Climate Change and Soil-Water Balance

Mehmet Aydin[1], Tomohisa Yano[2], Tomokazu Haraguchi[3]
Fatih Evrendilek[4], Yeong-Sang Jung[1]

[1]Department of Biological Environment, Kangwon National University, Chuncheon 200-701, Korea (Correspondence: maydin@kangwon.ac.kr).
[2]Arid Land Research Center, Tottori University, Tottori 680-0001, Japan.
[3]Faculty of Agriculture, Saga University, Saga 840-8502, Japan.
[4]Faculty of Engineering and Architecture, Izzet Baysal University, 14280 Bolu, Turkey.

ABSTRACT

The semi-arid and arid regions comprise almost 40 percent of the world's land surface. The low and erratic precipitation pattern is the single most significant contributor for limiting crop production in such regions where rainfall is the source for surface, soil and ground water. In a changing climate, the semi-arid and arid regions would increasingly face the challenge of water scarcity. According to the relevant literature; under the assumption of a doubling of the current atmospheric CO2 concentration, irrigation demand was estimated to increase for wheat and to decrease for second crop maize in a Mediterranean environment of Turkey in the 2070s. Crop evapotranspiration would decrease due to stomata closure. Reference evapotranspiration and potential soil evaporation were projected to increase by 8.0 and 7.3%, respectively, whereas actual soil evaporation was predicted to decrease by 16.5%. Drainage losses below 90 cm soil depth were found to decrease mainly due to lesser rainfall amount in the future.

Key words: Climate change, soil water, water balance, evapotranspiration

I. INTRODUCTION

An increase of 0.74 (± 0.18) oC has occurred in the global average temperature during the past 100 years. Precipitation has increased by 0.5-1.0% per decade over most mid-and high latitude in the Northern Hemisphere continents. There has been a 2-4% increase in the frequency heavy precipitation. The extent of snow cover has decreased about 10% since 1960's.The frequency and intensity of droughts in parts of Asia and Africa has been observed to increase in recent decades. Based on a range of several current climate models, the mean annual global surface temperature is projected to increase by 1.1 to 6.4 ? over the period of 1990 to 2099, with changes in the spatial and temporal patterns of precipitation (IPCC, 2007). All land areas will warm more rapidly than the global average. Globally averaged precipitation is projected to increase, but at the regional scale both increases and decreases have been reported. For example, the considerable increases in precipitation and average temperature have been observed in East Asia according to data analysis of the 20th century, and these variables are also projected to increase in the future (Min et al., 2004). Year to year variations in precipitation are larger over most areas where an increase in mean precipitation is projected. However, precipitation is not likely to increase in (semi)-arid regions where the effects of climate change on soil water balance are of major concern as the increased temperature stimulates the evaporative demand of the atmosphere (Aydin et al., 2008). In this paper, quantitative changes in soil-water balance compiled from the literature in response to climate change were explored for a semi-arid Mediterranean environment.

II. MATERIALS AND METHODS

Possible changes in water demand and supply for irrigation in the Mediterranean countries including Turkey, as a consequence of climate change may have serious implications for the agricultural production of the region countries. Cukurova plain is one of the most productive regions of Turkey, and a typical Mediterranean climate prevails in the region with the long term (1975-2006) mean annual temperature, precipitation and potential evapotranspiration of 19.0 oC, 650 mm and 1320 mm, respectively. Therefore, various studies (Evrendilek et al, 2005, 2008; Yano et al., 2007; Aydin, 2008; Aydin et al., 2008; Fujihara et al., 2008; Onder et al., 2009) were carried out to predict impacts of climate change on soil-water budget and plant growth and development under climate change scenarios by general circulation models (GCMs) and regional climate models (RCMs) in the Mediterranean region of Turkey. This study is a compilation of the data related to soil-water balance from the references cited above.

III. RESULTS AND DISCUSSION

Under the assumption of a doubling of the current atmospheric CO2 concentration, precipitation in the 2070s was projected to be 25-30% less than the present in the Mediterranean region of Turkey. Air temperature was estimated to increase by 2-3 °C (Kimura et al., 2007; Kitoh et al., 2007). The quantities of water balance components for present and future are summarized in Table 1. Irrigation demand for wheat was estimated to increase mainly due to decreased precipitation in the future. On the contrary, irrigation demand for maize was estimated to considerably decrease which reflects decreased crop evapotranspiration due to stomata closure (Yano et al., 2007). Reference evapotranspiration and potential soil evaporation were projected to increase by

8.0 and 7.3%, respectively, due to the elevated evaporative demand of the atmosphere, whereas actual soil evaporation was predicted to decrease by 16.5% due to lesser rainfall amount and erratic rainfall pattern (Aydin et al., 2008). Drainage losses below 90 cm soil depth were found to decrease mainly due to lesser rainfall in the future.

Table 1. The components of soil-water balance in the Mediterranean region of Turkey based on climate projections (Yano et al., 2007; Aydin et al., 2008)

Crop	Climate Model	Period	ETc[a] (mm)	Irrig (mm)	ETr (mm/yr)	Ep (mm/yr)	Ea (mm/yr)	Drn (mm/yr)
Wheat	CGCM2	1994-2003	349.2	0				
		2070-2079	250.9	16.8				
	MRI-RCM	1994-2003	301.8	24.8				
		2070-2079	276.6	68.9				
	CCSR-NIES	2070-2079	252.5	79.2				
Maize (second crop)	CGCM2	1994-2003	414.1	375.5				
		2070-2079	314.0	318.4				
	MRI-RCM	1994-2003	439.8	423.1				
		2070-2079	317.6	331.4				
	CCSR-NIES	2070-2079	326.6	328.2				
Reference crop	MRI-RCM	1994-2003			1052.7			
		2070-2079			1144.7			
Bare soil	MRI-RCM	1994-2003				876.4	301.3	329.2
		2070-2079				945.0	251.6	96.3

[a]ETc = actual crop evapotranspiration; Irrig = irrigation demand; ETr = reference crop evapotranspiration; Ep = potential and Ea = actual soil evaporation; Drn = drainage losses.

REFERENCES

Aydin, M., 2008. A model for evaporation and drainage investigations at ground of ordinary rainfed-areas. *Ecol. Model.* **217**: 148-156.

Aydin, M., Yano, T., Evrendilek, F., Uygur, V., 2008. Implications of climate change for evaporation from bare soils in a Mediterranean environment. *Environ. Monit. Assess.* **140**: 123-130.

Evrendilek F., Ben-Asher, J., Aydin, M., Celik, I., 2005. Spatial and temporal variations in diurnal CO2 fluxes of different Mediterranean ecosystems in Turkey. *J. Environ. Monit.* **7**: 151-157.

Evrendilek, F., Ben-Asher, J., Aydin, M., 2008. Diurnal photosynthesis, water use efficiency and light use efficiency of wheat under Mediterranean field conditions, Turkey. *J. Environ. Biol.* **29**: 397-406.

Fujihara, Y., Tanaka, K., Watanabe, T., Nagano, T., Kojiri, T., 2008. Assessing the impacts of climate change on the water resources of the Seyhan River Basin in Turkey: Use of dynamically downscaled data for hydrologic simulations. *J. Hydrol.* **353**: 33– 48.

IPCC, 2007. IPCC Fourth Assessment Report: Climate Change 2007(http://www.ipcc.ch).

Kimura, F., Kitoh, A., Sumi, A., Asanuma, J., Yatagai, A., 2007. Downscaling of the global warming projections to Turkey. The Final Report of ICCAP: The Research Project on the Impact of Climate Changes on Agricultural Production System in Arid Areas (ICCAP). Research Institute for Humanity and Nature (RIHN) of Japan, and The Scientific and Technological Research Council of Turkey (TÜBITAK), ICCAP Publication 10 (ISBN 4-902325-09-8), p. 21-37.

Kitoh, A., 2007. Future Climate Projections around Turkey by Global Climate Models. The Final Report of ICCAP: The Research Project on the Impact of Climate Changes on Agricultural Production System in Arid Areas (ICCAP). Research Institute for Humanity and Nature (RIHN) of Japan, and The Scientific and Technological Research Council of Turkey (TÜBITAK), ICCAP Publication 10 (ISBN 4-902325-09-8), p. 39-42.

Min, S.-K., Park, E.-H., Kwon, W.-T., 2004. Future projections of East Asian climate change from multi-AOGCM ensembles of IPCC SRES scenario simulations. *J. Meteor. Soc. Japan*. **82**: 1187–1211.

Onder, D., Aydin, M., Berberoglu, S., Onder, S., Yano, T., 2009: The use of aridity index to assess implications of climatic change for land cover in Turkey. *Turk. J. Agric. For.* **33**: 305-314.

Yano, T., Aydin, M., Haraguchi, T., 2007: Impact of climate change on irrigation demand and crop growth in a Mediterranean environment of Turkey. *Sensors* **7**: 2297-2315.