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الجمعية المغربية للاقتصاد الزراعي

AMAECO

The Moroccan Association of Agricultural Economics (AMAECO)

in partnership with

International Association of Agricultural Economics (IAAE) **&** **United Nations University-World Institute for Development Economics Research (UNU WIDER)**

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

The principal themes proposed are the following::

1. Analysis of the impacts of climate change on agriculture: simulations and projections
2. **Climate change and sustainability of agricultural production systems**
3. **Adaption strategies for agriculture in the face of climate change: systems of production, risks in agriculture, and policies for food security**
4. **Water management in the context of climate change**

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Climate Change and Agriculture: An Integrated Approach to Evaluate Economy-wide Effects for Turkey[1]

Hasan Dudu[2] Erol H. Cakmak[3]

Abstract

Effects of climate change in Turkey, which is already a water stressed country, are expected to be significant. The aim of this paper is to quantify the effects of climate change on overall economy by using an integrated framework incorporating a computable general equilibrium model and a crop water requirement model for the period 2010-2099. Since agriculture is the most important sector that will be affected by climate change, analysis of climate change effects on the overall economy necessitate taking into account backward and forward linkages of agriculture. The CGE model used in this paper models the links between agriculture and other sectors and economic agents at 12 NUTS1 regions level. On the other hand, the crop model is used to translate the results of global climate models to estimate changes in yields and irrigation requirements for the period 2010-2099 at 81 NUTS3 level for 35 crops. The results of the crop model are then introduced to CGE model as climate shocks.

The results suggest that the economic effects of climate change will not be significant until late 2030s; therefore Turkey has a chance to develop appropriate adaptation policies. However after 2030s, effects of climate change will be significant. Production patterns and relative prices will change drastically. The economic effects will differ among regions. The regions where irrigated agriculture is relatively low, the effects will be milder suggesting a need for putting more emphasis on the region-specific climate change policy design. Agriculture and food production will be the most affected sectors. Increasing irrigation requirements will cause farmers to reduce irrigated production. Combined with decline in yields, this will cause significant deterioration in agricultural production and prices will increase. The loss in household welfare will be significant. Some part of production decline will be compensated by imports, causing an increase in agrofood trade which will cause trade balance to worsen with declining manufacturing exports due to increasing cost of production.

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1. Introduction

A significant effort has been spent by scientist from various disciplines to shed light on the causes and effects of climate change in recent years (Tol, 2010). Although there are still some controversies about the details (Idso and Singer, 2009), it is widely accepted that climate change has already started to be effective and significance of the impacts will increase through the 21st century (Stern, 2006; Agrawala and Fankhauser, 2008; Parry et al., 2007). Although there is a wide range of social and physical effects that are linked to climate change in the literature, the most significant effects are expected to be increasing temperatures accompanied by declining precipitation as well as increasing frequency of climatic extremes (Stern, 2006). Hence, agricultural production, which is among the most climate dependent economic activities, is likely to be the most vulnerable sector (Fankhauser, 2005). Temperature and precipitation changes will affect the yields in crop production while climate related risks will increase due to increasing frequency of climatic extremes (Rosegrant et al., 2008).

Effects of climate change has already started to be observed in Turkey in the form of changes in mean temperatures, precipitation (Durdu, 2009; Kadıoğlu, 2008), growing degree days (Kadıoğlu and Şaylan, 2001) and number of frost days (Şensoy et al. 2008) and frequency of climatic extremes (Şensoy et al., 2008). Climate change effect on agricultural production in Turkey is expected to be significant, since agricultural production is heavily dependent on climatic conditions. A significant part of the agricultural production is held on rain-fed lands making the production to be significantly sensitive to changes in precipitation (Kadıoğlu, 2008). R&D activities to develop new drought resistant crop varieties are also quite limited. Further, although the share of agricultural value added in GDP has declined to 10 percent in recent years (TurkSTAT, 2010a), its share in employment is still significant with 25 percent (TurkSTAT, 2011c). Agriculture is still the most important source of income for the rural population.

Number of studies investigating the economic effects of climate change in Turkey has started to increase in the recent years. These studies can be grouped in 5 categories: The first group of studies consists of papers that survey the global literature and attempts to draw conclusions about Turkish economy by analyzing results of global models (Kaygusuz, 2004;

Önder and Önder, 2007; Aydınalp and Cresser, 2008, Arslan-alaton et al., 2011). The work in the second group attempts to model the link between climate change and economy by evaluating the effects of different policy options and focus on Green House Gas (GHG) abatement policies (Tunç et al., 2007; Kumbaroglu et al., 2008; Telli et al. 2008;). The third group of studies uses general circulation, hydrological, regional climate or crop based models to estimate the probable effects on non-economic indicators such as water resource availability or growing degree days without any reference to their implications for agricultural production or economy (Kömüşçü et al., 1998; Kadıoğlu and Şaylan, 2001; Göncü, 2005; Fujihara et al., 2008; Önol et al., 2009, Durdu, 2009; Şensoy et al., 2008). Lastly, there are a few papers that links the changes in climate variables under different climate change scenarios to agricultural production (Cline, 2007; Kapur et al., 2007; Özdoğan, 2011). Lastly, there are two well documented studies in the literature, Dellal and McCarl (2009) and Dudu et al. (2010), that try to link the climate change projections with agricultural and overall economy which suffer from various deficiencies. We will give the details of these studies in the following sections.

Consequently, although the effects of climate change are expected to be significant, research on the economic effects has been quite limited. Hence, there is a need for a more detailed economic analysis of climate change effects by combining the results of climate models with economic models at the regional level. In this study we aim to improve the current modeling efforts in the literature by using an integrated approach to evaluate the effects of climate change on overall economy of Turkey in a detailed regional setting. For this purpose we use a crop water model to translate the regionalized results of a global climate model to yield shocks and irrigation requirement changes and introduce these findings as simulation shocks to a CGE model. Following section presents the modeling approach in detail for the CGE model and crop water requirement model. Section 3 presents the data and results of crop water model that are used in simulations while Section 4 reports the results of CGE analysis. The last section is reserved for concluding remarks.

2. Integrated Modeling Approach

Climate change is a complex issue and any complete assessment of effects needs to take into account different aspects of the issue. The final effect is determined by interaction of various physical, economic and social effects. Hence in order to give a fully-fledged evaluation, different types of models are required. On the one side, the physical effects need to be estimated with complicated climate and hydrology models at the global level. Then these estimates need to be downscaled for smaller spatial resolutions in order to have an understanding of the effects at the regional level. On the other side, the interaction within an economy and the rest of the world needs to be considered in detail to have a solid interpretation of the economic effects. As mentioned afore, the most significant impact of climate change is supposed to effect the economy via agricultural sector. Hence, a special impact assessment model is required to link the results of climate models to the economic models. Hence, there are three pillars of a complete climate change impact analysis: Physical models, specific impact assessment models and economic models.

The “three pillar” approach has become more popular and started to dominate the literature in recent years, as detailed climate data become more accessible do the researchers and computational power has significantly increased to allow for handling of large scale models. Global Circulation Models are used extensively to make projections about the main climatic variables under different scenarios. Although the results of these models are controversial, especially at the regional level, the mean values of the results from many available GCMs are used as a proxy. The type and specification of special impact model used to translate GCMs’ output to economic impacts differs according to the aim of the study. Lastly, computable general equilibrium modeling has been the standard approach to estimate the economic effects. There is a vast literature related to the effects of climate change on agricultural production and economy. However, we will be selective and survey the studies that adopt a similar approach with this study. A more detailed survey about the studies that are based on integrated approach can be found in Hertel and Rosch (2010) and Palatnik and Roson (2009).

Bosello and Zhang (2005) also uses a GCM containing a crop- growth model, with a global CGE model (GTAP-E). The climatic scenario is endogenously produced by the economic model. They found a limited impact of climate change on agricultural sectors mainly due to smoothing effect of economic adaptation. Although effects are higher for developing countries Bosello and Zhang (2005) are separated from the other studies in the literature with their conclusion about the severity of effects.

Rosegrant et al. (2008) and Rosegrant et al. (2009) use a global food supply and demand model (IMPACT) together with a biophysical model (DSSAT) to estimate impacts of climate change on agricultural sector at the global level. They report that climate change will affect the human well-being negatively with declining yields and increasing prices. Calorie availability will be worsen and child malnutrition will increase by 20 percent. They estimate that USD 1.7 billion with 2000 prices is needed to offset the effect of climate change on calorie availability.

Cretegny (2009) gives a detailed discussion about the rationale of using integrated approach both at the national and global level and presents an implementation of bottom-up and top-down approaches. In bottom-up methodology the projected climatic changes from a multiplicity of General Circulation Models (GCM) are first downscaled to local levels which are then used to estimate the vector of impacts on key economic sectors of each country, using sector-specific impact assessment models. In the top-down methodology, climate projections are used to derive regional sector-specific damage functions which are used to calibrate a global dynamic multi-sectoral CGE model. Productivity changes in agriculture, irrigation, hydro-power and treated water sectors.

Thurlow et al. (2009) investigates the effect of climate variability and climate change on Zambian economy by using a hydro-crop model (CropWAT model of FAO) for maize in Zambia together with a dynamic CGE model. They use historical climatic data and HadCM3 results in hydro-crop model, to obtain yield responses of maize under different drought and climate change scenarios. They estimate yield losses up to 50 percent under severe drought years. The results of CGE model suggests that climate variability may cause USD 4.3 billion losses over a 10 year period, keeping 300.000 people below poverty line. Climate change effects add another USD 2.15 billion to the losses; pushing 74.000 more people below poverty line.

Ciscar et al. (2009) uses various impact-specific model with a CGE (GEM-E3) model in which most EU countries are modeled individually. DSSAT crop models have been used to quantify the physical impacts on agriculture. Their findings suggest that during 2020s, most European regions would experience yield improvements, but in the 2080s average crop yield will fall by 10 percent. Southern Europe would experience relatively higher yield losses. They estimate that annual damage of climate change to the EU economy in terms of GDP loss will be between € 20 billion to € 65 billion implying a 0.2 percent and 1 percent welfare loss, respectively.

Pauw et al. (2010) uses a general equilibrium model to estimate the economy wide impacts of drought- and flood-related crop production losses in Malawi. Climate simulations are based on production loss estimates from stochastic drought and flood models. Results show that 1.7 percent of GDP is lost due to climate change. Smaller farmers are effected more. Food shortages are likely to affect urban households significantly.

Calzadilla et al. (2011) investigates the impact of changes in water availability due to climate change on agricultural production world-wide. They use a multi-sectoral global VGE model (GTAP-W) and a Global Environmental Model, which includes a dynamic river routing model (HadGEM1-TRIP), to simulate changes in temperature, precipitation and river flow over the next century and under the IPCC scenarios. They report that global food production, welfare and GDP will decline under both scenarios. Higher food prices are expected. They also show that countries are not only influenced by regional climate change, but also by climate-induced changes in competitiveness.

Fernandes et al. (2011) uses an agro-ecological model together with an applied general equilibrium model (ENVISAGE) to assess the impacts of climate change in Latin America. The agro-ecological model consists of crop development, soil water, abiotic factors, management an crop suitability components. The results suggest that there will be significant decline in yields of major crops and effects will be higher after 2050. Adaptation is partially effective in off-setting the climate change effects. Economic impacts are also significant, adding up to a 1.3 percent decline in region's GDP.

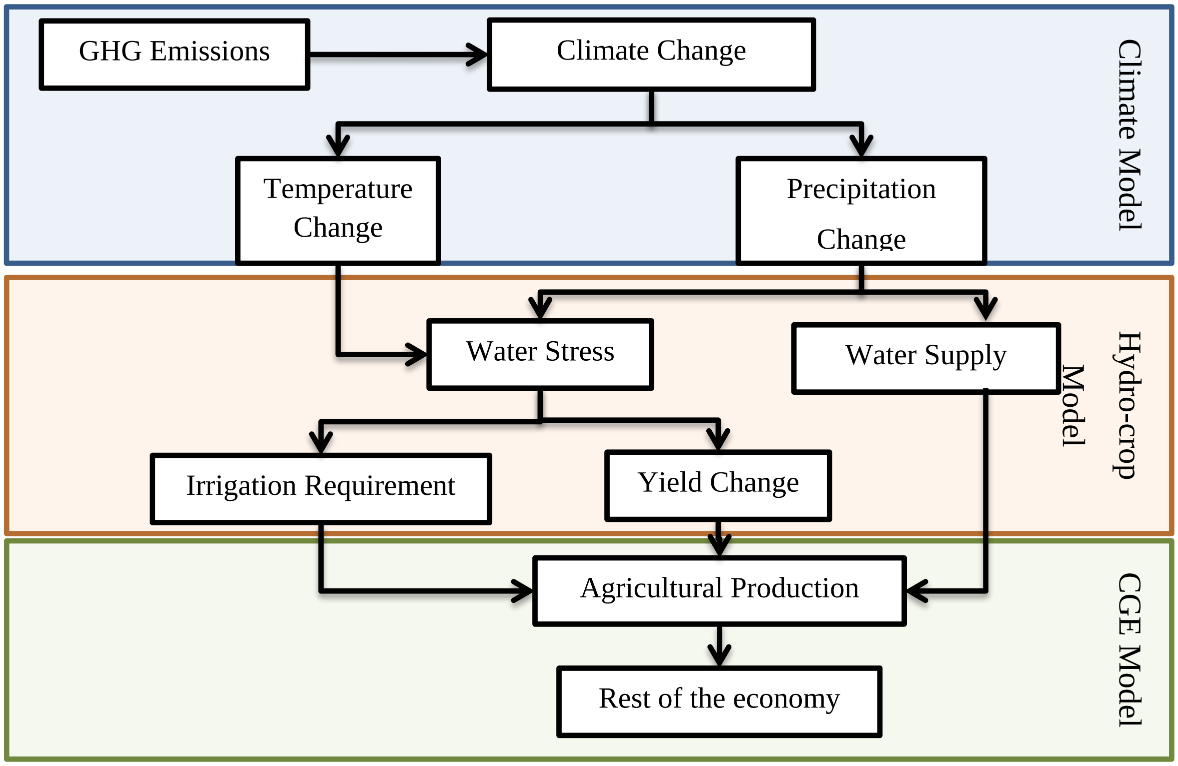

Figure 1: Summary of Modeling Approach

The common conclusion of these studies is two folds: Climate change effects on economy and particularly on agricultural production are significant, especially for developing countries where share of agricultural production in GDP is relatively higher. The effects accelerate in the second half of the 21st century, especially for developed countries. The results are region and crop specific and aggregation at any level under-estimates the effects. Adaptation policies can be effective to lessen the economic losses.

The current study uses a hydro-crop model together with a multi-sector static CGE model and contributes the literature in two ways: The hydro-crop model estimates the yield and irrigation requirements of 35 crops for 81 provinces by using the results of a regional climate model while the CGE model introduces these changes as climate impact shocks at 12 NUTS-1 regions. Figure 1 summarizes the modeling approach. Detailed explanation is given in the following sections.

3. Effects on Technical Conditions of Agricultural Production

The physical effects of climate change on agricultural production of Turkey has been the subject of various studies. These are generally, engineering based models that uses hydrology or crop simulation models to assess the effects on technical conditions of agricultural production such as yields, water availability and requirement, growing degree days etc… In this section we will provide a brief survey of these studies to compare our findings from the hydro-crop model. The results of hydro-crop model will follow this discussion.

Kadıoğlu and Şaylan, (2001) report the results of an analysis of 60 year daily temperature records at 74 Turkish meteorological sites between the years 1930 and 1990. They calculate monthly and seasonal growing degree days and try to identify the significant trends by using Mann-Kendall rank statistics. They found that there is a declining trend in growing degree days of the coastal regions while the results are insignificant for central and southeastern regions. They do not report any economic implications of those trends.

Kömüşçü et al. (1998) analysis the effects of climate change scenarios on the soil moisture availability in Souteastern Anatolia Development Project regions. They use Thornthwaite water-balance model, by using IPCC estimates of regional changes in temperature and precipitation predicted by the GCMs under different hypothetical climate change scenarios. They found that soil water deficit increases by “4 percent to 43 percent for a 2 ◦C warming and by 8 percent to 91 percent for a4◦C warming” (Kömüşçü et al., 1998). They do not relate these changes to any economic impacts for the region.

Göncü (2005) uses a hydrological simulation program to evaluate the effects of climate change on hydrological properties of hypothetical basins under A2 scenario of IPCC. Monthly data obtained from 4 meteorological stations based in the central Anatolia are used for the years 1975-2050. Göncü (2005) reports that total evapotranspiration under A2 scenario will be higher than the base values for all basin types. The study also reports the hydrological properties of different basin types and finds that the differences between A2 and base simulation are not always significant.

Evans (2006) states that 18 Global Circulation Models to evaluate the effects of climate change on the water resources of Middle East, including Turkey and concludes that the effects of climate change will be significant in the 2nd half of the 21st century. The most significant finding is a drastic drying in the Western regions of the Turkey.

Durdu (2009) represents statistical analysis of rainfall and temperature data for the period 1963-2007 to assess the effects of climate change on water resources in Buyuk Menderes river basin. The results suggest that decline in precipitation and increase in temperature has been significant in through the period. Durdu (2009) states that these trends are results of climate change.

Fujihara et al. (2008) uses an integrated approach by employing a Global Circulation Model, wheather generator and a hydrological model to investigate the frequency of current and future hydrological extremes in the Seyhan Basin. They found that "critical flood events will occur much less frequently…" while "…critical drought events will occur much more frequently" under A2 scenario of IPCC.

None of the above studies link their findings to economic consequences and are generally concerned with the physical effects. The common conclusion of these studies is that growing-degree days will be prolonged and Turkey will experience hotter and drier summers along with milder and drier winters. Further the frequency of hydrological extremes will increase implying more drought years.

Cline (2007) gives the most recent and detailed impact analysis for Turkish agriculture by downscaling the results of 5 global climate models to obtain country level impacts of climate change for 60 countries. The results for Turkey show that the average temperature will increase from 1.1 °C to 1.6 °C while average precipitation will decline by 30 percent which translates to a 11.8 percent decline in average agricultural yield for the period 2070-2099. This causes an average loss of 16 percent decline in the value added produced by agricultural sector (Cline, 2007: p.40 and p. 64 and p.71). Cline (2007) also reports that the agricultural sector benefits from the climate change effects for the first 1 to 2 °C increase. However, after 2°C effects are reversed (Cline, 2007: p. 60). However, results exposes the fact that estimates of climate change effects for Turkey has the highest coefficient of variation across different global climate models employed and thus probably are less robust with respect to different model assumptions.

Kapur et al., (2007) is another attempt to link the climate change effects to agricultural production. They employ a regional climate model (TECH-RAMS) to estimate the effects of climate change on wheat production for the period 2070-2099 under A2 scenario of IPCC in Cukurova basin which is one of the most advanced regions in terms of agricultural production. Their results suggests 35 percent decline in precipitation accompanied by a 2.8 °C increase in mean temperature. However, they do not report any quantitative results for the probable change in wheat yield.

The most recent study about the topic is Özdoğan (2011) where results of a GCM is used as an input for a crop model. The study analyzes the effects on wheat production in Thrace region. Özdoğan (2011) reports that CO2 effects is likely to be small and there will be a 15 to 20 percent decline in wheat yield.

Although these studies report the impact on yields or water availability, they still do not give much idea about the economic affects even at the agricultural sector. Further, these studies also lack spatial and sectoral depth in the sense that they are either at the national level or analysis specific sub-regions and they generally limit their analysis to a few major crops.

Climate data used for the yield estimations follows from the results of the "Climate Change Scenarios for Turkey" project carried out by Istanbul Technical University and General Directorate of State Meteorological Services. The results depend on the ECHAM5 model of which details can be found in Roeckner et al. (2003). Results of ECHAM5 model is disaggregated to smaller scales with RegCM3 regional climate model (Pal et al., 2006) to obtain monthly projections for key environmental variables starting from 2001 until 2099 (CCSTP, 2011). We used the results for the IPCC-B1 scenario which describes a relatively integrated world with rapid economic growth. Global population increases to 9 billion in 2050 but declines from then on. Economic development is primarily focused on services and communication sectors. Sustainability is important in economic decisions (IPCC, 2000). Estimations of westerly and southerly wind speed, precipitation and mean temperatures obtained from CCSTP (2011) are used to calculate the reference evapotranspiration and increase in water stress for different crops in each province (i.e. at NUTS3 level) until 2100. Önol et al. (2009) reports the details of the models used in CCSTP (2011).

We follow Allen et al. (1998) to calculate monthly reference evapotranspiration for each year in each of the 81 NUTS3 regions. Since CCSTP (2011) does not report minimum and maximum temperatures we used data supplied by CLIMWAT database of FAO (FAO, 2011) to calculate the spread of minimum and maximum temperature at NUTS3 level for each month and used these to calculate an approximate minimum and maximum temperature from the mean temperatures reported by CCTSP (2011). The wind speed is calculated as the vector sum of easterly and southerly wind speeds reported by CCSTP (2011). Lastly, since humidity data is not available we used the methods suggested in Allen et al. (1998) to estimate minimum and maximum humidity from minimum and maximum temperatures.

The average value of ET_0, the reference evapotranspiration, is presented in Figure 2, to give an idea of the effects of climate change. ET_0 increase slowly until 2060. However the oscillation around the mean value increases significantly between 2035 and 2060. Between 2060 and 2075, there is a significant increase in the pace of increase in ET_0. After 2075, ET_0 stabilizes with significantly high oscillations.

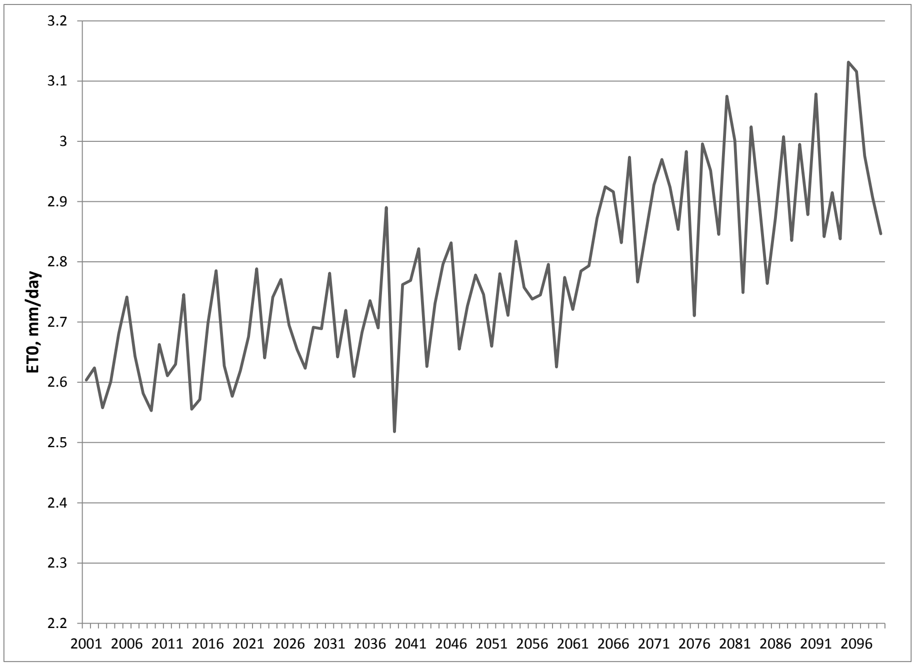

Figure 2: Reference evapotranspiration over 2001 – 2099 period

Crop evapotranspiration (ET_c) is obtained by multiplying the reference evapotranspiration with a crop coefficient (K_c). By following Allen et al. (1998) we adjust the supplied K_c values of 35 crops. Firstly we adjust K_c for stage of crop development, minimum humidity, wind speed and the height of crop for each development stage of the crop. Secondly we calculate the water stress coefficient (K_S), by estimating soil moisture balance from the soil type data supplied by Allen et al. (1998). We assumed that soil type is loam for all regions since changing the soil type does not change the final results significantly. By multiplying ET_c with K_s we found the crop evapotranspiration under water stress, ET_S.

Monthly ET_C and ET_S are used to estimate two model parameters: The yield change and irrigation water requirement. Yield change is calculated from the yield loss with respect to maximum yield according to the following formula:

$$Y_{loss} = 1 - \frac{Y_a}{Y_M} = \psi_c \left(1 - \frac{ET_s}{ET_c} \right)$$

where Y_{loss} is yield loss, Y_a is actual yield, Y_M is maximum yield, ψ_c is crop specific yield response coefficient, ET_s is crop evapotranspiration with water stress and ET_c is crop evapotranspiration without water stress. Accordingly the change in yields is given by

$$\Delta Y = 100\left(\frac{Y_a}{Y_M} - 1\right) = -100\psi_c\left(1 - \frac{ET_s}{ET_c}\right)$$

We use the change in yields for 35 crops to calculate the change in agricultural value added from the production value of agricultural products in 2008 for each NUTS3 regions and aggregate the results to NUTS1 regions.

$$\Delta VA_{R1} = \sum_{R3\in R1} \frac{\sum_c \Delta Y_{c,R3}.P_{c,R3}.Q_{c,R3}}{\sum_c P_{c,R3}.Q_{c,R3}}$$

Monthly irrigation requirements for each crop in each region and year are calculated as the deficiency between precipitation and ET_s. Then we used the areas in 2008 to find a weighted sum of the total irrigation for each NUTS1 region to find a region wide irrigation requirement per hectare.

$$IRQ_{R1,Y} = \frac{\sum_{R3\in R1}\sum_C\sum_M \left(ETS_{C,R3,M,Y} - P_{R3,M,Y}\right)A_{C,R3,2008}}{\sum_C A_{C,R3,2008}}$$

The change in the irrigation water requirement is calculated with respect to the average irrigation water requirement for the period 2001-2010.

$$\Delta IRQ_{R1,Y} = \frac{IRQ_{R1,Y}}{\sum_{B=2001}^{2010} IRQ_{C,R1,B} \Big/ 10}$$

Figure 3 shows the estimations of yield change and irrigation water requirement over 2001-2099. Both yields and water requirement follows a slightly different trend than ET_0. Yield change oscillates less compared to water requirement which is crucially dependent on precipitation. Both figures oscillate around base decade values until 2035. After 2035 yields start to decline while irrigation requirements start to increase. Consequently, after 2060 increase in irrigation and decline in yields become significant. Lastly, note that variation in yields and irrigation requirements are significantly higher than the variation in (ET_0).

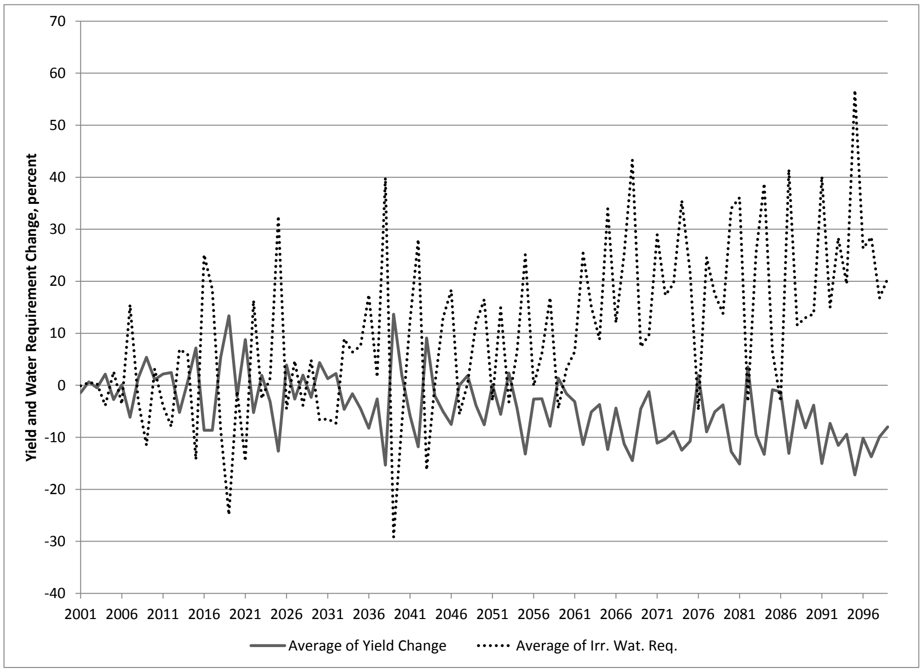

Figure 3: Crop model results for average yield change and irrigation water requirement

The spatial patterns of yield and irrigation requirement changes are given in the panels of Figure 4 for the periods 2010-2035, 2035-2060 and 2060-2099. The spatial variation in the effects is also significant. Western parts of the country are positively affected in terms of yield and irrigation water requirement in the first period. The yields generally does not change or decline slightly in the central parts with lower requirements for irrigation. The eastern parts, on the other hand are likely to experience an increasing water requirement and slight declines in the yields starting from the first period.

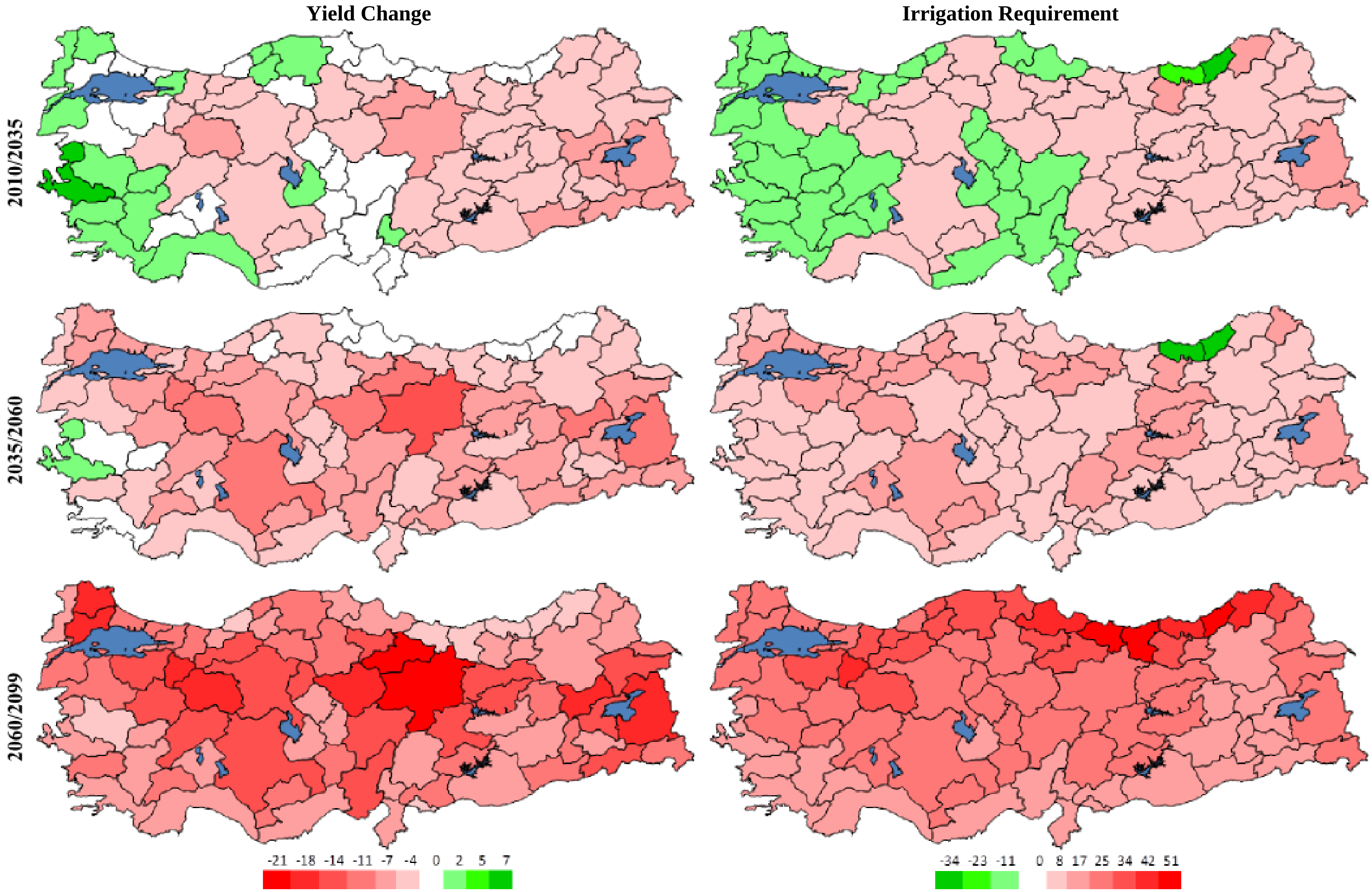

Figure 4: Spatial Effects of Climate Change

In the second period, the effects of climate change differ significantly between coastal zone, central regions and eastern parts of the country. Yield changes are not significant in coastal parts except Thrace while the increase in irrigation requirement slightly increases. Eastern parts of the country become slightly worse off with lower yields and higher irrigation requirements. However, central parts of the country start to seriously experience the negative effects of climate change: Average yield loss exceeds 10 percent for some provinces, while decreasing trend in irrigation water requirements completely reversed.

The difference in the effects of climate change becomes significant in the north-south axis, rather than east-west axis. Further, the change in yields and irrigation requirements follows approximately the same spatial pattern in the first two periods; they follow completely different patterns in the third period. The provinces that suffer from yield loss most constitute a belt like shape starting from Thrace, extending through the northern parts of the central regions and ending in the central parts of the eastern regions. However, the increase in irrigation requirement increases towards Northern regions. There is again a bended belt covering the central parts of western and southern coastlines and extending to the central eastern provinces. Irrigation requirement increases significantly in the central regions and Thrace. Lastly, northern regions are the most severely affected regions, effects being higher for the eastern parts.

Our results support the findings of the other studies in the literature, both at the national and global level. The effects become more significant after 2050s, while the effects are significant throughout the simulation period for some regions. Although it is not mentioned in any other study for Turkey, our results show that the variability in yields is higher than the variability in climatic conditions suggesting an increase in climate risk. Lastly, as predicted by many studies at the global level technical conditions of agricultural production become more favorable as the increase in mean temperature is below 2 °C at the early stages of climate change.

4. Effects on Overall Economy

There are only two well documented studies in the literature that employ economic models to investigate the implications of climate projections under different climate change scenarios. Dellal and McCarl (2009) uses a partial equilibrium model for agricultural sector to investigate the effects of a climate change scenario following from a global climate model. Dudu et al. (2010) on the other hand uses a computable general equilibrium model to analyze effects of yield changes on overall economy. Both models suffers from various deficiencies. Dellal and McCarl (2009) uses average of results from a global climate model to estimate yield responses. Regional dimension of the model is out dated and is not compatible with NUTS classifications. Further they run simulations for a limited number of crops. Dudu et al. (2010) uses the average of expected yield changes compiled from the existing literature. Their regions are aggregated and the model data follows from 2003 social accounting matrix.

The Walrasian CGE model presented in this paper disaggregates the economy into 7 activities producing commodities for 7 sectors in each of the 12 NUTS-1 regions. The activities are agriculture, food production, textiles, other manufacturing, services and private services. The production structure of the activities is presented in Figure 1. We use a 3 level nested production function which aggregates different factors and inputs at different levels.

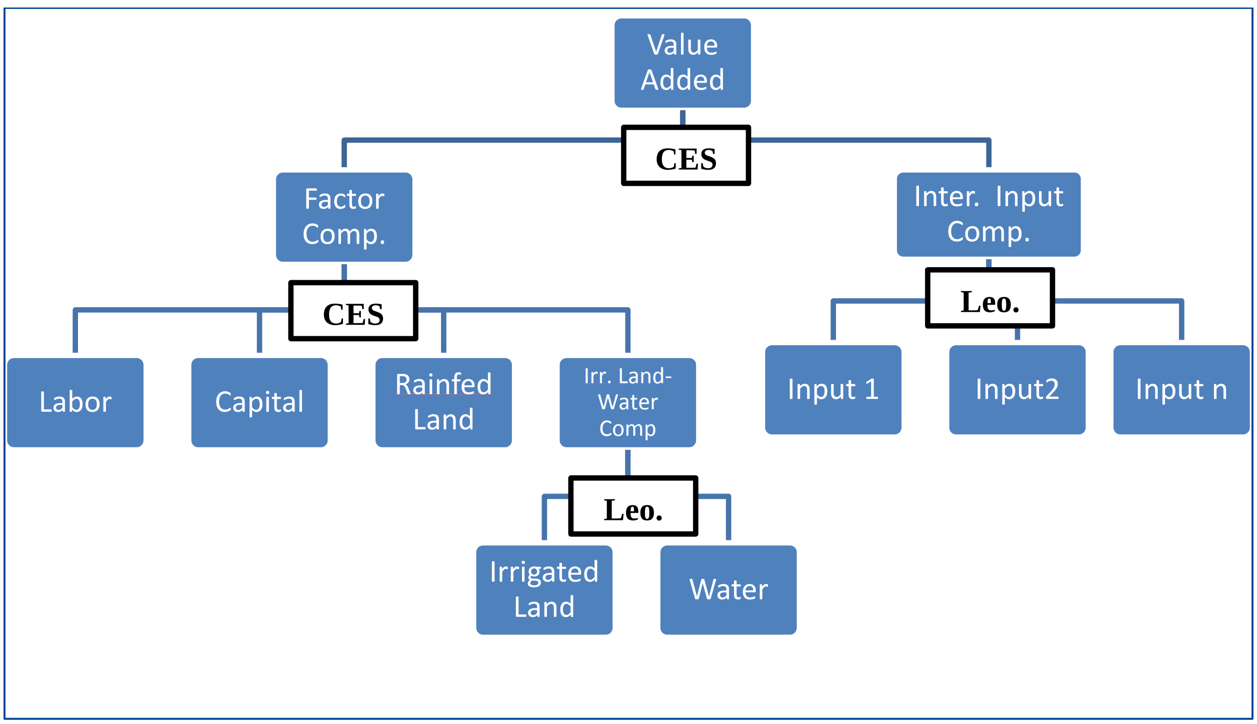

Figure 5: Production structure of the Model

Water is introduced as a factor of production which is perfectly complementary with irrigated land. Hence we introduced a Leontief nest to the production function. Composite factor that is produced at this nest enters to a CES production function with other factors. Finally this second composite value added enters a new CES nest with a composite intermediate input which is follows from a Leontief nest for intermediate inputs. Since water and irrigated land are perfect complement the price of water land composite will be a weighted sum of wages paid on water and irrigated land where the weights will be Leontief coefficients. Figure 5 summarizes the new production structure of agriculture.

Sectors except agriculture do not use irrigated or rain-fed land in production. Hence there is no additional Leontief nest of water-land composite for these sectors. However water is employed by all sectors. Hence water directly enters into CES with labor and capital for these sectors.

There is only one type of household in each region. Income generated by factors in a region is distributed to household in the same region. Households receive income from labor, land and water while capital income goes to firms. Firms pay institutional taxes and makes transfers to the rest of the world out of this income and the rest is distributed to households together with the transfers from government. Households use their income for consumption, leisure, savings and taxes. The consumption decision of household follows from the maximization of a Linear Expenditure System (LES) utility function. Leisure enters the utility function like any other commodities, while the wage income in included in budget constraint. The problem becomes:

$$\max U_{r,h} = \beta_0 \ln\left(L_{r,h} - \gamma_{0,r,h}\right) + \sum_{i=1}^{k} \beta_{r,i} \ln\left(QH_{i,r,h} - \gamma_{i,r,h}\right)$$

$$s.t.\ \sum_{i=1}^{k} P_{r,i} QH_{r,i} + w_{r,h} L_{r,h} = EH_{r,h} + w_{r,h} L_{r,h} = w_{r,h} T_{r,h} + YNL_{r,h} = Y_{r,h}$$

where the indices *i* denotes commodities, *r* denotes regions and *h* denotes the households. $QH_{i,r,h}$ is household demand for commodity *i*, $QFS_{r,h}$ is labor supply, $U_{r,h}$ is unemployment, $L_{r,h}$ is leisure, $P_{r,i}$ is commodity prices, $w_{r,h}$ is wage rate of labor, $EH_{r,h}$ is total consumption spending of household, $T_{r,h}$ is total number of working age people in household. $YNL_{r,h}$ is non-labor income, $Y_{r,h}$ is total income. The above formulation suggests that household owns the whole working age population as labor resource and decides how many people to send work to earn wages and how many of them stay home for leisure. Unemployment is determined in the labor market as the difference between labor supply and labor demand. We assume that Household neither receives leisure nor wage for unemployed people.

The analytical solution of this problem yields the following demand functions:

$$QH_{i,r,h} = \gamma_{i,r,h} + \frac{\beta_{i,r,h}}{\left(1-\beta_{0,r,h}\right)P_{r,i}}\left(EH_{r,h} - \sum_{i=1}^{k} P_{i,r}\gamma_{i,r,h}\right)$$

$$QFS_{r,h} - U_{r,h} = T_{r,h} - \gamma_{0,r,h} - \frac{\beta_{0,r,h}}{\left(1-\beta_{0,r,h}\right)w_{r,h}}\left(EH_{r,h} - \sum_{i=1}^{k} P_{r,i}\gamma_{i,r,h}\right)$$

In the above equations, $T_{r,h} - \gamma_{0,r,h}$ is the total working age population and it does not adjust according wages since household cannot control the total population $T_{r,h}$ or the parameter $\gamma_{0,r,h}$. Hence by following Thurlow (2008) we introduce the following "rule of motion" for total available working age population:

$$\frac{T_{r,h,t} - \gamma_{0,r,h,t}}{T_{r,h,b} - \gamma_{0,r,h,b}} = \left(\frac{wfr_{r,t}/cpi_t}{wfr_b/cpi_b}\right)^{\eta}$$

where the indices *t* denotes a post-simulation values and *b* denotes the base run values.

Government receives tax income from activities, commodities, firms and households as well as transfers from the rest of the world. This income is used for government consumption, transfers to households and firms, government savings and transfers to the rest of the world.

Lastly, commodities receive payments from the rest of the world for exports and make payments the rest of the world for imports.

Model closure rules follow conventional neoclassical assumptions. Since simulations are designed to account for long run climate change effects, price of capital and land is assumed to be fixed while their supply and demand adjusts in the new equilibrium. On the other hand water is assumed to be fully employed and mobile among activities within a region implying a fixed supply. Price and demand for water adjusts in the new equilibrium. Consumer price index is the numerairé and hence is fixed while domestic price index is flexible. We use a balanced closure for saving-investment closure with a fixed share of investment and scaled marginal propensity to save. Foreign savings are fixed by allowing exchange rate to be flexible. The share of government demand in total absorption is also fixed. Lastly, government savings are fixed, while direct tax rates are flexible and scaled for households and firms. Further discussion of closure rules are given in Lofgren et al. (2003).

5. Data and Simulations

The aggregate version of the SAM used in the analysis follows from Yiğiteli (2010) who presents a national SAM of Turkish Economy for the year 2008 with 49 production activities producing outputs for 5 household types using formal and informal labor, land and capital. We used various data sources to regionalize the 2008 National SAM for 12 NUTS-I regions.

The I/O table used in this model is a regionalized version of 2002 I/O table published by TurkSTAT (2011a). We use Augmented Flegg Location Quotients method presented in Flegg and Webber (2000) to regionalize the 2002 National I/O table by using regional employment data. The latest regional employment data available for all sectors of the model is for 2002. Hence we used the shares of each region in each sector to interpolate 2008 employment figures across regions. Then this employment figures are used in AFLQ formula as described in Flegg and Webber (2000):

$$AFLQ_{i,j}^{R} = \begin{cases} \dfrac{E_i^R / E_j^R}{E_i^N / E_j^N} \log_2 \left(1 + \dfrac{\sum_i E_i^R}{\sum_i E_i^N}\right)^{\delta} \log_2 \left(1 + \dfrac{E_j^R / \sum_j E_j^R}{E_j^N / \sum_j E_j^N}\right) & if \ \dfrac{E_i^R / \sum_i E_i^R}{E_i^N / \sum_i E_i^N} > 1 \\ \dfrac{E_i^R / E_j^R}{E_i^N / E_j^N} \log_2 \left(1 + \dfrac{\sum_i E_i^R}{\sum_i E_i^N}\right)^{\delta} & if \ \dfrac{E_i^R / \sum_i E_i^R}{E_i^N / \sum_i E_i^N} \leq 1 \end{cases}$$

where E_i^R is employment in sector *i* of region *R* and E_i^N is national employment in sector *i* while δ is a constant assumed to be 0.3 by following Flegg and Webber (2000). Once AFLQ coefficients are calculated, a_{ij}^R the element of I/O table in *i*th row and *j*th column is calculated as:

$$a_{i,j}^R = a_{i,j}^N . AFLQ_{i,j}^R$$

where a_{ij}^N is the national I/O share.

After calculating new regional I/O shares we made further adjustments in the SAM. Firstly, the regional coefficients do not necessarily add-up to one for an activity in a region, which makes I/O table imbalanced. To keep the balance of I/O columns, we have assumed that the deficiency (or excess) in the row sum of regional I/O table is due to the missing intermediate input trade among regions. Hence, by assuming that the intermediate input flow from one (exporting) region to another (importing) region is proportional with the share of exporting region in national production, we have calculated intermediate input trade among regions that make I/O table consistent. Secondly, the row sums of I/O table also do not necessarily add up to regional production figures. Hence we have adjusted regional production figures according to new I/O table. This causes an imbalance in the commodity accounts which is in turn balanced by introducing inter-regional trade.

The flow from commodity accounts to activity accounts is the key regional interaction term. Interregional trade is calculated as a residual and transportation costs are ignored. We first found the difference between a region's production and consumption. Then we distributed the difference as a transfer from other regions according to the share of other regions in national production. Regions of which production exceeds consumption are assumed to consume only their own products and export rest of the products to other regions. For importing regions, the imported amount is subtracted from the region's production to keep the balance between consumption and production. That is we assume that interregional trade is done among producers of exporting region and wholesalers of importing region. Hence value added produced in a region also includes the value of commodities obtained by trade. A better alternative would have been introducing interregional trade through households but due to lack of data this option is not viable for the current model. [4]

We can elucidate the need for intermediate input and commodity trade among regions with an example. Istanbul, namely TR1, is characterized by high industrial employment and production with small agricultural employment and production. However, the consumption of agricultural products is significantly higher than the production in Istanbul due to population. It is impossible to satisfy the consumption in Istanbul with regional production. Hence, we distribute the discrepancy in regional supply and demand as imports from other regions, according to the share of other regions in national production. Hence a region with higher agricultural production supplies more agricultural commodities to Istanbul. For the I/O part, again consider the inputs for agriculture. Since industrial employment is higher in Istanbul, an important portion of agricultural inputs is also produced in Istanbul. However, since Istanbul produces small amounts of agricultural products, we either have to increase the I/O coefficients of Istanbul unrealistically high levels compared to national I/O or we will allow for some of the intermediate inputs to be exported to the other regions. The distribution among regions is again proportional to production of the importing regions. By following this logic we create a bilateral intermediate input and commodity trade matrix.

[4] This interregional trade is neutral in the sense that, we do not introduce any behavioral assumption for wholesalers. They only transport the goods of the importing sector to the suppliers of exporting sectors and there is no transaction cost in the process. Further, we also assume that the commodities from different regions are perfectly substitutable.

Value added of water is calculated from the rent differentials in Quantitative Household Survey (QHS) of the G&G et al. (2004). We used the data for 1356 farm households to calculate the rent for irrigated and rain-fed land at NUTS-1 level. households are enrolled in renting land either as tenant or land owner. After calculating the average rent rate per ha. for 2004, we adjusted this rate for 2008 by assuming the increase in rent would be same as increase in wholesale price index for agricultural sector which is approximately 32 percent between 2004 and 2008. Then, the difference between the rent rate of irrigated land and rain-fed land is assumed to be due to irrigation and hence used as the price of water. Multiplication of the rent difference with the area of irrigated land is attributed as the value added of water in agriculture. The payments from other sectors to water factors are calculated from TurkSTAT Municipality Water Statistics (TurkSTAT, 2011a).

Regional shares employment is obtained for each sector from Annual Industry and Services Statistics (TurkSTAT, 2011b). These shares are used to distribute the national employment figures given in Regional Household Labor Force Statistics (TurkSTAT, 2011c). Total working age population is taken as the number of people above 14 years of age. Regional unemployment figures also follow from Regional Household Labor Force Statistics (TurkSTAT, 2011c).

Regional disaggregation of trade figures is done by using TurkSTAT’s Regional Foreign Trade database for the Year 2008 (TurkSTAT, 2010b). Agriculture, energy, manufacturing and services are disaggregated directly by using the shares of regions in the trade of these sectors. For exports of food and textile sectors regional trade data are not available. Hence we made an adjustment by taking into account the share of region in the national production of that sector and region's share in the trade of manufacturing. Formula used is as follows:

$$\frac{\frac{X_{Q\in R}}{\sum_R X_R}\frac{Y_{Q\in R}}{\sum_R Y_R}}{\sum_S \frac{X_{S\subset R}}{\sum_R X_R}\frac{Y_{S\subset R}}{\sum_R Y_R}}$$

where X is regions production in the sector and Y is volume of regions trade in manufacturing. We ignored the final shares that are less than 1 percent. For imports we used the regions share in manufacturing trade directly. Yiğiteli (2008) assumes a constant rate of tariff for all commodities. We have recalculated the tariffs in the SAM according to average applied tariff rates from 2008 tariff data at HS6 level (MCT, 2011).

Consumption is disaggregated according to TurkSTAT (2010c) by using 2003 household consumption data. We assume that share of a commodity in the total consumption of a household type does not change across regions[5]. We also assume that HHs does not consume any commodities from other regions. Government consumption is distributed according to the 2008 Public Accounts Bulletin of General Directorate of Public Accounts (GDPA, 2010a). Government consumption in each sector is distributed according to the region's share in total government expenditures on goods and services purchases. Transfers are also distributed according to 2008 Public Accounts Bulletin of General Directorate of Public Accounts (GDPA, 2010b). On the other hand, investments in different sectors are distributed according to region's share in value added.

Factor incomes are distributed according to shares of regions in factor value added. After finding the share of each region in factor income, income is distributed to Households. However since capital income is distributed through the regional firms, we had to make an adjustment to keep the balance of SAM. By discounting payments from firm of region *R* to the government and to the rest of the world, the remaining amount of income generated by capital factor of region *R* is distributed to the households. Then the difference between row and column sum of the firm account is added to government transfers to the firm.

[5] Distribution of household consumption according to regions and income quintiles data that TURKSTAT made available recently (TURKSTAT, 2010c) shows that the actual situation is not much different.

Profit transfers to abroad and workers' remittances from rest of the world are distributed according to shares of regions in national capital income[6]. We used the regions' share in number of people receiving pensions reported by SSI Yearbook 2008 (SSI, 2010) to distribute the transfers from SSI to households. Other transfers from government to households are distributed according to 2009 Annual Report of Social Assistance and Solidarity Fund by looking at the shares of regions in total transfers (SASF, 2009). Government savings and payments to ROW by government as well as tax incomes of government are not distributed since both accounts are national.

Tax payments of domestic institutions are distributed according to the 2008 Accrued and Realized Cumulative Tax Incomes in General Budget that is published by General Directorate of Public Accounts. We used accrued tax amounts in calculating the shares.

Some minor adjustments are done in the SAM to eliminate very small trade figures appearing in the energy trade of North West and Central Regions as well as food trade of East region. Small exports are added to S-I account. For imports, the import tax figures are deducted from S-I account. A similar adjustment is done for interregional trade, as well. Accordingly, the small interregional trade is eliminated by moving these figures to the production of consuming region. Then the difference is added to S-I account. The sum of moved figures are added to government savings and discounted from the transfers from rest of the world to government. I/O table is also adjusted for small figures. Small figures flowing from agriculture activity to energy, private and public services commodities are added to labor value added. The increase in the income generated by labor value added is distributed to households. Then the consumption of the 5th quintile household is increased respectively to balance the commodity accounts.

The simulations are designed to shock the yield of the agricultural production at the top nest and the coefficient of irrigation at irrigated land – water nest. In that way, we shock the

[6] The method of distribution of remittances from abroad does not have a significant effect on the model, since the share of remittances in household income is only about 0.2 percent.

model simultaneously for average yield and irrigation water requirement change at NUTS1 level. One important caveat about simulations is that they are static experiments derived from annual changes and hence the results lack any dynamic feedback effects.

6. Findings

Simulation results suggest that the effects of climate change on economy will be quite significant[7]. Table 1 shows the effect of climate change on main macroeconomic variables which follows a similar pattern as the production values. Welfare indicators such as absorption and household consumption do not change significantly in the first period but worsens in the second and third period. The change in the second period is likely to be caused by the extreme years, while the changes in the third period are due to declining average conditions. Although the maximum values are close to the first period, the minimum values are significantly lower. This implies the effect of climate change in the second period will be through "bad" years due to extreme climatic events, which will affect economy adversely. In the third period, the negative effects become considerably higher, with vast declines in maximum values and relatively small declines in minimum values. This suggests that in the third period, the effect of climate change will not only be through the extreme events but the average conditions will also worsen. The effect on exchange rate and the ratio of other macro indicators to the GDP is insignificant implying they all move parallel to GDP.

[7] We run statistical tests to see if the mean and variance of the total production differs across the periods. The average changes in the production value of all sectors among periods are significantly different at 5 percent confidence interval .

Table 1: Effects on selected aggregate variables (base values at billion TL)

		Base Level million TL.	% Change								
			2010-2035			2035-2060			2060-2100		
			Min.	Avg.	Max.	Min.	Avg.	Max.	Min.	Avg.	Max.
Real	GDP	843,603	-6.46	0.10	5.96	-8.02	-1.39	5.99	-9.72	-3.99	1.70
	Absorption	996,493	-6.13	0.08	5.56	-7.61	-1.33	5.60	-9.25	-3.78	1.57
	Household Cons.	688,900	-6.59	0.09	5.98	-8.20	-1.43	6.00	-9.96	-4.06	1.70
	Export	227,253	-6.14	0.08	5.89	-7.66	-1.39	5.86	-9.20	-3.83	1.57
	Import	269,388	-5.18	0.07	4.97	-6.46	-1.17	4.94	-7.76	-3.23	1.32
	Real Exch. Rate	100	-0.28	0.01	0.28	-0.37	-0.08	0.29	-0.40	-0.18	0.10
	Dom. Price Ind.	100	-2.54	-0.01	2.11	-3.19	-0.57	2.17	-3.92	-1.59	0.48
Ratio to GDP	Investment	22.23	-0.03	0.00	0.04	-0.03	0.01	0.05	-0.01	0.02	0.06
	Private Saving	15.08	-0.31	0.00	0.27	-0.39	-0.07	0.26	-0.49	-0.19	0.08
	Foreign Saving	5.24	-0.19	0.00	0.22	-0.19	0.05	0.27	-0.06	0.13	0.33
	Trade Deficit	6.62	-0.16	0.00	0.19	-0.16	0.04	0.24	-0.06	0.11	0.30
	Gov. Saving	1.91	-0.11	0.00	0.14	-0.11	0.03	0.17	-0.03	0.08	0.21

Source: Author's calculations

Table 1 shows the change in household income. The average change in the household income is small for the first period while it becomes significant in the following period. The differences between the average values also get wider in the second and third period. Further, the maximum and minimum values of the change in the household income differ significantly across regions. Accordingly, incomes of the households in the western and central regions are more sensitive to the extreme climatic conditions, suggesting significant decline in the prices of factors that are employed more in these regions. Since price of capital and land are fixed and the share of water in total income is quite small, the changes in household income are mainly driven by wages. The changes in wages are, in turn driven by the ability of firms to substitute water with labor in non-agricultural sectors, and with water-land composite in agriculture. Accordingly, the substitution is limited in the regions with lower water usage, namely the Thrace, central Anatolia and eastern regions. These regions benefits from the increase in the water price since income generated by water go to households as income. This brings about an important feedback effect. The increase in the demand of water will drive the price of water up and this will compensate the loss in household welfare due to decreasing wages in the mentioned regions.

Table 1: Household income according to regions (base values at billion TL)

	Base Level million TL.	% Change 2010-2035 Min.	Avg.	Max.	2035-2060 Min.	Avg.	Max.	2060-2100 Min.	Avg.	Max.
TR1	212,394	-11.13	0.13	10.44	-13.80	-2.50	10.45	-16.49	-6.90	2.67
TR2	41,916	-3.94	-0.14	4.21	-2.20	0.09	2.04	-3.95	-0.04	2.66
TR3	117,556	-7.71	-0.15	6.58	-9.65	-1.87	7.36	-11.60	-4.98	1.36
TR4	87,828	-7.86	0.10	7.25	-9.82	-1.71	7.39	-11.81	-4.92	1.73
TR5	89,146	-8.28	0.09	7.64	-10.32	-1.81	7.73	-12.52	-5.16	1.78
TR6	100,333	-5.74	0.10	5.35	-7.17	-1.18	5.54	-8.88	-3.61	1.30
TR7	38,343	-2.35	0.15	3.63	-2.32	0.17	2.81	-3.38	-0.45	1.45
TR8	46,688	-4.32	0.06	3.93	-4.70	-0.98	3.07	-5.57	-2.30	2.77
TR9	29,798	-2.80	0.05	2.82	-3.72	-0.80	2.26	-4.45	-1.92	0.19
TRA	21,083	-2.37	0.75	5.55	-3.46	0.69	5.44	-3.53	2.17	7.93
TRB	35,165	-1.02	0.88	3.41	-2.49	1.54	3.78	-1.10	2.94	6.05
TRC	70,180	-1.35	0.00	1.03	-1.43	-0.22	1.10	-2.01	-0.80	0.81
Turkey	890,431	-6.18	0.10	5.73	-7.66	-1.33	5.76	-9.28	-3.81	1.61

Source: Author's calculations

Table 2 reports the state of commodity and factor markets for all sectors. Climate change affects all sectors significantly, although the shocks are introduced directly to the agriculture. This is a result of complex interactions among the sectors. Although agricultural products are important intermediate inputs for agriculture and food production, this is not the only linkage between the sectors. All sectors compete for factors and hence a change in the factor demand of one sector affects all sectors. Secondly, the sectors also interact in the commodity markets, since all commodities are substitutable in household demand. Hence, a change in the price of one commodity affects the demand for other commodities as well.

Table 2: Sectoral results

Sector	Group	Variable	Base Level	% Change P1	% Change P2	% Change P3
Agriculture	Mark.	Prod.	107,560	0.36	-1.69	-5.12
		Cons.	64,939	0.19	-1.15	-3.31
		Prices	1.00	-0.07	2.58	7.30
	Empl.	Labor	5,018	0.08	1.54	4.52
		Irr. Land	5,261	0.78	-3.96	-13.92
		Rf. Land	16,708	0.21	1.40	3.49
		Capital	55,017	0.03	1.20	3.23
		Water	1,935	0.00	0.00	0.00
	Wage	Labor	7.68	0.00	-0.45	-1.69
		Irr. Land	0.28	1.24	0.96	0.47
		R. Land	0.33	-0.32	-0.71	-1.23
		Capital	1.09	0.00	0.00	0.00
		Water	1.00	-1.56	8.04	26.63
	Trade	Import	9,117	0.02	5.86	15.60
		Export	5,759	3.53	-5.76	-19.80
		Deficit	-3,358	-6.00	25.78	76.32
Food Production	Mark.	Prod.	30,330	0.11	-1.14	-3.32
		Cons.	92,422	0.08	-0.71	-2.12
		Prices	1.00	-0.06	0.64	2.05
	Empl.	Labor	687	0.04	-0.55	-1.66
		Capital	21,218	0.14	-1.37	-3.99
		Water	131	0.03	0.15	0.40
	Wage	Labor	13.07	0.11	-1.11	-3.13
		Capital	1.00	0.00	0.00	0.00
		Water	1.00	0.17	-1.98	-5.74
	Trade	Import	5,416	0.04	1.40	3.74
		Export	9,310	0.41	-3.89	-10.97
		Deficit	3,893	0.94	-11.25	-31.43

Note: Production and Consumption figures and quantity of water are quantities in terms of value added units, i.e. units that make base prices 1. Labor is in thousand person. Rest of the base values are in million TL.

Table headers are :
P1: 2010-2035; P2: 2035-2060; P3: 2060-2099

Sector	Group	Variable	Base Level	% Change P1	% Change P2	% Change P3
Total Non-Agrofood	Mark.	Prod.	705,713	0.06	-1.36	-3.85
		Cons.	665,690	0.06	-1.36	-3.85
		Prices	1.00	0.01	-0.51	-1.41
	Empl.	Labor	15,494	0.02	-0.65	-1.87
		Capital	428,803	0.11	-1.76	-5.00
		Water	3,775	0.00	-0.01	-0.01
	Wage	Labor	17.63	0.09	-1.41	-3.94
		Capital	1.00	0.00	0.00	0.00
		Water	1.00	0.16	-2.22	-6.35
	Trade	Import	275,867	0.09	-2.06	-5.69
		Export	212,184	0.00	-1.80	-4.87
		Deficit	-63,682	0.40	-2.95	-8.43
Manufacturing	Mark.	Prod.	142,478	0.01	-0.94	-2.63
		Cons.	103,317	0.08	-1.50	-4.25
		Prices	1.00	0.01	-0.60	-1.65
	Empl.	Labor	3,179	-0.01	-0.38	-1.07
		Capital	73,739	0.05	-1.43	-4.02
		Water	1,079	-0.02	0.32	0.90
	Wage	Labor	21.29	0.06	-1.40	-3.93
		Capital	1.00	0.00	0.00	0.00
		Water	1.00	0.15	-2.24	-6.38
	Trade	Import	229,988	0.08	-2.11	-5.83
		Export	135,216	-0.07	-1.45	-3.78
		Deficit	-94,772	0.31	-3.06	-8.76
Textile	Mark.	Prod.	35,046	0.04	-1.13	-3.15
		Cons.	46,251	0.03	-0.52	-1.50
		Prices	1.00	-0.01	-0.44	-1.19
	Empl.	Labor	1,657	0.03	-0.43	-1.18
		Capital	22,141	0.06	-1.52	-4.25
		Water	186	-0.01	0.21	0.63
	Wage	Labor	7.68	0.03	-1.46	-4.11
		Capital	1.00	0.00	0.00	0.00
		Water	1.00	0.14	-2.22	-6.36
	Trade	Import	11,830	0.04	-0.89	-2.45
		Export	32,308	0.06	-2.21	-6.05
		Deficit	20,478	0.07	-2.97	-8.14

Sector	Group	Variable	Base Level	% Change P1	% Change P2	% Change P3
Energy	Mark.	Prod.	14,031	0.06	-0.93	-2.68
		Cons.	12,786	0.05	-0.74	-2.13
		Prices	1.00	0.02	-0.36	-1.01
	Empl.	Labor	161	-0.05	-0.45	-1.25
		Capital	10,800	0.08	-1.08	-3.13
		Water	7.167	-0.01	0.40	1.13
	Wage	Labor	20.09	0.16	-0.87	-2.58
		Capital	1.00	0.00	0.00	0.00
		Water	1.00	0.18	-1.88	-5.52
	Trade	Import	18	0.04	-1.15	-3.17
		Export	101	0.00	-2.10	-5.69
		Deficit	82	0.00	-2.32	-6.27
Private Services	Mark.	Prod.	429,450	0.09	-1.59	-4.52
		Cons.	326,497	0.09	-1.82	-5.13
		Prices	1.00	0.01	-0.44	-1.22
	Empl.	Labor	10,012	0.03	-0.76	-2.22
		Capital	308,817	0.12	-1.89	-5.37
		Water	1,928	0.01	-0.14	-0.42
	Wage	Labor	11.86	0.09	-1.54	-4.27
		Capital	1.00	0.00	0.00	0.00
		Water	1.00	0.17	-2.30	-6.55
	Trade	Import	34,029	0.14	-2.12	-5.87
		Export	44,558	0.16	-2.56	-7.32
		Deficit	10,529	0.23	-3.97	-11.97
Public Services	Mark.	Prod.	84,707	0.02	-1.06	-2.96
		Cons.	19,477	0.04	-1.74	-4.84
		Prices	1.00	0.08	-0.72	-2.07
	Empl.	Labor	486	0.02	-0.93	-2.59
		Capital	13,306	0.14	-1.69	-4.84
		Water	573.957	0.01	-0.22	-0.59
	Wage	Labor	145.59	0.13	-1.06	-3.07
		Capital	1.00	0.00	0.00	0.00
		Water	1.00	0.18	-1.95	-5.64

Source: Author's calculations

The changes in the markets are not significant for the first period. There is a slight increase in production and consumption quantities for all commodities while prices are almost constant. The most important changes are in agriculture, food and textile trade. Agricultural trade increases significantly thanks to the increase in exports. Despite the slight increase in imports, the trade balance improves. Food and textile sectors follow the same trend, by increasing exports more than imports. Imports and exports in the other sectors do not change significantly. The second significant effect in the first period is on water and irrigated land markets. Declining water requirement causes the price of water to decline and this, together with the increasing productivity of agriculture, drives the price and demand of irrigated land upwards.

The effects are reversed and become significant in the second and third periods. All key variables change in the same direction in both periods and the magnitude of the effects get higher in the second period.

All sectors suffer from a serious fall in production quantities. The decline is higher in agriculture, food production and textile sectors as well as services. Consumption also falls for all commodities. Income and substitution effects work in the same direction for agriculture and food sectors since the consumption decline is associated with an increase in prices while they work in opposite directions for the other sectors. Consequently, the decline in the consumption becomes milder in non-agro-food sectors while it is drastically higher for agriculture and food.

Agricultural and food prices increase while prices in the other sectors decline in second third periods. Price changes get higher in absolute value throughout the periods. The price change also suggests that the increases in agricultural and food prices are supply side driven while the declines in the price of other commodities are demand driven. With the decline in productivity of agriculture both due to declining yields and decreasing productivity of water, agricultural production falls. This drives price of agricultural commodities up which in turn cause a negative supply side shock in food production which crucially depends on agricultural products. Once the prices increase for these two commodities, income effects dominates the substitution effects and households reduces their demand for the other commodities which causes a decline in their price.

Effects on factor markets occurs mainly through the price of water and employment of irrigated land for agriculture while the capital plays a more significant role in the other sectors. Farmers decrease their demand for irrigated land as increasing irrigation requirements causes a boost in the price of water. Factors are mobilized towards agriculture to compensate the productivity shocks. Hence, capital, rain-fed land and labor employment in agriculture increase. In the rest of the sectors, there is significant decline in capital and labor employment. Prices of labor and capital also fall since firms lay off labor due to decrease the production. Some of this labor is absorbed by agriculture with lower wages, causing a decline in household income.

Trade is affected significantly by climate shocks. As production shrinks, imports start to boost and exports decline in agriculture and food sectors. For the rest of the sectors, both imports and exports decline despite the falling prices. These changes are driven by income and substitution effects among imported and domestic good. For agricultural and food products, income and substitution effects work in opposite directions: Since imports become relatively cheaper, demand for imported goods is favored by substitution effect while falling household income suppresses it. For the rest of the sectors, since prices decline both effects work in the same direction. Since domestic goods become cheaper they are substituted for imported goods and since income of household declines demand for imported goods further declines. Trade deficit deteriorates in all sectors except manufacturing which means, the decline in imports is proportionally smaller than the decline in exports for the non-agrofood sectors. However, since manufacturing is the main trading sector with 80 percent share in imports and 60 percent share in exports, total trade deficit improves.

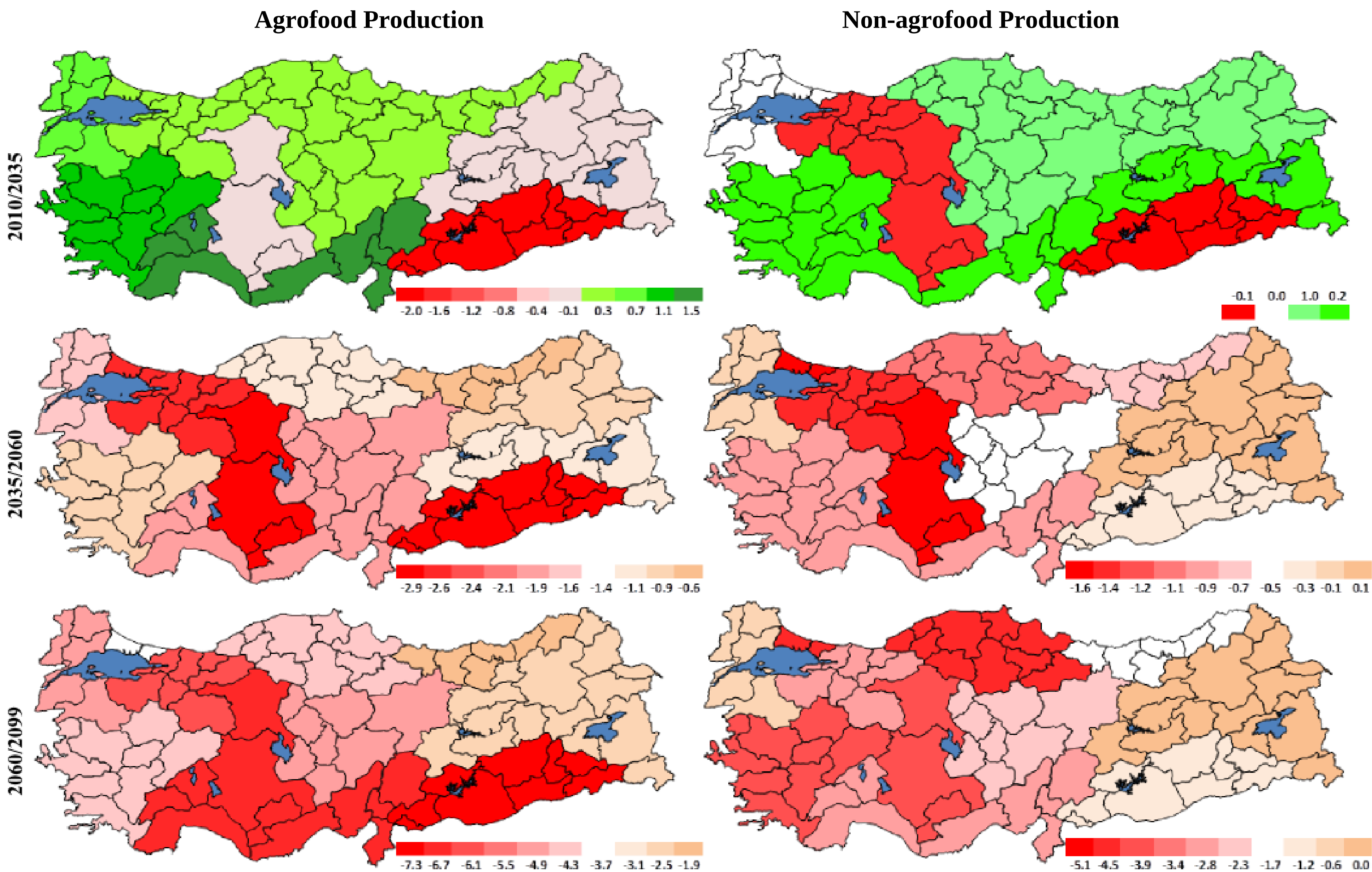

Figure 6: Regional production in agrofood and non-agrofood sectors in value added units.

Figure 6 shows the spatial distribution of value added production for agrofood sectors and other sectors. Although effects for the first period are small for all sectors, there are some regional disparities. In the first period agricultural production in Mediterranean and Aegean region increases relatively at a higher rate, while it declines by 1.87 percent in Southeastern Anatolia. In the second period west central regions and southeastern regions are amongst the most affected regions. Although effects are magnified for all regions, Mediterranean region is relatively worse off in the third period. In general, agricultural production declines or increases less in the eastern regions, except the southeastern Anatolia. This hints about the mechanism of climate change shock. In both periods, the regions which are more dependent on irrigation are affected more and hence we can conclude that the decline in yields is not more important than the increase in irrigation water requirement changes in determining the agricultural production.

Effects on the production of non-agrofood sectors are determined by the power of the link between agriculture and other sectors. However the relative condition of these sectors change between two periods. In the second period, west central regions are affected significantly. The effects are slightly positive in Northwest and eastern parts of the country, since in these regions share of agriculture in inputs of non-agrofood sectors is small. In the third period, the decline in non-agrofood sectors is higher in coastal regions, except the eastern Black Sea region. Although the change in agricultural production is significantly milder non-agrofood production declines quite significantly in Aegean region. This suggests that, coastal regions can substitute agricultural inputs with other inputs up to a threshold but once this threshold is past, non-agrofood sectors become more vulnerable to climate change. The effects on the manufacturing and services sectors of eastern regions are relatively small in both second and third periods, since the link between agriculture and the rest of the economy is relatively weaker in these regions.

7. Conclusion

Turkey consists of regions that are quite diverse in terms of social and geographical structures. The diverse structure of the regions is also reflected in economy in terms of different consumption and production patterns. Distinct regional structures bring about a quite complicated network of economic relationships. In order to develop a solid understanding of plausible effects of climate change on Turkish economy one needs to take into account the interaction between different regional structures.

In this paper we presented a CGE model that attempts to discover the links between regions and relationship of these links with a climate change shock. The effect of the climate change is introduced as changing agricultural productivity and irrigation requirements. A crop water requirement model is used to estimate these effects for the years 2010-2099. The estimated values of changes in climatic conditions follow from the results of a regionalized global climate model. Results of the climate model suggest that the effects of climate change will become significant after 2035. The average climatic conditions in the period 2035-2060 will be worsened mainly due to increasing frequency of "bad" years with lower yields and increased irrigation requirements. On the other hand, the changes after 2060 will be mainly caused by deteriorating mean conditions together with the increasing frequency of climatic extremes.

Climate change strikes the economy by drastically changing the production and prices of commodities. Production of agricultural and food commodities are severely affected by the shock and prices of these commodities increase drastically. In the first two periods, coastal regions are affected less, while in the third period they are significantly worse off. In all periods, effects on regions which use less irrigation water are milder suggesting that the effect of increasing irrigation requirement is more important than the effects of changing yields. A similar pattern is also observed in welfare indicators. Household in the eastern regions are affected less.

The volume of trade declines severely. Trade balance deteriorates in all sectors except manufacturing, but the total effect is positive. The need for agricultural and food imports become more severe and this in turn is likely to create concerns about food security.

Results presented in this paper are compatible with the findings of other studies at the national or global level. The economic effects are region specific. There are welfare gains in some regions while losses are significant in others. Further, the effects are also asymmetric among economic agents. As predicted by many studies, the effects become more significant after 2040s.

Our results support the fact that climate change adaptation should be considered as an integrated issue that would cause complicated results. Hence, any climate change adaptation policy needs to be region specific but should also consider the interaction among the regions.

The model presented in this paper suffers many deficiencies and more efforts need to be devoted to shed light on the regional impacts of climate change. First of all sectoral details, especially within the agricultural sectors, can be increased to reach more detailed results. Secondly, a dynamic model would have given more information about the convergence to the new equilibrium. Lastly, climate shocks can be introduced as stochastic shocks which will allow for results to be tested statistically.

The model presented in this paper suffers many deficiencies and more efforts need to be devoted to shed light on the regional impacts of climate change. First of all the linkage between regions can be modeled more explicitly. Secondly sectoral details can be increased to reach more detailed results. Lastly a dynamic model would have given more information about the convergence to the new equilibrium.

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