Assessment of climate change impacts in the Gediz River Basin, Turkey: application of the WEAP model

Dr. Barış YILMAZ
Celal Bayar University, Turkey

Research need

Due to rapid increases in the world's population, climate change, improved living standards, urbanization, and industrialization, water managers have been faced with more complex and difficult problems in the early 21st century, and it is expected that coping with water problems will be harder in the future.

Thereby, understanding the possible impacts of climate change is of great importance for water resources management.

A lot of efforts

have been made to better characterize and model the possible impacts of climate change; one of which is the project

“Climate Change Scenarios for Turkey”,

funded by

TÜBİTAK The Scientific and Technological Research Council of Turkey

Within this project, the detailed regional projections which can constitute the main inputs of the studies related with climate change impact have been developed.

Climate Change Scenarios for Turkey

http://gaia.itu.edu.tr/

Türkiye için İklim Değişikliği Senaryoları

Ana Sayfa | Veri Dağıtım Sistemi | Hakkımızda | Bağlantılar | Sıkça Sorulan Sorular

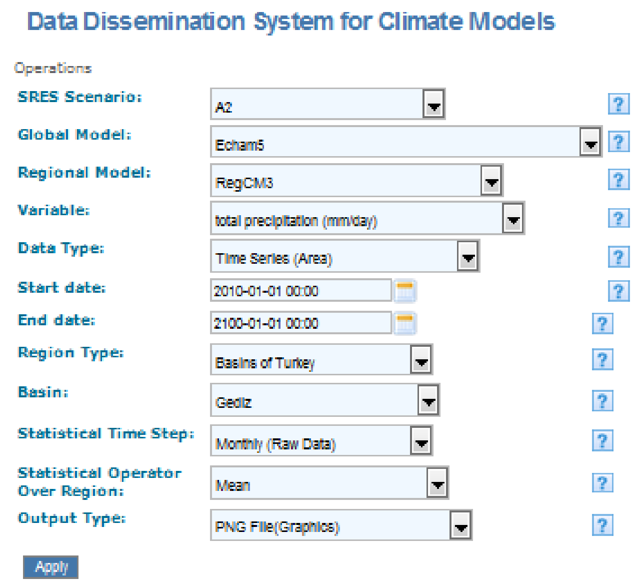
Türkiye için İklim Değişikliği Senaryoları

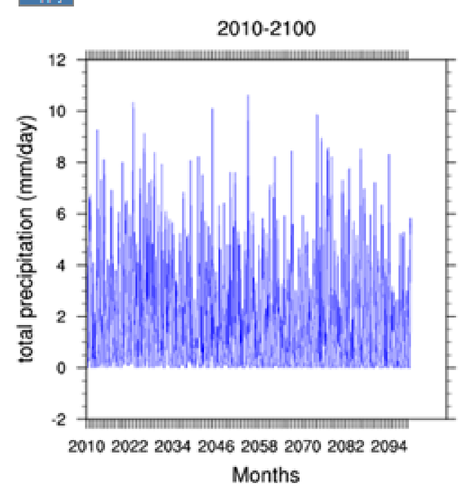
Bu site TÜBİTAK tarafından desteklenen 105G015 nolu "Türkiye için İklim Değişikliği Senaryoları" başlıklı proje kapsamında geliştirilmiştir. 2006-2008 yılları arasında gerçekleştirilen 105G015 nolu proje bir Kamu ARGE projesidir. Müşteri kurum Devlet Meteoroloji İşleri (DMİ) Genel Müdürlüğü'dür.

Proje kapsamında, insan kökenli etkiler sonucu oluşmuş ve oluşacak iklim değişikliklerinin Türkiye ve bölgesine nasıl yansıyacağı araştırılmıştır. Bu proje ile, küresel iklim modelleriyle (GCM) üretilen iklim projeksiyonlarının dinamik yöntemler yardımıyla ölçeklerinin küçültülmesi, ve bu yolla, özellikle iklim değişikliğinin etkilerini ve iklim değişikliklerine uyum çalışmalarının temel girdisini oluşturacak uzaysal ayrıntılı bölgesel projeksiyonların elde edilmesi hedeflenmiştir.

Yurtdışı bir kurumdan (Max Planck Meteoroloji Enstitüsü, Almanya) temin edilen A2 ve B1 salım senaryolarına ait GCM (= ECHAM5 modeli) simülasyon çıktıları RegCM3 bölgesel iklim modeli kullanılarak daha küçük ölçeklere indirgenmiştir. Bu yöntemle, 1961-2000 ve 2000-2099 zaman aralıkları için iklim projeksiyonları elde edilmiştir. Bu simülasyonlara ait çeşitli ürünler (sıcaklık, yağış, akış gibi) Veri Dağıtım Sistemi başlığı altında kullanıcılara sunulmaktadır.

Proje, gerek İTÜ'nün ilgili birimleri, gerekse DMİ bünyesinde bölgesel iklim projeksiyonlarının gerektirdiği becerilerle donanmış insan kaynaklarının gelişmesine ve ulusal düzeyde konunun öneminin kavranmasına katkı yapmıştır.

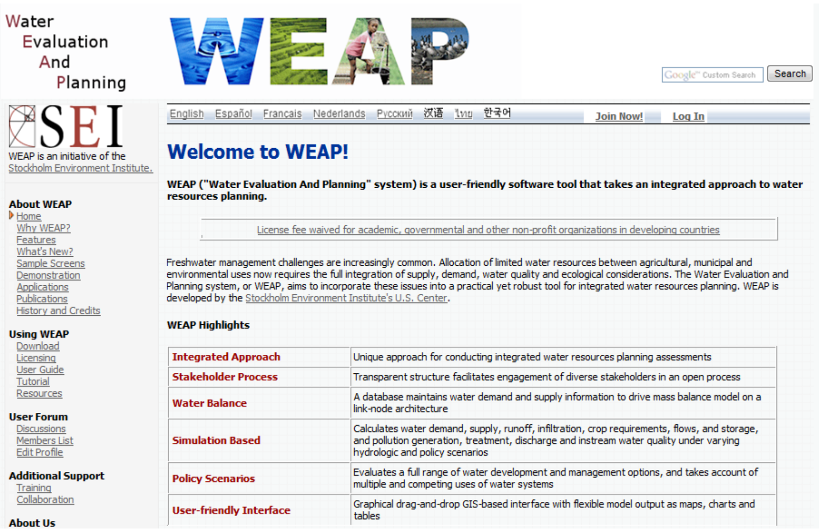




In this study,

the results of that project are used in the Water Evaluation and Planning System (WEAP), in order to assess the climate change impacts on surface water balance of the Gediz River Basin.

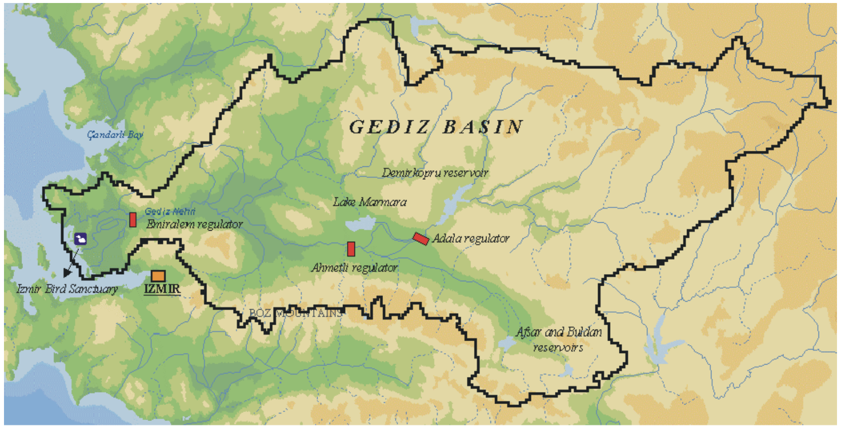
The water supply and demand interrelations in agriculture, which is the largest water consumer, constitute the main focus of the study.

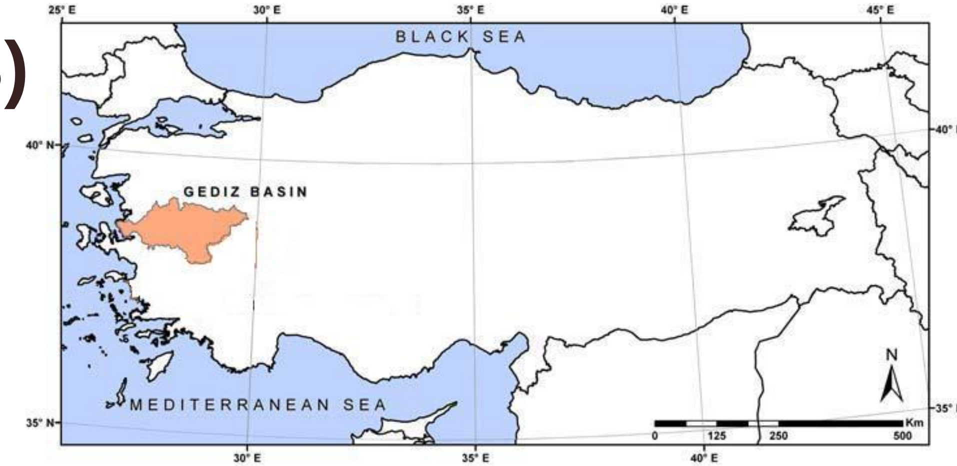


The WEAP is forced to simulate the water system between 2010 and 2100 with the time series of temperature, precipitation, evapotranspiration and surface runoff data obtained by web-based data dissemination system of the relevant project.

The basic aim of the study is to reach a comprehensive assessment with respect to variations in <u>supply reliability</u>, <u>unmet demand</u> and <u>crop yield</u> in future.

Gediz River Basin (GRB)





Basin area: 18,000 km^2

Population: apprx. 2.0 million

Growth rate: 1.5%/year

Climate: Mediterranean

Hot summer, cool winter

Annual precipitation: 635 mm

Mean temperature: 15.6 °C

Irrigation area: 110,000 ha

Water supply: 1,100 MCM

Water demand: 900 MCM

Water scarcity:

Current analyses on hydrological budget of the basin indicate that the overall supply of water for various uses is approximately equal to the overall demand (Harmancioglu et al., 2005).

→ sensitive to recurrent droughts

→ increasing domestic (2%) and industrial demand (10%)+ basin out water transfer

→ high ag.water use (75% of water res.)

* low irrigation efficiency (60%)

* high conveyance losses (32%)

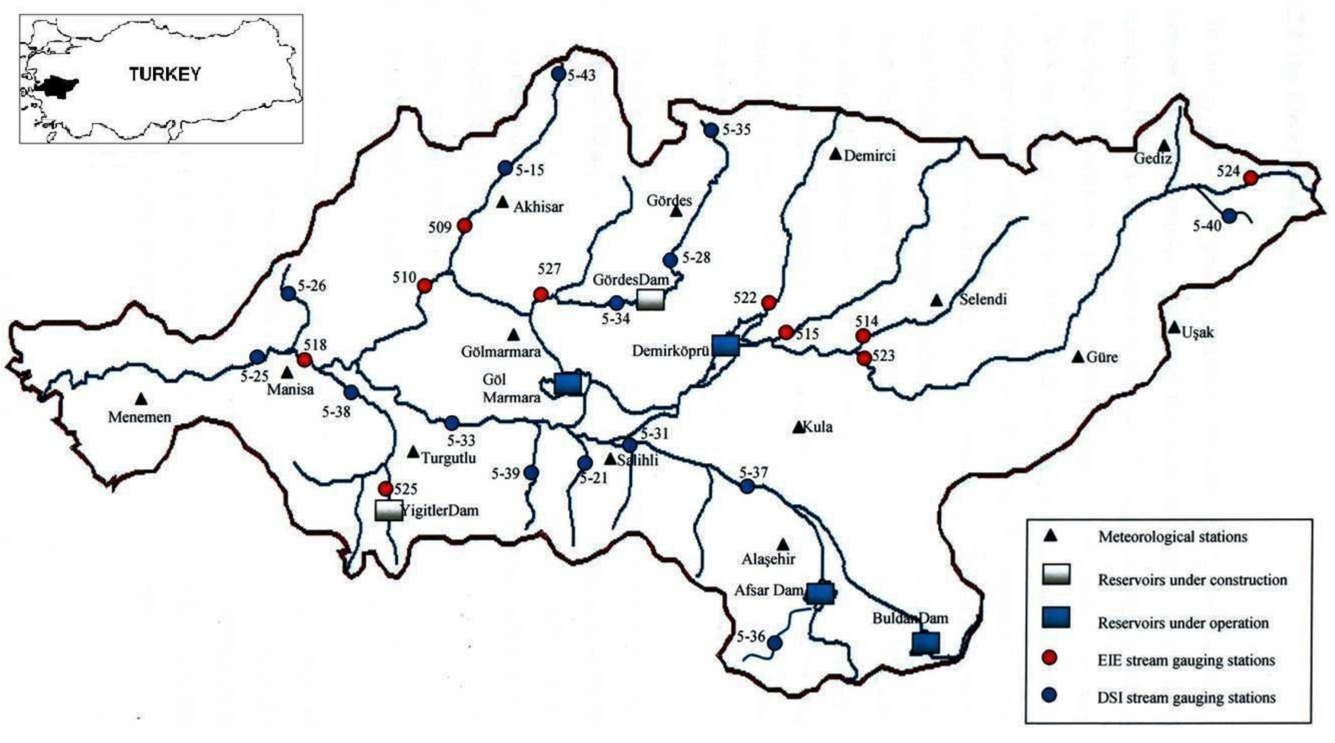
Scope of the study

* Surface water resources (only in quantity, water quality is excluded)

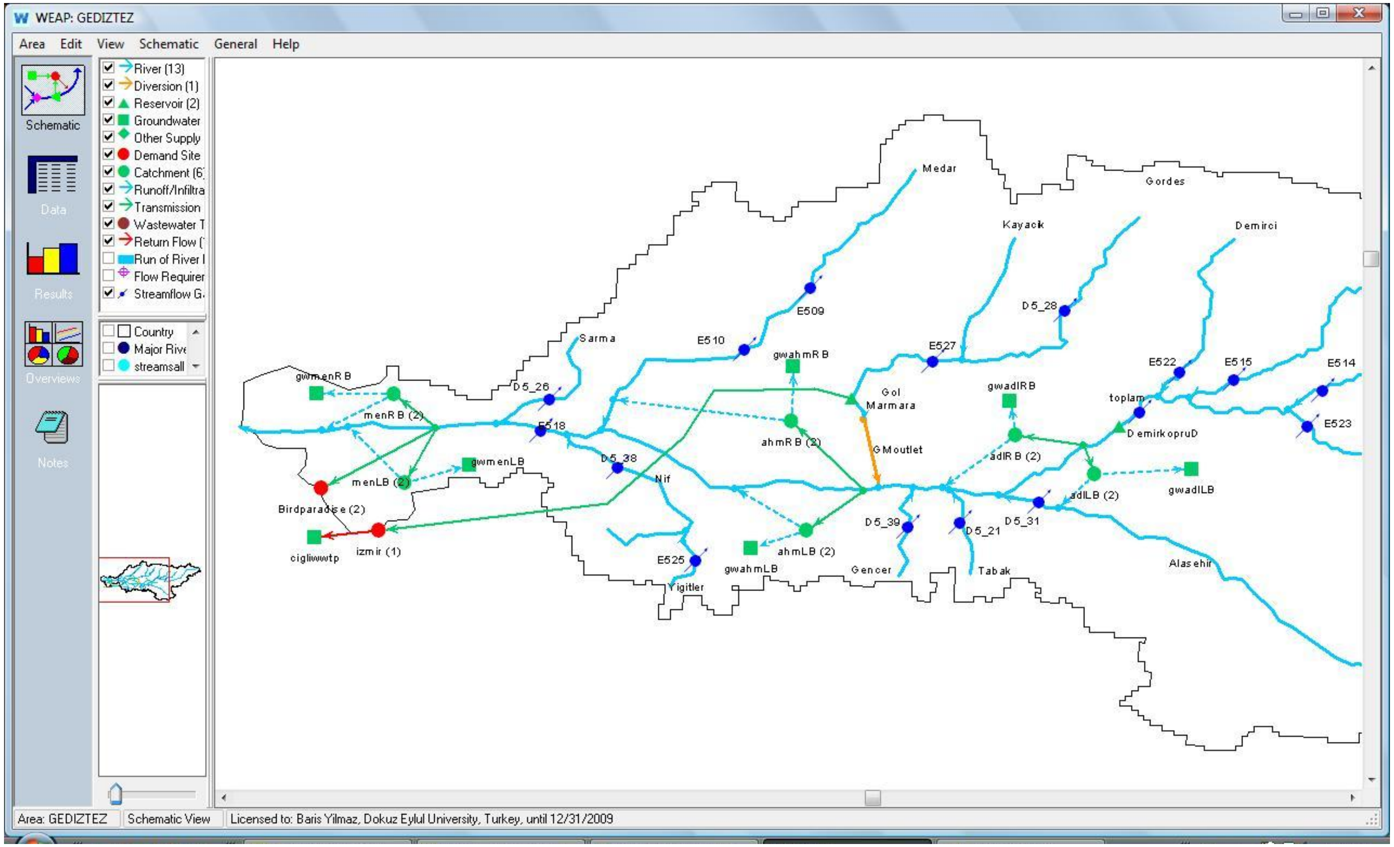
* Demirkopru Dam and Gol Marmara Lake (2 main reservoirs in the GRB)

* 3 large scale irrigation districts (Adala ID, Ahmetli ID, Menemen ID)

* Domestic & industrial demands are excluded.



Water Evaluation and Planning System (WEAP)



is a laboratory for examining alternative water development and management strategies.

is a simulation model base on node-link network.

operates on a monthly time steps.

WEAP ...

As a database, WEAP provides a system for maintaining water demand and supply information.

As a forecasting tool, WEAP simulates water demand, supply, flows, and storage, and pollution generation, treatment and discharge.

As a policy analysis tool, WEAP evaluates a full range of water development and management options and takes into account multiple and competing uses of water systems.

More information is available at : www.weap21.org

Stockholm Environmental Institute: www.sei-international.org

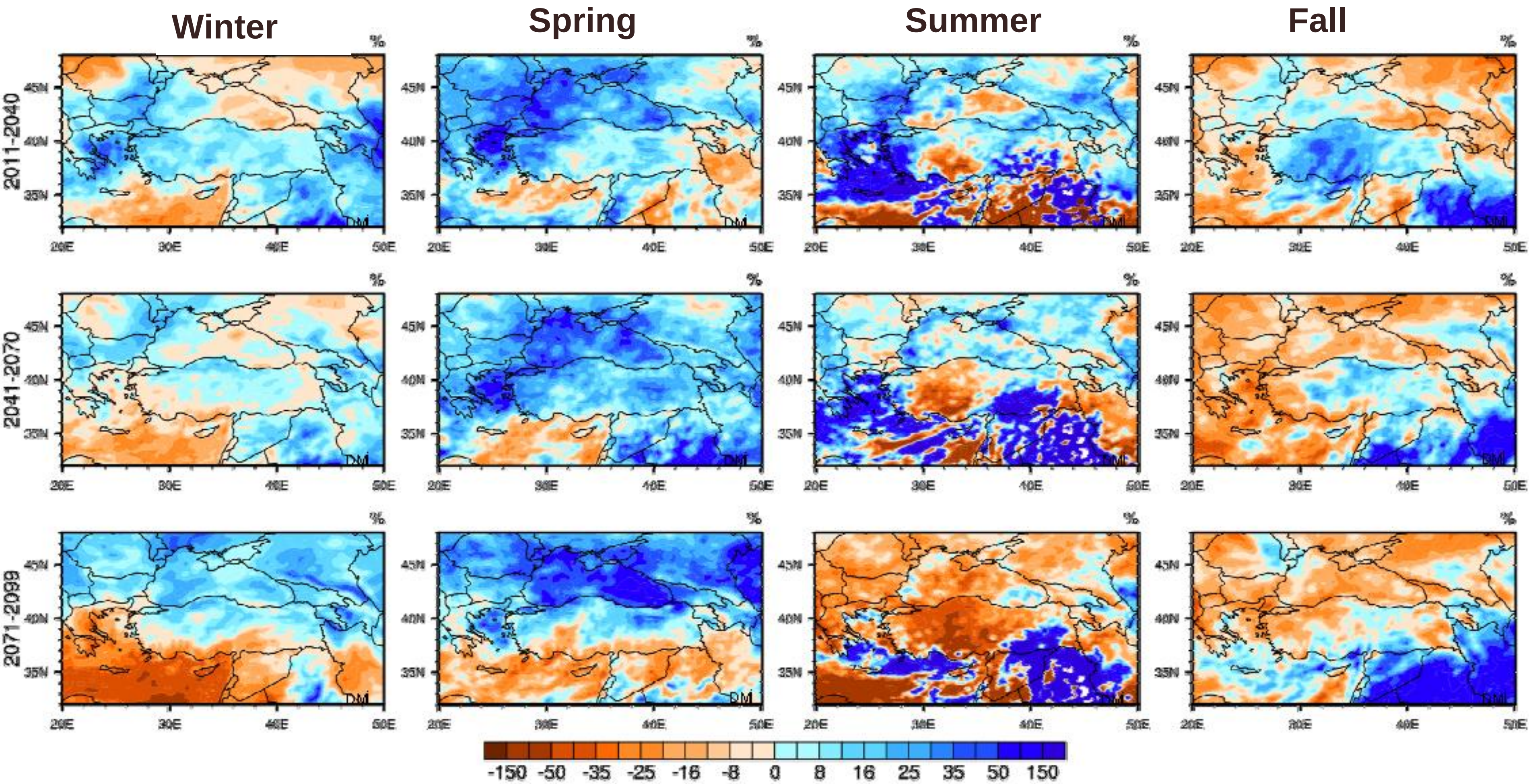
Climate scenario

The used climate scenario data are the simulation results of ECHAM5 general circulation model (European Centre Hamburg Model v5) RegCM3 regional climate model (Regional Climate Model v3) and base on IPCC (Intergovernmental Panel on Climate Change) A2 emission scenario.

The detailed data are obtained from the web-based data dissemination system of the project (**http://gaia.itu.edu.tr/**).

Expected total precipitation changes for Turkey

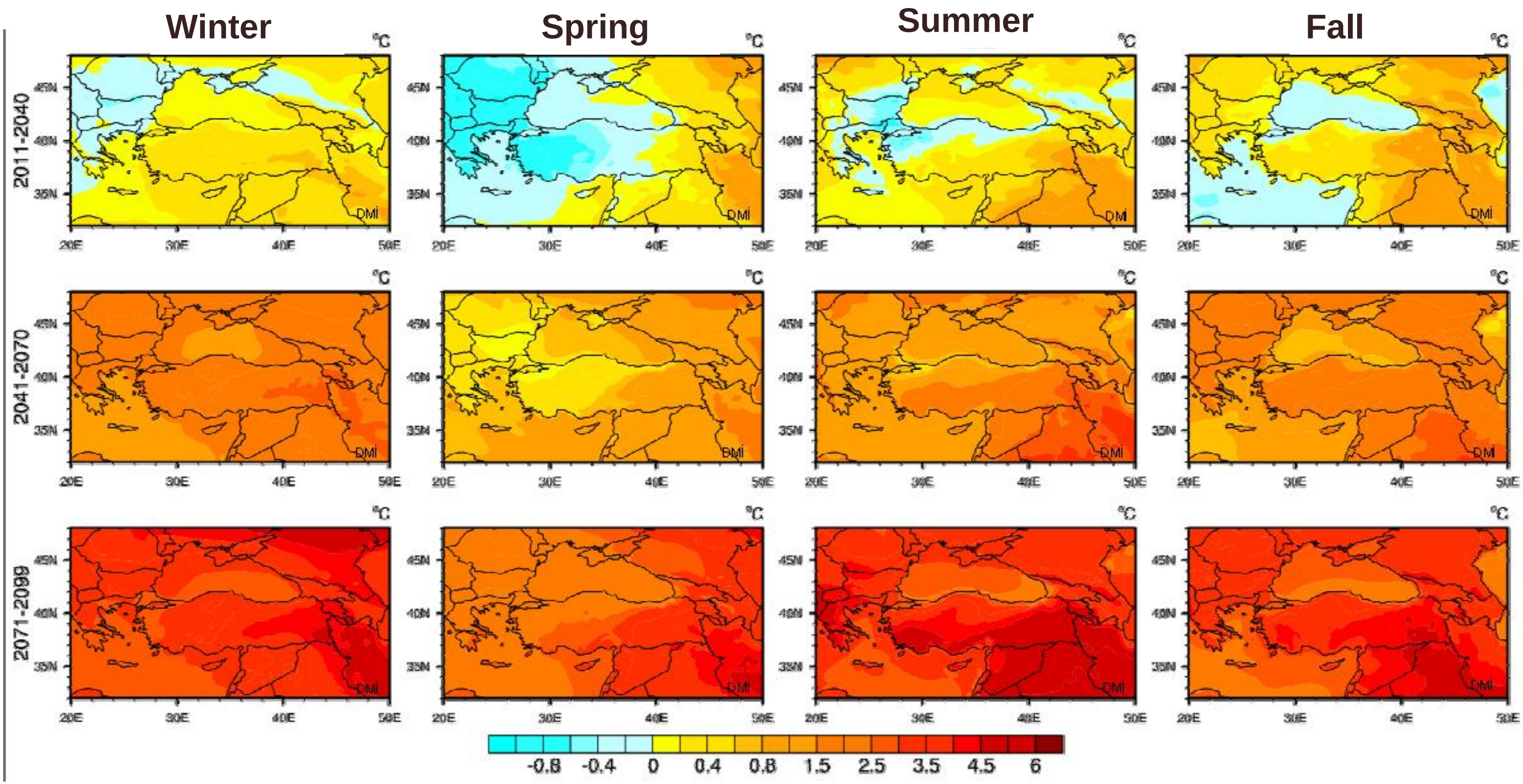
Turkish State Meteorological Service, http://www.dmi.gov.tr/iklim/iklim-degisiklgi.aspx?s=s1



Considering the location of Gediz Basin, it can be said that 4% and 8% decrement in total winter season precipitation should be expected between 2041-2070 and 2071-2099 periods, respectively.

Expected temperature changes for Turkey

Turkish State Meteorological Service, http://www.dmi.gov.tr/iklim/iklim-degisikligi.aspx?s=s1



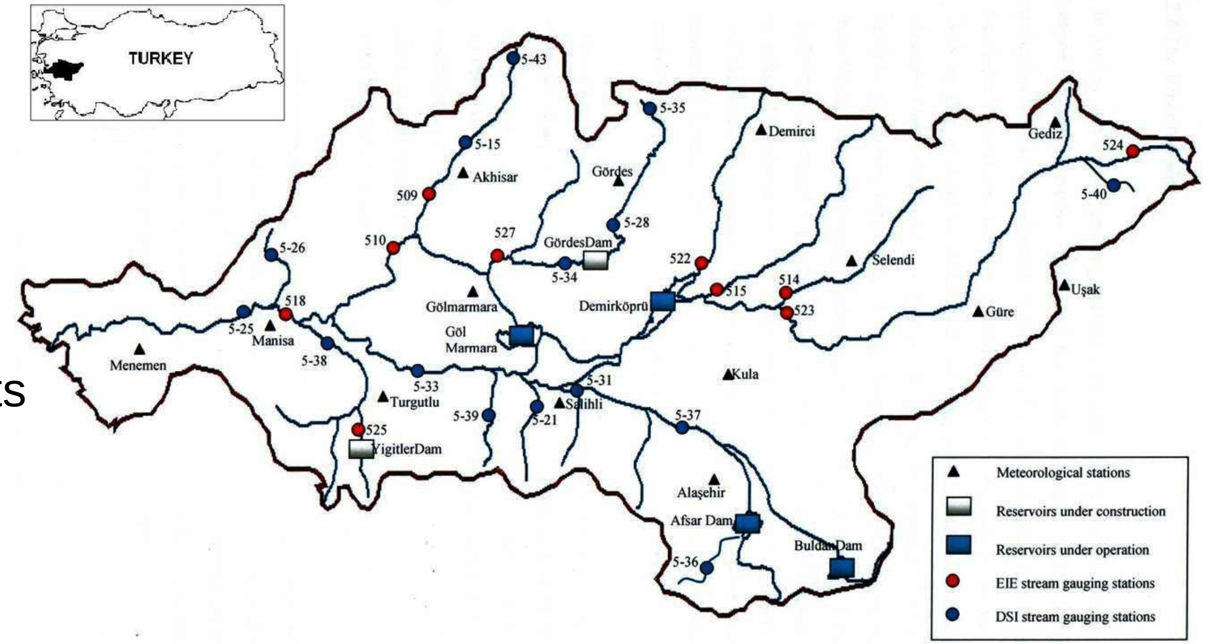
In future, increase in summer season temperatures can be estimated with a range of 2 and 4 °C.

Analysis Setup

The Gediz River network with primary tributaries, meteorological stations, stream gauging stations (SGS) and reservoirs can be seen in the figure.

Demirkopru and Gol Marmara are the reservoirs that supply water for downstream irrigation demands.

Demirkopru Dam supply water for all irrigation districts while Gol Marmara is operated to fulfill the water deficit in summer season.



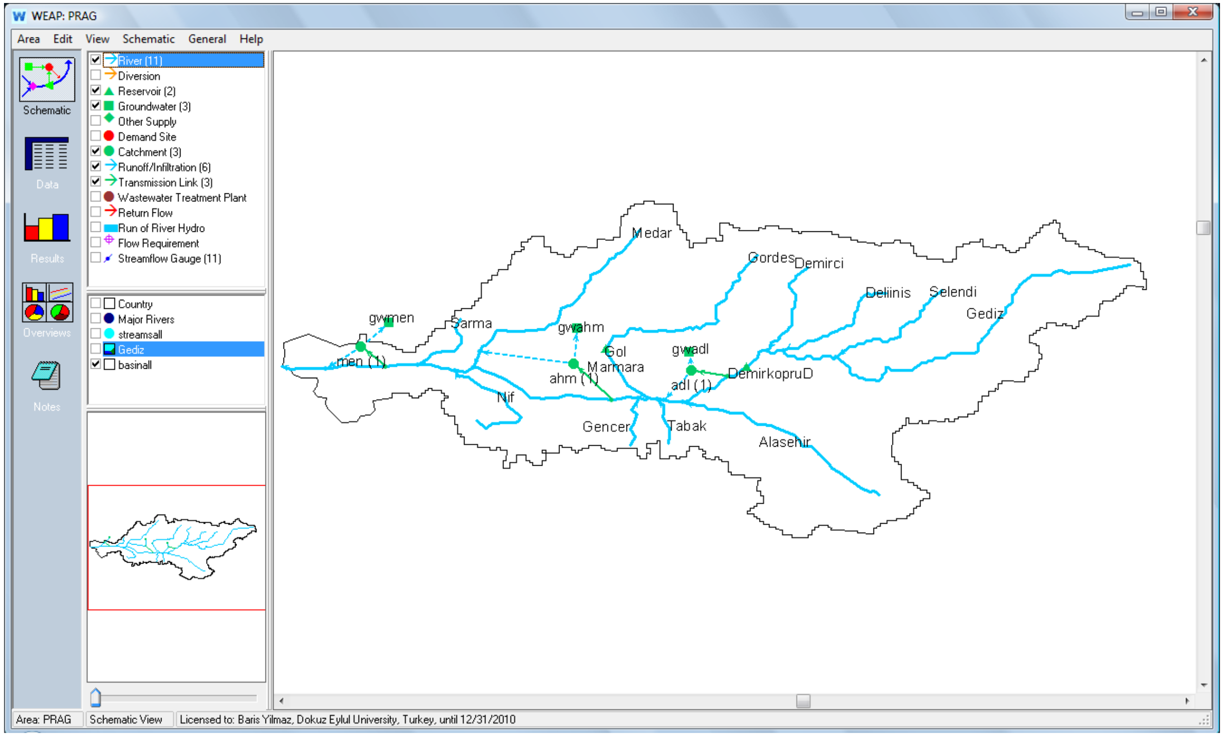
Since there are no sufficient and reliable long term streamflow data for the rivers that feed Afsar and Buldan dams, these dams are not taken into account in this study.

Modeling GRB in WEAP (1/2)

In the analysis, the Adala, Ahmetli and Menemen irrigation districts (IDs) are taken into account as demand sites. The priority of each demand site is equally set to 1 to reflect the highest priority.

The main crops accounted in the analysis are cotton, maize, grape, vegetables and cereals.

Physical and contractual constraints of regulators and canals are also incorporated to analyses.



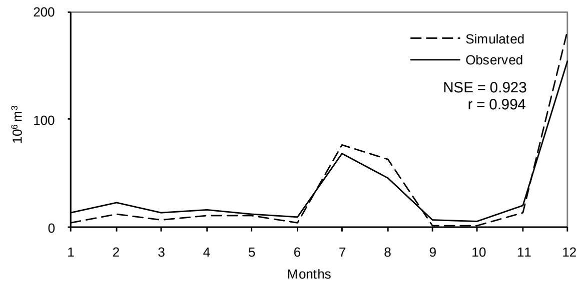
Modeling GRB in WEAP (2/2)

The last downstream station on Gediz River and the storage volumes in Demirkopru Dam are used to calibrate the model.

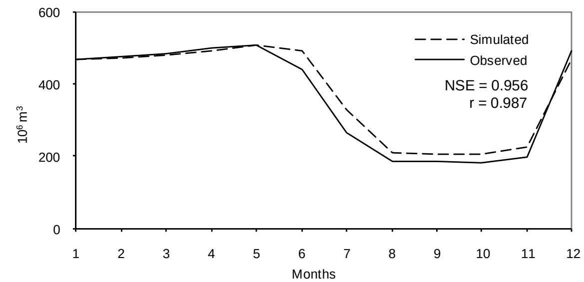
Since the operation rules of the dams are irregular and are arranged according to the yearly water demands, the calibration is executed individually with the relevant data for the years from 1995 to 2003.

The calibration graphs those refer to 2001 (dry year), 1996 (normal year) and 1999 (wet year) are depicted in Figure.

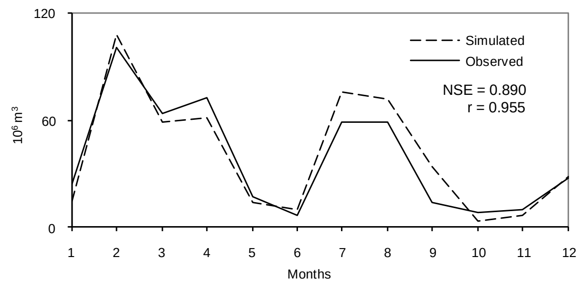
The Nash-Sutcliffe Efficiency (NSE) and Pearson's correlation coefficient (r) are represented the model performance as 'very good'.



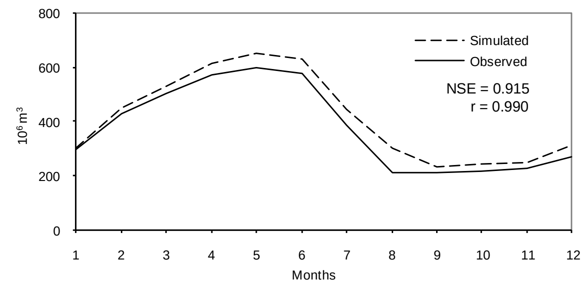
(a) Runoff volume at SGS 518 for 2001



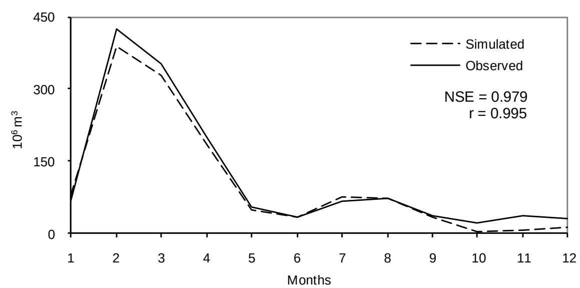
(b) Storage volume in Demirkopru for 2001



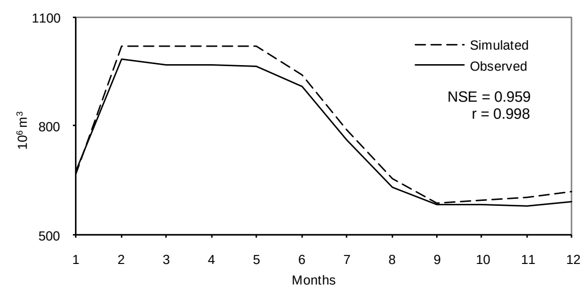
(c) Runoff volume at SGS 518 for 1996



(d) Storage volume in Demirkopru for 1996



(e) Runoff volume at SGS 518 for 1999

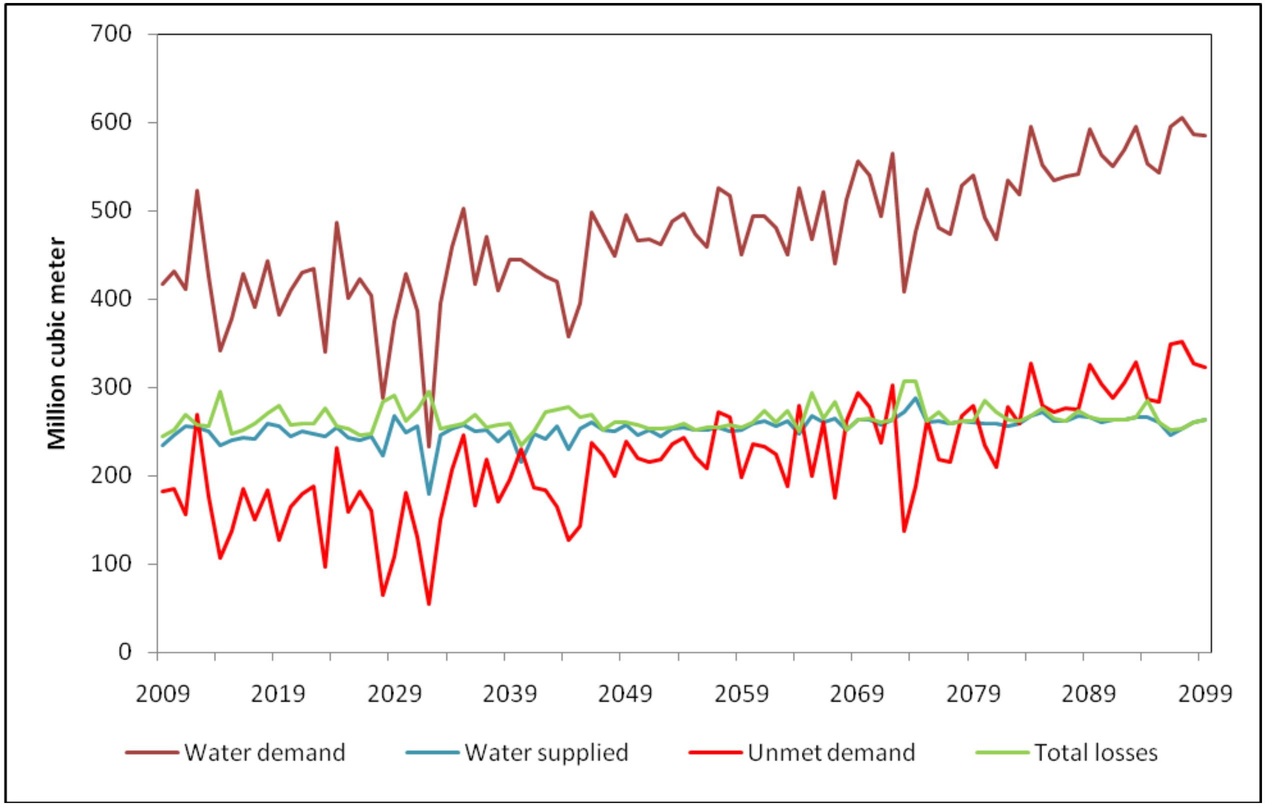


(f) Storage volume in Demirkopru for 1999

Through the model calibration, transmission link loss rate, irrigation efficiency and the irrigation return flow rate are determined as 32%, 60% and 16%, respectively.

Results (1/4)

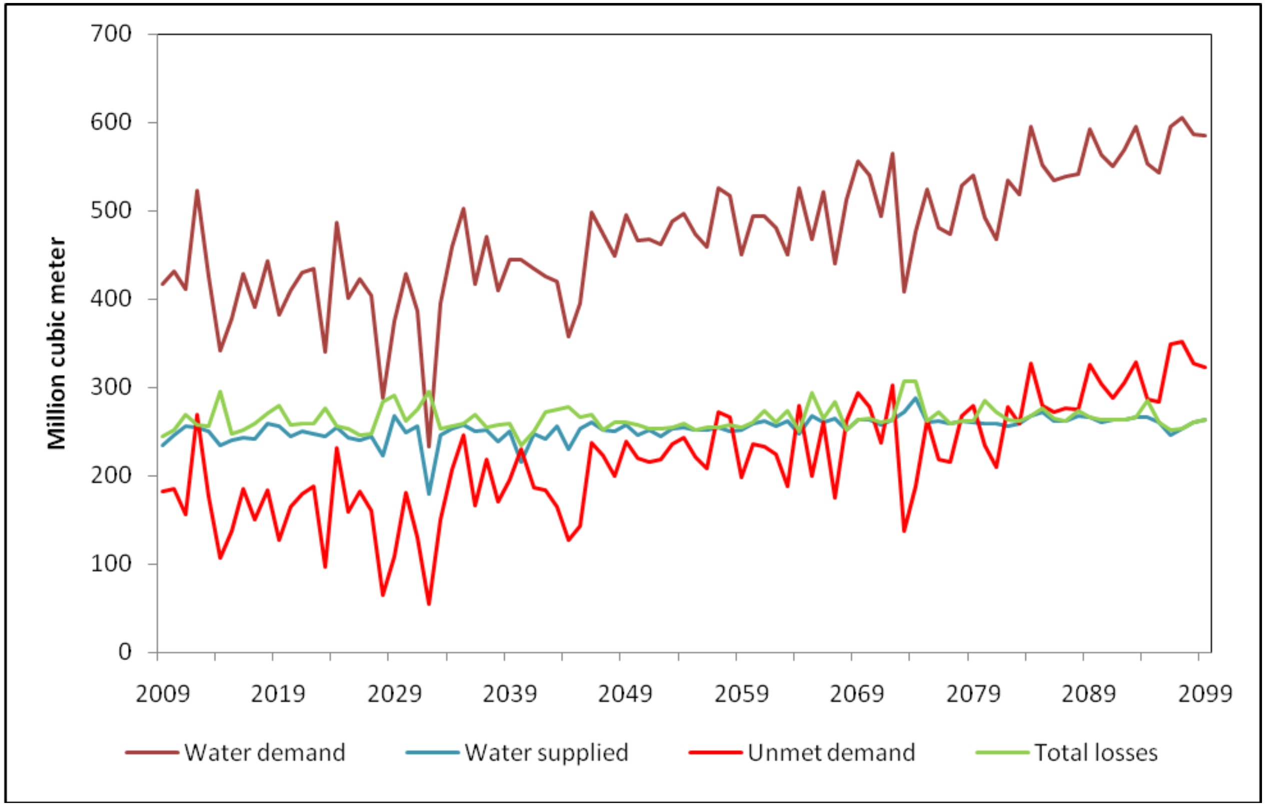
Below, water budget evaluation in summer season (as a total of June, July and August) is given for all simulation period.



Here, due to climate change impacts increase in total water demand is significant, and it is obvious that the basin will suffer from water shortage. Especially some years after 2050, the amount of unmet water demand is greater than supplied water.

Results (2/4)

The transmission link losses which are almost 30% of water passing through the link and low irrigation efficiency (60%) due to irrigation systems that employ wild flood or furrow methods are considered as the primary reasons for high amount of unmet water demand.



In the current system, total losses are almost 220 MCM, and that is approximately equal to supplied water. In other words, total losses of the system constitute half of total water demand.

Results (3/4)

Water-related changes due to climate change are also evaluated in accordance with the project results for three (30-year-long) periods, namely A (2011-2040), B (2041-2070) and C (2071-2099).

Since Supply/Demand ratio (S/D) is a valuable indicator for water resources management, it is computed for summer months of each period (Table 1).

Table 1 Average S/D ratios for the time periods

	A	B	C
June	0.47	0.39	0.34
July	0.61	0.57	0.52
August	0.69	0.64	0.59
Total summer season	0.60	0.53	0.49

Obviously, climate change impacts exacerbate the water scarcity when the time elapses, and it is not seen possible to fulfill the total demand in any period.

Results (4/4)

The average unmet demand amounts for each period are calculated for summer months in Table 2, where max and min amounts are given to reach an idea about the deficit.

Table 2 Amounts of unmet water demand in summer months for the time periods (10^6 m^3)

	A			B			C		
	max	mean	min	max	mean	min	max	mean	min
June	120	61	0	123	89	30	162	108	8
July	107	67	14	110	83	37	133	104	77
August	64	38	23	66	49	21	82	63	43

In Table 3, decreases in crop yield relative to max crop yield (%) are summarized. The decrease in crop yield can be explained by the yield response factors (k_y) of crops as well as decrease in available irrigation water due to climate change impacts.

k_y of maize (1.25) is higher than k_y of cotton and grape (0.85). Therefore, the yield decrease in maize is expected to be higher than cotton, if evapotranspiration deficits occur.

Table 3 Decreases in crop yield relative to max crop yield (%)

	A	B	C
Cotton	32	37	42
Grape	29	34	41
Maize	48	59	67

Conclusion (1/4)

i) The Basin is already under water stress and is also quite sensitive to drought conditions.

If the pessimistic conditions which lead to decreased water supply and increased water demand occur, the resulting water deficits will significantly affect the agricultural sector.

Accordingly, efficient water management policies are crucial to solve water problems and to ensure sustainable development in the Gediz River Basin.

Conclusion (2/4)

ii) Replacement of the water conveyance system by pressured lines coupled with the application of water saver technologies such as drip irrigation methods is seen as the most efficient management strategy for the Basin.

With this strategy, it is possible to minimize the negative impacts of climate change. It should be noted that, the proposed alternative should be supported by additional measures, such as crop change applications. On the other hand, the proposed alternative should be the basic and long term policy for socio-economic development in the Gediz River Basin.

If the proposed alternative is implemented in earliest time, this will ensure more benefits in agriculture and will lead to economic achievements.

Conclusion (3/4)

iv) The developed methodology is a valuable tool for the assessment of water resources systems and illustrates an efficient implementation of water resources management approach.

By further studies, possible management alternatives should be evaluated in similar manner to reflect the improvements of sustainability indicators.

WEAP model is a potentially useful tool for planning and management of water resources, and it provides a comprehensive, flexible and user friendly framework for evaluation of management strategies.

Conclusion (4/4)

v) For water resources management in developed countries, similar approaches have been widely used, but have not yet been effectively implemented for other river basins of Turkey. It is recommended to increase the number of similar studies that will also incorporate groundwater resources, water quality, industrial and domestic water demand, if adequate and accurate data is available.

THANK YOU SO MUCH !!