Evaluation of the Effects of Global Climate Change on Agriculture and Water Sources in the Gediz River Basin

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ABSTRACT

Global climate change is very likely to have a major impact on the hydrological cycle, and consequently on available water resources, flood and drought potentials, and agricultural productivity. As the largest user of water, the agricultural sector is expected to be affected by global climate change to an even greater extent than other sectors.

Sufficiency of water resources is generally evaluated in terms of total water potential for total population. According to this evaluation, the beginning of water stress is accepted as 1700 m^3 per capita per year. In Turkey, total water potential per capita per year was 2900 m^3 in 2000, but this value is estimated to fall to 2200 m^3 by 2025.

Rapid population growth, industrialization, and rising standards of living will decrease the annual per capita renewable water potential in Turkey, and in general, Turkey's water resources are set to decrease to critical levels. We took as an example the Gediz Basin in western Turkey, which has a total area of some 17 310 ha, and supplies water for domestic and industrial purposes. The water resources in the basin support wildlife, and are used to produce energy.

The objectives of this study are to examine the effects of global climate change on agriculture and water sources in the Gediz River Basin, to discuss the difficulties of management of the basin, and the measures which should be taken from today.

Keywords: Climate Change, water sources, irrigation, Gediz, Turkey

INTRODUCTION

Many scientists are concerned about possible climate change induced by anthropogenically caused increases in greenhouse gases. Such a climate change would have major impacts on water resources and irrigated agriculture. Predictions of climate change for the latitudes in which Turkey is situated indicate the possibility of a reduction in rainfall. Also, an analysis of rainfall data collected over many years shows a trend towards a reduction in winter precipitation, especially in the west of Turkey (Saylan and Çaldağ, 2007; Kukul et al, 2007).

The agricultural sector in Turkey is the largest consumer of water, and irrigation accounts for some 75% of water use. In 2003, the average amount of water used for agricultural purposes was 29.6 km^3 out of a total use of 40.1 km^3 of water (DSI, 2008). Sufficiency of water resources is usually evaluated in terms of water stress index. In this index, the beginning of water stress is accepted as 1700 cubic meters per capita per year. If this value decreases to 1000m^3/yr, this is called chronic water stress, and if it decreases to 500 m^3/yr, this is known as absolute water stress. In Turkey, total water potential per capita per year was 2900 m3 in the year 2000. However, this value is estimated to fall to 2200 m^3 by 2025, and by 2050 it is expected to be near the critical value (Onder and Onder, 2007). The advance of population growth, industrialisation and climate change will have their greatest effect on agriculture as the largest water user.

In this work, we consider the changes in water resources and the resulting effects on agriculture in the Gediz Basin, which is an important agricultural and industrial area in the west of Turkey.

Characteristics of the Gediz Basin

The Gediz river, at around 275 km in length, drains an area of 17 220 km^2, and flows from east to west into the Aegean Sea just north of Izmir, in western Turkey. Precipitation in the basin ranges from over 1 000 mm per year in the mountains to 500 mm per year near the Aegean coast. The total irrigated area in the basin is about 150 000 hectares (Kite et al, 2001).

Climatically the basin is ideally suited for irrigation development. During the winter months precipitation exceeds 700 mm, falling as snow at elevations above 1000 m. Since 1945, large-scale irrigation systems totaling some 105 000 ha have been constructed in the main valley. Crop production within the basin includes cotton, grapes, fruits, cereals, olives and vegetables.

The basin also serves as the source of much of the drinking water for the city of Izmir, now the third largest city in Turkey and an important harbour on the Aegean. The continuously growing metropolitan area of Izmir consumes a significant portion of the groundwater resources of the Gediz Basin (Murray-rust et al, 2003).

The hydrology of the Gediz Basin is typically Mediterranean. Precipitation falls between November and April, and peak river flows occur in February or March. After the construction of the Demirkoprü Dam and before the current drought, net annual surface water availability in the main basin and the delta is estimated to have been approximately 1 900 million $m^3 year^{-1}$. Since 1990, however, there has been a persistent decline in surface water flow into the dam, and water availability has only averaged some 940 million cubic meters (Harmancıoğlu and Onusluel, 2001). This decreasing trend in mean annual stream-flow is most likely explained by the downward trend in annual precipitation, and to some extent by a trend to an increase in temperatures. These changes in annual precipitation trends can be traced back to the 1980s (Kukul et al, 2007).

Groundwater resources are able to make up some of the potential shortfall in overall water availability. The central part of the Basin is an alluvial plain whose groundwater reserve is replenished in most years. Only during the peak of the drought, from 1991 to 1993, were there reports of declining year-to-year water tables, and these have since recovered. However, the estimated safe annual yield for groundwater in the main part of the valley is estimated to be 160 million cubic meters per year, which is about one-third less than the 219 million cubic meters estimated as being extracted from the main and Nif valleys. Despite the absence of definitive figures, it appears that groundwater use presently exceeds, by a sizeable margin, the sustainable limit (Harmancıoğlu and Onusluel, 2001; Harmancıoğlu et al, 2007).

Effects of Drought on Agricultural Irrigation in the Gediz Basin and Measures which Need to Be Taken

The river network is controlled by four main reservoirs and three regulators, which serve thirteen water users' associations (Fig 1). River flow from winter precipitation is stored in the main Demirkopru reservoir for release over the summer irrigation period.

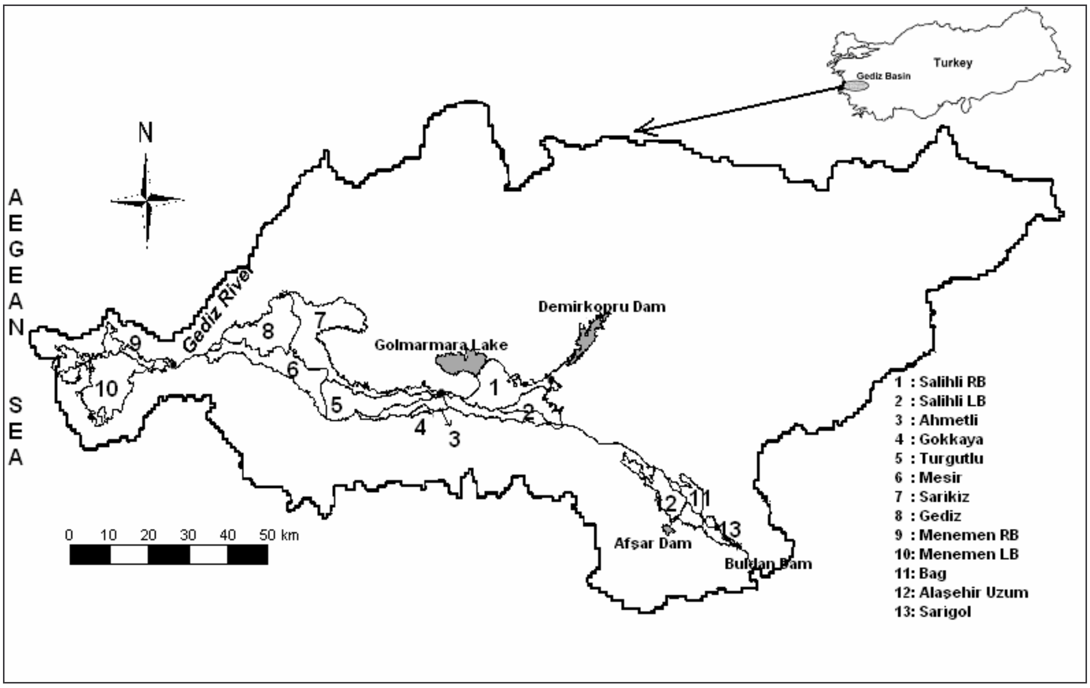

Figure 1. Gediz Basin Irrigation System

Irrigation currently uses a large share of the surface water resources of the basin (Table 1). From 1972 until 1988 there were no serious problems with water availability at basin level. The Demirkopru reservoir overflowed on several occasions, power generation continued throughout the winter months so as to maintain sufficient spare storage capacity for flood control, and irrigation water was available throughout the growing season. In 1989, however, the situation changed dramatically with the onset of a four-year drought (Turkeş, 1997). The drought had two major impacts: the start of disputes between sectors (power, irrigation, flood control, and urban and domestic supply) and the onset of significant groundwater exploitation (Murray-Rust et al, 2003). In the drought period and afterwards, the amount of water available for agriculture fell considerably (Figure 2). It can be seen from Figure 2, which shows the amounts of water diverted to the Menemen irrigation system between 1981 and 2005, that there were significant changes between before and after the drought. Figure 3 shows irrigation rates, which were very low in the drought period, but which rose again later to approach pre-drought levels. However, amounts of water supplied per unit of land area are much lower than previously. This would be expected to result in a fall in productivity, but the International

Water Management Institute (IWMI) examined the performance of the Gediz Basin irrigation systems and compared pre- and post-drought productivity, and found that in the period after the drought, productivity figures were higher, even though less water was being supplied to the system (Table 2). It was found that this increase resulted from such factors as the use of more productive crop varieties, and from the use of water from underground sources as well as from the irrigation network.

It has been pointed out in various studies of the irrigation system's performance at different levels that there are operational and structural problems in the basin: for example, water sources are insufficient and are not used efficiently, irrigation water is not distributed equitably either between irrigation systems or between users, and seepage losses are high in the systems' open canal water distribution networks.

Similar problems relating to the efficient use of water are to be found in all river basins where irrigated agriculture is practiced. In order to solve these problems, basic changes must be effected in irrigation water management. It is necessary to change from a traditional water management concept which cannot provide for measured and controlled water use, to an integrated water management concept which will maintain the sustainability of water sources and make use of water in an efficient and workable way. A management structure must be formed which takes account of the human factor, which ensures the long-term protection of water sources, which makes use of water in the most economic way without damaging the environment, and which aims at the integration of water resources.

Table 1. Estimated Water Use by Sector in the Gediz Basin (Harmancıoğlu et al, 2007).

Water User	Estimated Consumption		Notes
	[million m^3]	Share	
Surface Water			
Large Scale Irrigation	550	62%	From Demirkopru and Gol Marmara
	60	7%	Alasehir Valley
Small Scale Irrigation	50	6%	
Hydropower	0	-	No priority for hydropower
Bird Reserve	4	-	Current releases only; needs more
Groundwater			
Pump Irrigation Groups	30	3%	Only those outside surface irrigation area
Private Irrigators	5	1%	
Urban within the Basin	26	2%	18% of extraction, remainder is return flow
Transfer to Izmir City	108	12%	Trans-basin transfer, no return flow
Industry	50	6%	Estimated by DSI
Totals			
Annual	833	100%	
Summer (4 months)	760		

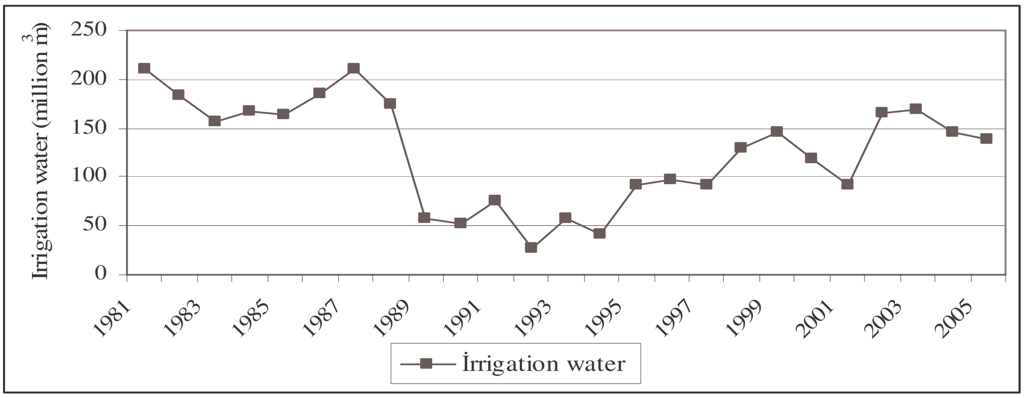

Figure 2. Amounts of Water Supplied to the Menemen Irrigation System between 1981 and 2005

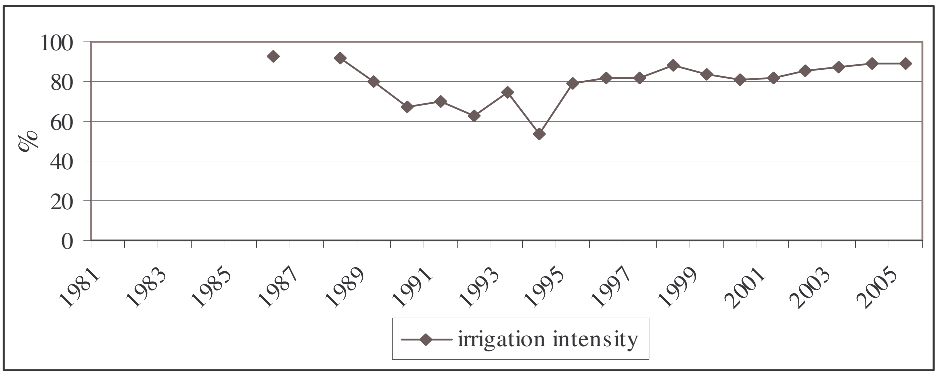

Figure 3. Irrigation Ratio in the Menemen Irrigation System for the Years 1987-2005

Table 2. Yields and Productivity of Water Before and After the Drought (KHGM-IWMI, 1999)

Year	**Average Yields (kg ha^{-1})**		**Productivity of Water**	
	Cotton	**Grapes**	**(kg m^{-3})**	**($ m^{-3})**
1988	2640	4830	0.42	0.29
1996	3060	5310	0.71	0.57

In the Gediz Basin, the greatest need is for a physical infrastructure which will enable more efficient use of water in the irrigation systems. Water losses and excessive use in the distribution networks must be prevented, and water must be used in a more productive way.

In order to prevent transmission losses and to achieve savings in the use of water in the basin's irrigation networks, surface irrigation methods need to be replaced by pressurised irrigation systems. This however necessitates the conversion of the current open canal distribution networks to a piped system, which is seen as difficult economically. Therefore, priority must first be placed on repair and maintenance of the open canal systems in order to prevent seepage losses, and on ensuring measured and controlled distribution of water in the networks. For this purpose, diverted water must first of all be measured and monitored in real time at main and secondary canal level. This could be achieved by a telemetric system, with such a system, irrigation associations responsible for system operation all along the Gediz River could keep a check on each other so that each association could use the water more efficiently. In this way, a self-regulating system of irrigation management would be created in the basin, and a more equitable distribution of water between systems would be possible.

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