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İKTİSAT İŞLETME VE FİNANS

Climate change and irrigation in Turkey: A CGE approach[*]

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Abstract

Agricultural production is heavily dependent on water availability for increasing productivity and decreasing volatility in production. However climate change is expected to increase the sectoral competition for water resources and raise the need for major changes in water policies. This study is the first to analyze the likely effects of climate change and changes in the Turkish economy via an economy-wide Walrasian Computable General Equilibrium model with a detailed account of the agricultural sector: 20 agricultural activities in each of the 5 regions are differentiated as irrigated and rainfed. Major macroeconomic indicators change significantly. The decline in GDP is significant. Wage rate falls, while other factors' prices increase. Production of irrigated crops decline significantly. Balance of trade in agricultural products becomes negative. Rural households benefits from the increase in the agricultural prices, while urban households are hit hard.

Keywords: *Computable General Equilibrium; Feedback Links; Climate Change; Turkish Agriculture; Irrigation Water*

JEL classification: *C68, O13, Q15*

Özet - Türkiye'de iklim değişikliği ve tarım: CGE modellemesi yaklaşımı

Tarım sektörü Türkiye için önemli bir gelir ve istihdam kaynağıdır. Tarımsal üretimde üretkenliği arttırmak ve üretim seviyelerindeki dalgalanmaları azaltmak büyük oranda sulama imkanlarının erişilebilirliğine bağlıdır. Ancak iklim değişikliğinin su için olan sektörler arası rekabeti ve su politikalarında önemli değişikliklerin yapılması ihtiyacını arttırması beklenmektedir. Çalışma, iklim değişikliğinin Türkiye ekonomisi üzerindeki muhtemel etkilerini ekonominin tamamını dikkate alan ve oldukça detaylı bir tarım sektörü olan bir Walrazcı Hesaplanabilir Genel Denge Modeli ile inceleyen ilk çalışmadır. Model tarım sektörünü çok detaylı bir şekilde ele almaktadır: 5 farklı bölgede sulanan ve sulanmayan olarak ayrıştırılmış 20 tarımsal faaliyet bulunmaktadır. Temel makroekonomik göstergeler belirgin bir şekilde etkilemektedir. GSYIH'da önemli düşüşler olmaktadır. Ücretlerin genel seviyesi düşerken su da dahil olmak üzere diğer faktörlerin fiyatları artmaktadır. Tarımsal ürünlerdeki ticaret dengesi eksiye dönmektedir. Tarımsal ürünlerin fiyatlarındaki artış tarımsal üretimle uğraşan hanehalklarının refah seviyesini olumlu etkilerken, şehirlerde yaşayan hanehalkları bundan olumsuz etkilenmektedir.

Anahtar Kelimeler: *Hesaplanabilir Genel Denge; İklim Değişikliği, Türk Tarımı, Sulama Suyu*

JEL Sınıflaması: *C68, O13, Q15*

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Introduction

Agriculture remains to be an important sector in the Turkish economy. This sector is a major source of employment accounting for 27 percent of the total workforce, and provide employment to approximately 70 percent of the rural workforce. However, the agricultural sector, overall, appears to lag behind the rest of the economy in transforming to one with comparable per capita value added[1].

Irrigation has a significant role in agricultural production. Irrigated agriculture forms about half of the crop production value. Diverse climatic zones, ranging from Mediterranean to semi-arid continental climate, and varied regional availability of water resources in Turkey, imply that water is a major factor in increasing productivity and decreasing volatility in agricultural production.

Development of water infrastructure in Turkey has gained momentum in the late 1960s. Irrigated area has more than doubled since then and the storage capacity of dams reached 140 billion m^3. The irrigation sector is currently consuming about 75 percent of total water consumption which corresponds to about 30 percent of renewable water availability. The non-agricultural demand for water is increasing rapidly due to the fast pace of urbanization and industrialization. However, supply-management practices targeting mainly the development of irrigation infrastructure, have continued to prevail as the major determinant of irrigated agriculture.

Several developments will certainly increase the competition for water resources and may stipulate radical changes in water policies in the medium- and long-run. The rapid pace of urbanization may lead to changes in the inter-sectoral allocation of water. Furthermore, the Mediterranean basin is expected to be severely affected by the climate change. This may further increase the pressure on an already stressed water economy with severe implications for the agricultural sector. Growing interest by developed countries in biofuels, combined with increasing demand for food, is aggravating the impact of climate change. Although recent surges in prices of basic staples have begun to decline, the agricultural commodity prices, however, are expected to remain high compared to historical averages. In addition, the renewal of the WTO-Agreement on Agriculture and Turkey's candidacy for membership to the European Union (EU) will add new dimensions to the deliberations on agricultural and water policies.

Based on this background it is therefore necessary to evaluate the consequences of recent changes in the national and international scenes in the Turkish economy to provide a better dialogue with policy makers and to

[1] Indeed, the growth rate of agricultural value added is about one fourth of the rest of the economy, which explains the declining share of agriculture in GDP over the past three decades.

develop proper policy responses.

The purpose of this study is to analyze the potential effects of climate change in the Turkish economy by using an economy-wide model. The Walrasian CGE model for Turkey disaggregates the economy into 20 agricultural and 9 non-agricultural activities. The agricultural sector is further disaggregated into 5 regions. The model incorporates agricultural and non-agricultural water use with the differentiated irrigated and rainfed agricultural production activities at the regional level. Furthermore, a farm level model is used to estimate the shadow value of water in agriculture. With the highly disaggregated nature of the agricultural sector, in response to climate change (as summarized by various scenarios) the model is expected to capture the reallocation of factors of production (labor, capital, and water) across various agricultural activities and also non-agricultural activities, along with the changes in returns to these factors of production, leading to changes in sectoral, regional and aggregate income.

In what follows, section 1 introduces the background in water and agricultural sectors in Turkey. Section 2 discusses the climate change phenomenon briefly, and considers the likely impacts on Turkish agriculture. These impacts are summarized under three scenarios of climate change: the likely changes in crop yields with changing rainfall and availability of water. Section 3 introduces the CGE modeling framework that implements these scenarios with a detailed account of agriculture, and section 4 presents the empirical results from the model. Finally, section 5 concludes with policy implications of the present study and future research agenda.

1. Overview of Water and Agricultural Sectors in Turkey

Import substituting agricultural commodities (maize and cotton) and most of the exported products (fruits and vegetables) are irrigation intensive. Although Turkey is currently using only 40 percent of its available water resources, it is estimated that the country will reach its limits of available water within two decades due to increasing demands from all sectors. The estimates are based on the increase in the non-agricultural demand and the full development of 8.5 million hectares of "economically irrigable" land. Supply-side water policies still dominate, despite the widely pronounced pressures from the demand side. Over-abstraction of groundwater in some regions and over-use of surface water in others continue to be the major supply side issues in the water sector.

Turkey's climate is moderated by both the Mediterranean and continental weather patterns which displays geo-climatic diversity when combined with a highly varied topography. The annual average precipitation is 643 mm, yet varies from 250 mm in the central part to 3000 mm in the Eastern Black Sea region. 75 percent of annual rain falls during winter. Annual rainfall is less than 500 mm in the inland Thrace and in the Eastern Anatolia regions. This diverse precipitation structure emphasizes the crucial importance of irrigation.

Generally, agricultural production is adversely affected by the shortage and inconsistency of rainfall during the growing season. Solar energy makes it possible to grow arid and semi-arid crops such as bananas and citrus. Moreover, it is possible to grow 2 to 3 different crops in irrigated areas that have crop growing seasons for a period of 270 days. However, some crops may be harvested before maturation, particularly in Eastern Anatolia with its 60 to 90 growing days. The coastal regions are humid with high precipitation rates. Inevitably, the topographic features are main factors shaping the distribution. The long-term annual evaporation rates are high, particularly in the southeast region, which receives almost no rainfall during summer, and reaches more than 2000 mm per year in winter (Kanber et al., 2005).

The average annual precipitation of the country corresponds to a water potential of 501 km^3 per year, of which 274 km^3 are lost to evapotranspiration, 69 km^3 feed aquifers and 158 km^3 flow through the rivers to the sea or lakes. The gross total surface and ground water potential of Turkey amounts to 234 km^3 (Table 1).

Table 1. Turkey: Water Resources Potential and Use

Surface water	**Groundwater**	**Total**
Surface flow 158 km^3	Feeding groundwater 69 km^3	Mean annual precipitation 501 km^3 (603mm)
Surface runoff [a] 193 km^3	Recharge 41 km^3	Renewable water potential 234 km^3
Usable surface runoff [b] 98 km^3	Safe yield 14 km^3	Usable (net) 112 km^3
Consumption 31	Consumption 12	Consumption 43

Source: DSI, 2008a.

Notes: [a] includes the contributions from underground (28 km^3) and from the neighboring countries (7 km^3); [b] includes the usable flow of 3 km^3 from the neighboring countries.

The amount of surface water utilized for consumption purposes is in the range of 98 km^3 per year, including the contributions from the neighboring countries. Total safe yield of groundwater resources is estimated to be 14 km^3. Thus, the total potential available water resources from surface flow and groundwater would amount to 112 km^3 per year.

The country's surface runoff is unevenly distributed in both time and place, consistent with precipitation. Surface and ground water resources are limited in the Aegean, Thrace and Central Anatolian regions where the demand for water is higher than the rest of Turkey. The Aegean and Thrace Regions are highly urbanized and industrialized, and have soil resources suitable for irrigation. They have 10.5 percent of total surface water resources for the country while covering 19.3 percent of the entire area. Almost 30 percent of the total surface water for the country flows through two rivers, the Tigris and Euphrates (DSI, 2007). An irregular regime of rivers requires reservoirs to regulate the water. It is estimated that 98 km^3 of surface water (51 percent of total surface water) can be consumed by technically and economically feasible projects. The actual utilizable water amount in Turkey is around 1,700 cum/person/year in 2007.

Sectoral consumption of water is presented in Table 2. Total human and utility water consumption is increasing steadily with population and income growth, totaling 6.2 km^3 per annum in 2004. The share of the population served by adequate water from the network connected at home or standpipes, reached 85 percent in rural areas, and 98 percent in urban areas. Annual water allocated to industry is about 4.3 billion m^3 supplied mainly from groundwater resources.

Table 2. Sectoral Water Use in Turkey

	Irrigation		Domestic		Industry		Total use (hm^3)
	Use (hm^3)	% of total	Use (hm^3)	% of total	Use (hm^3)	% of total	
1990	22,016	72	5,141	17	3,443	11	30,600
2000	29,300	75	5,800	15	4,200	10	39,300
2004	29,600	74	6,200	15	4,300	10	40,100
2023[a]	72,000	64	18,000	16	22,000	20	122,000

Sources: SPO, 2007; DSI, 2007.
Note: Both the sectoral and total use varies depending on the source. We have presented the most recent findings.a Target mentioned in DSI (2007) implies full utilization of all usable water supplies.

The total irrigated area was 5 million hectares in 2008 with 75 percent of the water allocated to irrigation. The irrigated area has already reached 60 percent of the total "economically irrigable" area of 8.5 million hectares.

Water consumption per hectare amounts to more than 6,000 m^3. With respect to geographical regions used in this study, more than 40 percent of the total irrigated area is located in the Western Region (DSI, 2008b ; GDRS, 2007 ; SPO, 2007). The Western region is more populated and industrialized compared to the rest of the country. In addition, the seven river basins in this area are estimated to have already exceeded their long-term capacity utilization rates (World Bank, 2007).

Pricing and cost recovery policies of water vary among sectors. There is almost no volumetric system for irrigation, whereas volumetric charges are common in domestic and industrial use. Almost all water users' organizations determine the per hectare fee for the operation and maintenance based on expected operation and maintenance costs. The government has been reluctant to recuperate the investment costs[2].

Several legislations and regulations address specific issues, but they are far from forming an integrated framework for effective management of water resources. Extended drought periods resulted in full use of available water in western and central regions, initiating transfer of water from irrigation to non-agricultural sectors. Increasing frequency of water shortages will augment the uncertainty of irrigation water availability, adversely affecting farmers' welfare. The legislative arrangements should, at least, cover priority determination for the intra- and inter-sectoral (irrigation, municipalities, industry, recreation, fishery etc.) allocation of water, and a proper pricing policy to recover full supply costs of water from the beneficiaries[3].

Turkey is resistant toward making any radical changes in agricultural and water management policies. However climate change, surging agricultural commodity prices in the medium and long term and rural-urban competition for water resources are expected to affect the resource allocation within agriculture. Further these factors will also have significant implications for the inter-sectoral allocation of resources. The impact on producers and consumers will be diverse, thus it is important to consider the economy-wide feed back effects of the conducted scenarios to design and prioritize proper policy responses for the agricultural and water sectors.

2. Climate change and Turkey: Quantification of the Scenarios

Climate change is expected to reduce precipitation in Turkey depending on the region. Reduced precipitation is anticipated to have severe adverse effects on rainfed agriculture. Even the irrigated agricultural production will demand more water as a result of reduced precipitation. Combined by the

2 Uluğbay et. al. (2003) give a detailed discussion of pricing and cost recovery problems of irrigation water in Turkey.

3 A discussion of implementation of a pricing scheme that will ensure cost recovery by taking environmental, social and economic aspects of the management issues into account found in Emek (2007).

increase in the urban demand, the pressure on water resources will certainly increase. The discussion on this topic is generally limited to the price (and hence production) effects of climate change. We attempt to simulate the effects of the anticipated climate change by shocking the yields of various crops to observe the economy-wide effects.

Climate change mainly affects agricultural productivity through reduced water availability (or runoff, i.e. the difference between rainfall and evapotranspiration)—both by reduced precipitation and increased temperatures. Most particularly, it has been reported that most of the Near East Region (including Turkey) will have a decrease in water availability of up to 40 mm per year, and that the decrease will increase to 80 mm per year in the Anatolian Plateau (FAO, 2008). Such water deficit stress can cause a decline in agricultural yields or require higher water use in irrigation to maintain yields (Yano et al., 2007). In arid and semi-arid parts of the world, climate changes could easily aggravate periodic and chronic shortages of water, and most importantly, climate change poses an important threat in developing countries, many of which are located in arid and semi-arid areas (Watson, et al., 1997). Watson et al. (1997) report also that these countries are especially vulnerable in the sense that they predominantly rely on single-point systems such as 'bore-holes' or 'isolated reservoirs' for their water sources, and once these primary systems fail to function, there is hardly any substitute system to provide adequate water supply. Additionally, these countries do not possess sufficient technical, financial or management resources to overcome the vulnerability and adjust to shortages and/or take on adaptation measures.

Turkey, which is located in arid Western Asia or the Middle East, is also expected to be significantly affected by climate change (Watson, et al., 1997). This region, which already is undergoing serious water shortages, is possibly one of the regions most influenced by climate change. Water shortages caused by climate change may also be a blessing in disguise for these countries as long as they adopt changes in cropping practices and improve efficiency of water use through efficient irrigation systems (Watson, et al., 1997). However, we have already mentioned that these countries are more likely to lack adequate technical, financial, or administrative resources to do so.

Although there are not many studies on the impacts of climate change on food and agricultural production in the Middle East, one projection finds that increases in temperature of up to 3-4°C will lead to a fall in yields of predominant regional crops across the region by 25 to 35 percent with weak carbon fertilization, or 15 to 20 percent with strong carbon fertilization[4].

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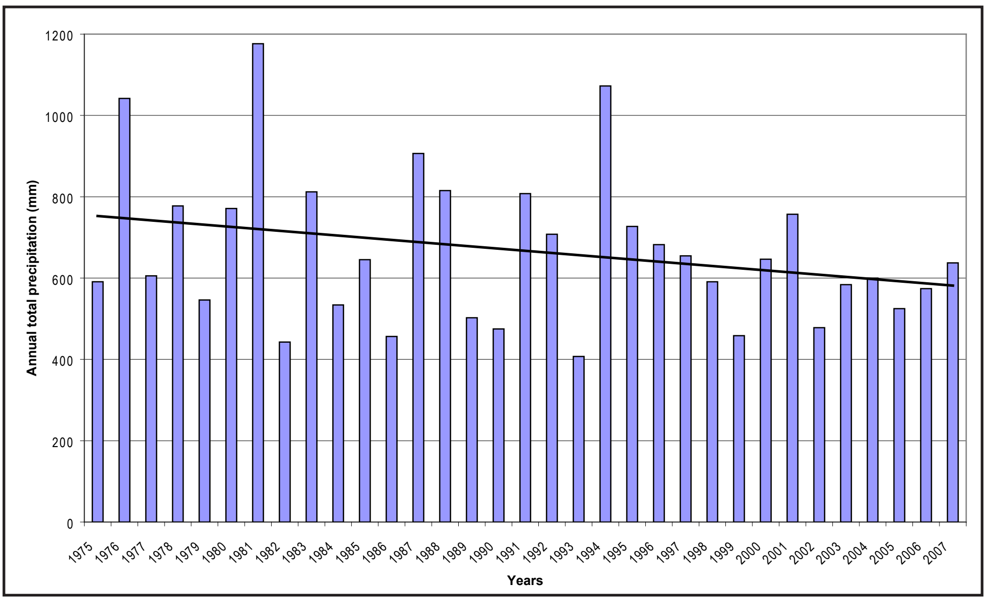
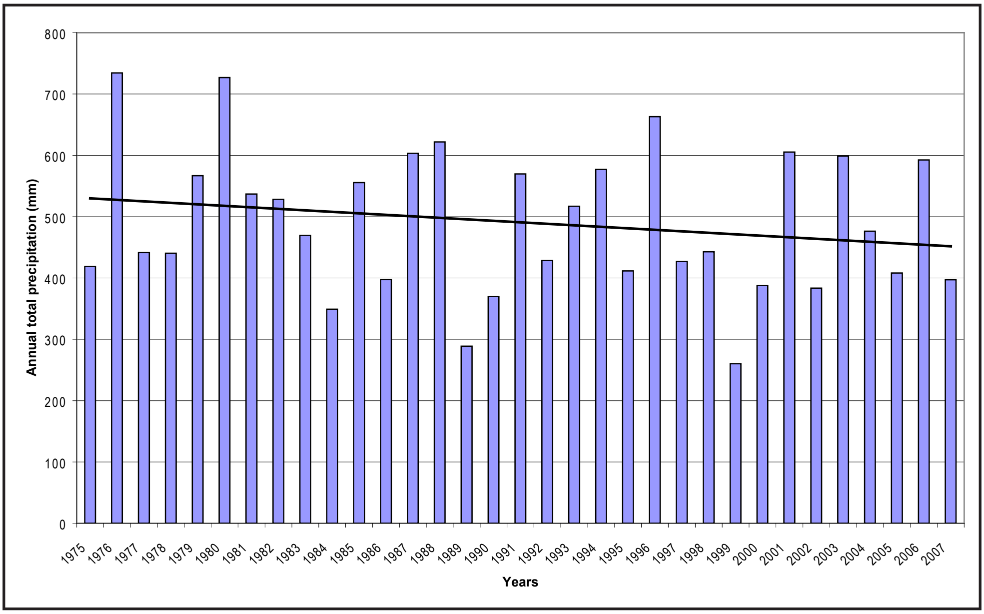
[4] The negative effect of increase in temperatures may be compensated by positive effects of increased CO_2 on crop tolerance to water deficit stress (Fuhrer, 2003; Yano, et al., 2007).

When we examine the annual total rainfall (mm) data for Turkish provinces from the year 1975 in Figures 1, 2, and 3, we see a clear downward trend in annual rainfall and water availability, particularly in Adana (predominantly producing wheat, maize, cotton, soybean and citrus), Diyarbakır (primarily supplying wheat, barley and pulses) and Konya (mostly supplying wheat, barley, sugar beet and pulses), which are important agricultural regions in the country (Turkish State Meteorological Service, 2008). Furthermore, Türkeş (1996) has observed that the area-averaged annual rainfall series has been on the decline slightly throughout Turkey, and particularly over the Black Sea and the Mediterranean regions between 1930 and 1993.



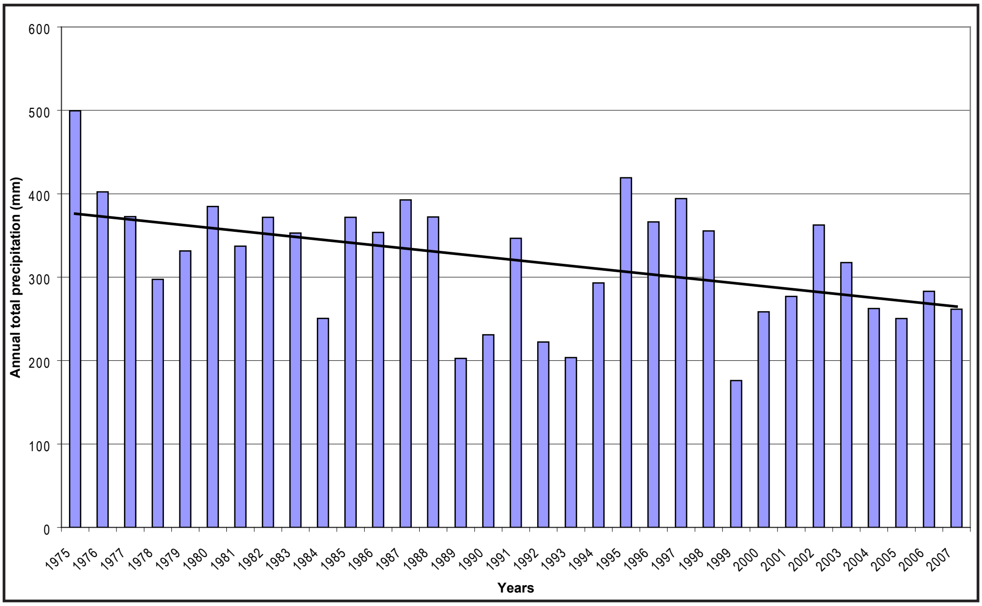
Source: (Turkish State Meteorological Service, 2008)

Figure 1. Annual total precipitation (mm), Adana, 1975-2007



Source: (Turkish State Meteorological Service, 2008)

Figure 2. Annual total precipitation (mm), Diyarbakır, 1975-2007



Source: (Turkish State Meteorological Service, 2008)

Figure 3. Annual total precipitation (mm), Konya, 1975-2007

In a simulation study focusing on the effects of climate change on crop growth and irrigation water demand for a wheat-maize cropping sequence in Adana province in Turkey, Yano et al. (2007) find that in the future (simulation period 2070-2079), irrigation water demand in wheat activity will increase due to decreased precipitation in this region. In these simulations, precipitation is expected to decrease up to 163 mm over the period of 1990 to 2100. They also find that with current (base) CO_2 levels and with increased air temperature of only 2.2^{o}C, wheat biomass and grain yield decrease by 24 percent and 12 percent respectively for the same simulation period. However they conclude that doubling the CO_2 levels, combined with an air temperature rise will result in a decrease in biomass by 4 percent, and an increase in grain yield by 16 percent in the 2070s. For maize, their findings suggest that its biomass and grain yield both decrease by 17 percent and 25 percent respectively, under the same scenario of elevated CO_2 levels and increased air temperature. Hence, ignoring the effects of carbon fertilization, one would expect a clear decline in the yields of these crops.

In the present study, the impact of climate change on agricultural production in Turkey and its implications for the Turkish economy are analyzed under three scenarios. First scenario simulates the impact of a decrease in the yields of rainfed crops by 30 percent (Scenario A), and then the yields of irrigated crops are decreased by 10 percent in addition to scenario A (Scenario B)). Final scenario (Scenario C) involves reducing the yield in all types of crops at varying degrees, ranging from 0 to 30 percent, depending on whether the crop is rainfed or irrigated, and the region it is produced in.

3. The Modeling Framework

The application of computable general equilibrium (CGE) modeling analysis on water management issues is relatively new in the literature. CGE modeling has made possible the exploration of economy-wide effects of the changes in water policy. The direct and indirect effects of climate change can be easily incorporated into the CGE models to illustrate the sectoral and economy-wide impact.

3.1. Overview of Water CGE Models

CGE models dealing with water issues can be broadly grouped into four categories according to their research questions. The first group of models deals with the competition of different sectors or alternative user groups for water. Seung et al. (2000) model the welfare effects of using water in irrigation or for recreational purposes. Briand (2004) on the other hand, introduces drinking water demand and analyzes the competition between drinking and irrigation water.

The second group of models investigates the cost recovery and pricing based water conservation policies. Beritella (2006) for example identifies the global and national level economic impacts of water transfer projects in China. Valezquez (2007) analyzes the effects of the increase in the price of irrigation water on the efficiency of the water consumption in agriculture and the possible reallocation of water to the other sectors. Letsoalo et al. (2005) test the 'triple dividend hypothesis' to see if water price policies can bring about reduced water use, more rapid economic growth and a more equal income distribution simultaneously. He concludes that it is possible to achieve triple dividends through water pricing.

Third group of models is related to the facilitation or liberalization of irrigation water trade. In fact, almost all relevant papers in the literature can be included in this group. However, some studies are missing the necessary constructs to simulate water markets. Goodman (2000) shows that water trade can replace construction of new irrigation facilities by increasing efficiency. Peterson (2004) illustrates that the impact of water shortages can be compensated by increasing water trade. Dywer (2005), extends the analysis of Peterson (2004) to urban water usage. Tirado (2004) deals with the effect of having a market for water rights between urban and agricultural sectors and argues that such a market would benefit both user groups. Kohn (2003), on the other hand, investigates the effect of international water trade by using Hecksher-Ohlin framework.

The last group of models attempts to combine CGE models with other types of models. Finoff (2004) introduces a bio-economic model based on general equilibrium approach while Smajgl et al.(2005) integrates theoretically agent-based modeling with CGE models. Lastly, some recent models aimed at analyzing the micro-macro linkages in water issues with CGE models. Roe et al. (2005) and Diao et al. (2005, 2008) use both top-down (trade reform) and bottom-up (farm water assignments and the possibility of water trading) linkages. They concluded that trade reform (top-bottom or macro to micro linkage) has a higher effect compared to water reform (bottom-up or micro to macro linkage).

Several CGE models were developed for Turkey aimed at analyzing macroeconomic issues in the 1990s. A selective list may include Harrison et al. (1993, 1996), Yeldan (1997), Karadag and Westaway (1999). Starting in the early 2000s, efforts devoted to develop CGE models for Turkey have increased. However, these models are also geared toward macro and trade analysis with an aggregated agricultural sector.

CGE models targeted specifically to analyze the issues of Turkish agriculture are relatively few. Agricultural CGE models on Turkey generally seek to address trade liberalization and structural reform issues. The first serious attempt to analyze the Turkish agriculture by using a CGE model is

Cakmak et al. (1996), where a partial equilibrium model is coupled with a CGE model. The CGE model had an aggregated agricultural sector together with three non-agricultural sectors. The dynamics in the agricultural sector were captured via the partial equilibrium model. Further, the simulations related to the agricultural sector were done via the partial equilibrium model, while the CGE simulations aimed to evaluate the effects of macroeconomic shocks and to reveal the role of the agricultural sector in the macroeconomic adjustment process.

Diao and Yeldan (2001) developed a general equilibrium model of the Turkish economy with a detailed agricultural sector. They have used an inter-temporal CGE model to analyze the effects of global agricultural trade liberalization. Turkey is one of the regions in the model along with Morocco and other Middle Eastern countries. Agriculture is disaggregated into five subsectors; grain crops, vegetables and fruits, sugar, other agriculture and animal products. Their main conclusion was in favor of trade liberalization.

Dogruel et al. (2003) used a CGE model to explore the feasible alternatives of agricultural reform and links between "the public sector fiscal balances, accumulation patterns, dynamic resource allocation, and consumer welfare under a medium-long-term horizon". The model consists of six sectors. Agriculture is modeled as an aggregate sector. Land is not included in the model as a production factor.

The intention of the CGE model developed by Çırpıcı (2008), is to analyze water management issues in Turkey. The model has 9 sectors, incorporating 4 factors of production. Agriculture is not disaggregated. Water enters agricultural production as land and water aggregate calibrated with a Leontief function. The Cobb-Douglas production function is used in the non-agricultural production. The model lacks the regional and sectoral detail in agricultural production.

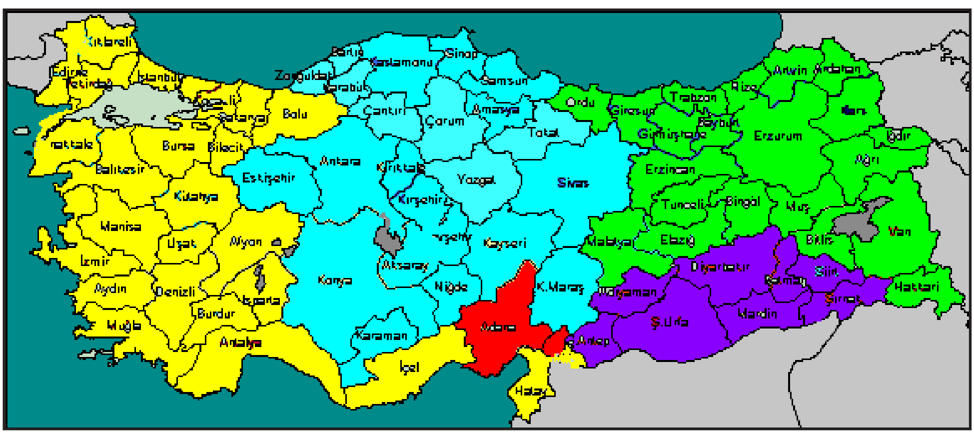
Studies using CGE models to conduct agricultural policy analysis incorporate agriculture as an aggregate sector both in production and consumption. Thus the policy simulations can not take into account possible interactions within the agricultural sector. The model used in this study namely, Turkish Agricultural Computable General Equilibrium Model with Water (TACOGEM-W), incorporates enriched treatment of agricultural production and consumption activities.

3.2. Model Structure

Turkish Agricultural Computable General Equilibrium Model with Water (TACOGEM-W) is the first attempt that exclusively models Turkish agriculture both in regional and sectoral details. The model utilizes the results of a farm level model developed for a micro region to estimate the shadow price of irrigation water. Hence, the rent created by the low prices for irrigation water is included in the model, linking the micro and macro aspects of irrigation water management.

TACOGEM-W is a Walrasian CGE model that includes the behavior of the three main sectors in the Turkish economy: the production activities, the institutions, and the foreign sector. In order to study the impact of a range of policy simulations, TACOGEM-W further disaggregates the economy into 20 agricultural and 9 non-agricultural activities. Agricultural activities are categorized by field crops, livestock, fishing and forestry (classified as 'other agriculture'). Non-agricultural activities include mining, consumer manufacturing, food manufacturing, intermediates and capital goods, electricity and gas, water, construction, private services and government services.

Among the agricultural activities, field crops and livestock are further disaggregated into production in four main regions and one micro region of the country, as given in Figure 4: West, East, Central, Southeastern, and the micro-region, LSCB (Lower Seyhan-Ceyhan Basin)[5]. Fishing, forestry and non-agricultural activities remain at the national level. Geographically, The West region includes Istanbul, Marmara, Aegean and the Mediterranean regions (except for Adana and Osmaniye provinces), the region East includes Northeastern Anatolian, Mid-eastern Anatolian and Eastern Black Sea Regions, Central region includes Western Anatolian, Mid-Anatolian and the Western Black Sea, and the LSCB micro region includes Adana and Osmaniye provinces. Figure 4 depicts the geographical distribution of the regions defined in the social accounting matrix (SAM).



Source: Authors' work

Figure 4. Regional Disaggregation in the Social Accounting Matrix

[5] The regional diversification can be easily enriched depending on the availability of necessary data.

The institutions block of the economy includes households, the government and the Water User Associations (WUA). Households are disaggregated into rural and urban households. Rural households are further disaggregated according to their geographical location. Hence in TACOGEM-W, there are five rural households and urban household is defined at the national level. Households earn income from factors of production (land, labor, capital), engage in expenditures on various commodities, save, and also pay taxes to and receive transfers from the government. The identification of rural household types links to the variation in resource endowments common to agriculture.

The government collects tax revenue from numerous sources: production, sales, households, and imports. The government uses these funds for purchases of goods and services at the respective markets and makes transfers to households, and engages in public savings.

Regional activities of field crops, in addition to land, labor and capital, use water as an input in production. These activities also make payments to WUAs in their respective regions. These water charges are income earned by the Water User Associations. In TACOGEM-W, it is assumed that this water income collected in each region is simply transferred back to the respective rural household in lump-sum.

Agricultural sectors are modeled in the same way as the sectors in the rest of the economy. Hence the linkage between agriculture and rest of the economy works through intermediate input and factor demand at the supply side and prices on the demand side. Further agriculture is also linked to the rest of the world accounts through international trade.

To construct the regionalized SAM for the year 2003, we combine various data from 2003 Agricultural Structure-Production, Price, Value Statistics (TurkSTAT, 2003); Telli (2004); 1998 Input Output Structure of the Turkish Economy (TurkSTAT, 2004); 2003 foreign trade statistics by Undersecretariat of Foreign Trade (UFT Website); TurkSTAT 2002 Household consumption expenditures and income survey statistics (TurkSTAT Website), ARIP Quantitative Household Survey (QHS) commissioned by the Treasury and implemented by the G.G. Consulting et al. conducted in 2002 and 2004 (G&G et al. 2002, 2004), and the Turkish SAM for 2001 developed by GTAP. This regionalized SAM includes information on the regional level employment of labor and capital as well as intermediate input use by crop, along with water charge and irrigated versus rainfed land rents by crop. Employment of capital, labor and data on intermediate input use are also entered for activities at the national level in the SAM. Detailed income, consumption and saving information for the five-types of households (urban, and four rural) are included in the institutions block of the SAM. Also included in the institutions block are the data on government consumption, net tax receipts, and public savings, along with the WUAs' accounts. Finally, import, export and tariff data concerning the EU-25 and the rest of the world constitute the foreign sector block of the SAM (the foreign trade partners to Turkey are the 25 European Union countries and the rest of the world). These detailed data are used to obtain the parameters for TACOGEM-W.

The algebraic structure of TACOGEM-W is based on the CGE model developed by Lofgren et al. (2002). The entire sequence of mathematical equations that define TACOGEM-W and the main characteristics of the model are provided in Cakmak et al. (2008). A farm model is used to estimate the shadow value of water in agricultural production. The algebraic details of the farm model are also available in Cakmak et al. (2008).

4. Empirical Results

Both nominal and real GDP declines under climate change (Table 3). However, the magnitude of the decline in nominal GDP is significantly high: The more severe the climate change, the more severe is the decline. Underlying reason is the decline in rainfed and livestock activities as well as food production sector. Value added created by rainfed activities deteriorates as a result of a declining yield in rainfed activities. Livestock and food production falls due to increasing crop prices and costs in livestock production. However, increasing production in irrigated land compensates for the decline in other sectors.

Although value added created by agriculture increases in all scenarios in nominal terms, real agricultural value added declines. This implies, that in all three cases the effects working on increasing domestic price dominates the effects working on the cost of production. The increase in the value added of agricultural sector is mainly due to the increase in production in irrigated activities. The decline in the nominal value added of other agricultural activities may reach 64 percent. Industrial activities also experience a decline of approximately 7 to 9 percent. The change in the non-agricultural value added is also higher. The changes in the real value added are milder.

The comparison of changes in nominal and real GDP and the sectoral value added show that an important account of GDP change is due to adjustment in prices. In real terms, effects are milder, and even in the opposite direction for rainfed agriculture.

For demand side macro variables we can conclude similar results. The changes are significant in all three cases. Increase in manufacturing goods consumption cannot compensate the decline in agricultural consumption, and total consumption falls (Table 4).

Table 3. Effects on GDP

			Base	% Change		
			Level (Million TL)	Sc. A	Sc. B	Sc. C
Nominal	at Factor Costs	Total	335,700	-5.82	-7.00	-5.90
		Agriculture	48,935	1.34	1.91	1.63
		Rainfed Agriculture	25,688	-6.48	-0.18	2.65
		Irrigated Agricultural	18,001	28.89	24.20	16.87
		Other Agriculture	5,246	-54.92	-64.36	-55.69
		Non-Agricultural	286,765	-6.96	-8.42	-7.11
		Services	168,529	-6.86	-8.24	-6.88
		Industry	118,235	-7.10	-8.68	-7.43
	at Market Prices		379,687	-5.56	-6.74	-5.69
Real	at Factor Costs	Total	335,700	-2.66	-3.47	-3.02
		Agriculture	48,935	-15.90	-20.02	-17.37
		Rainfed Agriculture	25,688	-37.67	-35.03	-27.16
		Irrigated Agricultural	18,001	15.60	1.73	-3.19
		Other Agriculture	5,246	-17.44	-21.21	-18.13
		Non-Agricultural	286,765	-0.37	-0.59	-0.53
		Services	168,529	-0.29	-0.49	-0.41
		Industry	118,235	-0.47	-0.75	-0.69
	at Market Prices		379,687	-1.94	-2.54	-2.23

Source: Results from TACOGEM-W.
Note: ScA: Yield of rainfed crops falls by 30 percent; ScB: Yield of rainfed crops falls by 30 percent and irrigated crops falls by 10 percent; ScC: Regional yields of all crops falls at various rates..

Table 4. Macroeconomic results of simulations

	Base	% Change		
	Level[a]	Sc. A	Sc. B	Sc. C
Absorption	384,423	-1.9	-2.5	-2.2
Household Consumption	245,161	-1.8	-2.4	-2.1
Investment	75,017	-3.8	-5.1	-4.5
Export	98,447	-2.1	-2.6	-2.4
Import	103,184	-2.0	-2.4	-2.2
PPP Real FX Rate	100	-4.2	-5.0	-4.2
Nominal FX Rate	100	-5.9	-7.1	-6.0
Domestic Price Index	100	-1.8	-2.2	-1.9

Source: Results from TACOGEM-W.
Notes: [a] Million TL for GDP accounts.See text and Table 3 for the description of the scenarios.

Under Scenario A, we first notice that overall production volume in irrigated crops such as vegetables, other grains (rice, etc.), wheat, oil seeds, fruits, and other crops category rise at varying rates. The highest increase is seen in the other grains category by 34 percent, followed by vegetables with 30 percent. Irrigated wheat activity, on the other hand, increases by 9.63 percent overall. We must mention that the crops named above are modeled as growing on both irrigated and rainfed land. While we observe production volume increases in crops which have activity in both irrigated and rainfed land, the production quantity in crops such as cotton (raw), sugar beet and potatoes, which are only grown on irrigated land, all decrease significantly (Table 5).

Table 5. Change in production of irrigated activities

	Base	% Change		
	Level (Tons)	**Sc. A**	**Sc. B**	**Sc. C**
Wheat	7,877	9.63	-4.41	-8.07
Maize	1,355	-1.81	-14.89	-16.02
Other grains	304	33.63	17.10	7.02
Sugar beet	12,622	-8.84	-13.71	-13.76
Cotton (raw)	2,295	-15.99	-23.52	-14.34
Oil seeds	976	19.76	5.11	-5.16
Potatoes	5,300	-5.54	-7.74	-7.90
Vegetables	9,827	29.77	14.50	6.66
Fruits	6,562	13.56	1.60	-3.56
Other crops	1,203	35.19	18.69	8.59

Source: Results from TACOGEM-W.
Note: See text and Table 3 for the description of the scenarios.

As a result of the fall in the yields of crops on rainfed land, and as production shifts to irrigated land, the shadow value of irrigation water is expected to rise due to increased competition for water. Particularly, the shadow value (or price) of irrigation water in the Central region increases by 27 percent, in the East region by 26 percent, in the LSCB region by 10.46 percent, and in the Southeast region by a moderate 3.34 percent (Table 6).

Table 6. Change in factor prices

	Region	Base	% Change		
		Level (TRY)	Sc. A	Sc. B	Sc. C
Labor[a]		1.00	-6.21	-7.13	-5.90
Irrigated Land	West	0.64	20.20	15.04	17.19
	Central	0.26	21.06	15.43	0.48
	East	0.27	22.06	16.76	7.65
	Southeast	0.53	13.53	8.67	-3.07
	LSCB	0.70	19.79	14.12	10.74
Rainfed Land	West	0.27	-3.63	2.21	11.24
	Central	0.11	0.28	5.69	-0.01
	East	0.11	-1.04	3.95	5.89
	Southeast	0.23	3.79	8.20	2.17
	LSCB	0.14	-3.74	3.49	21.86
Water	West	0.13	21.82	15.88	18.85
	Central	0.11	27.14	21.65	0.48
	East	0.05	26.09	20.83	9.60
	Southeast	0.09	3.34	-1.35	-13.82
	LSCB	0.13	10.46	5.54	2.25
	Urban	0.81	-7.31	-9.27	-7.88

Source: Results from TACOGEM-W.
Notes: [a] Labor employment is taken as value added created by labor. See text and Table 3 for the description of the scenarios.

Central region has the highest share in total production of wheat. About 40 percent of total agricultural land is devoted to wheat activity in the Central region. Part of the wheat is produced on irrigable land. In that sense, recognizing the significance of wheat production in the Central region, one can expect to observe a relatively high increase in irrigation water shadow prices in this region.

Employment of irrigated land increases for some cereals, vegetables and fruits, and crops classified as other grains such as rice. This is due to the shift from rainfed land in these activities towards irrigated land as an alternative. Employment of irrigated land in sugar beet, cotton, potatoes and maize production fall at different rates. We mentioned sugar beet, cotton and potatoes are grown only on irrigated land. As production of all crops shifts from rainfed land to irrigated land due to the yield shock in rainfed activity, the price of irrigated land increases in all regions at rates ranging from 13 to 30 percent. With this increase in the price of irrigated land, a drop in employment in irrigated-land-only activities can be expected.

As can be inferred from the discussion above, production volume in all rainfed crop activities drop at various rates. For example, production of fruits in rainfed land drops by 39 percent, while production of oil seeds drop by 36 percent from the base as a result of the 30 percent drop in yield. Overall, considering the sum of both irrigated and rainfed land production activity, we observe a fall in volume of production in all crops. Moreover, production in livestock related activities also declines around 5 to 10 percent. Most significant decline in manufacturing sectors is observed in food production industry with 13 to 16 percent. Construction and intermediate goods production declines around 2 to 4 percent. Decline in other sectors is less than 0.5 percent. Consumer manufacturing turns out to be the only sector of which output increases. But increase is less than 2 percent in all scenarios. For example, food manufacturing contracts by 13 percent as there is a reduction in production of intermediate goods in this sector. As a result of the contraction in domestic production, import volume in almost all crops increases except for raw cotton, which experiences a fall in production and a rise in domestic prices. The most significant increase in import volume is seen in other grains with 65 percent as well as an increase in nuts by 45 percent. It is also important to note that manufactured food imports rise by 85 percent in volume. Export volume, on the other hand, decreases significantly following the fall in production in agriculture and an increase in domestic commodity prices.

We must also note that urban household's real consumption decreases by about 3.3 percent, while that of rural households in all regions increases by 4 percent except in the East with a 1.6 percent increase (Table 7). We can attribute this disparity in rural and urban household response to differences in sources of income of these household types, and also to the composition of consumption expenditures. Urban households earn about 40 percent of the total income due to labor, and the rest from capital, while rural households have income from land and water resources as well. While there is a clear drop in labor and capital income overall, there is a rise in rents to both irrigated and rainfed land, and a slight increase in the water factor income in the West and Central regions (which inhabit a large share of rural households). Nevertheless, there is a significant decline in real GDP by about 6 percent as a result of the fall in yields in rainfed crops by 30 percent simulating a shortage of water caused by climate change.

Table 7. Change in disaggregated real household consumption

	Base	% Change		
	Level (Mil. TRY)	Sc. A	Sc. B	Sc. C
Urban HH	192,526	-3.30	-4.00	-3.50
West Rural	28,136	4.10	4.50	5.80
Central Rural	11,422	3.70	3.90	-0.30
East Rural	8,662	1.60	1.50	0.60
Southeast Rural	2,450	2.40	2.00	-3.90
LSCB Rural	1,965	3.90	2.90	2.50
Rural Total	52,635	15.70	14.80	4.70
Turkey	245,161	-1.80	-2.40	-2.10

Source: Results from TACOGEM-W.

Considering Scenario B, in which the crop yield in irrigated activities are reduced by 10 percent, in addition to the 30 percent reduction in rainfed activities, the changes in the production volume of irrigated crops are much less pronounced than those in Scenario A. For example, production quantity in wheat declines by 20 percent compared to 16 percent. Increase in irrigated fruit activity becomes insignificant. We further notice that the response in cotton (raw), sugar beet and potatoes production volume is stronger than that in the previous scenario: there is an additional 10 to 15 percentage point decline in the production of these crops. In this scenario, the changes in the water shadow price and irrigated land price are not as high as those in the former scenario. This is because there is not as much competition for these inputs as before, simply due to the fall in yields and the pursuing fall in production volumes. In all crops, a change in water consumption from the base is smaller than that in the first scenario. As in the first scenario, the import volume of all crops increases and the export volume decreases following a rise in commodity prices, however these changes occur at higher magnitudes. The fall in real GDP is also higher by 3.5 percent.

5. Conclusions, policy implications and future research agenda

This study investigated the economy-wide effects of climate change which is introduced as an external shock. It is recognized that because of spatial heterogeneity of the climate, the simulated scenarios have differential impact on the agricultural production and hence on the allocation of factors of production including water.

The effects on major macroeconomic indicators under the climate change simulations are significant. Nominal GDP declines drastically, but the real impact is limited. This situation points out the importance of the climate change in the performance of the overall economy. It is obvious that the impact of the climate change will not be confined only to the agricultural sector. Through the interactions with the rest of the economy, the negative impact of the climate change will be amplified. Irrigation is considered to be the most important adaptation measure to ease the negative impact of climate change, especially on farmers' income. Warming is also expected to affect the availability of water resources. This aspect of the climate change is not incorporated in these simulations. Hence, the climate change adaptation policies incorporating water and land management should be given priority.

Turkey has been fortunate in its endowment of water resources. However, the demand for water is growing rapidly. The pressure on usable water resources is predicted to increase with the rapid pace of industrialization and urbanization. Scarcity of water in some regions has already started to hamper agricultural production. Over-abstraction of groundwater in the Central Region and over-use of surface water in the West have affected not only the availability of water, but also degraded its quality with serious environmental impact. The response of the governments so far has been focused on building additional infrastructure to release the constraints on water availability. Shifting the irrigation pricing method to promote efficient use of water has never been considered as an alternative to the current pricing method which consists of a per area based operation and maintenance charge. Seven river basins (out of 26), mostly in the West, are already in a serious state of water shortage, with abstractions exceeding 200 percent of the annual renewable resource (World Bank, 2007). If all of the 8.5 million hectares of the "economically irrigable" area is developed, the World Bank (2007) found that almost 18 basins will face serious water shortages. This situation raises serious doubts about the sustainability of the prevailing policies in the irrigation sector.

The results of the simulations further prove deficiency in the currently implemented approach of supply management and the pricing policy in the irrigation sector. The pressure on irrigation water augments in all scenarios. High increases are observed in the shadow prices for irrigation water in all regions, except in the Southeast Region where the change remains more moderate. Hence, it is necessary to achieve more efficient use of irrigation water which requires not only the promotion of water saving irrigation techniques, but serious consideration should be given to fit the demand for water to meet the supply.

Water stress in Turkey is predicted to increase with the demographic changes and unfavorable global climatic and economic conditions. Fast implementation of the necessary policy measures at all levels will achieve more efficient use of public resources and water. The project stock in the irrigation sector remains to be large compared to the allocated financial resources (SPO, 2008). Priority should be given better use of existing water infrastructure and proper ranking of the unfinished projects. The first one requires improvement in irrigation management practices. More resources can be allocated to restrict water losses from irrigation infrastructure starting from the high evaporation regions. There have been improvements in adopting more efficient water application technologies induced by government subsidies. The uptake of these technologies by irrigators can be further increased by shifting towards volumetric pricing practices. SPO (2008) points out the importance of increasing the efficiency in the use of irrigation water by the determination of irrigation fees proportional to the actual amount used.

Although the results of the model simulations are rich, it is possible to further improve the model structure. The priority should be given to incorporate the heterogeneous labor structure in the model. The regions can be further disaggregated to NUTS-I level. Further disaggregation of food manufacturing and other agriculture related industries, such as textiles, are necessary to ameliorate the inter-sectoral interactions. Sooner or later Turkey may be tempted by the biofuels frenzy, hence making it necessary to have a detailed energy sector. One valuable extension can be separating rural and urban households according to income groups. This would allow analysis of welfare distribution that the model currently lacks. Structural enhancements will improve the performance of the model, i.e. nested structure in production, especially for irrigated land and water. Another enhancement could be transforming the model into a recursive dynamic one that provides the adjustment paths for external and policy shocks.

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