Implications of Future Climate Change for Irrigation Water Demand

in the Cukurova Region, Turkey

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1. Introduction

It has been reported that the globally averaged surface temperature is projected to increase by 1.4 to 5.8 oC over the period of 1990 to 2100 (IPCC 2001). It is not likely that precipitation will have increased in arid regions and the effects of future climate change on irrigation and water resources may become of major concern. Although the raised temperature increases evaporative demand of the atmosphere, actual crop water use is dependent on growth response to temperature rise. The purpose of the research is to predict future change of water demand in the Mediterranean climate regions of Turkey by using the predicted climate change data, considering the effect of temperature rise on crop growth.

2. Manuscript Submission

The GCM-based climate change data are available with seven climate models at the IPCC web-site (http://ipcc-ddc.cru.uea.ac.uk/). Among seven models, the GCGM2 model of Canadian Center for Climate Modeling and Analysis (CCCma) was selected, because the climate data are daily while those of other models are monthly. The predicted climate change data for the CCCma model are available for 4608 locations of the world which correspond to a grid distance of 412 km on the equator. The projected climate data of the regional climate model with the grid distance of 25 km which were supplied by the climate subgroup of ICCAPwere also used.

Monthly water balance was first calculated for a double cropping pattern of wheat and second crop maize grown in Adana (37.00°N, 35.25°E) for a period of 10 years from 2070 to 2079 using the SWAP model developed in the Netherlands (Kroes et al., 1999). The A2 scenario of the Special Report on Emission Scenarios (SRES) was

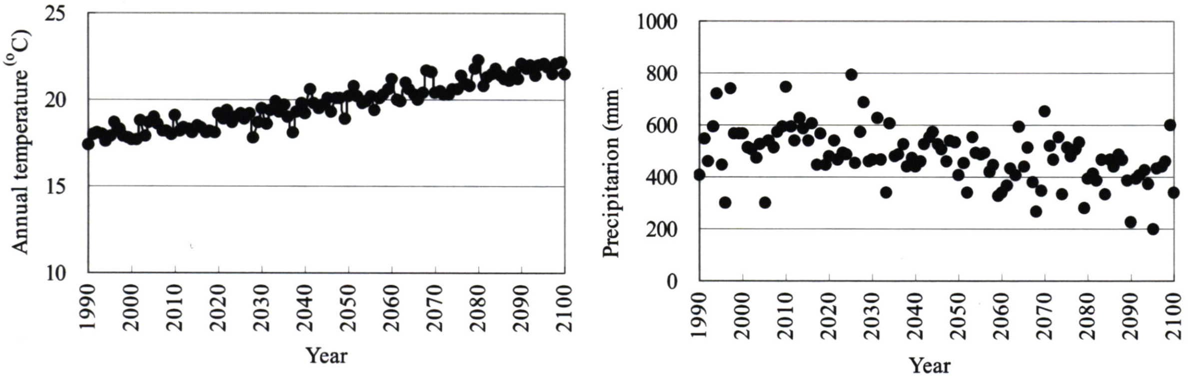

Fig. 1 Variations of annual air temperature and precipitation from 1990 to 2100

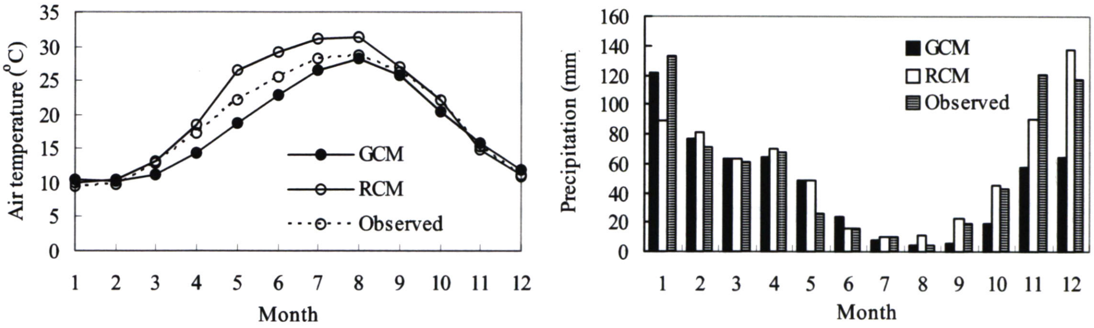

Fig. 2. Comparison of predicted air temperature and precipitation with the GCM, RCM and observed data.

used. This scenario depicts a very heterogeneous world. The underlying theme is that of strengthening regional cultural identities, with an emphasis on family values and local traditions, high population growth, and less concern for rapid economic development (IPCC, 2001).

3. Results and discussions

3.1. Projection of air temperature and precipitation

Variations of annual average temperature and precipitation for 111 years from 1990 to 2100 in Adana are shown in Fig. 1. These data were computed for Adana using the projected values by the CCCma model at the four nearest neighboring grid points using the inverse distance weighted method. Annual temperature increases gradually. According to the linear regression equation, averaged surface temperature is estimated to increase by 4.4 oC over the period of 1990 to 2100. Although annual precipitation denotes noticeable variations year by year, it is not likely that it will have increased in the future.

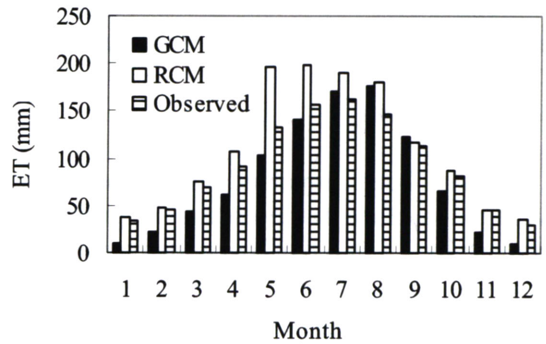

Fig. 3 Calculated reference ET from GCM, RCM and observed data.

A comparison of the predicted monthly temperature as well as precipitation with the GCM and RCM models and observed ones for 10 years from 1994 in Adana is given in Fig. 2. Generally, predicted air temperatures with the GCM and RCM models are lower and higher, respectively, than those with the observed one during spring and summer. Although precipitation values predicted by both models and observed ones are comparable, some considerable deviations are evident particularly during winter months.

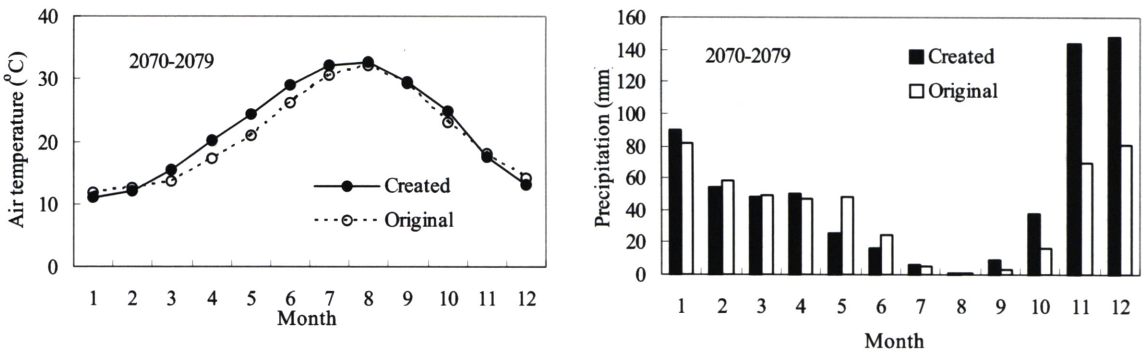

Fig. 4 Comparison of air temperature and precipitation created from the GCM model and the original data for a period of 10 years from 2070.

Monthly variations of potential evapotranspiration (ET) from reference crop to represent evaporative demand of the atmosphere are shown in Fig. 3. ET was calculated by the Penman-Monteith equation based on the GCM and RCM data and the observed data. Calculated potential ET from the different climate data shows the similar monthly variations with the air temperature variations. Since potential ET is the fundamental parameter for water demand prediction, it is supposed that direct use of the original GCM and RCM data would result in the erroneous results.

In the case of GCM data with large grid distance, the climatic scenarios for the future are sometimes created by superimposing the observed values to the change between the present and the future estimated values (Tao et al., 2003). The same procedure was used to create the future climate data using the GCM data.

Monthly air temperature and precipitation created for Adana are depicted in Fig. 4 Original data were added in the figures for comparison purpose. Also, created air

Table 1 Water balance components (mm) for grass

Period	Precipitation	ET	Irrigation
2070-2079	608.1±170.3	1155.1± 82.2	837.0± 85.2
1994-2003	666.9±171.0	1044.5± 69.6	700.2± 65.9

temperatures and precipitation were modified in accordance with the discrepancy between the predicted and observed values in Fig.2.

3.2. Water balance change due to global warming

The average values and standard deviations of the water balance components for grass as a perennial crop for the periods of 10 years from 1994, and from 2070 using the observed data and the created climatic data are presented in Table 1. The SWAP model developed in the Netherlands was used for calculation. Irrigation amount was calculated under the optimal irrigation condition. Reflecting the air temperature rise due to global warming, ET and therefore irrigation amount in the future are higher than those for the present. Both ET and

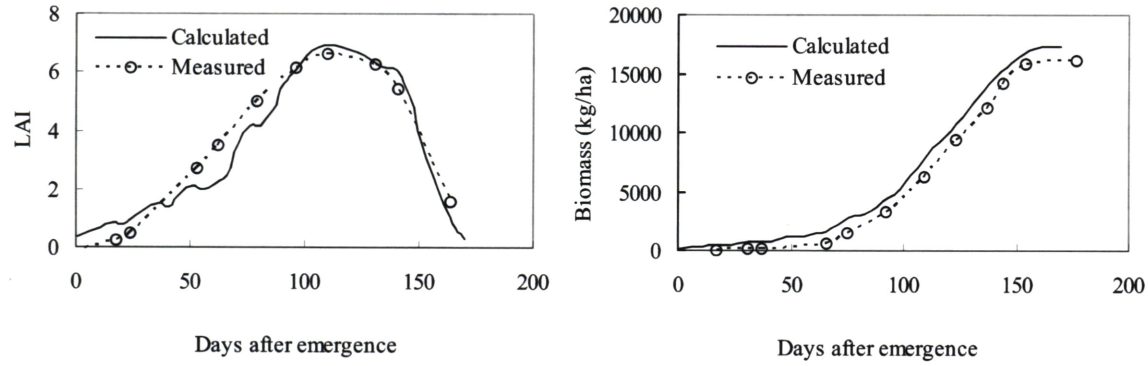

Fig. 5 Comparison of calculated leaf area index, and biomass, and the measured ones of wheat.

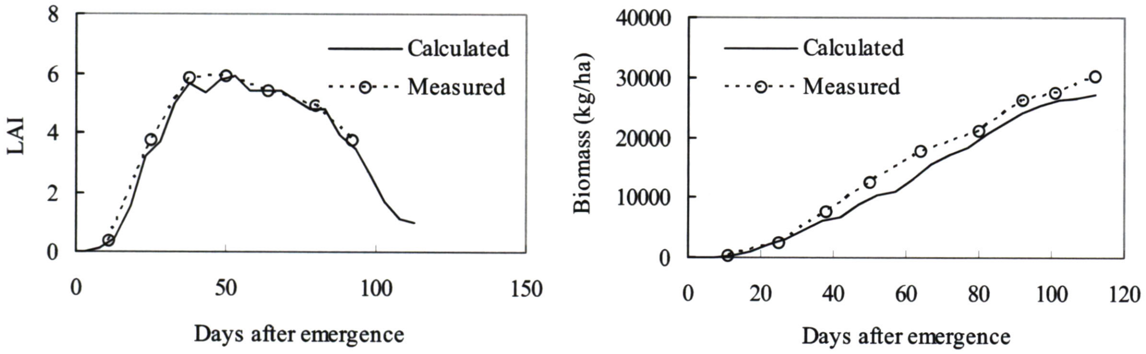

Fig. 6 Comparison of calculated leaf area index, and biomass, and the measured ones of maize.

Table 2 Prediction of water balance components (mm) and biomass and yield (ton/ha) of wheat

Period	Precipitation	ET	Irrigation	Biomass	Yield	Growing days
2070-2079	510.6±209.5	333.0± 24.2	67.4±59.2	14.33±1.37	4.83±0.70	167.4±5.4
1994-2003	531.1±184.7	373.9± 30.6	74.8± 72.8	16.50±1.39	5.11±0.73	183.4±6.3

Table 3 Prediction of water balance components (mm) and biomass and yield (ton/ha) of maize

Period	Precipitation	ET	Irrigation	Biomass	Yield	Growing days
2070-2079	24.9±18.0	393.1±33.9	383.3±44.2	20.57±1.34	10.48±1.03	105.9±0.7
1994-2003	47.5±23.8	399.9±29.8	371.1±49.4	27.48±1.53	15.19±1.29	115.2±3.6

irrigation amount are projected to increase by 11 and 20%, respectively, due to temperature rise in the future.

However, high temperatures accelerate the phenology of plants, resulting in quicker maturation. The shortened growth cycle, in turn, may reduce the yield potential of annual crops (Rosenzweig and Hillel 1998). Before the water balance calculation for wheat and maize, crop growth was simulated using a detailed growth model of SWAP. It was parameterized with the measured crop growth (T. Yano, personal communication). In parameterization, the effect of increase in CO_2 concentration on crop growth was not considered. Maize is one of C4 plants, and increases of CO_2 concentration are not so effective in crop growth as C3 plants. Although wheat is a C3 plant and raised CO_2 concentration promotes photosynthesis, raised temperature may compensate it with stomata closure. Calculated and measured leaf area index (LAI) as well as biomass for wheat and maize are compared in Fig. 5 and Fig. 6, respectively. It can be inferred that estimated and observed values are in agreement. The comparative deviations of LAI and biomass values might be related to the errors in measurements and/or in the model assumptions. Predicted water balance components for the periods of 10 years from 1994, and from 2070 together with biomass and growing days for wheat and maize are given in Table 2 and Table 3, respectively. Duration of growth period becomes shorter by about 16 and 10 days and results in lower biomass and yield in the future. ET and irrigation amount slightly decreases due to shorter growing days except slight increase in irrigation amount for maize.

Table 4 Annual water balance components (mm) for the double cropping of wheat and maize for 1994-2003

Data	Precipitation	ET	Irrigation
Observed	589.1	772.7	445.9
GCM	581.6	805.1	503.3
RCM	598.0	835.7	503.9

Table 5 Future change in water balance components (%) for the double cropping of wheat and maize

Data	Precipitation	ET	Irrigation
GCM scenario	-1.7	-5.2	-7.1
GCM	-0.4	-7.8	-9.4
RCM	-26.9	-8.4	-7.1

Calculated water balance components for wheat and maize from the different data for a time period from 1994 to 2003 are shown in Table 4. ET values calculated from the GCM data and the RCM data are about 4% and 8% higher, respectively, than those from the observed data due to higher evaporative demand of the atmosphere. Irrigation amou nts are also about 13% higher. Since it is generally difficult to downscale GCM data with large grid point distance accurately to the target area, the approach used in this study to predict the future change in water demand must be necessary. The RCM model used for water balance calculation has been being developed and should be finalized as soon as possible.

Predicted change in water balance components of the double cropping of wheat and maize is summarized in Table 5. Future increase in ET for grass shown in Table 1 represents increase in evaporative demand of the atmosphere due to air temperature rise. However, decrease in ET for the double cropping of wheat and maize shown in Table 4 can be attributed to reduction of growing days and LAI due to temperature rise regardless of increase in evaporative demand.

4. Conclusions

GCM data were downscaled for the target area with the projected data at the four nearest neighboring grid points using the inverse distance weighted method. The future climate scenario was created based on the observed values and the change of predicted values between present and future, assuming that only change between the present and the future is correct. Parameterization of the growth model for wheat and maize was done using observed data. ET and irrigation amount for grass as a perennial crop for the period of 2070-2079 relative to those for 1994-2003 are projected to increase by 11 and 20%, respectively. However, those for double cropping systems of wheat and maize as annual crops decrease by 5 and 7%, respectively unlike those for grass. Although the original GCM data and the RCM data were also used, discrepancy between predicted values and observed ones of air temperature noticeably affected the calculated water balance components.

Parameterization of the crop model was done based on only one year's experimental data and the parameterized crop model should be validated under the different climatic conditions. The combined effects of increases in CO_2 concentration and air temperature on the growth response should be clarified for major crops.

Acknowledgement

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References

IPCC (2001). Climate Change 2001: The Scientific Basis. IPCC Third Assessment Report. Cambridge University Press, Cambridge.

Kroes, J. G., van Dam, J.C. and Huygan, J. (1999). Technical document 53, DLO Winard Staring Centre, Wageningen.

Rosenzweig, C. and Hillel, D. (1998). Climate Change and the Global Harvest. Oxford University Press, New York.

Tao, F., Yokozawa, M., Hayashi, Y. and Lin, E. (2003). Terrestrial water cycle and the impact of climate change. Agriculture Ecosystem & Environment, 95: 203-215.