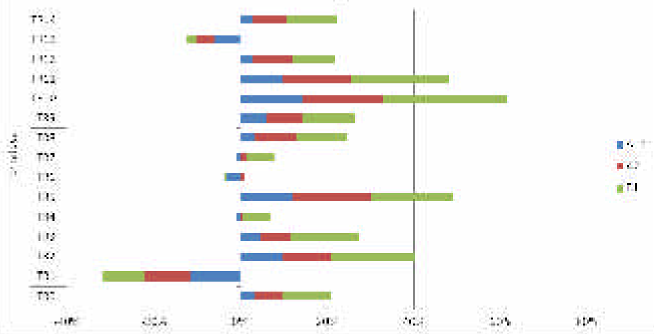


Figure 11: National and regional projected yield impacts for Olives for all SRES by 2050

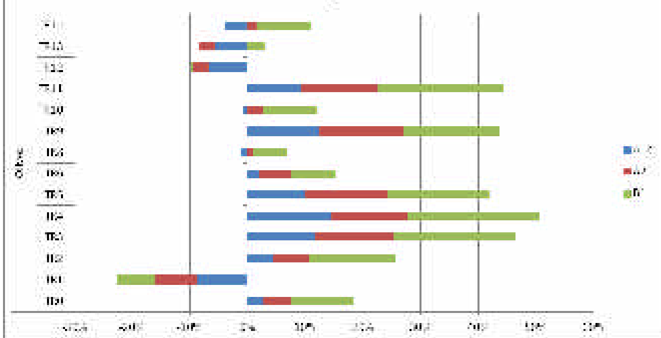


Figure 12: National and regional projected yield impacts for Citrus for all SRES by 2050

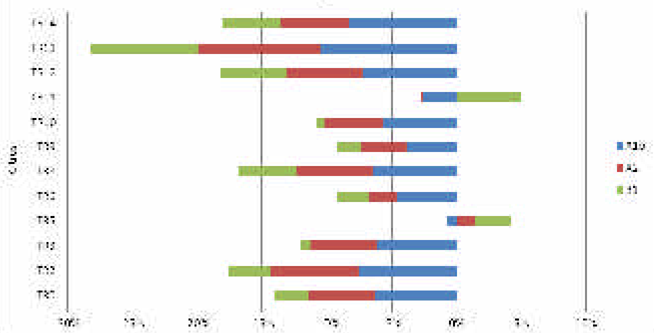
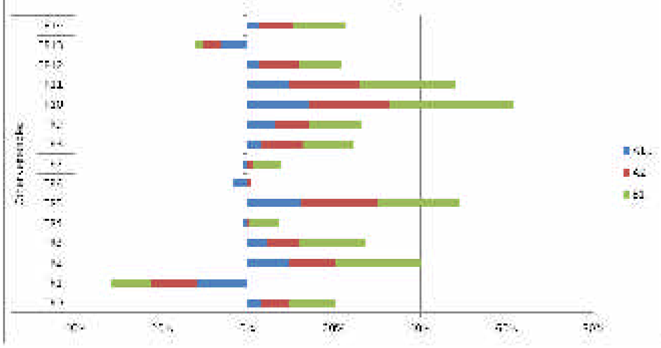


Figure 13: National and regional projected yield impacts for Other vegetables for all SRES by 2050



Source: CliCrop model simulations

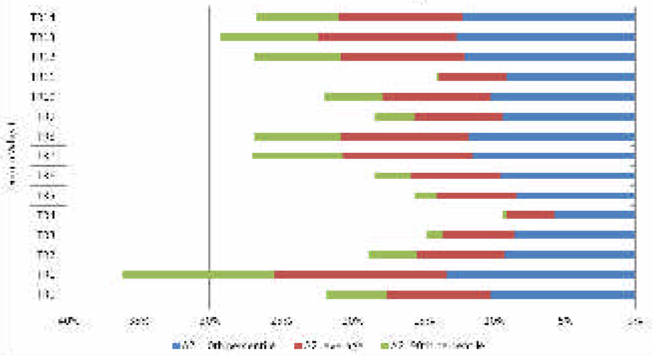


Figure 14: Distribution of national and regional projected yield impacts for Durum wheat for SRES A2 by 2050

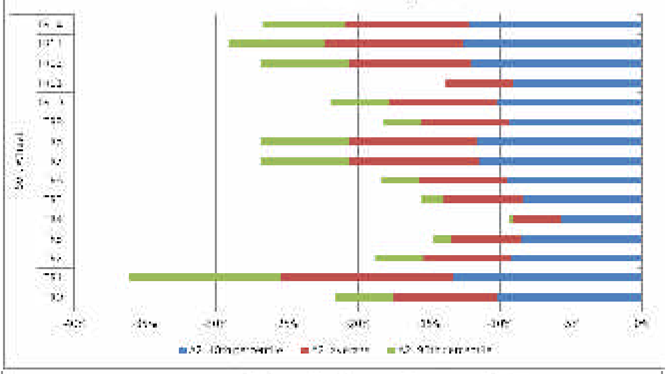


Figure 15: Distribution of national and regional projected yield impacts for Soft wheat for SRES A2 by 2050

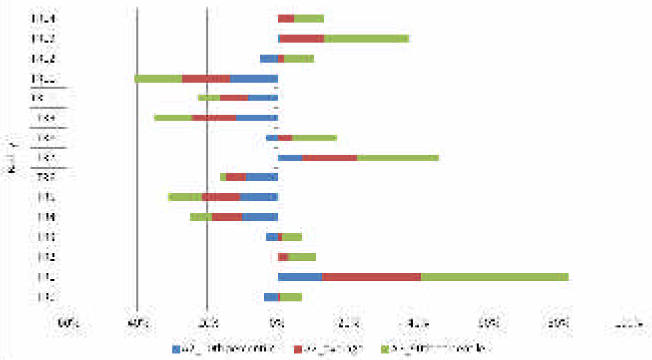


Figure 16: Distribution of national and regional projected yield impacts for Barley for SRES A2 by 2050

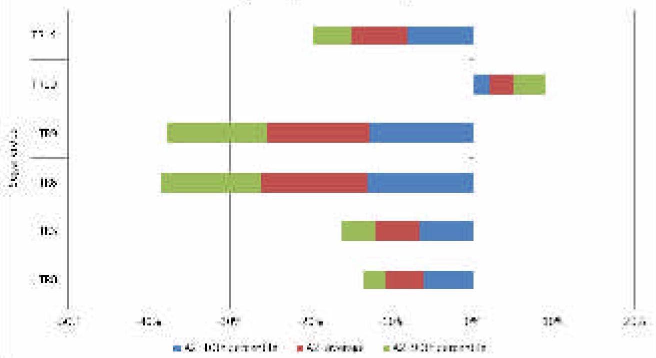


Figure 17: Distribution of national and regional projected yield impacts for Sugar crops for SRES A2 by 2050

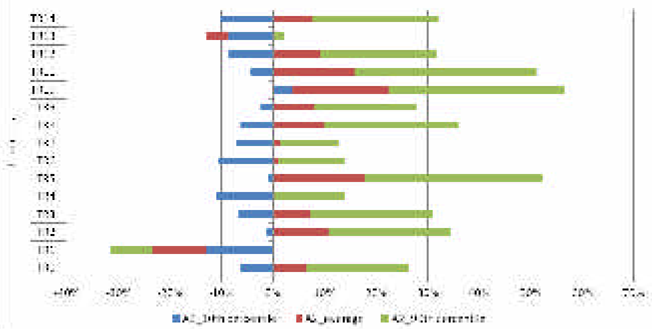


Figure 18: Distribution of national and regional projected yield impacts for Tomatoes for SRES A2 by 2050

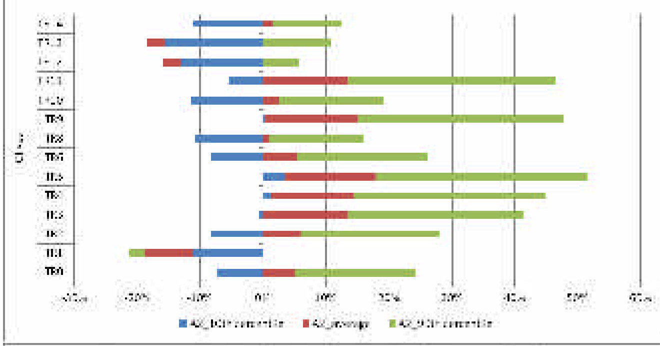


Figure 19: Distribution of national and regional projected yield impacts for Olives for SRES A2 by 2050

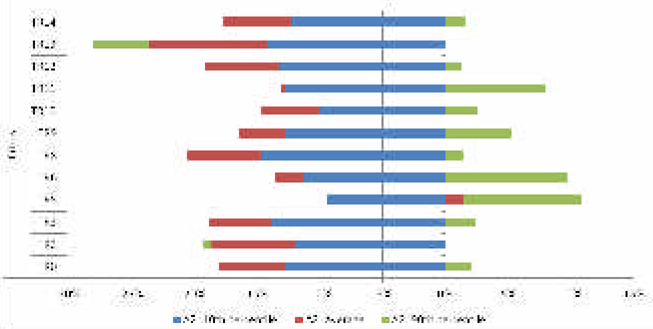


Figure 20: Distribution of national and regional projected yield impacts for Citrus for SRES A2 by 2050

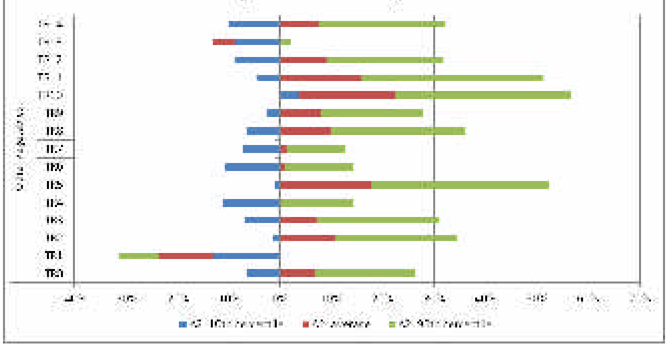


Figure 21: National and regional projected yield impacts for Other vegetables for SRES A2 by 2050

Source: CliCrop model simulations

Table 10: Impacts on aggregate and sectoral GDP (Values in million Dhs)

		BASE	A2_2050	A1b_2050	B1_2050	A2_10th percentile	A2_average	A2_90th percentile
Nominal	**Total**	**424,652.50**	**424,857.83**	**424,071.39**	**426,251.68**	**420,880.07**	**424,857.83**	**428,349.22**
	Agriculture (incl. Livestock, Forestry and Fishery)	**69,444.49**	**69,413.90**	**69,323.61**	**69,550.75**	**68,971.72**	**69,413.90**	**69,799.83**
	Crops	52,047.40	52,049.21	52,000.55	52,106.49	51,831.95	52,049.21	52,241.46
	Livestock	11,260.09	11,224.37	11,194.33	11,287.19	11,055.40	11,224.37	11,373.24
	Forestry and Fishery	6,137.00	6,140.32	6,128.73	6,157.07	6,084.37	6,140.32	6,185.13
	Manufacturing and Industry	**122,318.01**	**122,329.89**	**122,099.26**	**122,761.06**	**121,126.09**	**122,329.89**	**123,368.70**
	Food processing	22,751.41	22,737.77	22,661.06	22,879.27	22,340.62	22,737.77	23,089.84
	Other manufacturing and industry	99,566.60	99,592.12	99,438.20	99,881.79	98,785.47	99,592.12	100,278.86
	Services	**232,890.00**	**233,114.04**	**232,648.52**	**233,939.87**	**230,782.26**	**233,114.04**	**235,180.69**
Real	**Total**	**424,652.50**	**424,683.08**	**424,032.47**	**425,996.79**	**421,371.89**	**424,683.08**	**427,924.96**
	Agriculture (incl. Livestock, Forestry and Fishery)	**69,444.49**	**69,420.31**	**69,020.22**	**70,251.93**	**67,411.51**	**69,420.31**	**71,502.21**
	Crops	52,047.40	52,038.58	51,650.44	52,853.02	50,090.34	52,038.58	54,073.44
	Livestock	11,260.09	11,241.25	11,233.20	11,256.89	11,195.49	11,241.25	11,279.18
	Forestry and Fishery	6,137.00	6,140.48	6,136.58	6,142.02	6,125.68	6,140.48	6,149.59
	Manufacturing and Industry	122,318.01	122,295.87	122,233.46	122,439.42	121,939.23	122,295.87	122,607.41
	Food processing	22,751.41	22,717.99	22,677.59	22,788.93	22,510.91	22,717.99	22,900.84
	Other manufacturing and industry	99,566.60	99,577.88	99,555.87	99,650.49	99,428.32	99,577.88	99,706.57
	Services	232,890.00	232,966.90	232,778.79	233,305.44	232,021.15	232,966.90	233,815.34

Source: Model Simulations

Table 11: Impacts on aggregate and sectoral GDP expressed in percent change from Base (Base in million Dhs)

			% Change					
		BASE	**A2_2050**	**A1b_2050**	**B1_2050**	**A2_10th percentile**	**A2_average**	**A2_90th percentile**
Nominal	**Total**	**424,652.50**	**0.05%**	**-0.14%**	**0.38%**	**-0.89%**	**0.05%**	**0.87%**
	Agriculture (incl. Livestock, Forestry and Fishery)	**69,444.49**	**-0.04%**	**-0.17%**	**0.15%**	**-0.68%**	**-0.04%**	**0.51%**
	Crops	52,047.40	0.00%	-0.09%	0.11%	-0.41%	0.00%	0.37%
	Livestock	11,260.09	-0.32%	-0.58%	0.24%	-1.82%	-0.32%	1.00%
	Forestry and Fishery	6,137.00	0.05%	-0.13%	0.33%	-0.86%	0.05%	0.78%
	Manufacturing and Industry	**122,318.01**	0.01%	-0.18%	0.36%	-0.97%	0.01%	0.86%
	Food processing	22,751.41	-0.06%	-0.40%	0.56%	-1.81%	-0.06%	1.49%

	Other manufacturing and industry	99,566.60	0.03%	-0.13%	0.32%	-0.78%	0.03%	0.72%
	Services	**232,890.00**	**0.10%**	**-0.10%**	**0.45%**	**-0.91%**	**0.10%**	**0.98%**
Real	**Total**	**424,652.50**	**0.01%**	**-0.15%**	**0.32%**	**-0.77%**	**0.01%**	**0.77%**
	Agriculture (incl. Livestock, Forestry and Fishery)	**69,444.49**	**-0.03%**	**-0.61%**	**1.16%**	**-2.93%**	**-0.03%**	**2.96%**
	Crops	52,047.40	-0.02%	-0.76%	1.55%	-3.76%	-0.02%	3.89%
	Livestock	11,260.09	-0.17%	-0.24%	-0.03%	-0.57%	-0.17%	0.17%
	Forestry and Fishery	6,137.00	0.06%	-0.01%	0.08%	-0.18%	0.06%	0.21%
	Manufacturing and Industry	**122,318.01**	**-0.02%**	**-0.07%**	**0.10%**	**-0.31%**	**-0.02%**	**0.24%**
	Food processing	22,751.41	-0.15%	-0.32%	0.16%	-1.06%	-0.15%	0.66%
	Other manufacturing and industry	99,566.60	0.01%	-0.01%	0.08%	-0.14%	0.01%	0.14%
	Services	**232,890.00**	**0.03%**	**-0.05%**	**0.18%**	**-0.37%**	**0.03%**	**0.40%**

Table 12: Effects on selected aggregate variables (Base values in million Dhs)

		% Change					
	BASE	**A2_2050**	**A1b_2050**	**B1_2050**	**A2_10th percentile**	**A2_average**	**A2_90th percentile**
Absorption	492,093.18	0.03	-0.11	0.31	-0.68	0.03	0.72
Household Consumption	272,986.39	0.11	-0.09	0.45	-0.82	0.11	1.00
Government Consumption	85,485.29	0.00	-0.08	0.16	-0.44	0.00	0.38
Exports	139,735.57	0.20	0.06	0.48	-0.47	0.20	0.89
Imports	153,254.30	0.18	0.05	0.44	-0.43	0.18	0.81
Real exchange rate	100.00	-0.08	-0.08	-0.09	-0.10	-0.08	-0.10
Nominal exchange rate	100.00	0.04	-0.05	0.15	-0.37	0.04	0.34
Domestic price index	100.00	0.12	0.03	0.23	-0.27	0.12	0.44
Investment	27.92	0.00	0.00	0.00	0.00	0.00	0.00
Private savings	23.39	0.00	0.00	0.01	-0.02	0.00	0.03
Foreign savings	2.75	0.00	0.00	-0.01	0.01	0.00	-0.02
Governnment savings	1.78	0.00	0.00	-0.01	0.02	0.00	-0.02
Trade deficit	8.13	0.02	0.03	0.01	0.05	0.02	-0.01

Source: Model simulations

Table 13: Regional (%?) in household income

Regions	A2_2050	A1b_2050	B1_2050	A2_10th percentile	A2_average	A2_90th percentile
				Urban household		
TR1	-0.22%	-0.37%	0.03%	-0.96%	-0.22%	0.40%
TR2	0.12%	-0.01%	0.84%	-1.04%	0.12%	1.24%
TR3	0.17%	-0.02%	0.78%	-1.03%	0.17%	1.37%
TR4	-0.06%	-0.17%	0.19%	-0.72%	-0.06%	0.52%
TR5	0.28%	0.05%	0.47%	-0.73%	0.28%	1.15%
TR6	-0.04%	-0.25%	0.13%	-0.94%	-0.04%	0.80%
TR7	-0.02%	-0.17%	0.24%	-0.78%	-0.02%	0.62%
TR8	0.02%	-0.16%	0.23%	-0.75%	0.02%	0.66%
TR9	0.10%	-0.05%	0.37%	-0.79%	0.10%	0.89%
TR10	0.50%	0.25%	1.06%	-0.55%	0.50%	1.50%
TR11	0.19%	-0.01%	0.54%	-0.79%	0.19%	1.05%
TR12	-0.08%	-0.27%	0.10%	-0.89%	-0.08%	0.52%
TR13	-0.34%	-0.46%	-0.16%	-0.89%	-0.34%	0.12%
TR14	0.03%	-0.18%	0.28%	-0.88%	0.03%	0.76%
				Rural households		
TR1	-0.23%	-0.39%	0.03%	-1.00%	-0.23%	0.42%
TR2	0.12%	-0.01%	0.85%	-1.05%	0.12%	1.26%
TR3	0.18%	-0.02%	0.79%	-1.04%	0.18%	1.39%
TR4	-0.06%	-0.17%	0.19%	-0.73%	-0.06%	0.53%
TR5	0.28%	0.05%	0.48%	-0.74%	0.28%	1.17%
TR6	-0.04%	-0.26%	0.13%	-0.98%	-0.04%	0.82%
TR7	-0.02%	-0.18%	0.25%	-0.82%	-0.02%	0.65%
TR8	0.03%	-0.17%	0.24%	-0.80%	0.03%	0.70%
TR9	0.10%	-0.06%	0.37%	-0.79%	0.10%	0.90%
TR10	0.50%	0.25%	1.07%	-0.55%	0.50%	1.50%
TR11	0.20%	-0.01%	0.56%	-0.82%	0.20%	1.08%
TR12	-0.08%	-0.29%	0.11%	-0.94%	-0.08%	0.55%
TR13	-0.33%	-0.45%	-0.16%	-0.86%	-0.33%	0.11%
TR14	0.03%	-0.19%	0.29%	-0.91%	0.03%	0.79%
				National household		
TR1	-0.22%	-0.37%	0.03%	-0.97%	-0.22%	0.41%

TR2	0.12%	-0.01%	0.84%	-1.04%	0.12%	1.25%
TR3	0.17%	-0.02%	0.78%	-1.03%	0.17%	1.38%
TR4	-0.06%	-0.17%	0.19%	-0.72%	-0.06%	0.52%
TR5	0.28%	0.05%	0.47%	-0.73%	0.28%	1.15%
TR6	-0.04%	-0.25%	0.13%	-0.95%	-0.04%	0.80%
TR7	-0.02%	-0.17%	0.24%	-0.79%	-0.02%	0.63%
TR8	0.02%	-0.16%	0.23%	-0.76%	0.02%	0.67%
TR9	0.10%	-0.05%	0.37%	-0.79%	0.10%	0.89%
TR10	0.50%	0.25%	1.06%	-0.55%	0.50%	1.50%
TR11	0.19%	-0.01%	0.54%	-0.80%	0.19%	1.06%
TR12	-0.08%	-0.27%	0.10%	-0.90%	-0.08%	0.52%
TR13	-0.33%	-0.46%	-0.16%	-0.88%	-0.33%	0.11%
TR14	0.03%	-0.18%	0.29%	-0.88%	0.03%	0.77%

Source: Model simulations

Table 14: Regional (%?) in household consumption

Region	**A2_2050**	**A1b_2050**	**B1_2050**	**A2_10th percentile**	**A2_average**	**A2_90th percentile**
				Urban household		
TR1	-0.18	-0.34	0.10	-0.90	-0.18	0.53
TR2	0.13	0.06	0.60	-0.59	0.13	0.86
TR3	0.13	0.01	0.63	-0.76	0.13	1.07
TR4	-0.11	-0.18	0.25	-0.83	-0.11	0.64
TR5	0.42	0.21	0.55	-0.42	0.42	1.18
TR6	-0.07	-0.26	0.01	-0.78	-0.07	0.59
TR7	0.13	-0.07	0.51	-0.81	0.13	1.08
TR8	0.05	-0.18	0.27	-0.80	0.05	0.84
TR9	0.16	0.05	0.39	-0.54	0.16	0.87
TR10	0.42	0.23	0.88	-0.38	0.42	1.22
TR11	0.40	0.16	0.78	-0.65	0.40	1.33
TR12	0.00	-0.24	0.18	-0.89	0.00	0.70
TR13	-0.23	-0.36	-0.03	-0.78	-0.23	0.30
TR14	0.04	-0.19	0.30	-0.90	0.04	0.85
				Rural household		
TR1	-0.35	-0.53	-0.01	-1.21	-0.35	0.52
TR2	0.17	0.07	0.83	-0.85	0.17	1.20

TR3	0.19	0.04	0.90	-1.04	0.19	1.49
TR4	-0.12	-0.21	0.44	-1.15	-0.12	0.97
TR5	0.62	0.32	0.84	-0.55	0.62	1.80
TR6	-0.17	-0.42	-0.04	-1.13	-0.17	0.73
TR7	0.09	-0.11	0.36	-0.80	0.09	0.97
TR8	-0.05	-0.36	0.23	-1.18	-0.05	1.00
TR9	0.10	-0.04	0.44	-0.88	0.10	1.10
TR10	0.49	0.23	1.13	-0.62	0.49	1.59
TR11	0.58	0.25	1.17	-0.95	0.58	1.96
TR12	-0.15	-0.49	0.08	-1.38	-0.15	0.81
TR13	-0.48	-0.67	-0.16	-1.30	-0.48	0.33
TR14	-0.04	-0.37	0.34	-1.34	-0.04	1.07
				National household		
TR1	-0.20	-0.36	0.08	-0.94	-0.20	0.53
TR2	0.15	0.07	0.70	-0.70	0.15	1.01
TR3	0.16	0.03	0.75	-0.89	0.16	1.26
TR4	-0.11	-0.20	0.34	-0.98	-0.11	0.79
TR5	0.51	0.26	0.69	-0.48	0.51	1.47
TR6	-0.10	-0.31	-0.01	-0.88	-0.10	0.63
TR7	0.13	-0.07	0.51	-0.81	0.13	1.08
TR8	0.04	-0.20	0.27	-0.84	0.04	0.86
TR9	0.13	0.01	0.42	-0.71	0.13	0.98
TR10	0.45	0.23	1.01	-0.50	0.45	1.40
TR11	0.45	0.19	0.90	-0.74	0.45	1.52
TR12	-0.03	-0.29	0.16	-0.97	-0.03	0.72
TR13	-0.40	-0.56	-0.12	-1.12	-0.40	0.32
TR14	0.02	-0.24	0.31	-1.03	0.02	0.91

Source: Model simulations

Table 15: Impacts on agricultural crop production, livestock and food processing sectors (in % change from Base)

Sector	Activities	% Change					
		A2_2050	A1b_2050	B1_2050	A2_10th percentile	A2_average	A2_90th percentile
Crop production activities	HDWHT-A	-4.73%	-4.91%	-3.44%	-7.29%	-4.73%	-2.07%
Crop production activities	SFWHT-A	-5.11%	-5.29%	-3.68%	-7.83%	-5.11%	-2.22%
Crop production activities	BARLY-A	-0.22%	-0.30%	-0.03%	-0.70%	-0.22%	0.20%
Crop production activities	SGRCR-A	-0.36%	-0.44%	-0.17%	-0.86%	-0.36%	0.09%
Crop production activities	TOMAT-A	10.93%	8.83%	18.57%	-2.23%	10.93%	25.84%
Crop production activities	XVEGTS-A	7.31%	4.44%	11.32%	-4.17%	7.31%	18.96%
Crop production activities	XVGIN-A	-0.11%	-0.24%	0.08%	-0.74%	-0.11%	0.38%
Crop production activities	FORAGS-A	-0.18%	-0.26%	-0.03%	-0.65%	-0.18%	0.20%
Crop production activities	OLIVE-A	2.92%	1.22%	5.69%	-3.99%	2.92%	10.04%
Crop production activities	AGRMS-A	-8.83%	-10.98%	-4.82%	-18.95%	-8.83%	2.68%
Crop production activities	XFRUTS-A	-0.04%	-0.05%	0.03%	-0.16%	-0.04%	0.07%
Crop production activities	XCROPS-A	-0.18%	-0.33%	0.14%	-1.00%	-0.18%	0.60%
Livestock activities	BOVIN-A	-0.12%	-0.20%	0.02%	-0.55%	-0.12%	0.22%
Livestock activities	AVINE-A	-0.08%	-0.11%	-0.04%	-0.22%	-0.08%	0.04%
Livestock activities	OVINE-A	-0.40%	-0.49%	-0.17%	-1.01%	-0.40%	0.12%
Livestock activities	XMEAT-A	-0.27%	-0.33%	-0.10%	-0.68%	-0.27%	0.12%
Food processing activities	DAIRY-A	-0.26%	-0.25%	-0.31%	-0.24%	-0.26%	-0.31%
Food processing activities	SUGAR-A	-0.38%	-0.46%	-0.19%	-0.88%	-0.38%	0.07%
Food processing activities	MILHW-A	-1.70%	-1.82%	-1.09%	-2.95%	-1.70%	-0.42%
Food processing activities	MILSW-A	-2.61%	-2.76%	-1.79%	-4.24%	-2.61%	-0.89%
Food processing activities	OILPR-A	0.01%	-0.08%	0.07%	-0.33%	0.01%	0.30%
Food processing activities	OLVOL-A	2.70%	1.05%	5.31%	-3.92%	2.70%	9.42%
Food processing activities	OLVWH-A	3.04%	1.31%	5.57%	-3.33%	3.04%	10.08%
Food processing activities	XFDPR-A	-0.01%	-0.15%	0.21%	-0.74%	-0.01%	0.57%

Source: Model simulations