# IMPACT OF CLIMATE CHANGE ON AGRICULTURAL WATER USE IN THE MEDITERRANEAN REGION

***Sevilay TOPCU*** [(1)*] ***Burak SEN*** [(2)] ***Filippo GIORGI*** [(3)] **Xunqiang BI** [(3)] **E. Galip KANIT**[(2)] **Tayfun DALKILIC** [(2)]

[(1)] *Cukurova University, Agricultural Faculty, Adana, Turkey (corresponding author, stopcu@cu.edu.tr)*
[(2)] *General Directorate of State Meteorological Services, Ankara, Turkey*
[(3)] *Abdus Salam International Center for Theoretical Physics -ICTP, Trieste, Italy*

## Abstract

The Mediterranean region is declared to be the most vulnerable region in the world regarding to man-made climate change and its impacts in the IPCC reports and many other scientific articles. In addition to extreme weather conditions such as increased floods and/or droughts, global climate change causes lower and more erratic rainfall combined with increased temperature, thus resulting in higher evaporation and water demand. Since the agricultural sector consumes about two thirds of all fresh water resources in the world, there is a strong concern over the impacts of future climate changes on the water resources and agricultural production. Thus, it is important to provide information on future regional changes in climate and possible scenarios and policy implications for the future. The Seyhan River Basin, located in the Mediterranean region of Turkey, has an important agricultural potential not only for the region but also for the entire country considering the soil and water resources, agricultural industry and high population density. The aim of this study was to predict future climate using the regional climate model RegCM3 for the period 2071-2100 and assess the regional impacts of climate change on agricultural water use in the Seyhan Basin. Climatic parameters such as daily mean, annual maximum and minimum temperatures as well as total annual precipitation were selected for the model simulation. The data from the period 1961-1990 were considered as reference, and A2 scenario conditions were used for the future climate projections. Effective rainfall, reference and crop evapotranspirations as well as net irrigation requirement were estimated. RegCM3 predicts for Turkey that the annual average temperature will increase by 3.4 to 4.8 ºC during the period 2071-2100. Results also revealed that there is a decrease in effective rainfall and consequently a decline in water resources. Reference and crop evapotranspiration rates are likely to increase by 24.3 mm to 163.7 mm and 10.8 mm to 98.47 mm respectively. Results also show projections of significant increase in irrigation requirement. We envisage that due to the combined effect of the predicted reduction in effective rainfall, and increases in temperature and crop water use could have an adverse impact on agricultural production in the Seyhan Basin.

***Keywords*****:** *Climate change, evapotranspiration, precipitation, regional climate models, temperature, water resources, Turkey.*

## 1 Introduction

The climate system of the earth, globally and regionally, has changed from the pre industrial period to the present. Some of the changes are due to natural phenomena and some due to human activities. In particular, the increase in atmospheric concentrations of so-called greenhouse gasses e.g. carbon dioxide ($CO_2$) and methane ($CH_4$) has resulted in greenhouse effect and global warming. According to the forth assessment report of IPCC, the natural range of the last 650,000 years, the carbon dioxide and methane concentrations were ranging 180-300 ppm and from 320-790 ppb respectively, however observed concentrations of these two gasses in 2005 were 379 ppm for $CO_2$, 1774 ppb for $CH_4$. Thus, global warming in the last 100 years has caused about a 0.74 C increase in global average temperature. This is up from the 0.6 C increased in the 100 years prior to the Third Assessment Report of IPCC. Also the eleven years between 1995 and 2006 are recorded within the top 12 warmest years since the instrumental recording has begun (IPCC, 2007). Along the last decade, the direct impacts of climate change registered in the Mediterranean basin consist of lower levels of precipitations, a modification of the intensity and distribution of the precipitations, an increase in floods and a raise in temperatures (IPCC, 2001 and 2007).

Recent analyses of Turkey's climate data reveal that minimum temperatures in the winter, and minimum and maximum temperatures in the spring and summer months are increasing. On the contrary, observed temporal distribution patterns of winter rainfalls are significantly changing, while moderate decreases in the total amount of rainfall have also been noted. These decreasing trends in rainfall amounts, particularly in winter months, are correlated with drought events. The most droughts, both hydrological and agricultural, occurred in the 1970s and 1990s and affected the Aegean, Mediterranean, Marmara and Southeastern Anatolia regions in Turkey. Drought classifications shifted in particular, from semi-humid to semi-dry, from semi-dry to dry conditions in the Aegean, Mediterranean and Middle Anatolia regions. Furthermore the middle and the eastern part of Anatolia, considering the land use and cover as well as climatic conditions, are under threat of desertification (Türkes, 2003).

According to the IPCC fourth assessment report, a temperature rise of about 0.1 °C per decade would be expected for the next two decades, even if greenhouse gas and aerosol concentrations were kept at year 2000 levels. A temperature rise of about 0.2°C per decade is projected for the next two decades for all SRES scenarios. Drought-affected areas will become larger. Heavy precipitation events are very likely to become more common and will increase flood risk. Dry regions are projected to get drier, and wet regions are projected to get wetter: "By mid-century, annual average river runoff and water availability are projected to increase by 10-40% at high latitudes and in some wet tropical areas, and decrease by 10-30% over some dry regions at mid-latitudes and in the dry tropics. In Southern Europe, climate change is projected to worsen conditions (high temperatures and drought) in a region already vulnerable to climate variability, and to reduce water availability, hydropower potential, summer tourism and, in general, crop productivity (IPCC, 2007).

Climate change is threatening the fresh water supplies, food production and sustainable development throughout the world. Rising sea level, extreme weather events and desertification are just a few of the adverse effects of global climate change. Mediterranean countries, in particular, are highly vulnerable to climate change regarding summer conditions, which are very pronounced with severe warming and drying, and also from the side impacts such as more frequent extreme weather conditions, increased floods and/or droughts (e.g. Giorgi, 2006). It is very likely that global climate change will turn already marginal areas into drought areas in those countries.

Semi-arid and arid areas are particularly exposed to the impacts of climate change on freshwater (IPCC, 2001 and 2007). Among the others the Mediterranean basin, will suffer significantly from a decrease in water resources due to climate change, thus even efforts to offset declining surface water availability due to increasing precipitation variability could be hampered by the fact that groundwater recharge will decrease considerably in some already water-stressed regions, especially with a rapid increase in population (Kundzewicz et al., 2007). Moreover, stream flows at low-flow periods may well decrease and cause a further deterioration of water quality (World Water, 2003). Evaluations of annual minimum, maximum and mean stream flows of the Turkish rivers show that they are significantly decreasing in most basins of the western part of the country (Topaloglu, 2006). It is likely that, due to less and erratic rainfalls, less water will infiltrate and recharge groundwater. Irrigation and, as a consequence, food security will be adversely affected if available water resources are decreasing. Prolonged summer aridity in addition to enlarged arid and semiarid regions may also accelerate desertification, salinity and erosion processes (Türkes, 2001).

The interactions between climate and water availability have been fundamental to many human activities, in particular agricultural production, in the past and will continue in the future as well. An increase in temperatures could also lead to a net deficit in atmospheric water content, thus excessive evaporation from soil, water and plant surfaces would occur. Land ecosystems would require more water to match increased water demand consequently to prevent drought. Elevated CO2 and temperatures affect plant growth and the water balance in a complex way, sometimes compensating for drought, sometimes aggravating it (Kimball et al., 2002). For instance elevated atmospheric CO2 concentrations primarily enhance CO2 diffusion into the leaf and increase the photosynthetic rate of C3-plants over a wide range of radiation intensities, despite decreasing stomatal conductance (Lawlor and Mitchell, 1991). Therefore, the chain reaction of elevated CO2-temperature-evapotranspiration is important and could be destructive for an ecosystem especially agriculture.

Future vulnerability depends not only on climate change but also on development plans, so that appropriate strategies followed by sustainable development can reduce vulnerability to climate change. Therefore climate simulation models serve as useful tools for assessing possible effects of climate change. Once these effects are determined, the appropriate adaptation and mitigation measures can be undertaken. Recent developments in climate change forecast using global (GCM) and regional (RCM) climate models made it possible to provide more detailed information on temperature and precipitation changes. Although GCMs are useful tools for long-term predictions, their horizontal resolutions of the GCMs are quite low, e.g., grid intervals may vary between 100 and 300km. In contrast, regional climate models have much better resolutions than GCMs, and can also take regional effects such as land cover into account. The regional climate model RegCM has already been used for various regions in the world (e.g. Giorgi and Mearns, 1999; Giorgi et al. 2004b). A number of regional climate model simulations of future climate change have been carried out in some parts of the world e.g. in Europe and Mediterranean region using grid intervals 50 and/or 20 (e.g. Christensen et al., 2002; Giorgi et al. 2004b Gao et al., 2006; Pinhas et al., 2006). There are only few climate change studies using global and regional climate models in Turkey, and no results for Turkey as a whole are available yet. Onol et al., (2006) used RegCM3 to downscale present and future scenario output simulated by the NASA-Finite Volume General Climate Model with a resolution of 30 km over Turkey.

Since a coordinated international attempt to mitigate global warming remains elusive, accurately predicting the impacts on a regional scale in order to assist adaptation efforts is essential. The Seyhan River Basin, located in southern Mediterranean Region in Turkey, has an important agricultural potential not only for the region but also for the country considering the soil and water resources, agricultural industry and high population density. Hence, for a sustainable agricultural production in the Seyhan Basin, future climate change and its possible effects have to be projected. Therefore the main objective of this study was to predict future climate and to assess its possible impacts on water resources and agricultural water use in Seyhan River Basin using regional climate model RegCM3 for the period 2071-2100.

## 2 Study Area, Data and Methods

This study was conducted in Seyhan River Basin, which is one of the major land and water resources basins in Turkey. The Seyhan River is located in the Eastern Mediterranean Region of Turkey, and the drainage area of the basin is about 21,750 $km^2$ extending between 37º 13' – 40º 12' N and 35º 03' – 37º 56' E. The Seyhan River with a length of 560 km originates from Taurus Mountains, runs through the city of Adana and outfalls to the Mediterranean Sea (Fig. 1). There are four dams already in operation fed by Seyhan River and its tributaries, and the biggest Seyhan Dam serves besides hydropower and flood control for irrigation of 134,00 ha in present, however the irrigated area is planned to be enlarged up to 174,000 in near future. The physiography of the Seyhan Basin varies from south to north, the lowlands characterizing the south while the north is represented by harsh topography as seen in figure 1. The climate in the basin is under the influence of the Mediterranean climate, with hot and arid summers and mild and rainy winters. Grain production is dominating in the lower part of the basin, and among the grains, wheat is grown under rain fed conditions while maize grown as first and second crop is irrigated. Industrial plants such as cotton and fresh fruits particularly citrus and vegetables are taking also significant place in the cropping pattern of the region. In the upper part of the basin dominates mixed forest, meadow and pastureland.

The model used in this study, RegCM3, is described by Pal et al. (2005) and is used with the same physics options as in Giorgi et al., (2004a,b). The model domain originally covers the entire Mediterranean Region and surrounding areas with a grid spacing of 20 km, and extends from the Eastern Atlantic to the eastern side of the Black Sea and from Northern Africa to the plains of central Germany. The RegCM3 is a three dimensional hydrostatic atmospheric model and uses its standard vertical configuration of 14 sigma levels, model top at 80 hPa and five levels below about 1,500 m. It also includes both direct and indirect sulfate aerosol effects as described by Giorgi et al. (2002, 2003). To produce the lateral meteorological boundary conditions for the RegCM3, the HadAm3H fields (Pope et al., 2000; Jones et al.; 2001), which has horizontal grid interval 1.25º latitude by 1.875º longitude was used. The RegCM3 model was run in the double nested code (at both 50 km and 20 km resolutions) for the 60 years total simulation (1961-1990 and 2071-2100 periods). Model verification studies have been performed by the Giorgi et al., (2004a) for Turkey and by the Sen et al., (2008) for Seyhan Basin. The climate projected using RegCM3 under the Special Report on Emissions Scenarios (SRES) A2 emission scenario which is the closest to a "business as usual" scenario in the SRES family was performed for calculations of crop evapotranspiration and net irrigation requirement for the 30-year future period. The actual land and water conditions were used in the present and future period simulations, thus no adoption strategies have been considered within this study.

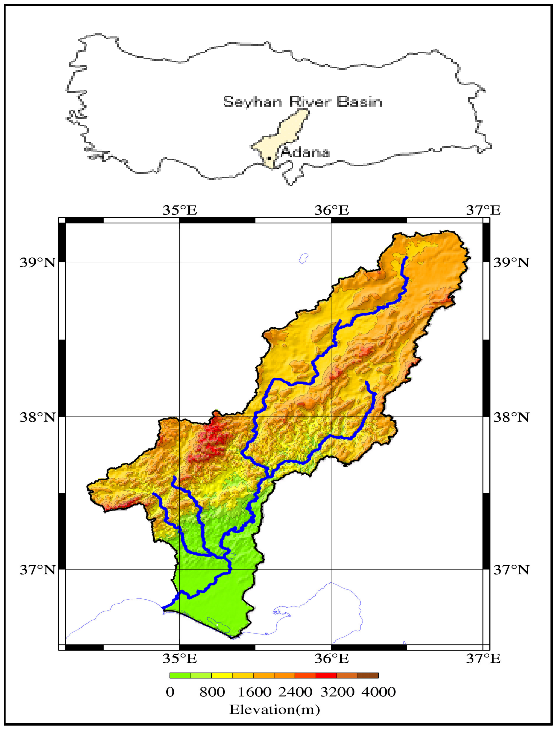


Figure 1. Location map of the study area

Climate of Seyhan Basin is projected for two 30-year periods namely for present day conditions (1961–1990) and for future (2071-2100), whereas the simulation for the period from 1961 to 1990 was reference run, which has also been defined by IPCC as the standard control simulation period. Data sets (annual mean of maximum and minimum temperatures, daily mean temperature and daily rainfall) used for RF simulation obtained from 11 observation stations of the General Directorate of State Meteorological Services. Data were checked at first for missing dates and values, and then missing values were replaced using different approaches depending on duration of missing data. Model simulations were performed for entire basin, which comprise 125 grids with an interval of 20 km. To compare the simulation results of A2 (2071-2100) and RF (1961-1990), differences of two periods were calculated for each grid and these differences were examined for independence and significance using f and t tests, respectively (Sanders, 1995). Finally the differences have been drawn in a map as likely changes expected in the future.

To assess the likely impact of projected climate on water resources, the most relevant factors namely effective rainfall (PE), (Brouwer and Heibloem, 1986), reference evapotranspiration (ETo) and actual evapotranspiration (ETc) rates have been determined using approaches given by Hargreaves and Samani, (1985) and by Allen et al., (1998) respectively. The land use considering the type and the area of crops in each grid was reflected in crop water use calculations.

## Results and discussion

As described in detail by Giorgi et al., (2004a), the RegCM3 model was first evaluated for its appropriateness to produce good quality simulations for the future climate. Surface air temperature and precipitation biases were mostly less than 1-2 ºC, and 20%, respectively. Model was run for a domain including Spain at the west and Turkey at the east end for present day and future periods (1961-1990 and 2071-2100 having grid spacing of 50 km (Giorgi et al., 2004b) and 20 km (Gao et al., 2006). From these simulation results, 125 grids covering entire Seyhan River Basin have been selected for present study. Considering the whole picture of Turkey, daily mean temperatures will likely increase more than 4 C except coastal areas of Black Sea and Marmara regions. Warming increases to the east direction (not shown) in the country. On the regional scale, temperature increases 3.2ºC to 4.6ºC have been projected (Fig. 2). Temperature increase was greater in high latitudes (above 500 m) more than 4 ºC in upper basin however in the lower basin namely Lower Seyhan Plain, about 3-4 ºC increases have been simulated. Increases in annual maximum and annual minimum were higher compared to daily max, min and average temperatures. Increased annual maximum and annual minimum temperature could cause some problems including drought spells in lower basin, thus increased water demand, and also the increased minimum temperatures could not be enough to meet the cold requirement for dormancy of some crop species grown in the Taurus Mountains. These predicted temperature increases were statistically significant ($\alpha$=0.01) in all grids in the entire basin. Krichak et al. (2007) reported similar results from their simulation study undertaken with different parameterisation of RegCM. Precipitation changes simulated by RegCM3 for the future period (2070-2099) relative to the present period (1961-1990) are shown in Figure 3**.** Although the magnitude of precipitation changes differ from one region to another in Turkey, it is worth mentioning that especially in Mediterranean and Aegean Regions, RegCM3 projects a substantial decrease (300 mm) of annual precipitation (not presented here) for the period 2071-2100. In the Eastern Mediterranean where Seyhan River Basin is located, decreases vary between 100 mm and 170 mm. Under A2 scenario conditions, most of the basin shows rainfall reduction of about 15 to 254 (Fig. 3), which is equivalent to drops of about 2-30%. The reduction in rainfall due to climate change was consistent temporally and spatially in the basin.

The expected possible change in the effective rainfall and reference evapotranspiration in Seyhan Basin is illustrated in Figure 4. It is estimated that the average effective rainfall in 2071-2100 period will decrease from 23.8 mm to 189.9 mm compared to RF values. The maximum decrease is observed in the middle region of the basin and the decrease in the basin in general is estimated to be 16.3 %. In the average reference evapotranspiration, an increase of 24.3 mm to 163.7 mm in the 2071-2100 period, is estimated under A2 scenario. The reduction in the middle and southern parts of the basin seems to be more significant (Fig. 4). Throughout the basin, the average increase in the reference evatranspiration is 16.4%. Under A2 scenario conditions it is likely for the average actual evapotaranpiration to increase from 10.2 mm to 98.5 mm in the 2071-2100 period. The increase will be relatively more in the middle, south-west and north-west regions of the basin. Throughout the basin the increase in the average actual evapotranspiration is 9.1 %.

The monthly increase in the ETc (Fig. 5) on the grid scale will be the highest with an increase of 24.26 mm and with a decrease of 0.97 mm in July, which illustrates that the spatial variation in the basin is more important than temporal (seasonal) changes. Maximum increase for monthly averages in actual crop evapotaranspiration were simulated in June (11.4 mm)

An increase of 68.6mm to 238.6 mm is estimated in the net irrigation requirement-NIR (Fig. 6), however, it is simulated that the increase in the middle regions of the basin will be relatively more. The increase of net irrigation requirement (Fig. 7) throughout the basin is estimated to be 206.9 %. Similar results for potential evapotaranspiration were obtained using another GCM and RCM by Fujihara et al., (2007) and Tezcan et al., (2007) as well.

Considering the 16.3% reduction in effective rainfall in addition to an increase about 9.1% in actual evapotranspiration rates (Etc), irrigation requirement will likely be doubled.

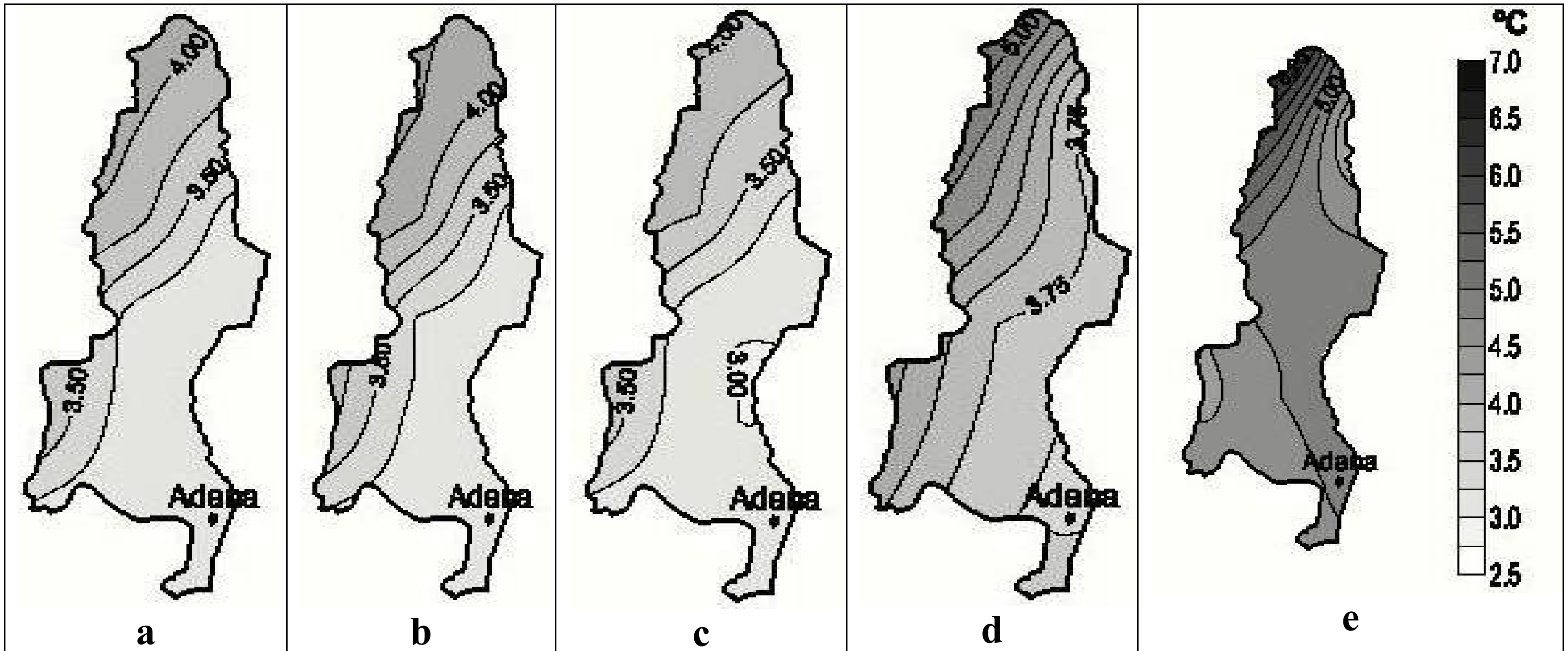


Figure 2. Predicted changes in temperatures A2-RF a) Daily mean, b) Daily maximum, c) Daily minimum, d) Annual maximum, e)Annual minimum,

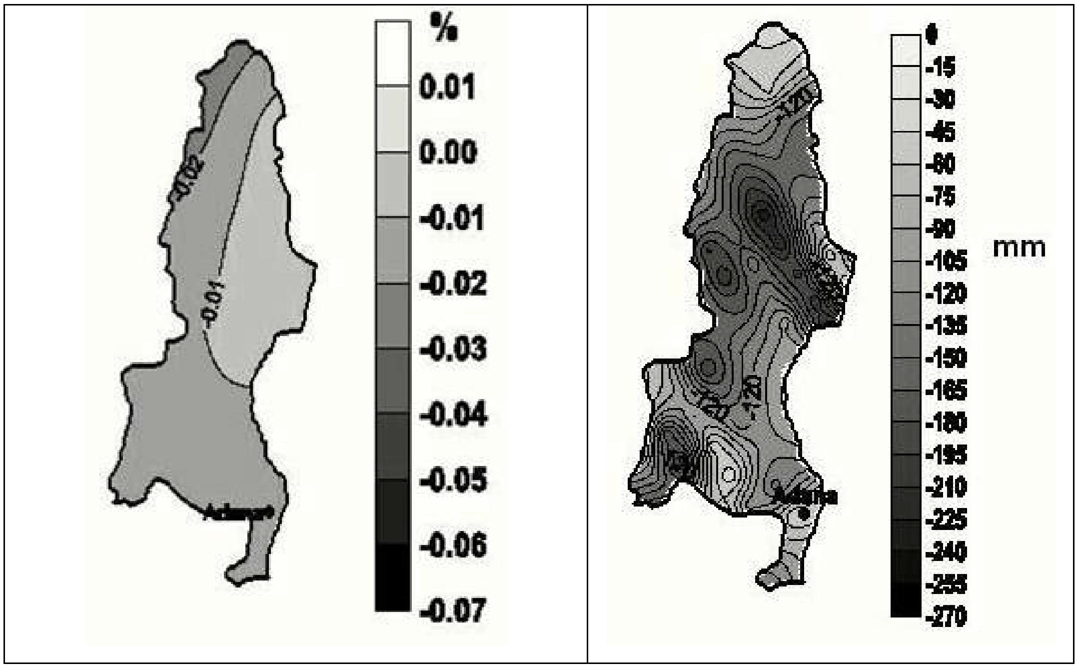

Figure 3 Predicted changes in relative humidity and in average annual rainfall (A2-RF)

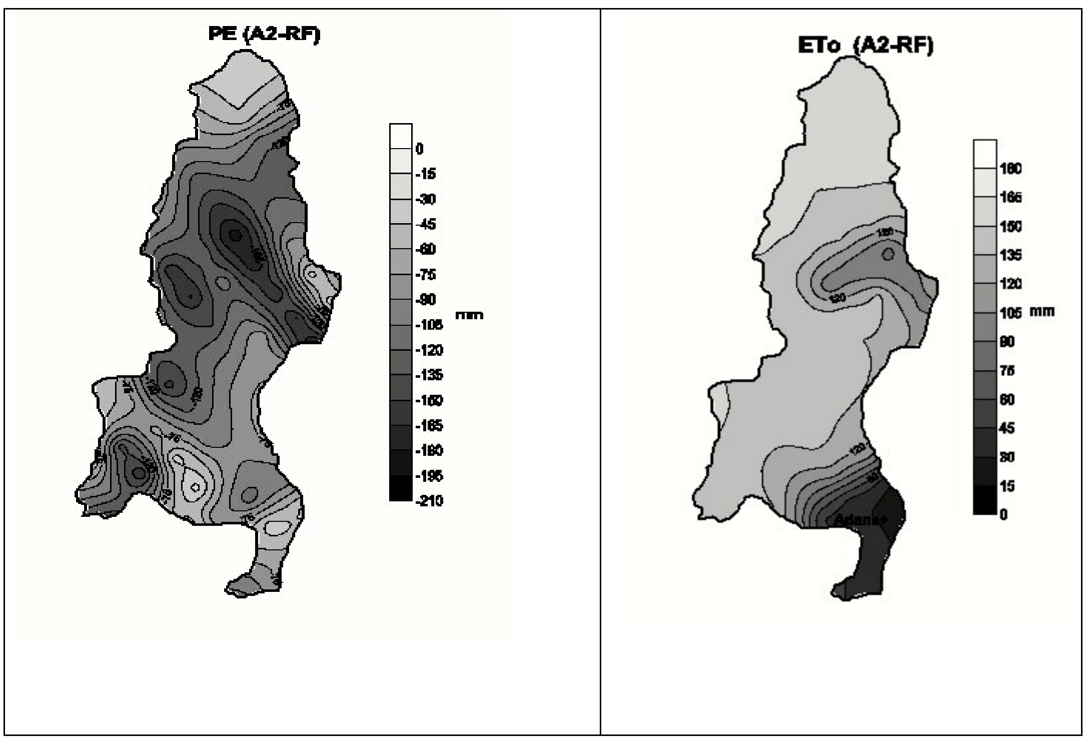

Figure 4. Predicted changes in effective rainfall and reference evapotranspiration

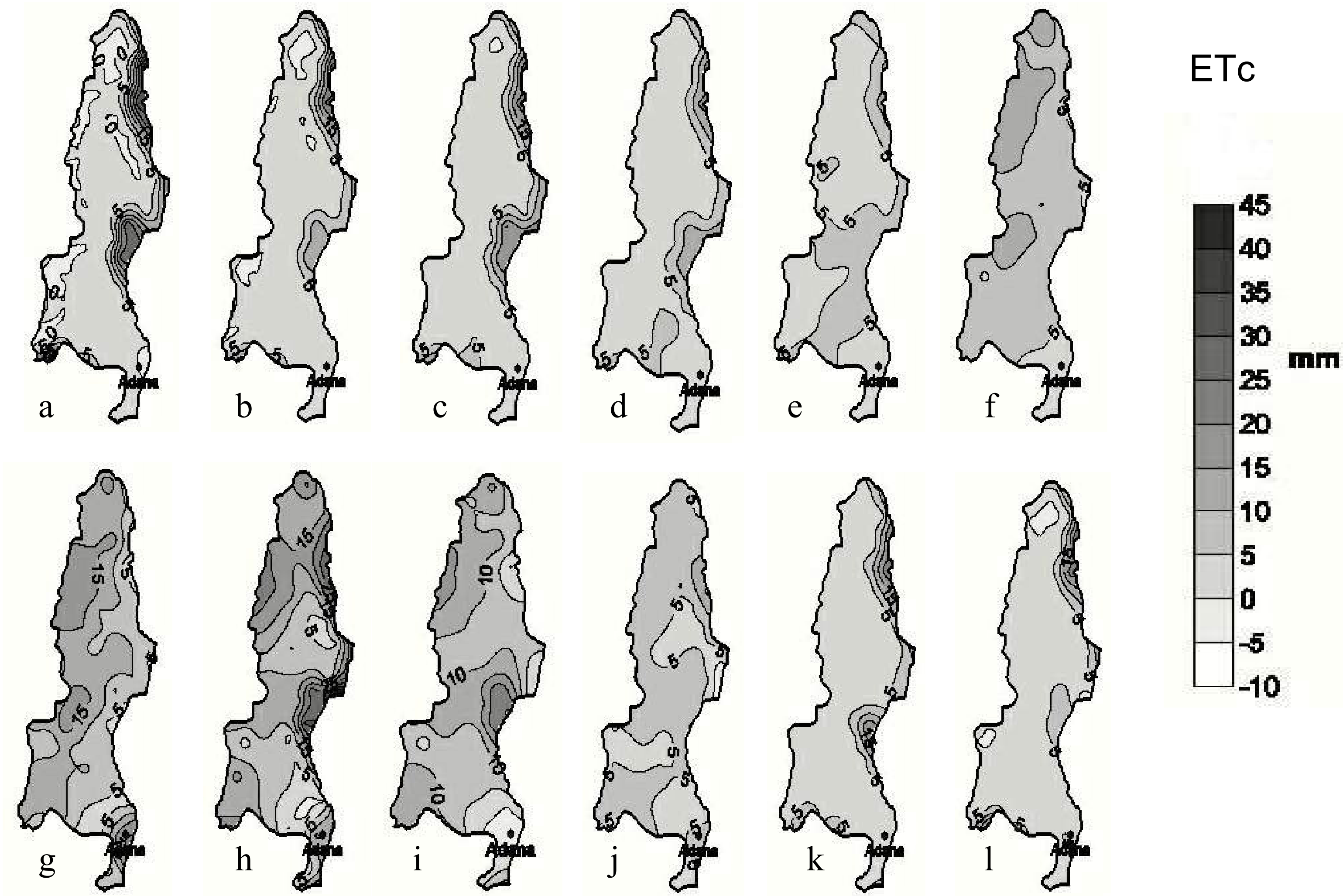


Figure 5. Monthly changes in actual evapotranspiration; a)December, b)January, c)February, d)March, e)April, f)May, g)June, h)July, I)August, j)September, k)October, l) November

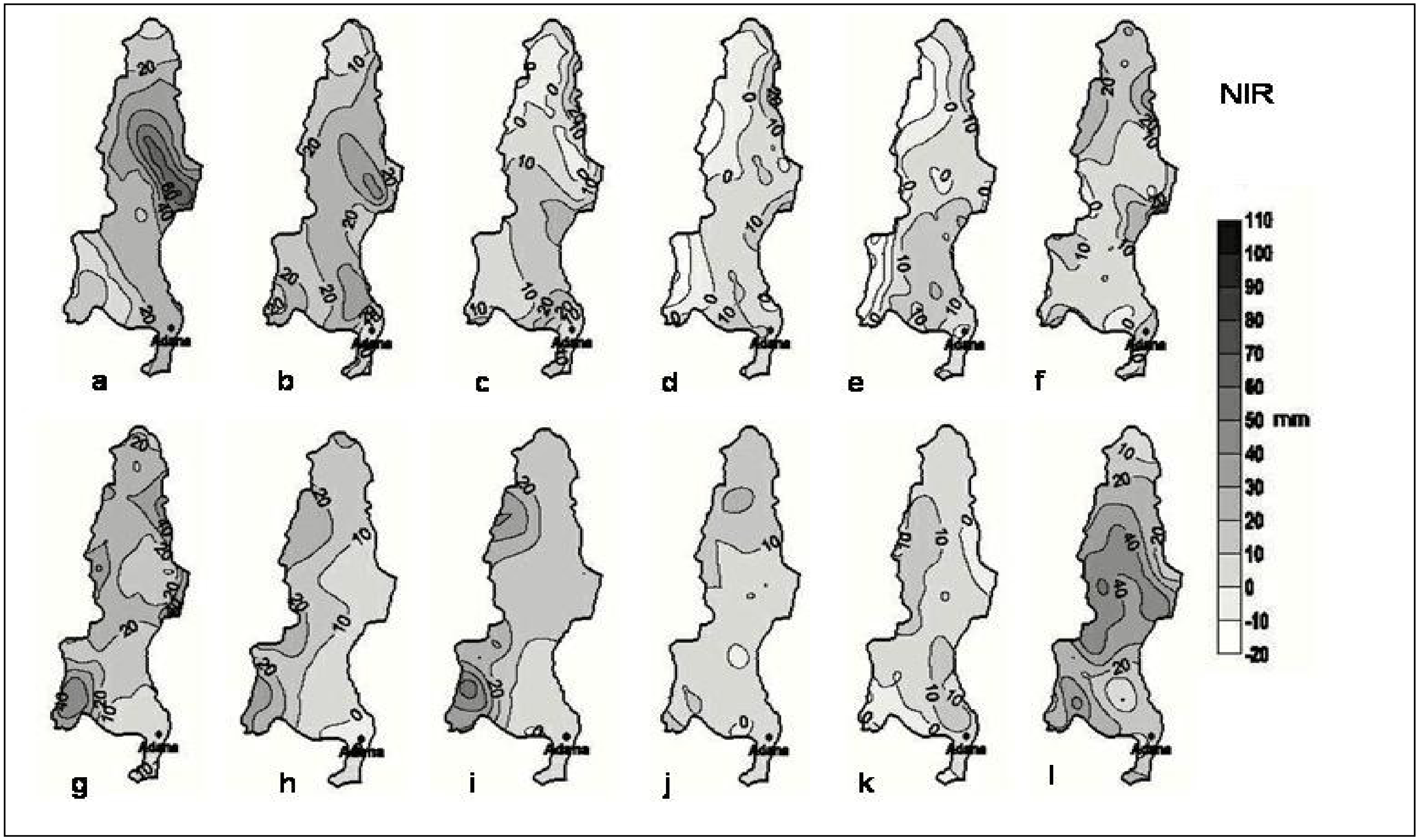


Figure 6. Monthly changes of net irrigation requirements, a)December, b)January, c)February, d)March, e)April, f)May, g)June, h)July, I)August, j)September, k)October, l) November

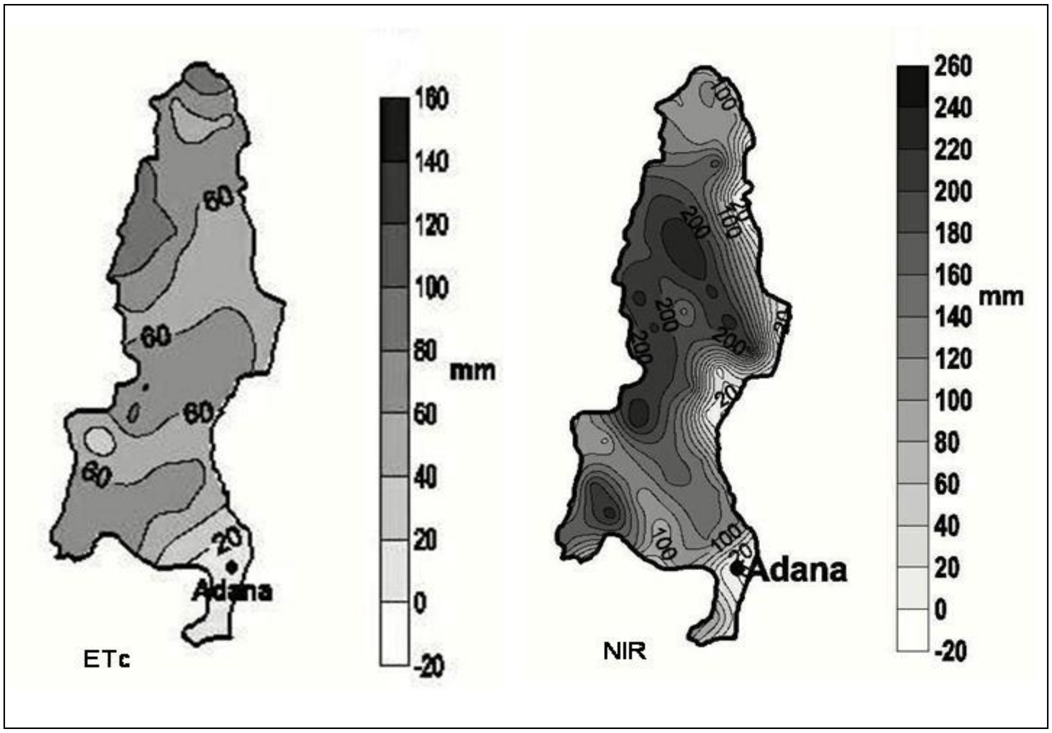


Figure 7. Annual total of crop evapotranspiration (ETc) and net irrigation requirement (NIR)

**Summary and Conclusion**

We analyzed climate change simulations produced by the regional climate model RegCM3 based on the RF and A2 IPCC scenarios. RegCM3's ability to simulate the present climate over the Mediterranean was found realistic by scientist (e.g Giorgi, 2004a and Pinhas et al. 2006) previously. Temperature change in the future scenario simulation is 3-4 ºC, although changes in annual maximum and minimum temperatures expected to be higher than daily maximum, minimum and averages. RegCM3 project a negative picture of changes in precipitation and temperature (less rainfall and hotter weather) generally indicate that more water will be used in the basin. Model predictions indicate a decrease in effective rainfall but increase in reference as well as actual crop evapotranspirations, the most alarming being the areas in upper stream and partly agricultural areas in downstream. Rising temperatures would increase evaporation thus crop water demand will be higher than present day (control period). Increased intensity and shifted period for rainfall could force runoff and worsen erosion that results in flood events. Furthermore decrease in effective rainfall will affect the recharging groundwater. Farmers using drip irrigation for protected cultivation and citrus withdrawn the water from wells. Soil water content in root-zone is also an important element in water budget. Thus, reduced soil water content could cause also delay in sowing dates, which is already being a problem for wheat in the basin during the last decade.

Since the irrigation sector with a share of 74% is the largest user of water, it is necessary to optimize water use and promote conservation, and improve irrigation efficiencies. (DSI, 2006). Considering the socio-economic and demographic conditions of the Seyhan River, simulation results of the present study indicate considerable effects on the future activities such as agriculture. Therefore, implementation of results could serve a basis for development strategies for dealing with the climate change.

Mitigation strategies can be general but also region specific. Also mitigation strategies can be planned for short-, mid- and long-term. Therefore the potential options for improving water use efficiency should cover a combination of measures in different areas such as physical (engineering), agronomic, environmental, institutional and managerial as well as socio-political (e.g. Howell, 2001). In regional scale, rehabilitation and modernization of irrigation network, completion of on farm works can increase irrigation ratio and efficiency, and also decrease conveyance losses in lower part of the Seyhan River Basin. Developing varieties of better yielding crops under water scarcity, selecting drought tolerant varieties, replacing crops that consume large amounts of water with those which consume less water, intercropping such as growing a deep-rooted crop with a shallow-rooted crop to utilize soil water in an efficient way are some of agronomic measures. Water harvesting in upper stream areas of the Basin can help to increase soil water content. In the field scale however, water saving methods like drip and sprinkler irrigation can be applied. Minimum tillage and mulching would help to keep soil water content in balance. Also low quality waters can be used especially near to the coastal areas, for this purpose irrigation return flows from irrigated upstream would be appropriate.

**References**


Allen, RG., Pereira LS., Raes, D., Smith, M., 1998. Crop Evapotranspiration (guidelines for computing crop water requirements). FAO Irrigation and Drainage Paper No. 56, Rome.

Brouwer and Heibloem, 1986. Irrigation Water Management: Irrigation water needs. FAO, Training manual no. 3, Rome.

Christensen JH, Carter TR, Giorgi F, 2002. PRUDENCE employs new methods to assess European climate change. EOS 83: 147.

DSİ, 2006. . General Directorate of State Hydraulic Works. 52. Year, 1954-2006, http://www.dsi.gov.tr

Fujihara, Y.; Tanaka, K., Watanabe, T. and Kojiri, T., 2007. Potential impacts of climate change on hydrology and water resurces of the Seyhan River Basin. The Final Report of ICCAP, ISBN 4-902325-09-8, 53-58.

Gao, X., J. S. Pal, and F. Giorgi (2006), Projected changes in mean and extreme precipitation over the Mediterranean region from a high resolution double nested RCM simulation, Geophys. Res. Lett., 33, L03706, doi:10.1029/2005GL024954.

Giorgi F. ve Mearns L.O., 1999. Introduction to special section: Regional climate modeling Revisited, J Geophys Res-Atmos, 104, 6335-6352.

Giorgi, F, Bi X, QianY, 2002. Direct radiative forcing and regional climatic effects of anthropogenic aeresols over east Asia: a regional coupled climate-chemistry/aerosol model study. J Geophys Res 107: Art No 4439, doi: 10.1029/2001JD001066.

Giorgi, F, Bi X, QianY, 2002. Indirect versus direct effects of anthropogrnic sulfate on the climate of east Asia as simulated with a regional coupled climate-chemistry/aerosol model study. Clim Change 58: 345-376.

Giorgi F. ve Mearns L.O., 1999. Introduction to special section: Regional climate modelling Revisited, J Geophys Res-Atmos, 104, 6335-6352

Giorgi, F., X. Bi, and J. S. Pal 2004a. Mean, interannual variability and trends in a regional climate change experiment over Europe. Part I: Present day climate (1961–1990), Clim. Dyn., 22, 733– 756.

Giorgi, F., X. Bi, and J. S. Pal 2004b. Mean, interannual variability and trends in a regional climate change experiment over Europe. Part II: Future climate scenarios (2071–2100), Clim. Dyn., 23, 839– 858.

Giorgi, F., 2006. Climate change projections over the Mediterranean region. Geophysical Research Abstracts, Vol. 8, 10946.

Hargreaves G.H., Samani Z.A. 1985. Reference crop evapotraspiration from ambient air temperature. ASAE Pap. No., 85-2517, ASAE, St. Joseph, MI.

Howell, T.A., 2001. Enhancing water use efficiency in irrigated agriculture. Agron. J. 93:281-289

IPCC, 2001. Climate Change: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Third Assessment Report of Interngovernmental Panel on Climate Change. 398-400.

IPCC, 2007: Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22.

Kimball BA, Kobayashi K, Bindi M., 2002. Responses of agricultural crops to free-air CO2 enrichment. Adv. Agron. 77, 293-368.

Kimura, F., Kitoh, A., Sumi, A., Asanuma, J., Yatagai, A., 2007. Downscaling of the global warming projections to Turkey. The Final Report of ICCAP, ISBN 4-902325-09-8, 59-72.

Krichak, S.O.; Alpert, P., Bassat K., Kunin P., 2007. The surface climatology of the eastern Mediterranean region obtained in a three-member ensemble climate change simulation experiment. Adv. Geosci., 12, 67-80.

Kundzewicz, Z.W., L.J. Mata, N.W. Arnell, P. Döll, P. Kabat, B. Jiménez, K.A. Miller, T. Oki, Z. Sen and I.A. Shiklomanov, 2007: Freshwater resources and their management. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 173-210.

Landscheidt, T., 2000. Solar wind near Earth: Indicator of variations in global temperature. Proceedings of the 1st Solar and Space Weather Euroconference on the solar cycle and terrestrial climate, 497-500.

Lawlor, DW., Mitchell RAC, 1991. The effects of increasing CO2 on crop phytosynthesis and productivity- areview of field studies. Plant Cell Environ. 14, 807-818.

Onol B., Semazzi, FHM, Unal, YS., Dalfes, HN., 2006. Regional climatic impacts of global warming over the eastern mediterranean. International Conference on Climate Change and the Middle East Past, Present and Future.20-23 November 2006, Istanbu Technical University, Yurkey.

Pinhas, A., Krichak, SO., Osetinsky, I, Dayan,M., Haim, D., Shafir, H., 2006. Climatic trends to extremes and regional modeling over the E. Mediterranean

Pope, VD, Gallani ML, Rowntree PR, Stratton RA, 2000. The impact of new physical parametrisation in the Hadley Centre Climate Model. Clim Dyn 16:123-146

Sanders, H. D., 1995. Statistics: A First Course, 5th Edition, Mc Graw-Hill: New York.

Schönweise, C.D., Rapp, J., 1997. Climate trend atlas of Europe based on observations 1891-1990.Kluwer Aademic Publichers, Dordrect.

Sen, B., Topcu, S., Giorgi, F., Bi, X., Kanıt, E.G., Dalkılıç, T., 2008. Seyhan Havzasında iklim değişikliğinin tarımal su kullanımına etkileri. TMMOB 2. SU POLİTİKALARI KONGRESİ 20-22 Mart 2008 Ankara.

Soon, W.; Posmentier, E.S.; Baliunas, S., 2000. Climate hypersensitivity to solar forcing? Ann.Geophys.-Atm. Hydr. 18 (5), 583-588.

Tatlı H., 2004. Genel dolaşım model benzeşimlerinin istatistiksel ölçek küçültme yöntemleri: Türkiye üzerine çalışmalar, Doktora tezi, Fen Bilimleri Enstitüsü, İTÜ.

Tatli H, H.N. Dalfes, S.S. Mentes, 2004: A statistical downscaling method for monthly total precipitation over Turkey. Int. J. Climatol., 24,161-180.

Tezcan, L, Ekmekci, M., Atilla, Ö., Gürkan,D. Yalcınkaya, O., Namkhai, O, Evren Soylu, M., Donma, S., Yılmazer, D., Akyatan, A. Pelen, N., Topaloglu, F., Irvem, A., 2007. Assessment of climate change impacts on water resources of Seyhan River Basin. The Final Report of ICCAP, ISBN 4-902325-09-8, 59-72.

Topaloglu, F., 2006. Trend detection of stream flow variables in Turkey. Fresenius Environmental Bulletin, 15 (6): 644-653.

Türkes, M., 1998. Influence of geopotential heights, cyclone frequency and southern oscillation on rainfall variations in Turkey. Int. J. Climatol. 18: 649–680 (1998)

Türkeş, M. 2001. Küresel iklim değişikliği: Tarım ve su kaynakları üzerindeki olası etkiler. İklim Değişikliklerinin Tarım Üzerine Etkileri Paneli, Bildiriler Kitabı, 91-128, Tarım ve Köy İşleri Bakanlığı, KKGM, Ankara.

Türkeş, M., 1999. Vulnerability of Turkey to Desertification With Respect to Precipitation and Aridity Conditions. Tr. J. of Engineering and Environmental Science, 23:363-380

UKMO/DETR. 1999. Climate Change and Its Impacts, Stabilisation of CO2 in the Atmosphere, United Kingdom Meteorological Office and Department of the Environment, Transport and the Regions (UKMO/DETR), the Hadley Centre for Climate Prediction and Research, Bracknell.

WWC, 2003. Turkey Country Report. Prepared for the 3rd World Water Forum March 2003. World Water Council; Ministry of Foreign Affairs, Department of Regional and Transboundary Waters, General Directorate of State Hydraulic Works; Southeastern Anatolia Project, Regional Development Administration, Republic of Turkey.