Moroccan agriculture, climate change, and the Moroccan Green Plan: A CGE analysis

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Abstract

This paper provides estimates of the economic impacts of climate change and estimates the adaptation potential of the current Moroccan agricultural development and investment strategy, the Moroccan Green Plan (MGP). We develop a regionalised Morocco Computable General Equilibrium model to analyse the linkages of climate-induced productivity losses (gains) at the level of administrative and economic regions in Morocco. We model the climate change impacts as productivity shocks in the agricultural sector. The yield projections are for 2050, which we introduce with respect to a 2003 baseline. The results indicate no major differences between the climate change impacts without and with the MGP. With no MGP adaptation, GDP impacts range from -3.1% to +0.4%. When including the MGP targets, GDP impacts range from -2.9% to +0.43%. A potential cause for such results is the limited scope in terms of agricultural sector coverage of our MGP simulations owing to modelling and data constraints.

Key words: CGE models; agricultural policy; adaptation; climate change; uncertainty

1. Introduction

In its Fifth Assessment Report (AR5), the Intergovernmental Panel on Climate Change (IPCC) states that the African continent is poised to be among the most vulnerable regions to climate change and climate variability. Recent findings suggest that the evidence for warming across the continent has increased based on decadal analyses of temperature trends in the last 50 to 100 years. Current projections indicate that mean annual temperature under the emission scenarios A1B and A2 could rise by > 2°C by the end of the 21st century relative to the 20th century. But under the newly developed emission scenarios in the IPCC Fifth Assessment Report (AR5) – namely the Representative Concentration Pathways (RCPs)[1] – the exceedance of the 2°C threshold could occur as early as mid-century and reach between 3°C and 6°C by the end of the century (IPCC 2013). These trends increasingly put pressure on climate-sensitive sectors such as agriculture.

Despite the gains registered in terms of agricultural productivity globally since the Green Revolution from the 1960s onwards, the regional distribution of the gains remains unequal and highly concentrated in developed countries, and more recently in emerging economies. In addition, a growing body of literature is providing evidence for a slowdown in productivity gains globally, especially for cereal crops, where there is no evidence of compound and/or exponential rates of yield

[1] For further details, refer to the IPCC Working Group I final report: http://www.climatechange2013.org/

increases (Grassini *et al*. 2013; Hall & Richards 2013; Ray *et al*. 2013). In Africa, the existing developmental challenges, such as endemic poverty, complex governance and institutional dimensions, as well as limited access to capital, infrastructure and technology, will tend to aggravate the potential negative impacts of climate change (IPCC 2007).

In this context, we developed a regionalised, comparative, static computable general equilibrium (CGE) model for Morocco. Our first objective was to analyse the regional impacts of climate change in Morocco via the agricultural sector. We captured the impact of climate change via a set of region-specific productivity shocks. We derived the latter from projected crop yield impacts under climate change in Morocco.[2] The second objective was the assessment of the adaptation potential of the Moroccan Green Plan (MGP), which is an investment strategy launched in 2009 with the aim of modernising the Moroccan agricultural sector (Agence pour le Développement Agricole [ADA] 2011). The paper is organised as follows: Section 2 discusses the literature on CGE analysis related to the economic impact assessment of climate change. In Section 3, we present a brief background to Moroccan agriculture. Section 4 summarises our methodological approach and data sources. Key findings and a discussion follow in Section 5. Last, we present concluding remarks and recommendations in Section 6.

2. Economic impact assessment of climate change: A literature review

The literature on the impact assessment of climate change is extensive and rich in terms of its methodological approaches. Three major approaches emerge from the literature: the biophysical modelling approach, the socio-economic modelling approach, and the integrated assessment modelling (IAM) approach (Feenstra *et al*. 1998). The choice of which approach to implement is usually driven by the research questions being investigated, but also by data availability. Given our choice of model, we limited our review of the literature to the socio-economic approach, with a focus on CGE models.

In the early 1990s, CGE models began to feature more prominently in the field of environmental policy and nature resource allocation. Owing to the scale of current environmental problems analysed and their wide economy linkages, CGE models are becoming an important tool for the analysis of welfare impact, and adaptation and/or mitigation policies (Hazilla & Kopp 1990; Burniaux *et al*. 1992). Within the climate change literature, the trend accelerated significantly following the adoption of the United Nations Framework Convention on Climate Change (UNFCC) in 1992 and the Kyoto Protocol in 1997. On the global level, CGE model-based applications span a wide range of issues, across different regional scales. For instance, the Global Trade Analysis Project (GTAP) database, and its variants of CGE models, have been used in many studies focusing on climate change linkages with land-use change (LUC), greenhouse gas (GHG) emissions, biofuels and bioenergy, and poverty (Birur *et al*. 2008; Tyner & Taheripour 2008; Golub *et al*. 2009; Hertel *et al*. 2010; Tyner 2010; Hussein *et al*. 2013; Taheripour & Tyner 2015). Additionally, single-country CGE models are increasingly used in studies of impact analysis, especially with the development of data on climate change at the country and/or sub-country level (Arndt *et al*. 2010, 2012a, 2012b; Thurlow *et al*. 2012; Çakmak & Dudu 2014; Dudu & Çakmak 2018).

[2] We used the crop yield impacts from a study by the World Bank (WB) and the Moroccan Ministry of Agriculture, Rural Development, and Fisheries (MPAM), and conducted the study in collaboration with the National Institute for Agricultural Research (INRA), the Food and Agriculture Organization (FAO) and the National Meteorology Authority (DMN). From this point forward, we will refer to it as the "WB/Morocco/FAO" study for ease of reference (Gommes *et al*. 2009).

3. Background on Moroccan agriculture and climate

3.1 Moroccan agriculture: A historical perspective

Cereals represent 60% of cultivable agricultural area in Morocco. The dominance of cereals, and especially wheat, is a direct result of colonial policies pursued by the French Protectorate authorities (Swearingen 1988). This fact remains true today, despite many attempts at reforms in the post-colonial period. In addition, most cereal production occurs under rainfed conditions. Hence, productivity is contingent upon precipitation levels, which induces a high level of volatility in agricultural value-added (Figure 1). As a result, gross domestic product (GDP) exhibits a similar pattern, owing to the strong linkages between the agricultural and non-agricultural sectors (Figure 2).

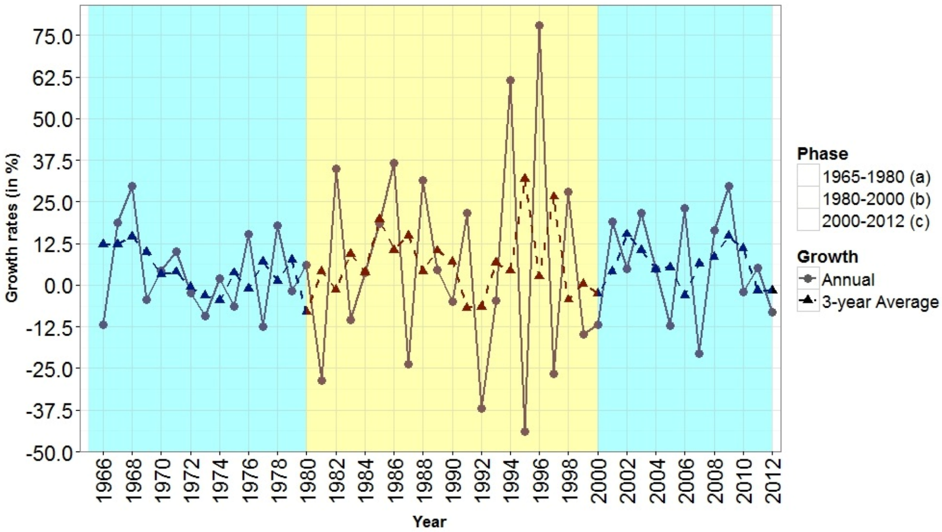

Figure 1: Evolution of agricultural value-added real growth rates (in %) from 1965 to 2012
Source of data: World Development Indicators (2013)

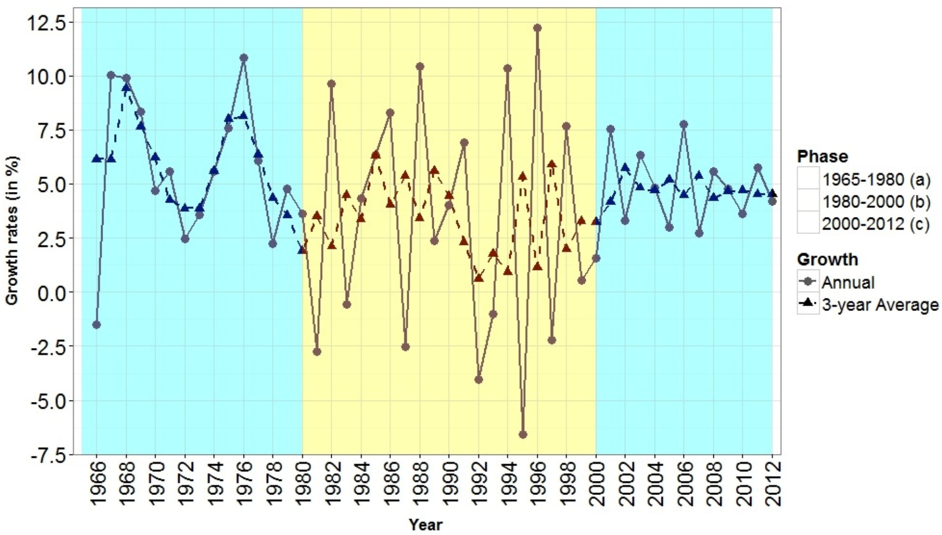

Figure 2: Evolution of gross domestic product (GDP) real growth rates (in %) from 1965 to 2012
Source of data: World Development Indicators (2013)

Between 1980 and 2000, agricultural value-added growth increased compared to the previous period. This was primarily driven by relatively favourable climatic conditions, but also due to the combined impact of the King's plan in 1985 to double areas cultivated to wheat, a sustained liberalisation effort, and the exoneration of agricultural revenues from income tax. Agricultural area expanded, with a substantial fall in the number of small-scale farmers. Based on the General Agricultural Census of 1996, arable area increased by 21%. In comparison with data from 1974, the number of landless farmers and farmers with < 1 ha decreased by 86% and 28% respectively (Doukkali 2006). As a result, average growth rates for the period reached 6.6% compared to 3.7% for the period 1965 to 1980, which represents an increase of 76%.

Nevertheless, the expansion of cereal production initiated under the King's plan resulted in increased volatility in cereal production. As wheat expanded onto the most favourable lands, other cereals were pushed to marginal lands (e.g. barley, maize, etc.). Therefore, agricultural value-added growth rates depicted increased volatility. For instance, the standard deviation and coefficient of variation increased by 167% and 52% respectively from 1965 to 1980 and from 1980 to 2000. Hence, the performance of gross domestic product (GDP) growth rates experienced an increase in volatility as well, with standard deviation and coefficient of variation exhibiting an increase of 69% and 184% respectively. Despite the increase in volatility, the level of growth in agricultural value-added from 1966 to 1980 and from 1980 to 2000 increased by 76% on average.

Starting with the 2000s, a reverse dynamic unfolds in which agricultural value-added growth experienced a slowdown. However, volatility measures improved, as captured by the decline in the standard deviation and coefficient of variation registered from 1980 to 2000 and from 2000 to 2012 (53% and 42% respectively). A similar trend unfolded for GDP, for which a reduction in volatility is observed, with a decline in standard deviation of 67% and in coefficient of variation of 77% from 1980 to 2000 and from 2000 to 2012.

3.2 Moroccan climate profile: Current and projected trends

The historical record of Morocco depicts a situation of increasing temperatures and diminishing precipitation, which can transform into severe droughts. Studies using tree-ring analysis in Morocco have shown that, from the 14th to the 20th century, the country suffered through 147 droughts (Chbouki *et al*. 1995; Esper *et al*. 2007). In recent decades, intense drought episodes have increased in frequency, especially from the 1980s onward (Stour & Agoumi 2008). The economic implications of such trends in the Moroccan climate can be devastating, especially for the agricultural sector. For instance, during the 1995 drought, aggregate agricultural output fell by 45%, with a 60% decline in rural employment, resulting in a loss of 100 million work days in agricultural employment (Shetty 2006; Ouassou *et al*. 2007).

Recent projections suggest a drier and hotter climate compared to the historical record (IPCC 2007, 2013). Average annual temperatures are expected to increase by 1.1°C to 3.5°C by the 2060s and by 1.4°C to 5.6°C by the 2090s. Despite the variability observed in climate models, it remains true that the increasing trend in temperatures is robust. In terms of precipitation, simulations from climate models exhibit a pattern of decreasing rainfall. Deviations with respect to the historical baseline range from an increase of 10% to a maximum decline of 52%, with a median range of -15% to -29% (Figure 3).

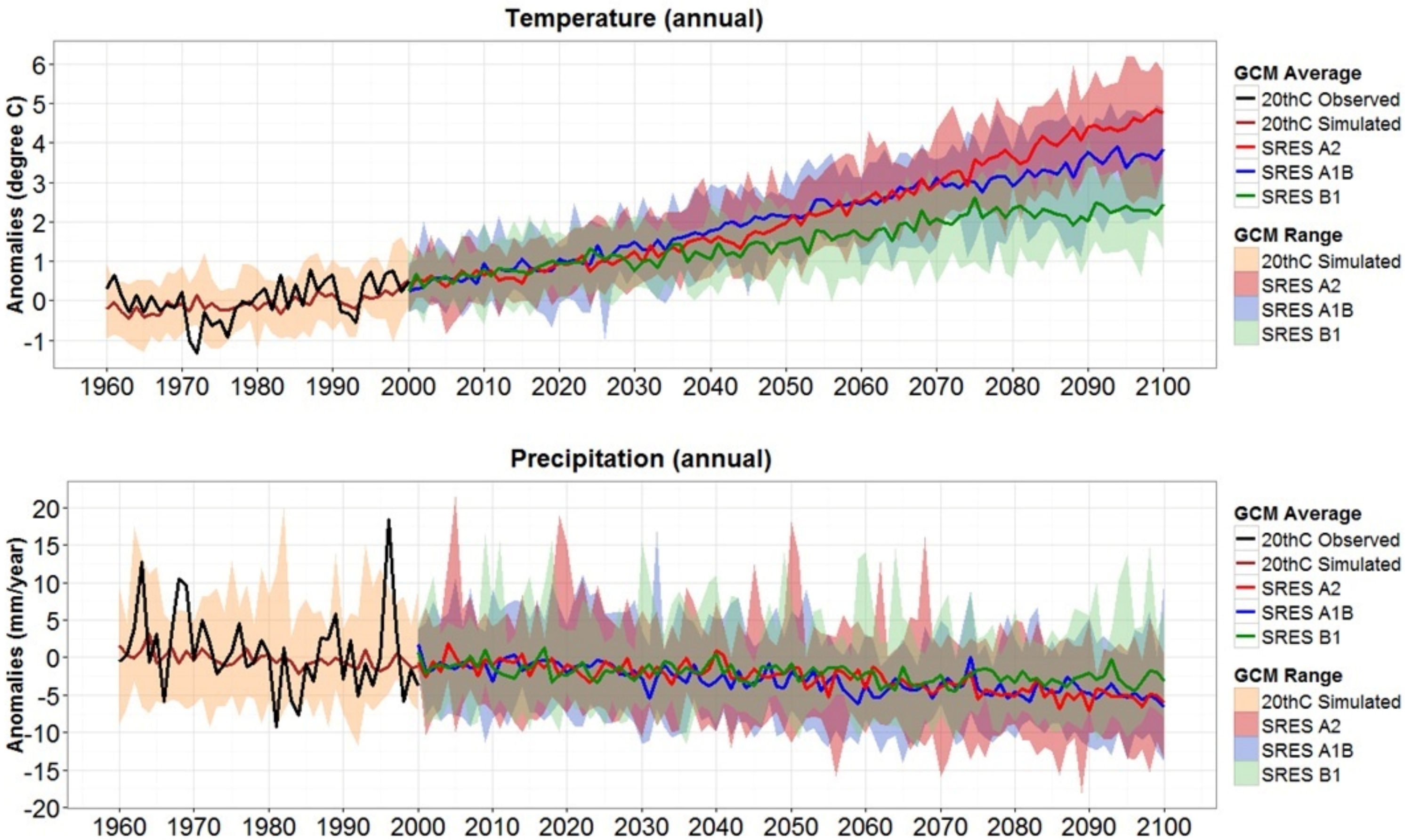

Figure 3: Evolution of observed and simulated projected average annual temperatures and precipitation by Special Report on Emissions Scenario (SRED)[3] scenario for Morocco[4]
Source: Author's adaptation from McSweeney *et al*. (2006)

[3] For further information on the IPCC's SRES scenarios, please refer to https://ipcc.ch/pdf/special-reports/spm/sres-en.pdf
[4] Note: Indicated values are anomalies with respect to the mean for 1970 to 1999

4. Methods, data and scenarios

4.1 Morocco CGE model

The analysis used a regionalised comparative static CGE model for Morocco. The model development followed the IFPRI CGE modelling framework (Löfgren *et al*. 2002) and the Turkish regional CGE model developed by Dudu and Çakmak (2018). The regionalisation is based on the administrative and economic regional disaggregation of Morocco (Figure 4).

Figure 4: Administrative and economic regions of Morocco
Source: Authors' construction

The data used in the model is based on a national social accounting matrix (SAM) for 2003 developed by Rachid Doukkali of IAV/Hassan II in Rabat, Morocco, and the modified version by Dominique Van der Mensbrugghe.[5] Given the regional dimension of the model, the SAM accounts have been aggregated in order to keep the analysis tractable (Ouraich 2015).

In order to regionalise the data in the SAM, we used official statistics on regional production and household surveys obtained from many sources, mainly the Ministry of Agriculture and Fisheries, the Agency for Agricultural Development, the Ministry of Economy and Finance, the Ministry of Industry, and the Haut Commissariat au Plan. Ouraich and Tyner (2014) and Ouraich (2015) provide a detailed discussion of the regionalisation assumptions and procedure followed.

Production is modelled under the assumption of profit maximisation subject to a production technology (Figure 5). The profit-maximising decision process assumed for each activity implies that factors are used up to the point where the marginal revenue product of each factor is equal to its wage (or factor price). In the model, an economy-wide 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.

[5] Dominique van der Mensbrugghe is research professor and director of the Center for Global Trade Analysis (GTAP) at Purdue University. Prior to joining Purdue, he worked at a trio of international agencies – senior economist and team leader of the Global Perspectives Studies Team at the Food and Agriculture Organization of the United Nations (FAO), lead economist in the Development Prospects Group at the World Bank, and senior economist at the Organisation for Economic Co-operation and Development (OECD).

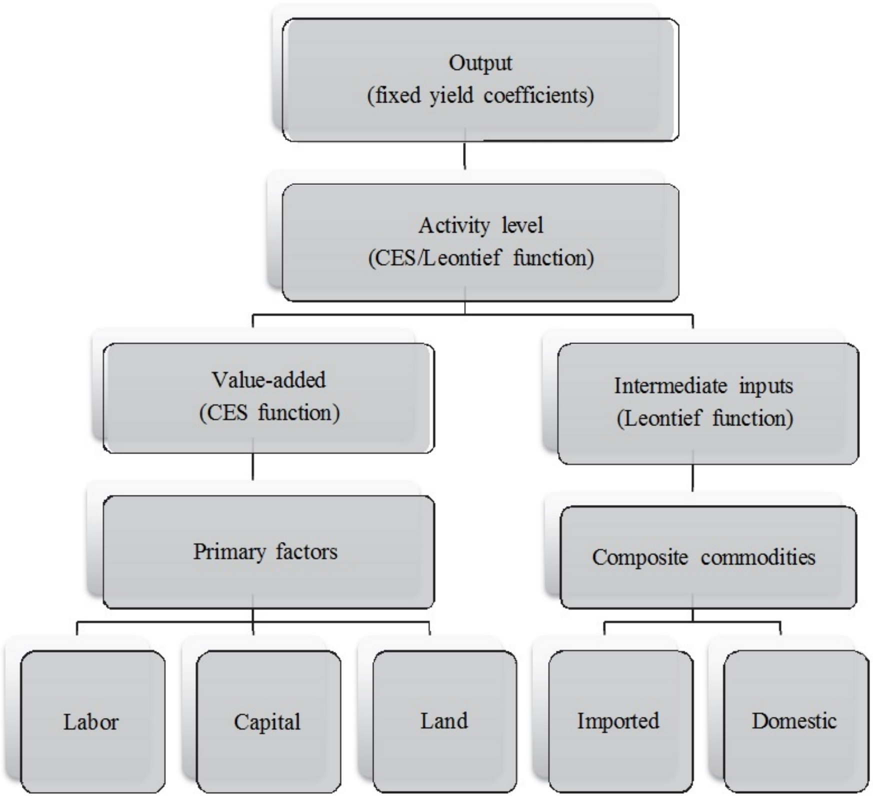

Figure 5: Production technology
Source: Authors' adaptation based on Löfgren *et al*. (2002).

Household consumption is modelled via a linear expenditure system (LES), which results from the household's utility maximisation 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 producer prices. A regional household, which includes two household categories, represents each region: rural and urban. The government collects taxes (fixed at ad valorem rates) and receives transfers from other institutions, which constitute its revenue. Government consumption expenditures are assumed to be fixed in real terms.

The calibration of the model parameters, particularly elasticities, is based on a survey of the literature. For household expenditure elasticities, we obtained estimates from a study by the Ministère de la Prévision Économique et du Plan ([MPEP] 2002). For the remaining elasticities (i.e. for the CES/CET production and transformation functions, the Armington elasticities), estimates were obtained from Löfgren *et al*. (1999).

4.2 Scenario analysis

The analysis adopted a multi-scenario framework with the objective of capturing the uncertainty underlying the yield impacts of climate change on crop production. This was achieved on two levels: first, by modelling the impact under different climate scenarios, SRES A2 and B2; and second, by using the percentile distribution of yield impacts within each climate scenario as given by the WB/Morocco/FAO study.

4.3 Yield projections under climate change

4.3.1 Data sources

Yield estimates were obtained from the WB/Morocco/FAO study (see Section 1) (Gommes *et al.* 2009; Ouraich 2015). Table 1 (in the Appendix) summarises the moment distribution of the projected impacts of climate change for Morocco for temperature and precipitation by 2050 in absolute and percentage change.

4.3.2 Yield projections: A descriptive analysis

At the national level, the projected yields depict variation across crops and climate scenarios. If we consider the median of climate change impacts on yield, we can divide the crops into two categories: negative yield impacts and positive yield impacts. The main difference between the two categories lies in the fact that crops affected negatively by climate change are grown under rainfed conditions, whereas crops in the second category are produced under irrigated conditions. The first category includes wheat (durum and common), barley, olives, forage crops, other fruits and other crops that are negatively affected by climate change under both scenarios. The second category consists of tomatoes, citrus, other vegetables and other industrial vegetables, for which yields are projected to increase on average (Figure 6).

Crop production in Morocco is regionally diverse owing to different climates and land-crop tenure. On average, climate change affects agricultural productivity negatively in all regions. However, the magnitude of the impacts differs regionally. For instance, regions located within the most favourable agro-ecological zones are expected to be the biggest losers from climate change. Average productivity losses across all crops in Chaouia-Ouardigha [4], Marrakech-Tensift-ElHaouz [5], Rabat-Sale-Zemmour-Zaer [8], Meknes-Tafilalet [11], Fes-Boulemane [12], and Taza-Taounate-Al Hoceima [13] are in excess of 10% under SRES scenario A2 without CO_2 fertilisation effect. These regions represent the breadbasket of Morocco, with 57% of total cereals production. Under the B2 scenario, only four out of above six regions display productivity losses in excess of 10% (Figures 7 and 8 in Appendix).

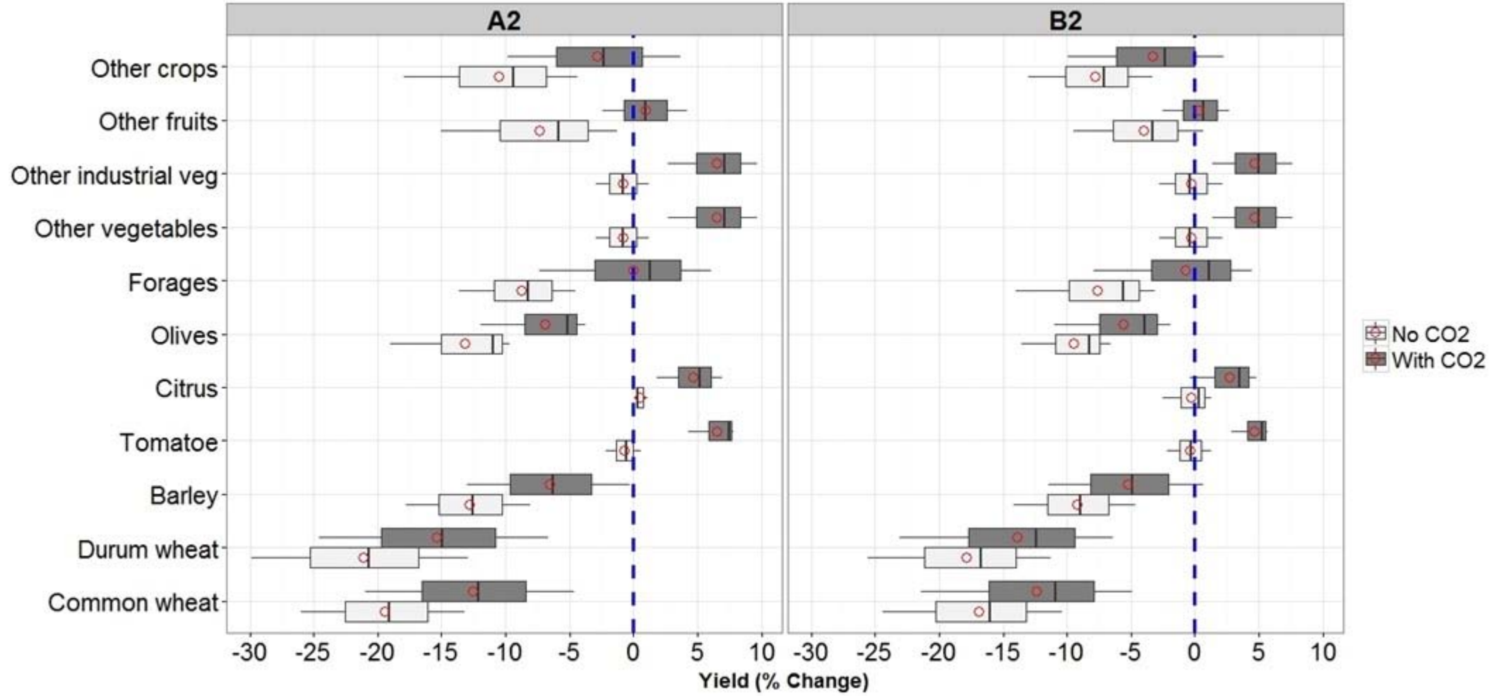

Figure 6: Projected yield impacts by 2050 at the national level for SRES A2 and B2 with and without CO_2 fertilisation effects
Source: Authors' adaptation based on the study of WB/Morocco/FAO (Gommes *et al*. 2009)

4.4 The Moroccan Green Plan (MGP)

By 2020, the Moroccan Green Plan (MGP) aims to increase the agricultural GDP from 38 billion to ~100 billion Moroccan dirhams, add 1.5 million jobs, increase exports from 1.35 to 4.6 million tons/year, increase area equipped with localised irrigation from 154 to 692 thousands hectares, and double or triple agricultural revenues. To achieve such objectives, the MGP is articulated around two pillars: Pillar I targets high value-added crop varieties (e.g. fruit and vegetables) with the aim to transform production modes to industrial-scale farming. The rationale is to increase the size of farms in order to benefit from economies of scale and facilitate access to finance. Ouraich (2015) offers a more detailed discussion of the MGP projects and their regional and sectoral targets for the selected crops of interest. Table 2 summarises the projected estimates of productivity gains under the MGP by crop and by region.

Table 2: Projected impacts on crop yields under the Moroccan Green Plan (MGP) for strategic crops by region by 2020

Regions	MGP - Crop sectors targeted			
	Cereals	Vegetables	Olives	Citrus
Souss-Massa-Draa [2]	n.a.	47%	59%	33%
Gharb-Cherarda-Bni Hsan [3]	73%	n.a.	63%	67%
Chaouia-Ouardigha [4]	69%	68%	91%	n.a.
Marrakech-Tensift-El Haouz [5]	52%	n.a.	80%	30%
L'Oriental [6]	n.a.	n.a.	26%	96%
Grand Casablanca [7]	86%	80%	n.a.	n.a.
Rabat-Sale-Zemmour-Zaer [8]	87%	68%	83%	n.a.
Doukkala-Abda [9]	93%	62%	n.a.	n.a.
Tadla-Azilal [10]	38%	n.a.	79%	50%
Meknes-Tafilalet [11]	80%	n.a.	78%	n.a.
Fes-Boulemane [12]	93%	57%	92%	n.a.
Taza-Taounate-Al Hoceima [13]	85%	n.a.	44%	77%
Tanger-Tetouan [14]	n.a.	n.a.	53%	79%

Source: Author's adaptation from ADA (2014)
Note: n.a. = not available

In order to investigate the impact of climate change and the adaptation potential of the MGP, we adopt a scenario-based structure in the analysis. First, we introduce the climate change shocks to the model as productivity shocks. This step will be referred to as climate change without MGP adaptation ("CC-Only"). This step allows us to assess the implications of climate change on the agricultural sector and the economy in the absence of adaptation measures. Second, we introduce the MGP shocks as specified in Table 2. We proceed by introducing the MGP shocks on the initial baseline of the Moroccan economy as captured by the 2003 SAM. This step allows us to simulate a new economic equilibrium for the Moroccan economy inclusive of the MGP targets. Subsequently, we introduce the climate change shocks taking the new economic equilibrium as our new baseline. In effect, we are simulating the impacts of climate change in a state of nature for the Moroccan economy that assumes the MGP targets have been achieved. Hence, we will refer to this scenario as climate change with MGP adaptation ("CC-MGP"). We therefore will contrast the two states of nature, namely "CC-Only" and "CC-MGP", to infer the adaptation potential of MGP (Figure 9).

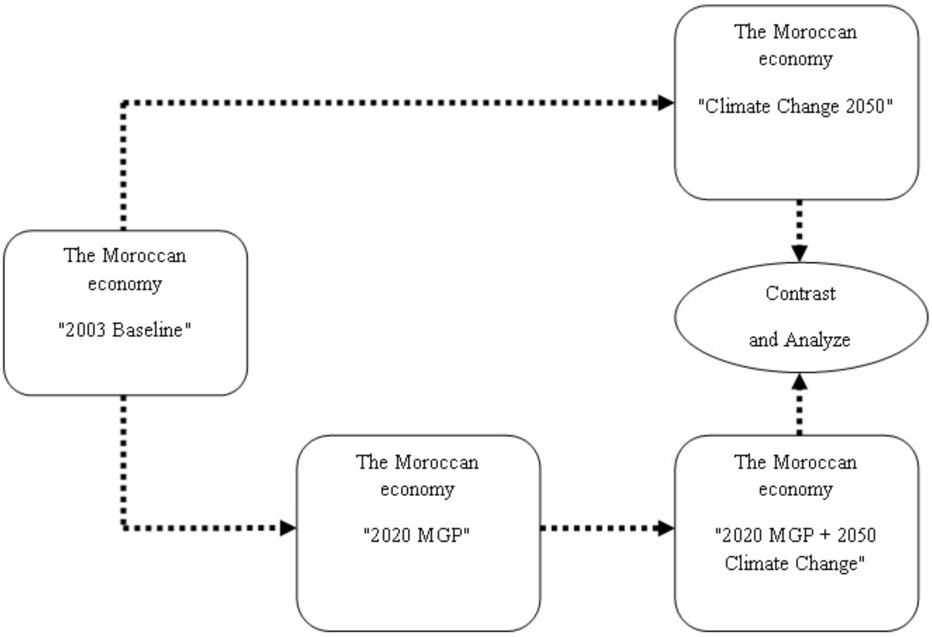

Figure 9: Schematic of the structure of the analysis

Table 3 summarises the scenarios identified for the analysis.

Table 3: Description of scenario analysis

	Scenario	Label	Description
CC-Only	Sc. 1	A2_noCO_2	Projected yield impacts by 2050 under SRES A2, with no CO_2 fertilisation effect and no adaptation
	Sc. 2	B2_noCO_2	Projected yield impacts by 2050 under SRES B2, with no CO_2 fertilisation effect and no adaptation
	Sc. 3	A2_wCO_2	Projected yield impacts by 2050 under SRES A2, with CO_2 fertilisation effect and no adaptation
	Sc. 4	B2_wCO_2	Projected yield impacts by 2050 under SRES B2, with CO_2 fertilisation effect and no adaptation
CC-MGP	Sc. 5	A2_noCO_2_MGP	Projected yield impacts by 2050 under SRES A2, with no CO_2 fertilisation effect and with MGP adaptation
	Sc. 6	B2_noCO_2_MGP	Projected yield impacts by 2050 under SRES B2, with no CO_2 fertilisation effect and with MGP adaptation
	Sc. 7	A2_wCO_2_MGP	Projected yield impacts by 2050 under SRES A2, with CO_2 fertilisation effect and with MGP adaptation
	Sc. 8	B2_wCO_2_MGP	Projected yield impacts by 2050 under SRES B2, with CO_2 fertilisation effect and with MGP adaptation

Source: Authors' construction

5. Results and discussion

5.1 Macroeconomic impacts

Table 4 summarises the macroeconomic impacts of climate change without the MGP (CC-Only) and with the MGP (CC-MGP). The results include the average across the percentile distribution ("Ave"), and the range of impacts captured by the maximum and the minimum.[6] Since we start from an updated baseline under the CC-MGP case, the "BASE" column displays larger levels owing to the impact of the implementation of the MGP strategy.

[6] The maximum ("Low") boundary point in terms of climate change impacts represents the case where agricultural productivity is assumed to be at its lowest, and vice versa for the minimum ("High") boundary point.

The results suggest that climate change can have a large, negative effect on the economy. Under the CC-Only case, GDP impacts vary between -1% to -2% across the two SRES climate scenarios, A2 and B2. The rest of the macroeconomic variables display a similar trend, with private consumption and investment declining by -2% to -3% on average. For the rest of GDP components, the magnitudes are smaller with government and imports declining by -1 to -2%. For exports, a slight increase is observed, varying from +0.6% to +0.8%.

With respect to the uncertainty of climate impacts, the percentile distribution depicts a relatively wide range, which varies for GDP from -3% to +0.4% across climate scenarios. Private consumption and investment exhibit the largest variation. Indeed, the impacts of climate change on consumption vary from -4.5% to -1%, whereas investment varies from -4.3% to -1% across both climate scenarios. For government and imports, impacts vary by -3% to -0.6% and -3.3% to -0.8% respectively. The exception is exports, for which a positive impact is exhibited, but with no significant variation. The magnitude of the reported increase varies from +0.4% to +1% across scenarios. Under the CC-MGP case, i.e. climate change with the MGP, macroeconomic impacts are marginally lower in magnitude than for the CC-Only case for GDP. For instance, the net effect of the MGP on GDP is slightly positive and varies on average between +0.02% and +0.03% across climate scenarios when comparing the CC-Only and CC-MGP cases (Table 4).

Overall, the macroeconomic impacts of climate change without the MGP strategy (CC-Only) do not differ in a major way from the impacts with the MGP strategy (CC-MGP). A potential cause for such results is the limited scope in terms of agricultural sector coverage of the MGP simulations. As discussed previously, MGP simulations are limited to the strategic agricultural crop sectors in Morocco, which include durum and common wheat, tomatoes, citrus and olives. Jointly, these sectors represent no more than 35% of aggregate agricultural GDP, whereas the rest of the sectors account for 65% (Table 5). Hence, the productivity targets of the MGP affect only one third of Moroccan agriculture, whereas climate change effects span the entire agricultural crop sectors.

Table 4: Macroeconomic impacts of climate change – Without and with the MGP strategy by 2050 (in % change from BASE)

		Climate change impacts (in % Change from BASE)											
		Without CO_2 fertilisation						With CO_2 fertilisation					
	BASE[a]	A2			B2			A2			B2		
		Ave	Low	High	Ave	Low	High	Ave	Low	High	Ave	Low	High
CC-Only													
— Consumption - C	272 986	-2.82	-4.48	-1.45	-2.06	-3.45	-0.89	-0.85	-2.26	0.38	-0.83	-2.19	0.29
— Investment - I	133 622	-2.82	-4.43	-1.51	-1.99	-3.22	-0.95	-1.17	-2.34	-0.14	-1.01	-2.13	-0.08
— Government - G	85 485	-1.69	-2.63	-0.92	-1.22	-1.97	-0.60	-0.76	-1.48	-0.13	-0.66	-1.34	-0.08
— Exports - X	139 736	0.84	1.23	0.54	0.64	0.84	0.49	1.02	1.14	0.88	0.78	0.89	0.67
— Imports - M	-153 254	-1.84	-2.79	-1.06	-1.29	-2.13	-0.60	-0.62	-1.38	0.01	-0.51	-1.24	0.08
— Gross domestic product (GDP)	478 574	-1.86	-3.01	-0.91	-1.35	-2.29	-0.54	-0.45	-1.43	0.41	-0.48	-1.42	0.30
CC-MGP													
— Consumption - C	281 920	-2.86	-4.53	-1.48	-2.10	-3.51	-0.92	-0.93	-2.34	0.30	-0.90	-2.25	0.21
— Investment – I	136 852	-2.76	-4.35	-1.49	-1.94	-3.14	-0.93	-1.16	-2.27	-0.19	-0.99	-2.05	-0.12
— Government - G	86 462	-1.76	-2.72	-0.97	-1.28	-2.05	-0.64	-0.85	-1.57	-0.21	-0.73	-1.43	-0.15
— Exports - X	14 ,075	0.63	0.87	0.45	0.45	0.50	0.43	1.06	0.99	1.10	0.77	0.69	0.82
— Imports - M	-156 457	-2.21	-3.32	-1.29	-1.61	-2.61	-0.78	-0.88	-1.80	-0.11	-0.76	-1.64	-0.05
— Gross domestic product (GDP)	489 853	-1.83	-2.98	-0.89	-1.33	-2.27	-0.52	-0.42	-1.39	0.43	-0.46	-1.39	0.31

[a]: BASE values are in 2003 million Moroccan dirhams
Source: Results of simulation

Table 5: Agricultural Gross Domestic product (GDP) by Crop Sector (in 2003 million Moroccan dirhams)

Category	Sector	Value	Share (in %)	Total share (in %)
MGP crops	Durum wheat (HDWHT-A)	4 414	8%	35%
	Common wheat (SFWHT-A)	8 005	15%	
	Tomatoes (TOMAT-A)	1 859	4%	
	Citrus (AGRMS-A)	2 225	4%	
	Olives (OLIVE-A)	1 828	4%	
Non-MGP crops	Barly (BARLY-A)	4 558	9%	65%
	Forage crops (FORAGS-A)	2 795	5%	
	Other vegetables (XVEGTS-A)	7 963	15%	
	Other industrial veg (XVGIN-A)	160	0%	
	Other fruits (XFRUTS-A)	10 993	21%	
	Other crops (XCROPS-A)	7 248	14%	
Total		52 047	100%	

Source: Authors' adaptation

5.2 Impacts on household income and expenditure

The impacts on the income of rural and urban households appear to be similar across scenarios and regions. The similarity of results between rural and urban households is driven primarily by the manner in which the preferences of households are modelled. Despite using data on income elasticities identified by household type, it remains true that the 2003 SAM data on factor payments to households assume the same proportions across household types. This is a limitation that can be improved upon by assuming a different household typology, along the lines of income sources (e.g. agricultural households vs. non-agricultural households) and/or level of skills (unskilled vs. skilled).

Nevertheless, some regions depict a significant change in terms of household incomes when comparing the results of without CO_2 and with CO_2 fertilisation. For instance, impacts on incomes switch from negative under the without CO_2 case to positive under the with CO_2 case in the regions of Souss-Massa-Draa [2], Gharb-Cherarda-Bni Hsan [3] and Tadla-Azilal [10]. These regions represent the leading agricultural production regions in Morocco, and specialise – especially in the case of the Souss-Massa-Draa [2] – in the intensive agricultural production of vegetables and fruit. As discussed previously, the structure of production in these regions is dominated by crop sectors that are projected to benefit from climate change. Hence, it is not surprising that we observe positive effects on households' income.

To investigate the impacts of the MGP strategy on incomes, we compared the CC-Only and CC-MGP cases. The effect of climate change on incomes remains negative even after accounting for the MGP strategy. Nevertheless, the final net effects are slightly positive, which suggests that the MGP induces a partial alleviation in income losses. Net impacts on incomes vary from -0.2% to +0.7% for rural households, and similarly for urban households across regions (Figure 10 in the Appendix). Despite similar impacts on rural and urban incomes due to climate change, there exists a substantial differential in terms of other welfare measures, such as real consumption expenditures (Figure 11 in the Appendix). In general, real consumption expenditures for rural households tend to vary more across regions compared to urban households.

5.3 Sectoral impacts

The impacts on crop production value-added range from -3% to -14% across climate scenarios in the without CO_2 fertilisation case. When we include the CO_2 fertilisation, the impacts range from -7% to +3%. For livestock, the magnitude of impacts is smaller, ranging from -1% to -5% without CO_2 fertilisation, and from -3% to +1% with CO_2 fertilisation. The impacts on food processing value-added are similar, as they range from -1% to -6% without CO_2 fertilisation and from -3% to +1%

with CO_2 fertilization. The impacts for the rest of the sectors are not large, but remain negative (Figure 12).

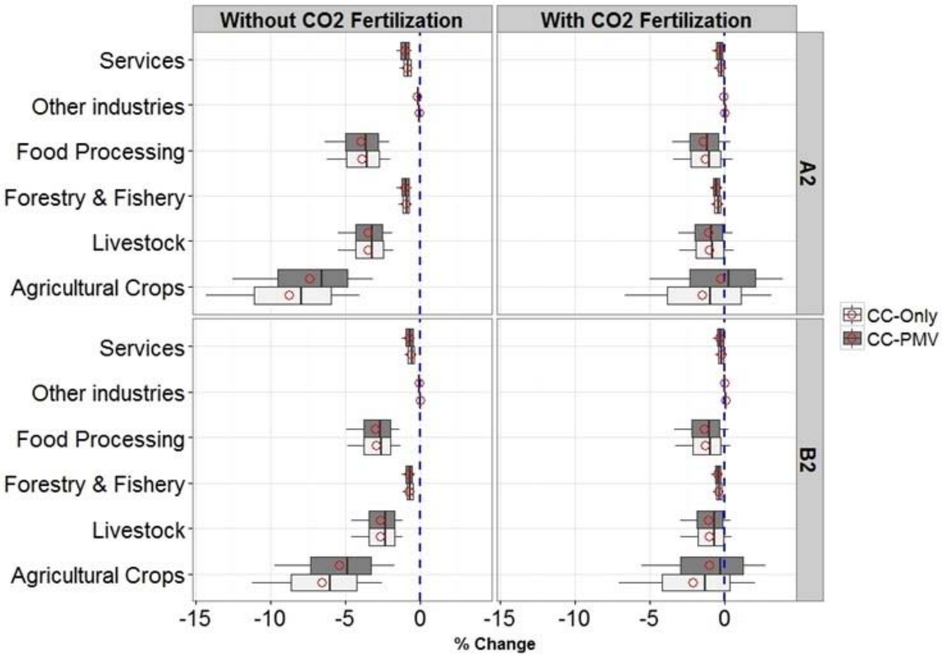

Figure 12: Percentile distribution of climate change impacts on sectoral value-added – With and without the MGP strategy by 2050 (% change from BASE)
Source: Results of simulation

The MGP strategy induces some gains in terms of mitigating the impact of climate change on climate-sensitive sectors. For instance, the net impacts associated with the MGP on crop production value-added vary from +1% to +2% across climate scenarios. For the remaining sectors, the net impacts of the MGP are marginally negative (Figure 13).

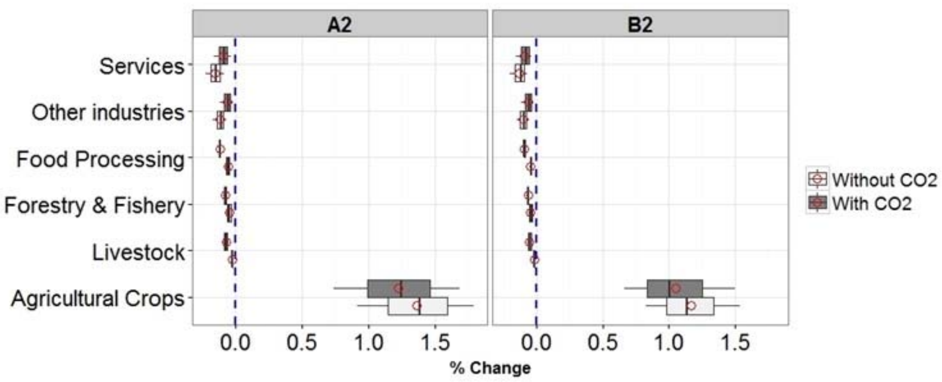

Figure 13: Percentile distribution of net impacts of the MGP strategy on sectoral value-added by 2050 (% change from BASE)
Source: Results of simulation

6. Conclusions

In this paper, we have explored the economy-wide impacts of climate change under different climate-driven agricultural productivity scenarios for Morocco. We developed a regionalised country-based CGE model. When we compare the CC-Only and CC-MGP cases at the macroeconomic level, the MGP induces very small net gains. The net impacts of MGP on GDP vary from +0.02% to +0.04% across climate scenarios. At the sectoral level, agricultural crop value-added exhibits the largest net gains, ranging from +0.7% to +2% across climate scenarios. For the food-processing sectors, the net impacts associated with the MGP range from -0.04% to -0.12%. The remaining sectors exhibit marginal net losses, ranging from -0.01% to -0.2% across climate scenarios. In addition, the MGP induces marginal gains in terms of household income owing to the positive impacts on agriculture, which enhance returns to factor of production. Nevertheless, the income gains do not translate into welfare gains, as they remain limited in magnitude.

Overall, the potential of the MGP strategy to mitigate the climate change impacts seems quite limited. The main cause of the previous results remains the limited scope of the agricultural crop sectors modeled in the analysis owing to data limitations. In the present study, we focused explicitly on the strategic crop sectors for which data availability was most accurate. However, it is worth mentioning that, in addition to the majority of the crop sectors, the MGP strategy targets the livestock sector as well. Owing to data limitations and the specificity of the climate impacts modeled, which covered only the crop sectors, the latter were not included explicitly in the analysis. The very limited scope of the sectoral coverage planned in the MGP targets only a third of total agricultural production, whereas the negative effects of climate change affect all crop sectors. Furthermore, it is likely that the MGP targets are unrealistic and cannot be achieved. In an attempt to evaluate the feasibility of reaching the productivity targets under the GMP, we performed a benchmark comparison using data on corn yield in the United States prior to and after the introduction of genetically modified organism (GMO) corn. The choice of corn is deliberate, as it represents the most researched crop in the field of GMO crops. GMO corn was first introduced in 1996. Hence, we provide a historical analysis of corn crop yields from 1996 to 2014. The results depict a yield gain of 35% between 1996 and 2014 (Figure 14 in the Appendix). By comparison, the productivity targets assumed under the MGP suggest an increase in average cereals yields by 76% by the end of the implementation period in 2020. We conclude that the likelihood of achieving such an evolution in yields based on the policy prescription of the MGP is low.

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APPENDICES

Table 1: Percentile distribution of climate change impacts on precipitation and temperature by 2050[a]

		Anomalies		Percentage	
		Precipitation (in mm)	**Temperature (in ˚C)**	**Precipitation (in mm)**	**Temperature (in ˚C)**
SRES A2	min	-11.43	0.82	-56.90	4.80
	25th	-5.95	1.75	-37.48	9.45
	median	-1.42	1.97	-12.70	11.20
	75th	2.35	2.25	16.18	12.15
	max	18.05	2.61	86.00	15.00
	HadCM3	**-11.43**	**1.92**	**-52.00**	**10.80**
SRES A1B	min	-7.01	1.05	-47.50	6.30
	25th	-4.45	1.80	-34.13	10.00
	median	-1.91	2.12	-10.50	11.30
	75th	0.07	2.73	1.28	15.20
	max	6.33	3.30	43.70	19.40
	HadCM3	**2.26**	**2.81**	**10.30**	**15.80**
SRES B1	min	-9.17	0.60	-41.30	3.60
	25th	-3.49	1.40	-25.98	7.23
	median	-0.81	1.45	-5.20	8.70
	75th	0.43	2.00	2.40	10.63
	max	7.61	2.50	36.20	14.30
	HadCM3	**1.13**	**1.20**	**5.10**	**6.70**

Source: Authors' construction using data from the UNDP climate change country profile for Morocco (McSweeney *et al*. 2006)
[a]: Indicated values are anomalies and percentage change with respect to the mean of 1970 to 1999

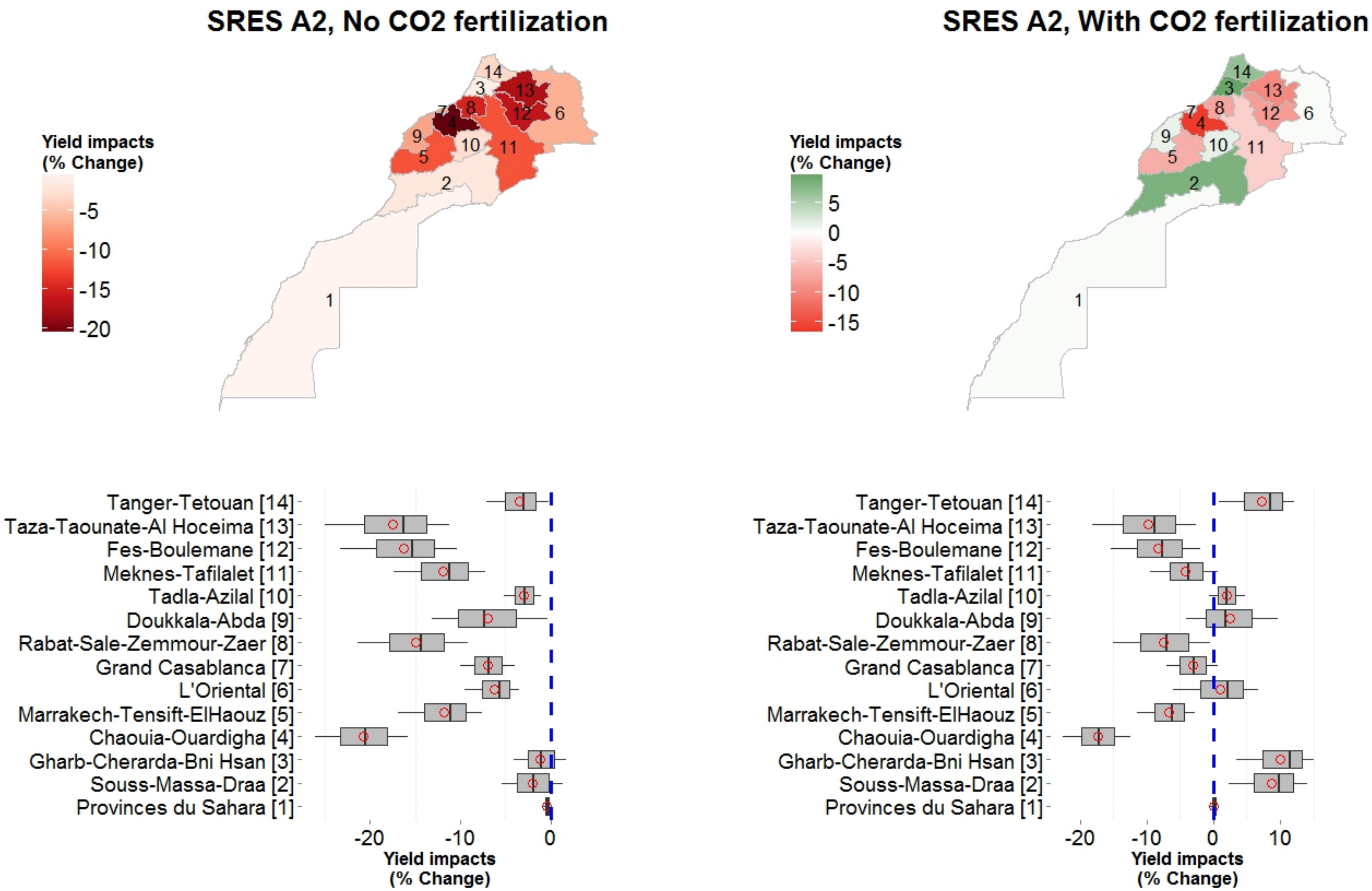

Figure 7: Distribution of average projected yield impacts by 2050 across crops under the SRES A2 by region
Source: Authors' adaptation based on the WB/Morocco/FAO study (Gommes *et al*. 2009)

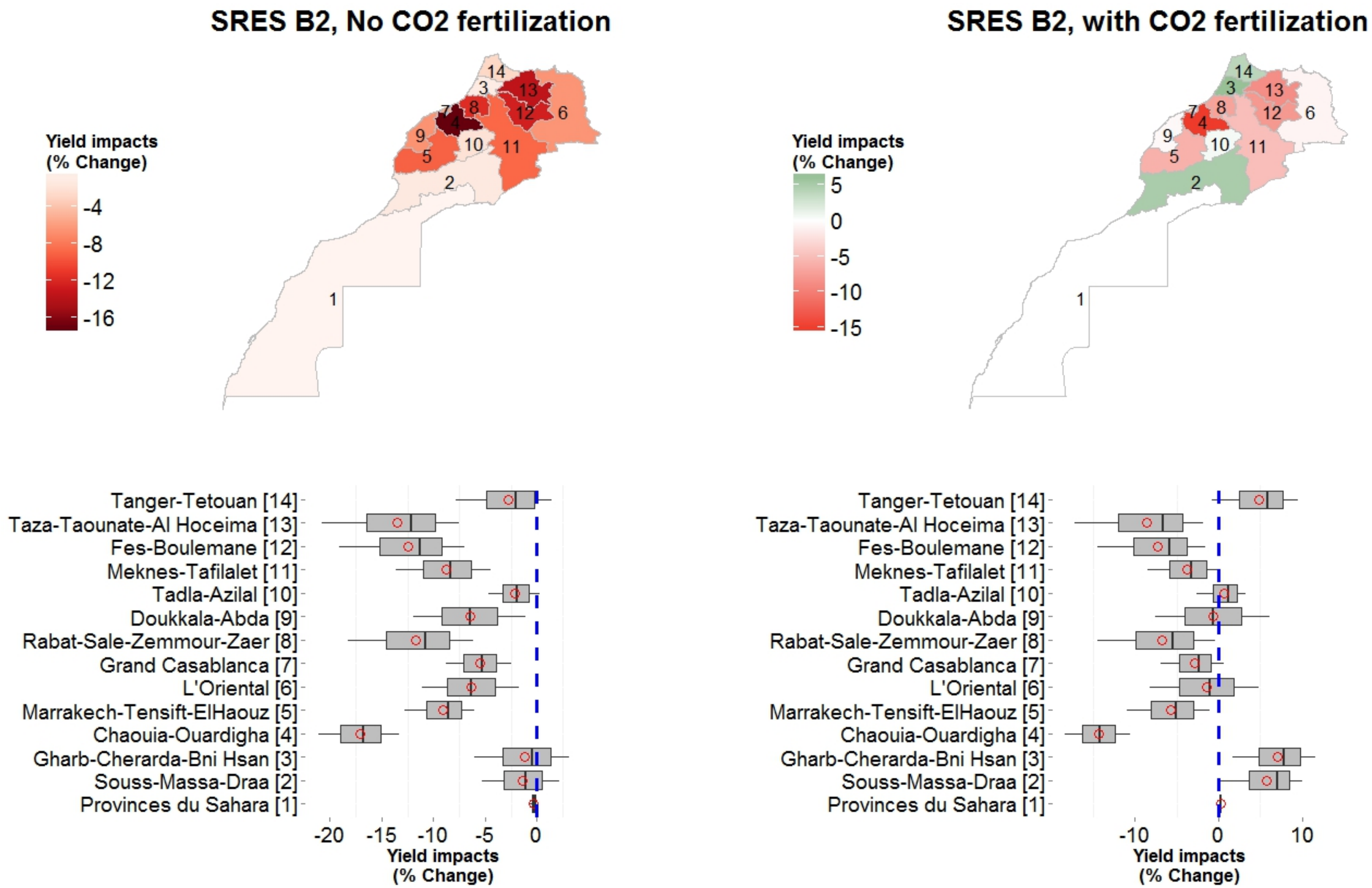

Figure 8: Distribution of average projected yield impacts by 2050 across crops under the SRES B2 by region
Source: Authors' adaptation based on the WB/Morocco/FAO study (Gommes *et al*. 2009)

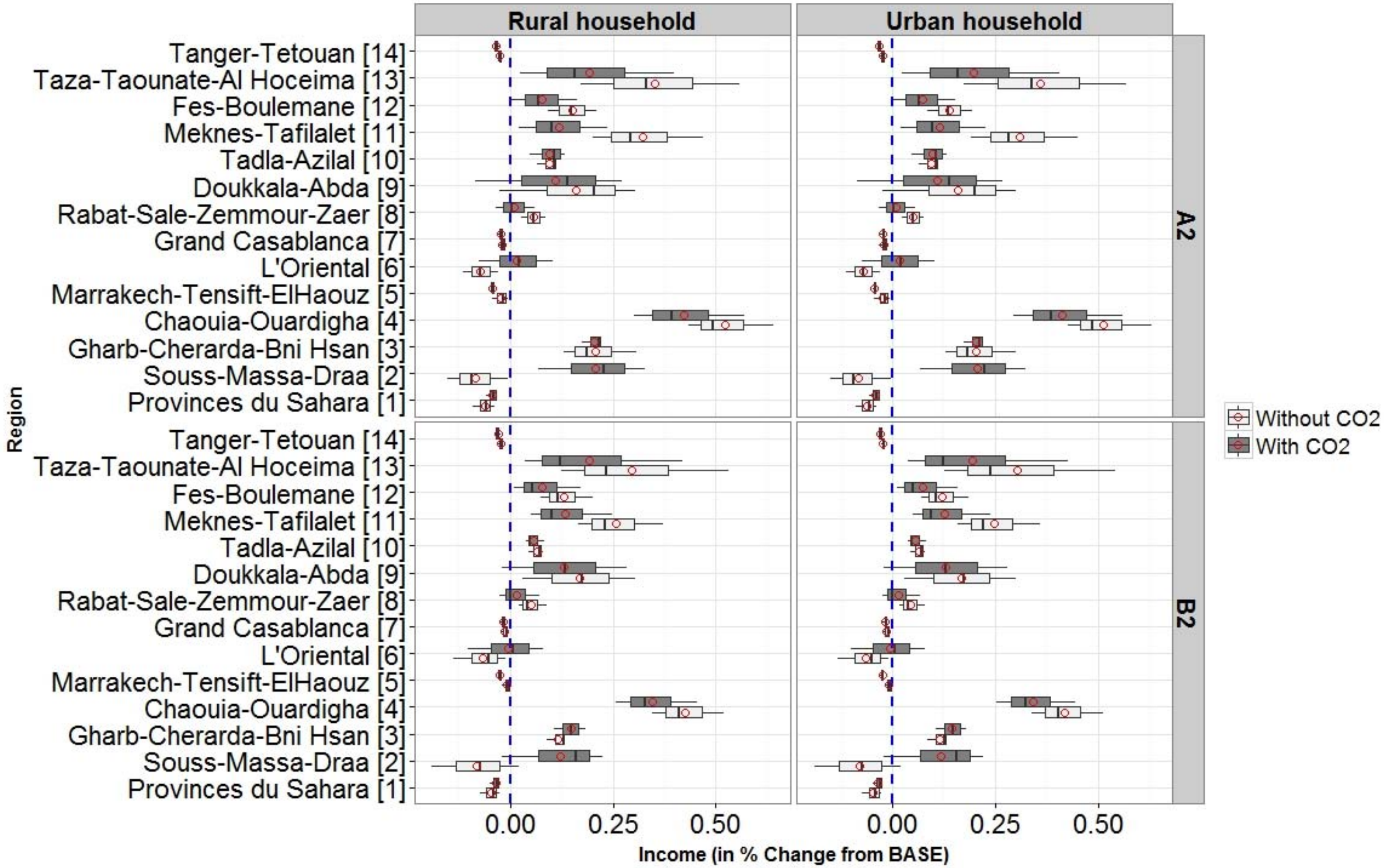

Figure 10: Distribution of net impacts of the MGP strategy on the incomes of rural and urban households by 2050 (% change from BASE)
Source: Result of simulation

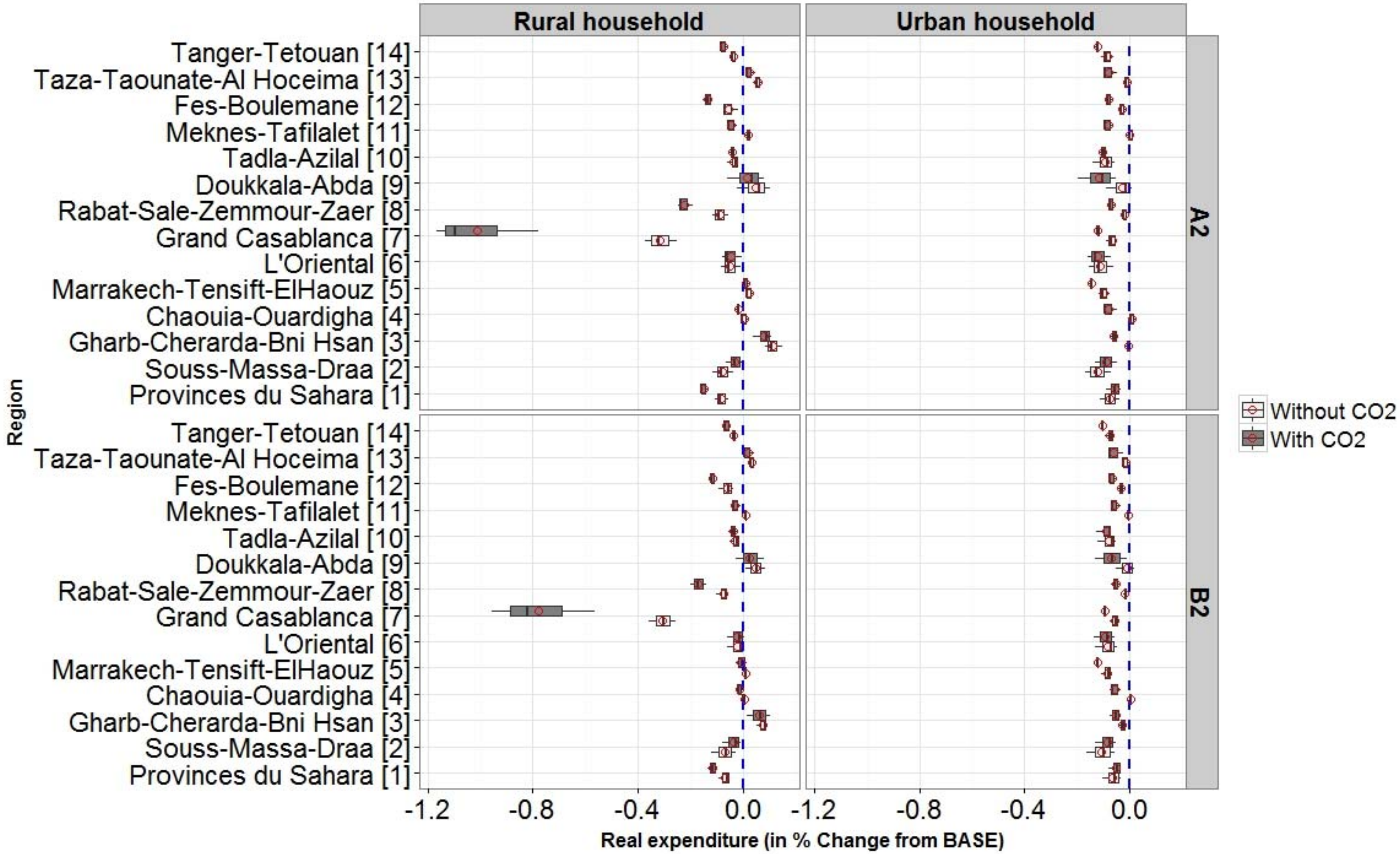

Figure 11: Distribution of net impacts of the MGP strategy on the real expenditure of rural and urban households by 2050 (% change from BASE)

Source: Result of simulation

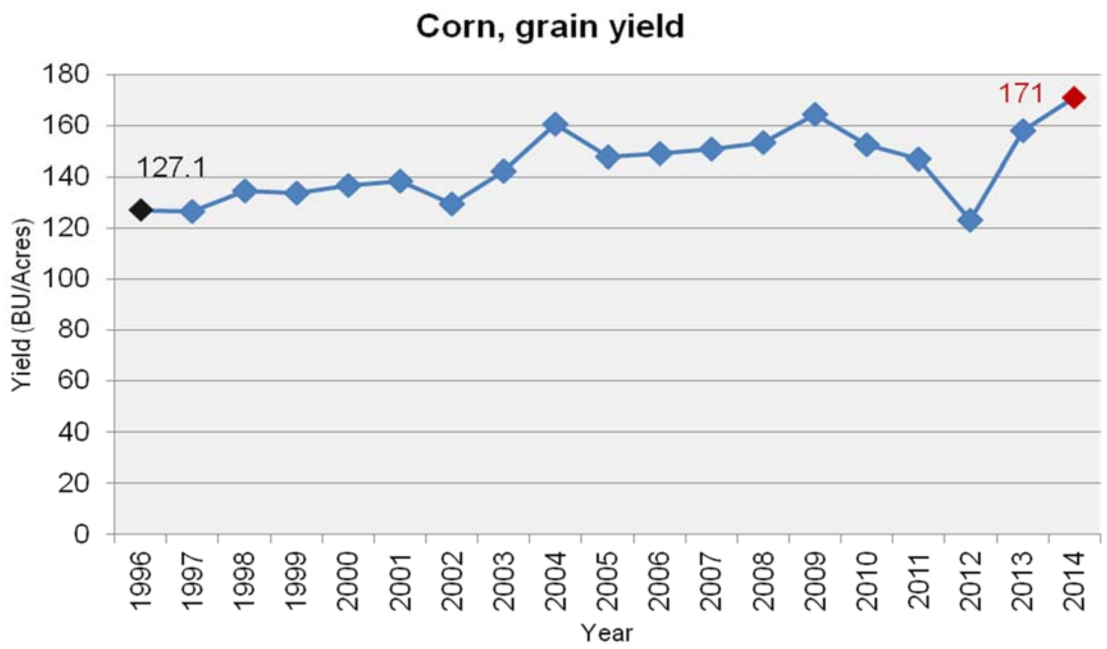

Figure 14: Historical evolution of corn grain yield (in BU/acres) from 1996 to 2014
Source: Authors' adaptation from United States Department of Agriculture, National Agricultural Statistics Service (2014)