Water Evaluation and Planning System Gediz basin - Turkey

WatManSup project

WatManSup report no 5

PARTNERS VOOR WATER
Bundeling van krachten

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WATERSCHAP
Hunze en Aa's

FutureWater
Science for Solutions

Water Evaluation and Planning System
Gediz basin - Turkey

WatManSup project

WatManSup report no 5

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Preface

This report is written in the context of the WatManSup project (Integrated Water Management Support Methodologies). The project is executed in two countries: Kenya and Turkey. Financial support is provided by Partners for Water. For more information on the WatManSup project see the project website: http://www.futurewater.nl/watmansup.

The Dutch consortium:

FutureWater (Wageningen)
Institute for Environmental Studies (Amsterdam)
Water Board Hunze en Aa's (Veendam)

Foreign clients:
SASOL Foundation (Kitui, Kenya)
Soil and Water Resources Research Institutes of the Turkish Ministry of Agricultural and Rural Affairs (Menemen, Turkey)
SUMER (Izmir, Turkey)

Additional technical support:
the University of Nairobi (Kenya)
EA-TEK (Izmir, Turkey)

Reports so far:
Report No.1: Water Management Support Methodologies: State of the Art
Report No.2: Water Evaluation and Planning System, Kitui – Kenya
Report No.3: Soil and Water Assessment Tool, Kitui - Kenya
Report No.4: Multi-criteria analysis, Kitui - Kenya
Report No.5: Water Evaluation and Planning System, Gediz Basin - Turkey

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1 Introduction

The challenge to manage our water resources in a sustainable and appropriate manner is growing. Water related disasters are not accepted anymore and societies expect more and more that water is always available at the right moment and at the desired quantity and quality. Current water management practices are still focused on reacting to events occurred in the past: the re-active approach. At many international high level ministerial and scientific meetings a call for more strategic oriented water management, the pro-active approach has been advocated. Despite these calls such a pro-active approach is hardly adopted by water managers and policy makers (Droogers, 2006).

Water managers and decisions makers are aware of the necessity of this paradigm shift: from a re-active towards a pro-active approach, but are confronted with the lack of appropriate methodologies. To be prepared for the paradigm shift Integrated Water Management Support Methodologies (IWMSM) are needed that go beyond the traditional operational support tools. Note that these IWMSM are more than only tools, but include conceptual issues, theories, combining technical and socio-economic aspects. To demonstrate and promote this new way of thinking the WatManSup (Water Management Support Tools) has been initiated. The IWMSM approach comprises three different components: a water allocation component, a physical based component and a decision support component. This report describes the water allocation component for one of the study areas included in the project: Gediz basin in Turkey.

Turkey's economy is growing fast and the demand for water is vastly growing along. Industrial areas expand and so does the water demand. Agricultural land is still the highest water user. All agricultural lands in Turkey are irrigated, mainly through surface irrigation and the area of agricultural irrigation systems is still growing. The dry years from 1989-1994 show that Gediz basin is vulnerable. Water supply is not unlimited and the agricultural sector suffered from severe economic losses. With future plans for expansion of the agricultural area and the industrial sector growing rapidly, it is clear that the water delivery in Gediz basin needs a closer look. Smart water allocation is important to maintain all deliveries to all sectors (Kite et al. 2001, Droogers and Torabi, 2002).

The overall objective of this report is to demonstrate opportunities offered by the water allocation component of IWMSM, the WEAP tool, to support water managers and policy makers responsible for basin scale water supply, in dry regions with large irrigation schemes and reservoirs.

2 Background

2.1 *The WEAP model*

Water managers and policy makers are in need to have tools at their disposal that will support them in their decision-making. The WEAP tool is one of the components of IWMSM that can be implemented relatively easy to evaluate scenarios on different water allocation strategies in a user-friendly environment.

WEAP is short for Water Evaluation and Planning System and is originally developed by the Stockholm Environment Institute at Boston, USA (SEI, 2005a). WEAP is distinguished by its integrated approach to simulating water systems and by its policy orientation. WEAP places the demand site of the equation – water use patterns, equipment efficiencies, re-use, prices and allocation – on an equal footing with the supply site – streamflow, groundwater, reservoirs and water transfers. WEAP is a laboratory for examining alternative water development and management strategies (SEI, 2005a).

WEAP represents the system in terms of its various supply sources (e.g. rivers, creeks, groundwater, and reservoirs); withdrawal, transmission and wastewater treatment facilities; ecosystem requirements, water demands and pollution generation. The data structure and level of detail may be easily customized to meet the requirements of a particular analysis, and to reflect the limits imposed by restricted data.

WEAP applications generally include several steps. The *study definition* sets up the time frame, spatial boundary, system components and configuration of the problem. The *Current Accounts*, which can be viewed as a calibration step in the development of an application, provide a snapshot of the actual water demand, pollution loads, resources and supplies for the system. *Key assumptions* may be built into the Current Accounts to represent policies, costs and factors that affect demand, pollution, supply and hydrology. *Scenarios* build on the Current Accounts and allow one to explore the impact of alternative assumptions or policies on future water availability and use. Finally, the scenarios are *evaluated* with regard to water sufficiency, costs and benefits, compatibility with environmental targets, and sensitivity to uncertainty in key variables (SEI, 2005a).

WEAP, in contrast to many other tools, is not optimization oriented in the sense that the optimal water allocation will be presented. The entire approach is based on scenarios (alternatives) to ensure that stakeholders, water managers and policy makers are actively involved in the entire process of planning in order to guarantee the ownership feeling of the final decisions taken.

WEAP consists of five main views: Schematic, Data, Results, Overviews and Notes (Figure 1). A typical stepwise approach will be followed to develop WEAP for a particular area: (i) create a geographic representation of the area, (ii) enter the data for the different supply and demand sites, (iii) compare results with observations and if required update data, (iv) define scenarios and (v) compare and present the results of different scenarios. In general, the first three steps will be done by technical experts like hydrologists, while for the last two steps input and exchange with stakeholders, water managers and policy makers is essential.

More detailed information about the WEAP model is in WatManSup report No. 1.

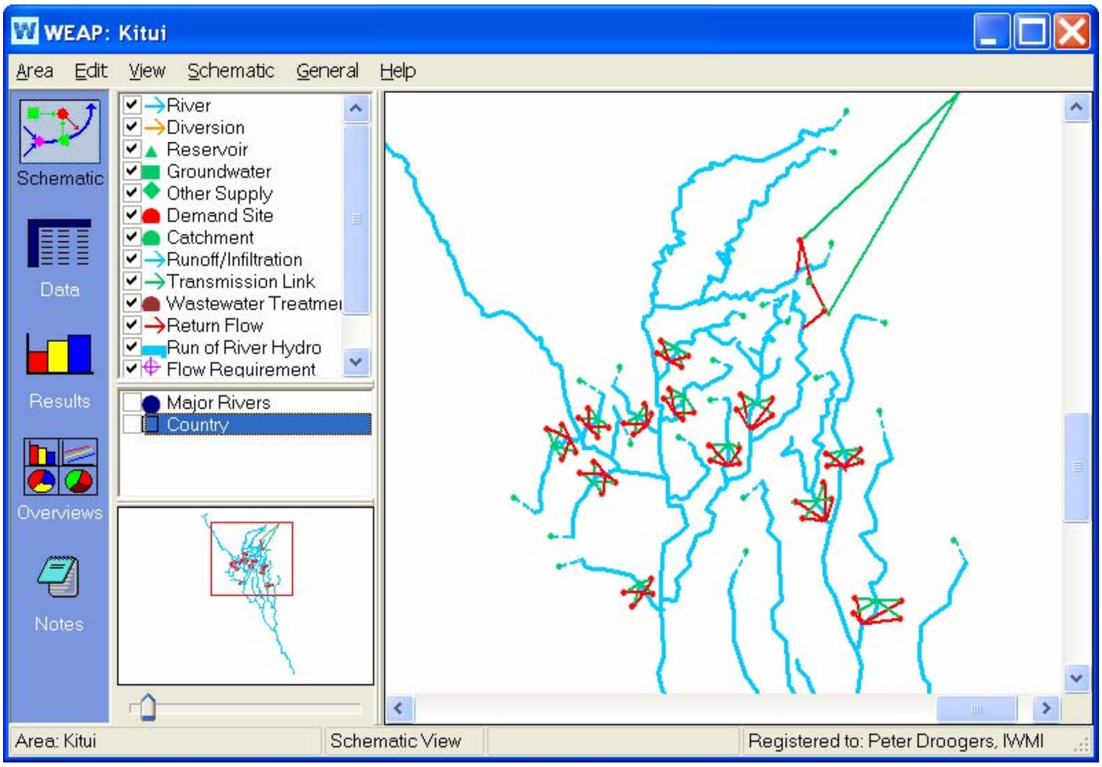


Figure 1: User interfaces of WEAP with on the left the five main views.

2.2 Gediz basin Turkey

2.2.1 Regional setting

The WatManSup project aims at testing and demonstrating the IWMSM components in contrasting settings. The Gediz basin is selected as it represents a typical case for a basin consisting of large scaled irrigation schemes with large agricultural water demands, suffering from water shortages in meteorological dry periods.

Gediz basin is located in the west of Turkey. Gediz River flows from east to west into the Aegean See just north of Izmir. Gediz river is about 275 km long and drains an area of 17 200 sq km as shown in Figure 2. The total water use in Turkey is about 40 billion cubic meters of which 75 percent is directed to irrigation, 10 percent to industry and 15 percent is for domestic use (DSI, 2007).

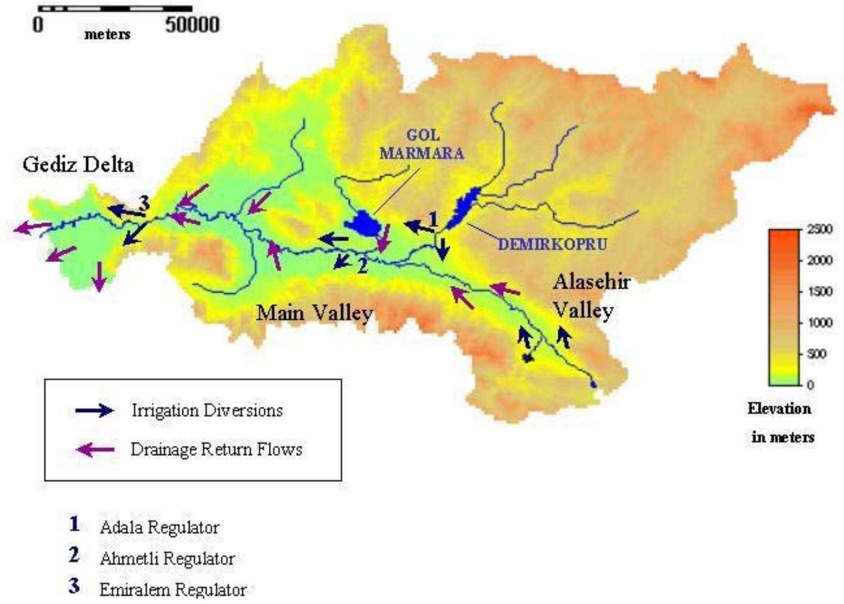


Figure 2: Overview of Gediz basin.

2.2.2 Geography and climate

The Gediz Basin is part of the Aegean region and the Mediterranean rainfall regimes. It has hot dry summers and cool winters. The average annual rainfall amount is some 500 to 530 mm, but extremes of 300 mm and 850 mm also occur. Precipitation is concentrated in the winter period. Precipitation in the basin ranges from over 1 000 mm per year in the mountains to 500 mm per year near the Aegean coast. In the mountains the precipitation mainly falls in forms of snow (Mathijssen, 2007).

The Gediz basin is bounded by mountain ranges in the northeast and in the south. The northeastern plateau is gently sloping southwestwards, with mountains from over 2000m elevation. Precipitation from the northeastern plateau drains into the Gediz River. The southern mountains have a steep drop on their northern flanks. The western part of the basin is a flat delta with elevations below 200 m (Figure 2).

2.2.3 Socio-economical data

Turkey's dynamic economy is a complex mix of modern industry and commerce along with a traditional agricultural sector that still accounts for more than 35% of employment. It has a strong and rapidly growing private sector, yet the state still plays a major role in basic industry, banking, transport, and communication. The largest industrial sector is textiles and clothing, which accounts for one-third of industrial employment. Other sectors like electronics industries are rising in importance within Turkey's export mix. The GDP per capita is 8400 US$ in 2005 estimate of the CIA. The composition of GDP per sector is 12% from agriculture, 30% from industries and 58% form services. Real GNP growth has exceeded 6% in many years since the 1990's and in 2004 GDP growth reached 9%. Inflation fell to 7.7% in 2005 (CIA factbook).

2.2.4 Water management and institutional aspects

There are two governmental organizations involved in major irrigation and drainage development. The first one is DSI (Devlet Su Isleri = State hydraulic works). DSI was established in 1954 as a legal entity and brought under the aegis of the Ministry of Public Works and Settlement. DSI is responsible for the planning, design, construction, operation and water resource development for various purposes like irrigation, flood control, swamp reclamation, hydropower development, navigation and water supply to cities with over 100 000 inhabitants (FAO, Aquastat 2004). Until 1995 DSI was responsible for the operation and maintenance of the large irrigation schemes. In 1995 the management was transferred to the newly formed Water Users Associations (WUA's). WUA's are small scaled governmental bodies that are only responsible for the operation and maintenance of an irrigation area (Murray-Rust et al., 2006).

The second governmental organization is General Directorate of Rural Services (GDRS) which was established in 1984 by incorporating the soil conservation and irrigation organization, the rural settlement organization and the rural roads, water and electricity organization into one organization. GDRS is responsible for the development of small-scale irrigation schemes and small reservoirs, rural roads and water supply to rural areas. It is also responsible for land consolidation and the on-farm development of all irrigation projects, including the projects developed by DSI. It was formerly under the Ministry of Agriculture and Rural Affairs, but now falls under the Prime Minister's Office (FAO, Aquastat 2004).

Figure 3: Demirköprü reservoir (Webshots.com).

3 WEAP Gediz basin

WEAP is an integrated water management tool that allows basin evaluations including all water related activities in a specific area. Focus of WEAP is balancing water supply and water demand in a swift and transparent way. The aim of this report is to show the usefulness of WEAP for the Gediz basin, rather than to provide a complete and rigorous analysis of basin issues. Neither was the objective to provide direct solutions to water related issues in the Gediz basin.

In this chapter the overall set-up of the model is explained. The WEAP model includes several steps of explanation which are: Schematic Setup, Current Accounts, Reference Scenario and Other Scenarios. Schematic Setup builds the basic structure of the model on which the calculations will be based. The Current Accounts is the dataset from which the scenarios are built. The Current Accounts is a one year basis. The Reference Scenario carries forward the Current Accounts data into the entire project period specified and serves as a point of comparison. The Reference Scenario is the default scenario. Other Scenarios explore possible changes to the system on future years after the Current Accounts year. For the Other Scenarios changes are made to the system data from the default scenario (SEI, 2005a).

3.1 *Schematic setup*

In Figure 4 an overview of the Gediz basin in WEAP is given. Gediz river runs from north east to the west were it discharches into the Aegean see. On the way three smaller rivers flow into Gediz river: Alasehir, Gordes and Kumçay river. In the Gediz Basin eight large scale irrigation schemes and a few hundred small scale irrigation systems are present. This study focuses on the large scale irrigation systems. In WEAP we simulate eight irrigation schemes. Sarigol, Aleshir, Adala Right Bank, Adala Left Bank, Ahmetli Right Bank, Ahmetli Left Bank, Menemen Right Bank, Menemen Left Bank are shown as the green dots in Figure 4.
The headflow of the rivers is represented by five catchment areas. From these catchment areas the precipitation runoff is directed as a river headflow.
Near the Aegean See there is a bird paradise called Kuş Cenneti. This is an important estuary for birds, recognized by the Ramsar convention in Iran. Kuş Cenneti is represented as a demand site and shown as a red dot in Figure 4.

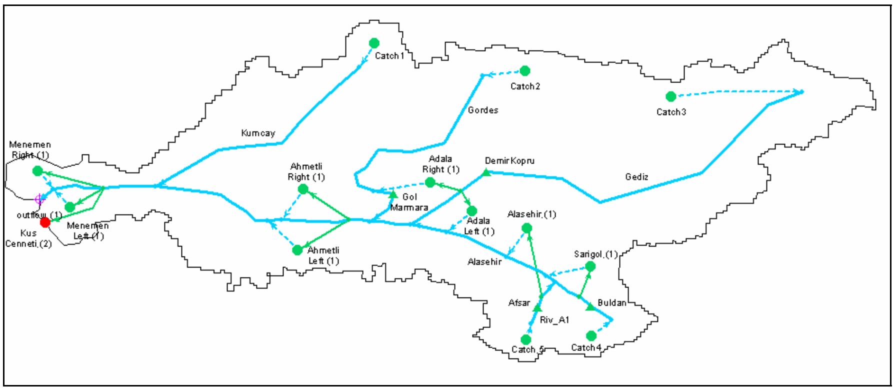


Figure 4. Schematic view of the WEAP model for Gediz basin.

3.2 *Current accounts*

The year 1990 is chosen as the "Current Accounts" year, or base year, for this project and the entire project period is set to 1990 to 2005. This period is regarded as representative based on data of the precipitation (Appendix A1).

The data input in WEAP is structured according to the schematic set-up of the catchment. The following classification is used:

1. key assumptions
2. demand sites and catchments
3. hydrology
4. supply and resources
    a. linking demands and supply
    b. runoff and infiltration
    c. river (including the reservoirs per tributary)
    d. groundwater
    e. local reservoirs
    f. return flows

This chapter starts with a description of the demand sites and catchments, then the supply and resources are described and the chapter ends with the key assumptions.

3.2.1 Demand sites and catchments

The demand sites in WEAP are eight large irrigation schemes included as catchments and one wetland included as a demand site. A description of both demand sites as incorporated in WEAP is presented below.

Irrigation schemes

The total irrigated area in Gediz basin is about 120 000 hectares. There are eight large irrigation schemes totaling up to about 100 000 hectares of irrigated area. The large irrigation schemes are dominated by cotton and grape cultivation. Another 20 000 hectares of extensive small scale irrigation areas cultivate wheat, barley, vegetables and fruit orchards. Data of the eight large irrigation schemes is shown in Table 1 (Geçgel, 1998).

Table 2 shows the cropping area in the irrigation schemes as they are entered in WEAP for the reference scenario.

Table 1: Main irrigation schemes in Gediz basin.

Irrigation scheme	**Irrigated area (ha)**	**Location**	**Main crop**	**Regulator**
Sarigol	1 927	Upper valley	Grapes	Alasehir
Alasehir	13 343	Upper valley	Grapes	Alasehir
Adala right bank	9 237	Main valley	Grapes and cotton	Adala
Adala left bank	9 101	Main valley	Grapes and cotton	Adala
Ahmetli right bank	24 664	Main valley	Grapes and cotton	Ahmetli
Ahmetli left bank	17 951	Main valley	Grapes and cotton	Ahmetli
Menemen right bank	16 500	Delta	Cotton	Emiralem
Menemen left bank	6 365	Delta	Cotton	Emiralem
Other small schemes	20 000			
Total	119 088			

Table 2: Cropping pattern in the irrigation schemes.

	Cotton (%)	Grapes (%)	Others (%)
Menemen Left bank	50	9	41
Menemen Right bank	73	22	5
Ahmetli Left bank	30	62	8
Ahmetli Right bank	30	62	8
Adala Left bank	40	48	12
Adala Right bank	50	33	17
Alasehir	30	50	20
Sarigol	0	80	20

In a catchment site the FAO rainfall runoff method is used to calculate the water demand. For the calculations with this method the land use and climate of a catchment site need to be defined. Land use is composed of the parameters area, crop coefficient and effective precipitation, while climate is defined by the precipitation and reference evapotranspiration. The climatic data and the crop coefficient are incorporated as key assumptions and will be described in detail later in this chapter.

Wetland

The Kuş Cenneti wetland has been established in 1997 as a Ramsar area. The Kuş Cenneti, with 8 000 hectares, is located 25 km to the west of Izmir harbor, and forms the main feeding and breeding location within the delta, although the birds use the entire delta as a habitat. The fresh water area of Kuş Cenneti is estimated to be 1 100 ha. Table 3 shows the estimated monthly fresh water requirements for Kuş Cenneti (De Voogt et al., 2000). From Table 16 it is concluded that the annual water demand for Kuş Cenneti is about 12 000 m3/ha for a dry year.

The supply priority for Kuş Cenneti is 2. The operation of the irrigation system in Gediz basin has prioritized water supply is for the irrigation schemes above the supply for the bird paradise. This means that in case of water scarcity Kuş Cenneti is the last demand site to meet its water demands. As shown in Figure 5 also in WEAP one can give supply priorities to demand and catchment sites. The irrigation schemes have a higher priority (1) than Kuş Cenneti (2).

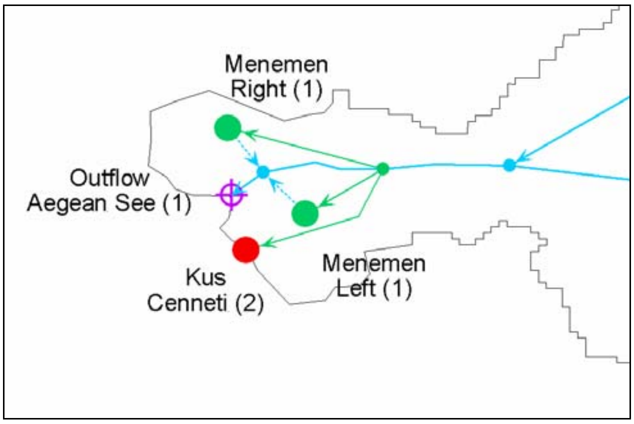
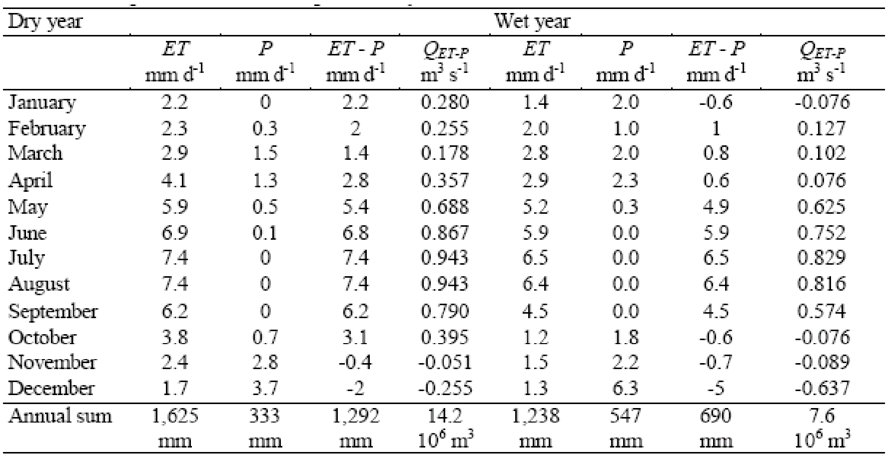


Figure 5: Supply priorities in Gediz basin.

Table 3: Minimum water requirement for Kuş Cenneti to maintain a constant water level (De Voogt et al., 2000).



Dry year					Wet year			
	ET mm d^{-1}	*P* mm d^{-1}	*ET - P* mm d^{-1}	Q_{ET-P} $m^3 s^{-1}$	*ET* mm d^{-1}	*P* mm d^{-1}	*ET - P* mm d^{-1}	Q_{ET-P} $m^3 s^{-1}$
January	2.2	0	2.2	0.280	1.4	2.0	-0.6	-0.076
February	2.3	0.3	2	0.255	2.0	1.0	1	0.127
March	2.9	1.5	1.4	0.178	2.8	2.0	0.8	0.102
April	4.1	1.3	2.8	0.357	2.9	2.3	0.6	0.076
May	5.9	0.5	5.4	0.688	5.2	0.3	4.9	0.625
June	6.9	0.1	6.8	0.867	5.9	0.0	5.9	0.752
July	7.4	0	7.4	0.943	6.5	0.0	6.5	0.829
August	7.4	0	7.4	0.943	6.4	0.0	6.4	0.816
September	6.2	0	6.2	0.790	4.5	0.0	4.5	0.574
October	3.8	0.7	3.1	0.395	1.2	1.8	-0.6	-0.076
November	2.4	2.8	-0.4	-0.051	1.5	2.2	-0.7	-0.089
December	1.7	3.7	-2	-0.255	1.3	6.3	-5	-0.637
Annual sum	1,625 mm	333 mm	1,292 mm	14.2 10^6 m^3	1,238 mm	547 mm	690 mm	7.6 10^6 m^3

3.2.2 Supply and resources

The water supply and water resources in Gediz basin include Gediz River and its tributaries, the river headflows, groundwater and reservoirs.

Gediz River

Gediz River flows from the northeast mountain area to the Aegean See. On the way three more river streams join the Gediz River. From the southeast Alasehir River flows in, from the northern main valley Gordes River is joining and Kumçay River is joining from the Northwest (Figure 4). Water supply from the river network to the irrigation schemes is through cement canals.

There are eight main irrigation schemes as shown in Figure 4. All irrigation schemes have the same design concept. From a regulator in the main river the canals divert to the irrigation schemes. The irrigation canals are constructed around the irrigation area to maximize the area that can be irrigated. The canals are very long with frequent bends, flumes and siphons across tributary steams and some tunnels. The canals have trapezium cross section made out of concrete. The construction is build of prefabricates connected by a cement layer (Mathijssen, 2007).

The total irrigated area in the basin is about 150 000 hectares. The losses in the canals are estimated at 10%. Due to evaporation and leakage a significant amount of water is leaking out of the canals.

River headflow

The headflow of the rivers in Gediz Basin is dependent on the runoff from the mountains. In WEAP this is simulated by the rainfall runoff from the catchments. Figure 6 shows catchments 1 to 5 representing the headflows of the Gediz River and its tributaries. The amount of water in the rivers is fully dependent on the rainfall runoff from the catchments.

Figure 6: River headflows simulated by catchment runoff.

The vegetation in the catchments consists mainly of shrubland or Maki (bay, myrtle, shrub oak and juniper trees) and coniferous forest with large outcrops of barren limestone mountain. The vegetation types in the mountain region as represented in WEAP are Maki, non-irrigated land and conifers (IWMI, 2000). WEAP calculates the rainfall runoff for these catchments at the same way as for the irrigation systems. Therefore the crop coefficients of the vegetation are needed as an input. For Maki and conifers the coefficients are estimated at 1, for the non-irrigated crops the coefficients are shown in Table 5 (University of California, 2000).

Groundwater

Since the recent dry period (from 1989 to 1994) there is a growth in small individual groundwater pumps. Mainly in the delta around Menemen groundwater supply has developed to a vast amount. Falling groundwater levels does not seem to be a big problem because the ground water is recharged by the winter rains and in summer the excess canal water infiltrates (Geçgel, 1998). Groundwater is not simulated in the model because no information is available on groundwater resources and supplies.

Reservoirs

Gediz Basin has four reservoirs in the upstream part of the basin (Figure 6) to store the water from winter precipitation for irrigation in the summer period. Gol Marmara is a natural lake of which the outflow is dammed and regulated. Gol Marmara has a great surface area but is a shallow lake. Demirköprü is an artificial lake, constructed from 1954 to 1960 (DSI, 2007) with multi purposes of irrigation, flood control and energy generation. Afsar and Buldan reservoir are small artificial lakes in the southern mountain area of Gediz Basin.

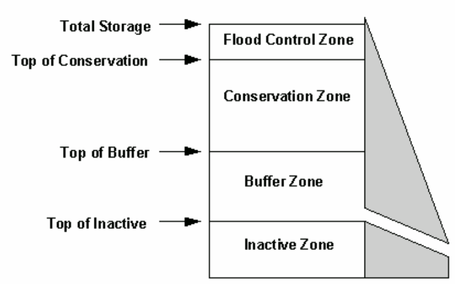


Figure 7: Reservoir zones and operation in WEAP.

Demirköprü reservoir and Gol Marmara reservoir are the main reservoirs in the Gediz basin. Asfan and Buldan reservoir are more locally important but do not contribute to downstream supply. Storage volumes of the reservoirs are shown in Table 4.

Table 4: Storage volumes of the reservoirs in Gediz basin in Million Cubic Meters (MCM).

	Demirköprü (MCM)	Gol Marmara (MCM)	Buldan (MCM)	Asfan (MCM)
Top of Storage	1100	321	100	100
Top of conservation	1022	320	100	100
Top of buffer	500	50	10	10
Top of inactive	200	15	5	5

3.2.3 Key assumptions

Key-assumptions are user defined parameters that can be used throughout the WEAP model. The use of key-assumptions is especially worthwhile when the model has a large number of similar objects, for example demand sites, and when performing scenario analysis. With key-assumptions you can easily create scenarios without having to edit the data of each and every demand site – simply by changing the key-assumption value (SEI, 2005a). The use of key-assumptions enables a faster set-up of the current situation and the scenarios, and simplifies changes in the characteristics of reservoirs and demand sites. This is especially useful when we present our partners with the model and they propose corrections or additions. In this case study key assumptions have been used for crop coefficients and climatic data.

Crop coefficients

FAO crop requirements are calculated assuming a demand site with simplified hydrological and agro-hydrological processes such as precipitation, evapotranspiration, and crop growth emphasizing irrigated and rainfall agriculture. Non-agricultural crops can be included as well (SEI, 2005b). Crop Coefficients (Kc) are crop specific evapotranspiration values generated by research used with reference evapotranspiration data to estimate the crop's evapotranspiration requirement. Main crops in the irrigation schemes in Gediz basin are cotton and grapes. Irrigation schemes have different cropping pattern depending on their location in the basin. Within an irrigation scheme the cropping pattern also changes per year for example triggered by market prices. In general cotton is mainly cultivated in the delta and towards the mountains the area of grape orchards is increasing. Other crops growing in the irrigation schemes are summer wheat and vegetables. Non-irrigated crops are cultivated in the catchment areas in the mountains; crops include wheat, barley, fruits and vegetables. Cropping patterns as incorporated in WEAP are shown in Table 5 (based on FAO, Allen et al., 1998, Van der Gulik and Nyvall, 2001).

Table 5: Crop coefficients for Gediz basin.

	crop coefficient per month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Cotton	0	0	0	0	0.35	0.78	1.20	1.20	1.20	1.20	0.60	0
Grapes (raisins)	0	0	0.15	0.80	0.80	0.80	0.80	0.80	0.80	0.40	0	0
Other	1	1	1	1	1	1	1	1	1	1	1	1
Non-irrigated crops	0	0	0	0	0.5	1	1	1	0.5	0	0	0

Climate

The Gediz Basin is part of the Aegean region and the Mediterranean rainfall regimes. It has hot dry summers and cool winters. The average annual rainfall amount is some 500 mm, but extremes of 300 mm and 850 mm also occur. Precipitation is concentrated in the winter period. Precipitation in the basin ranges from over 1 000 mm per year in the mountains to 500 mm per year near the Aegean coast. In the mountains the precipitation mainly falls in the form of snow (Mathijssen, 2007).

Three precipitation zones have been distinguished in WEAP, the delta, the main valley and the mountains. The data for precipitation and evapotranspiration is obtained from the measurement stations that are located in Gediz basin (Figure 8). The data is shown in appendix A1. Measured data was available from 1990 to

1996. The data for 1997 to 2005 is the exact copy of the year 1996. 1996 Can be considered as normal year regarding the amount of rainfall and therefore is suitable to represent rainfall in other years.

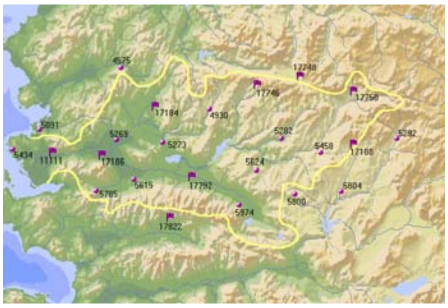


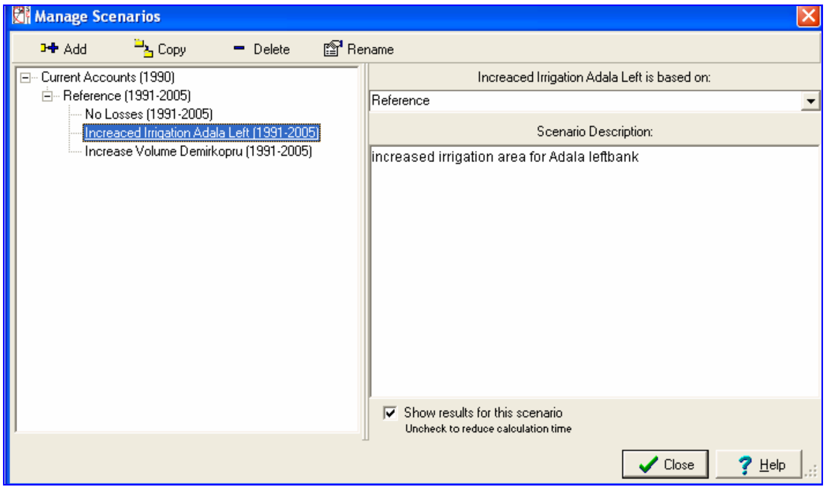
Figure 8: Location and name of the meteorological stations in Gediz basin

3.3 Reference scenario

The WEAP model as described in the previous section can be considered as the Reference scenario. The Reference scenario is the scenario in which the current situation (1990) is extended to the future (1991-2005). No major changes are imposed in this scenario. Only the cropping pattern slightly changes over the years. The cropping patterns of all years (1990-2005) are in appendix A2. Furthermore the meteorological data (both precipitation and evapotranspiration) is different in all years, as presented in Appendix A1. Cropping pattern and meteorological data are both based on field measurements in Gediz basin.

3.4 Other scenarios

Besides the Reference scenario three other scenarios are analyzed. These scenarios represent management changes that are considered for the future.
Including scenarios in WEAP is straightforward and follows a logical tree framework. Figure 9 shows the three scenarios of the Gediz case study, which are all based on the Reference situation.



- Current Accounts (1990)
  - Reference (1991-2005)
    - No Losses (1991-2005)
    - Increaced Irrigation Adala Left (1991-2005)
    - Increase Volume Demirkopru (1991-2005)

Increaced Irrigation Adala Left is based on: Reference

Scenario Description: increased irrigation area for Adala leftbank

☑ Show results for this scenario
Uncheck to reduce calculation time

Figure 9: Manage Scenarios screen in WEAP.

3.4.1 Scenario: No losses

An efficient use of the water within the irrigation system is important in a water scarce environment. Problems with maintenance and high evaporation standards are responsible for high losses within the irrigation canals. In the Reference scenario 10% water loss in the irrigation canals was taken into account, which is a rough estimate from experts (personal communication with H. Gundogdu). The losses in the transmission links are changed from 10% in the Reference scenario to 0% in the No losses scenario.

3.4.2 Scenario: Increased irrigation area

Development of a new irrigation scheme increases the water demand in Gediz basin. This option is mainly attractive because of its economic potential. Plans are made to construct a new large irrigation scheme near Adala Left Bank. The expectation is that in normal and wet years enough water is left for other irrigation schemes. For this scenario it is mainly important to look at the consequences if another sequence of dry years will occur. In WEAP the new irrigation system is simulated by enlarging the Adala Left irrigation scheme because the new scheme would be located near Adala Left bank. Adala Left Bank is enlarged from 9 000 hectares to 12 000 hectares.

3.4.3 Scenario: Decreased volume Demirköprü

Due to siltation the volume of Demirköprü reservoir might decrease in future situation. Furthermore this scenario is expected to show the importance of the Demirköprü reservoir contributing to the demand coverage for the irrigation systems during summer period. In the Decreased volume scenario the volume of Demirköprü has been decreased by decreasing the conservation zone volume and by increasing the volume of the inactive zone and the buffer zone. The top of the inactive zone has been changed from 200 Million Cubic Meters (MCM) to 500 MCM. The top of the buffer zone is set at 700 MCM. Therefore the conservation volume of Demirköprü is decreased from 522 MCM to 322 MCM in the Decreased volume Demirköprü scenario.

4 Results

One of the strong components of WEAP is the way results can be presented and combined in graphs, tables or maps. Many options exist to aggregate data in time, space or per hydrological component. Moreover different scenarios can be compared easily. Additionally, data can be exported to Excel for further analysis. The most important features to display output will be presented in this chapter. Focus will be on results for the Reference scenario the comparison with the other scenarios.

4.1 Reference Scenario

The Reference scenario (1990 to 2005) contains the same data and structure as the Current accounts year (1990). Only the cropping pattern and the meteorological data are different for all the years. Results for the Reference scenario are presented on: (i) availability of water, (ii) demand and demand coverage, and (iii) streamflow. Focus in this chapter will be on the options WEAP offers to present results.

4.1.1 Water availability

The first output to focus on is the amount of water available for further use. As explained before, WEAP deals with water allocation and not so much with high detail hydrological processes. In earlier versions of WEAP water supply could be included only as a fixed amount flowing into the study area as so-called headflows. However, the WEAP version used for this study has a new node component called Catchments, which considers simplified rainfall-runoff processes.

Processes in Catchment nodes include precipitation as input, and losses by evapotranspiration that are based on the potential evaporation the crop coefficients of the vegetation and the water availability. The difference between precipitation and actual evapotranspiration is than the available water that can be used downstream.

As an example of WEAP's capability to present results at different levels of detail and aggregation, the following figures are presented for the Catchments.

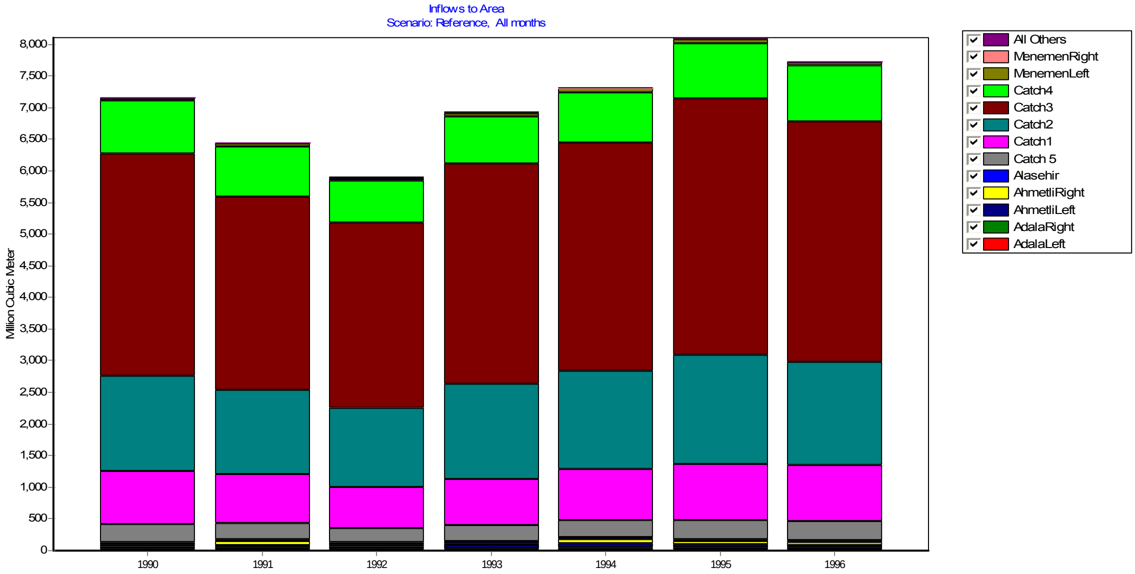


Figure 10: Inflow to the catchments (yearly total).

Figure 10 shows the water entering the system in the years 1990-1996. For the Gediz basin the water entering the system is limited to the precipitation in the catchment areas. But other possible river inflows in WEAP are river headflows, surface water inflows to reaches, groundwater discharge, local reservoir inflows and local supply inflows. Figure 10 shows that the water availability roughly fluctuates between 5000 MCM for a dry year and 8000 MCM for a wet year. The results for the years 1997-2005 are the same as for 1996 because precipitation and evapotranspiration data were copied from 1996. The results after 1996 show no fluctuation and are therefore not presented in the graph. Furthermore Figure 10 shows that catchment 3 has the largest contribution to the water inflow in the system. This is due to its large surface area because the precipitation data is the same for the catchments.

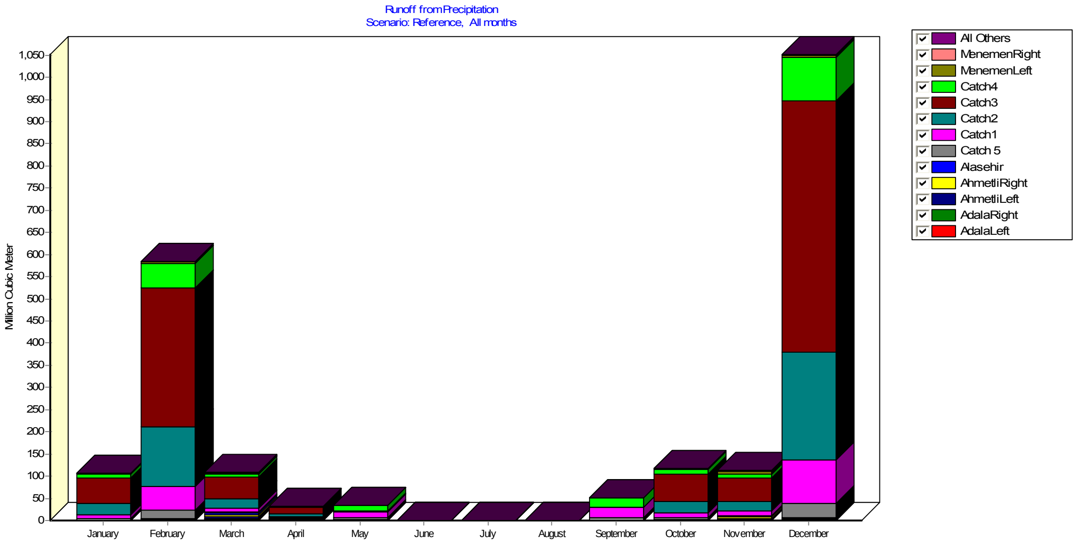


Figure 11: Runoff from catchment sites (monthly average 1990-2005).

Because of evapotranspiration not all water in the catchments will runoff to the rivers. WEAP uses the rainfall runoff method (FAO) to calculate the ratio between demand of the crops and the runoff to the river. The Rainfall Runoff Method uses crop coefficients to calculate the potential evapotranspiration in the catchment, then determines any irrigation demand that may be required to fulfill that portion of the evapotranspiration requirement that rainfall cannot meet. The remainder of rainfall not consumed by evapotranspiration is simulated as runoff to a river, or can be proportioned among runoff to a river and flow to groundwater via catchment links (SEI, 2005a).

Figure 11 shows the monthly variation of the runoff from the catchments. In the irrigation schemes the runoff is very low, in the supply catchments upstream this runoff is very high. The graph indicates that runoff is mainly generated in winter. The runoff in December is not as high as calculated by WEAP. The precipitation actually falls in the form of snow (which is not included in WEAP). The precipitation in December is actually gradually released in spring. These processes are not part of the Rainfall Runoff Method in WEAP. June, July and August are critical months when the water supply is dependent on the reservoirs because runoff from the catchments into the river is zero.

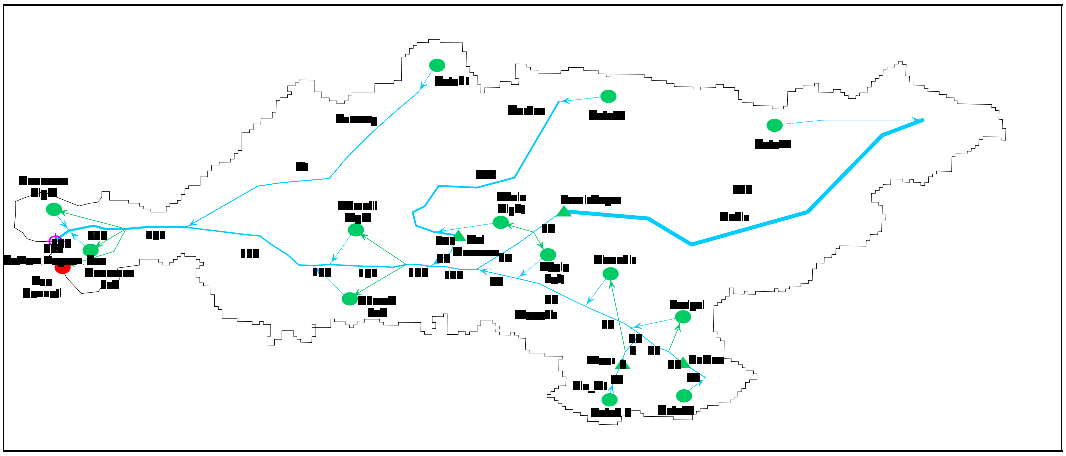


Figure 12: Map of the streamflow in December (average 1990-2005, streamflow in MCM).

WEAP offers the opportunity to visualize streamflow and other results in a map as shown in Figure 12. This map shows the amount of streamflow represented by the width of the river reach. These kinds of figures are essential in terms of communication with stakeholders such as water managers and policy makers.

4.1.2 Demand and demand coverage

The main focus of WEAP is supply management of demand sites. In this paragraph, the results of the reference years (1990 to 2005) regarding the demand, supply and coverage of the demand sites are displayed and analyzed.

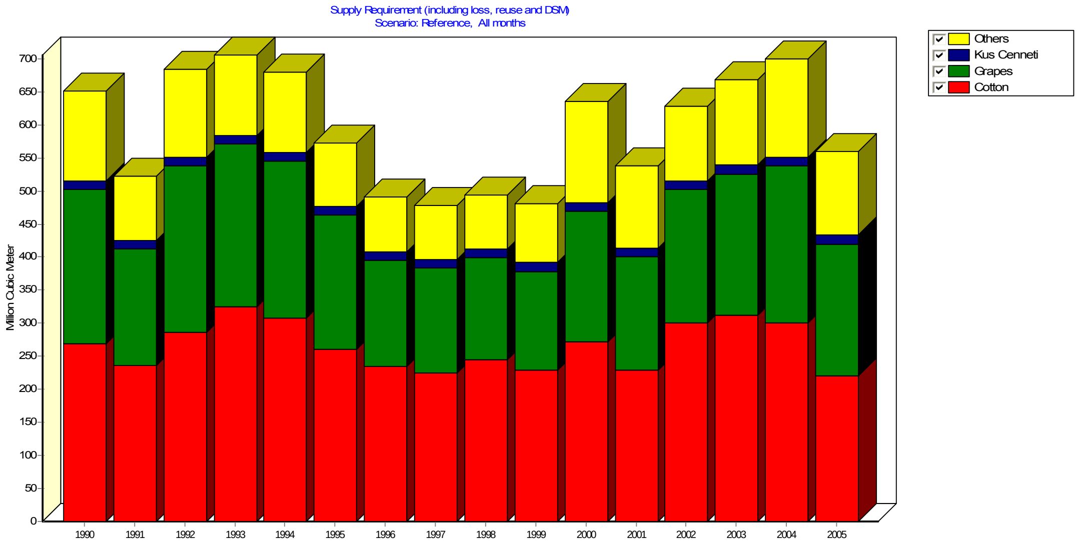


Figure 13: Total yearly demand for irrigation schemes and demand sites, stacked by land use.

The actual demand for the various irrigation schemes and demand sites is the sum of the crop demand, diversion losses and reuse. Results can be grouped by catchment or by land use. In agricultural systems it is useful to evaluate the water demand of the different crops. Figure 13 shows the demand grouped by land use. It can be read from the graph that cotton has the largest water demand in Gediz basin.

WEAP offers the opportunity to present the unmet demand (water shortage) in a graphical way that is very powerful to understand the system. WEAP is able to show seasonality as well as variation between years. Figure 14 shows the unmet demand at the different irrigation systems. In a dry year like 1992 Alasehir, Ahmetli and Menemen irrigation systems are very vulnerable to drought. Figure 15 shows that the unmet demands mainly occur from July to November.

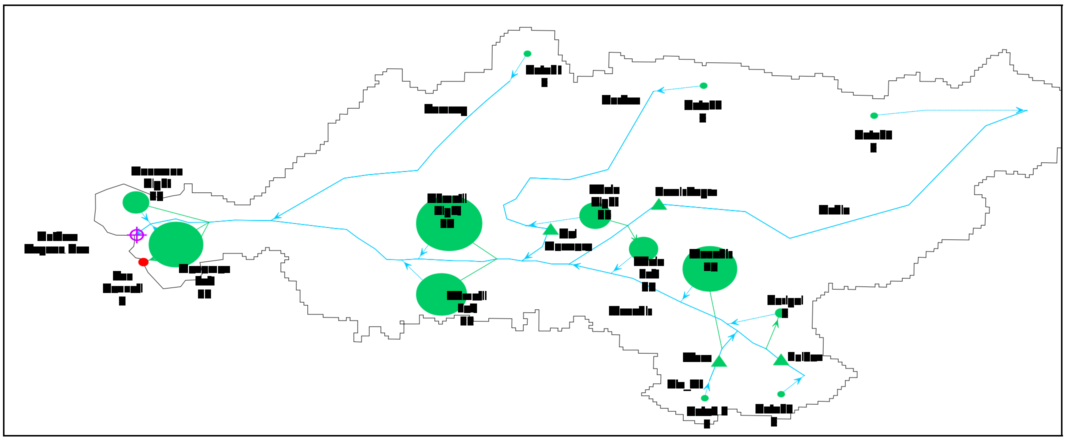


Figure 14: Unmet demands in the irrigations systems for the year 1992 (in MCM).

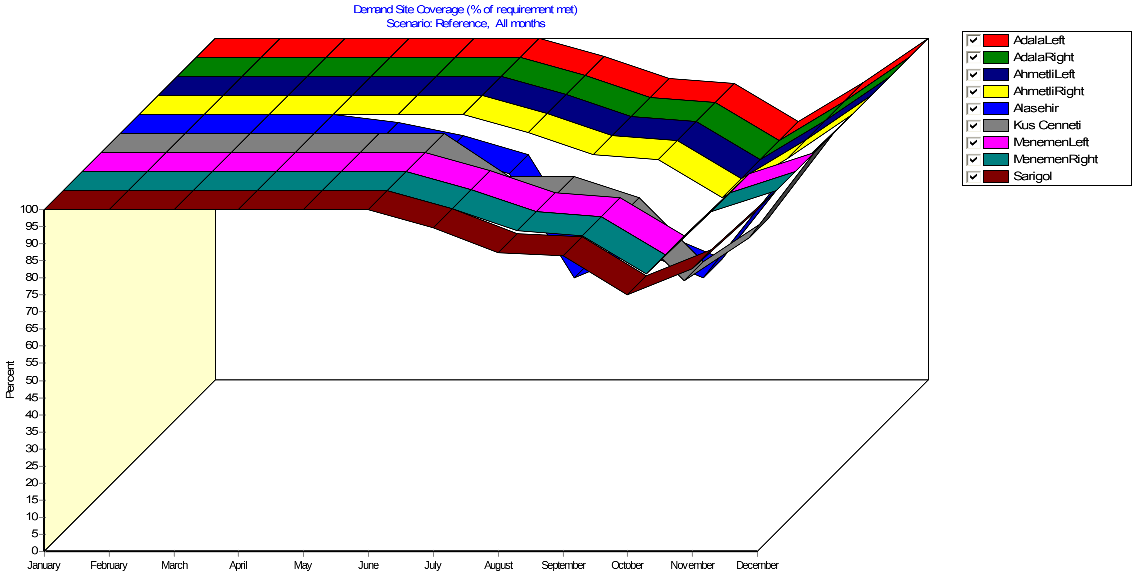


Figure 15: Demand site coverage: percentage of requirement met (monthly average 1990-2005).

4.1.3 Reservoirs

Figure 16 shows the inflows and outflows of the main reservoir in Gediz basin. The graph is a balance between inflow and outflow. This graph is very useful to understand the operation of the reservoir during the year. The outflow from the reservoir occurs in the summer period, when there is no rainfall. The outflow results in decreases of the storage volume in the reservoir. From October onwards the rainfall is exceeding the demand again and the reservoir will be filled with water. In December there is a lot of rainfall and this is mainly used to increase the storage of Demirköprü. By the end of December the top of the storage is nearly reached. That is why in January and February the inflow from precipitation is mainly used for outflow to downstream and not for increase in storage of Demirköprü.

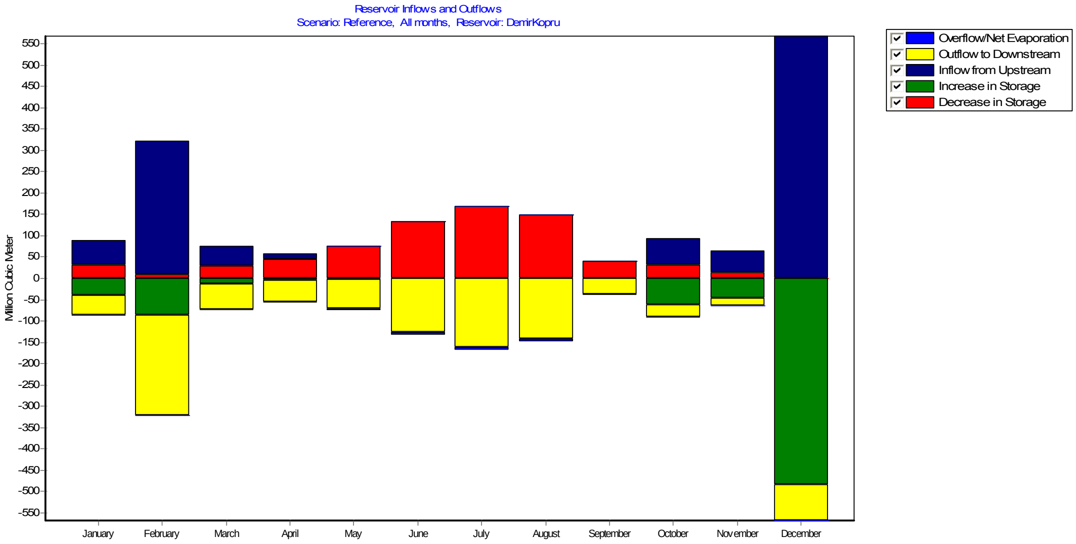


Figure 16: Demirköprü inflows and outflows per month (average 1990-2005)

4.2 Scenario: No losses

The No losses scenario is assuming a better maintenance of the irrigation canals then in the Reference scenario. The irrigation canals in WEAP are represented by transmission links. The losses in the irrigation canals are lowered form 10% in the Reference scenario to 0% in the No losses scenario. If losses are lower this will lower the supply requirement and therefore the unmet demand will be lower. Figure 17 shows the total water flow through all transmission links for the Reference scenario and the No losses scenario. Figure 18 shows the difference in unmet demand which obviously shows a difference of 10% in water shortage for every year. In 2002 the Reference scenario does show an unmet demand while the No losses scenario does not. Therefore these graphs can be strong in showing the importance of losses reduction.

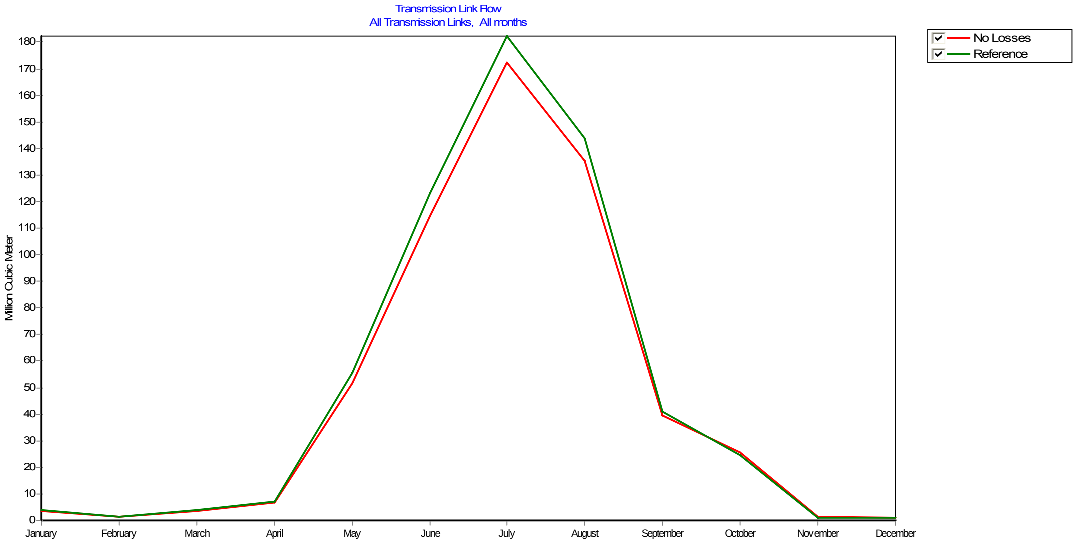


Figure 17: Water flow through all transmission links (average 1990-2005).

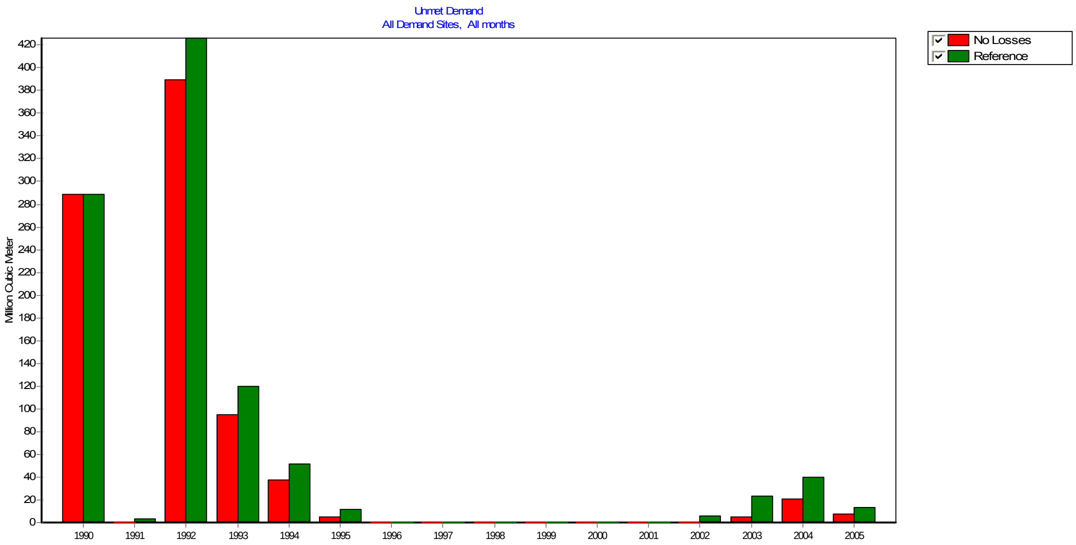


Figure 18: Total MCM water shortage per year in Gediz Basin.

4.3 Scenario: Decreased volume Demirköprü

In the Reference scenario the maximum storage volume of Demirköprü is 1022 MCM and the inactive storage volume is 200 MCM. The scenario Decreased volume Demirköprü assumes that the storage volume is decreasing because of siltation. Therefore, in the scenario Decreased volume Demirköprü the inactive storage volume is 500 MCM.

Differences in storage volume give good insight in the performance of the reservoir. Mainly seasonal performance is important. In dry periods the storage volume lowers and in wet period the storage volume increases (Figure 19). However, for the scenario Decreased volume Demirköprü the storage volume stays higher in the summer period.

The effect of storage volume on the demand coverage for Menemen Right Bank is shown in Figure 20. Menemen Right Bank is situated downstream of Demirköprü reservoir. This example shows that in the dry months the demand coverage for Menemen Right Bank is lowering from around 85% coverage in the Reference scenario to around 60% coverage in the scenario Decreased volume Demirköprü. The results for the other irrigation systems show the same pattern because all irrigation schemes have the same priority for water supply and the same peaks in water demand.

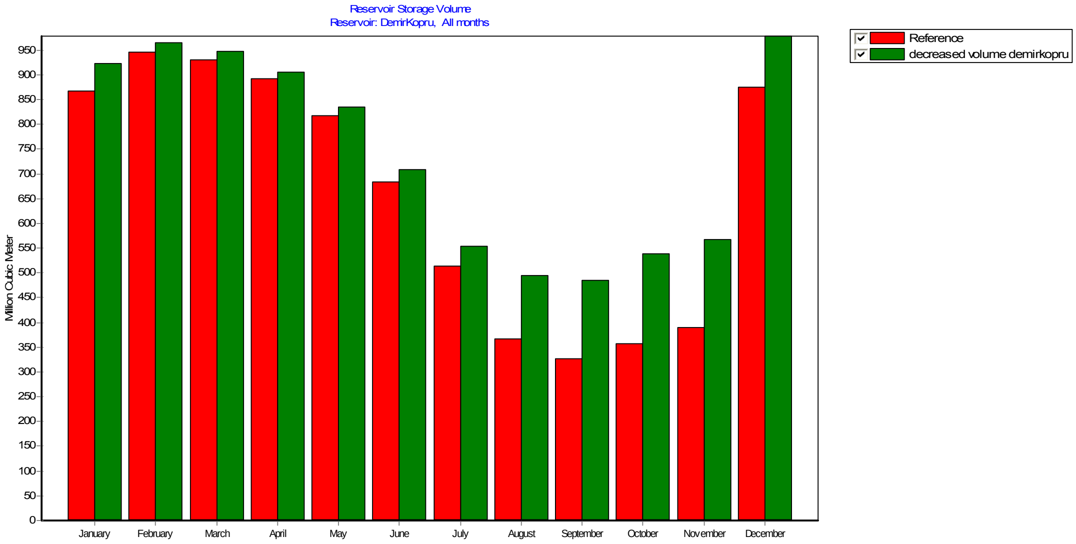


Figure 19: Reservoir storage volume per month (average 1990-2005)

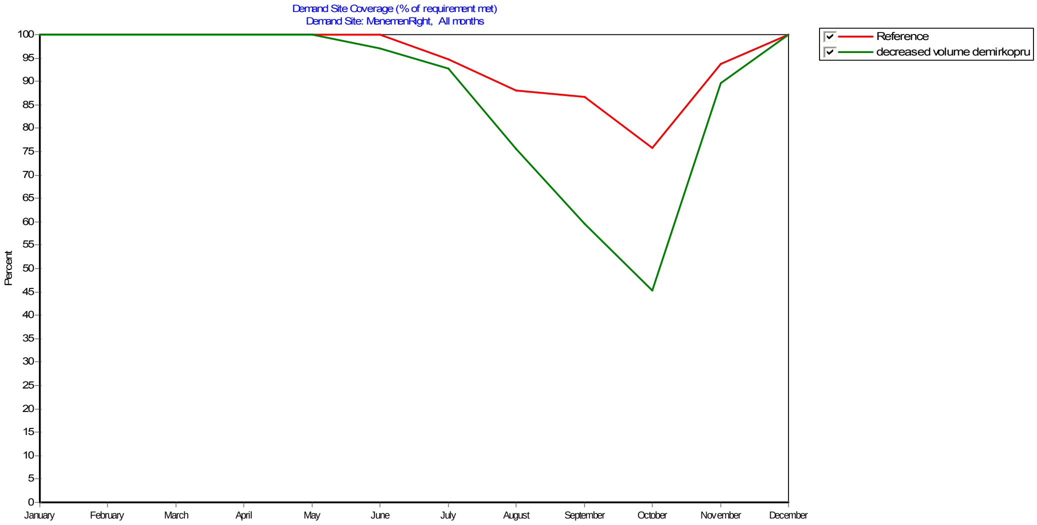


Figure 20: Demand site coverage (%) for Menemen Right Bank

Differences in reservoir volume also influence the streamflow in Gediz river. Figure 21 shows the streamflow below the intake point for Menemen Right and Left Bank irrigation schemes. Consequence of a smaller reservoir is that in wet years more runoff is directly discharge into the Aegean See and less water is available in the next dry season. In a dry year more water is extracted from the reservoir, so the next year more water is needed to refill the reservoir and therefore the streamflow is lower. As a consequence one can observe that in the scenario Decreased volume Demirköprü peaks are more pronounced while at the same time low flow periods are more extensive.

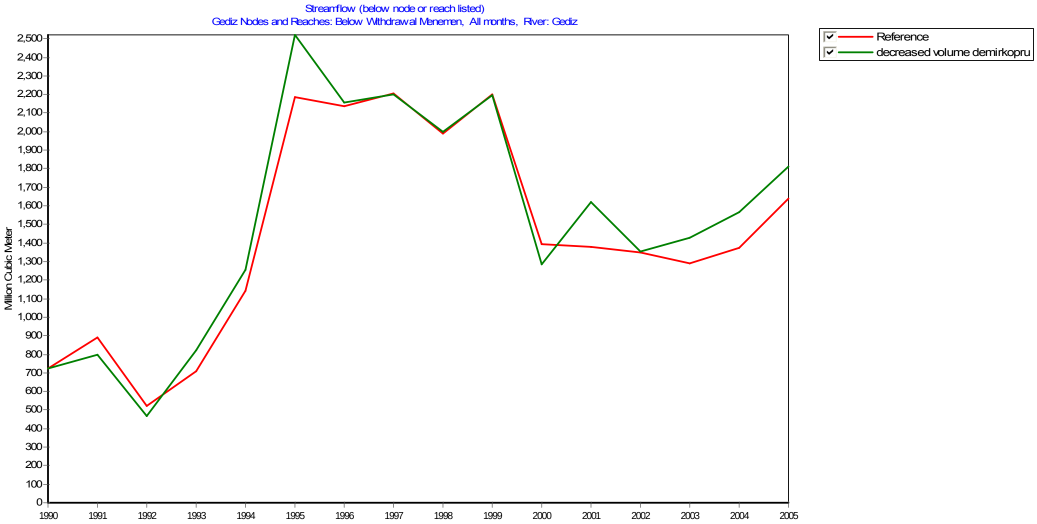


Figure 21: Streamflow in Gediz river below Menemen intake

4.4 Scenario: Increased irrigation area

Increasing the irrigation area in Adala Left bank has consequences for the whole basin. Figure 22 shows the total demand in the basin. The demand of the new irrigated area adds up to the total demand of the Reference scenario. The growing season clearly has increased demand, in the winter season the difference is little.

Besides comparing the scenario Increased irrigation area with the Reference scenario it is also interesting to compare this scenario with the No losses scenario. Figure 23 shows that the demand coverage is lower with and extra irrigation system and the demand coverage is higher in the No losses scenario. The blue line shows the demand coverage when you combine these two scenarios. Figure 23 shows that the combination of the No losses scenario and the Increased irrigation area scenario has a higher demand coverage than the Reference scenario which implies that more irrigation area is possible with a more efficient irrigation system.

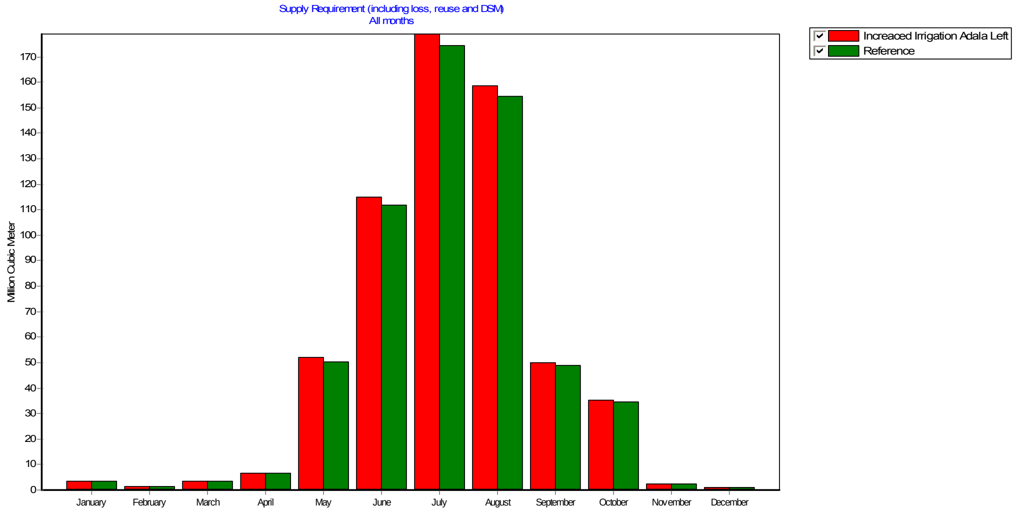


Figure 22: Total demand in Gediz basin per month (average 1990-2005).

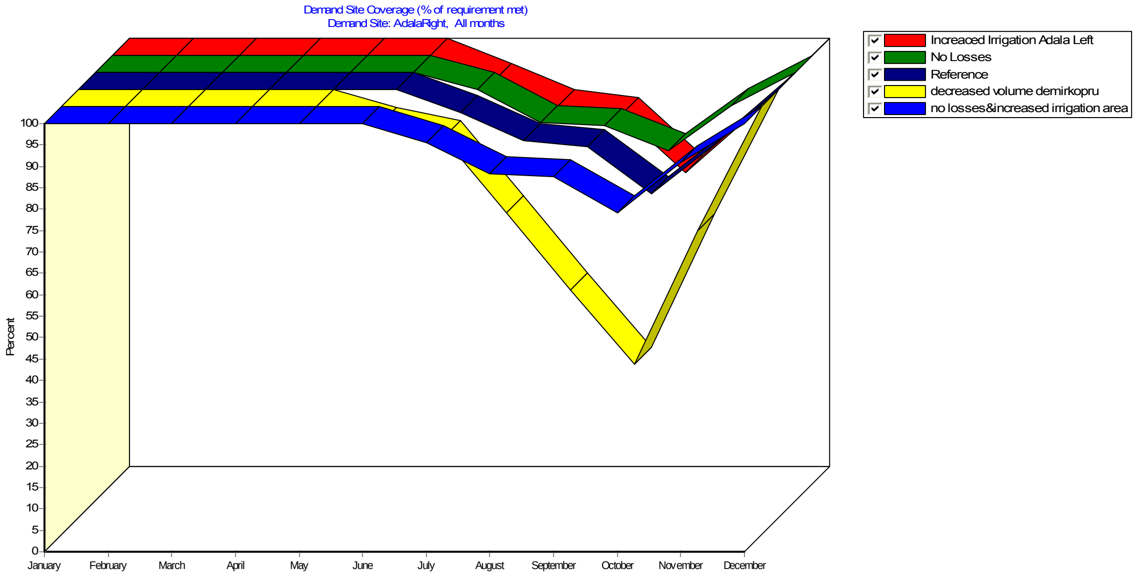


Figure 23: Demand coverage Adala Left Bank.

A difference in water demand upstream influences the water availability and streamflow downstream, for example for Kuş Cenneti. Figure 24 shows the demand coverage for Kuş Cenneti bird paradise for all scenarios. Kuş Cenneti has supply priority 2, which is a lower priority than all other demand sites. Therefore, Kuş Cenneti is the first demand site that will be affected if there is water shortage in Gediz basin. Figure 24 shows that water shortage for Kuş Cenneti is highest in the scenario Decreased volume Demirköprü and lowest in the No losses scenario.

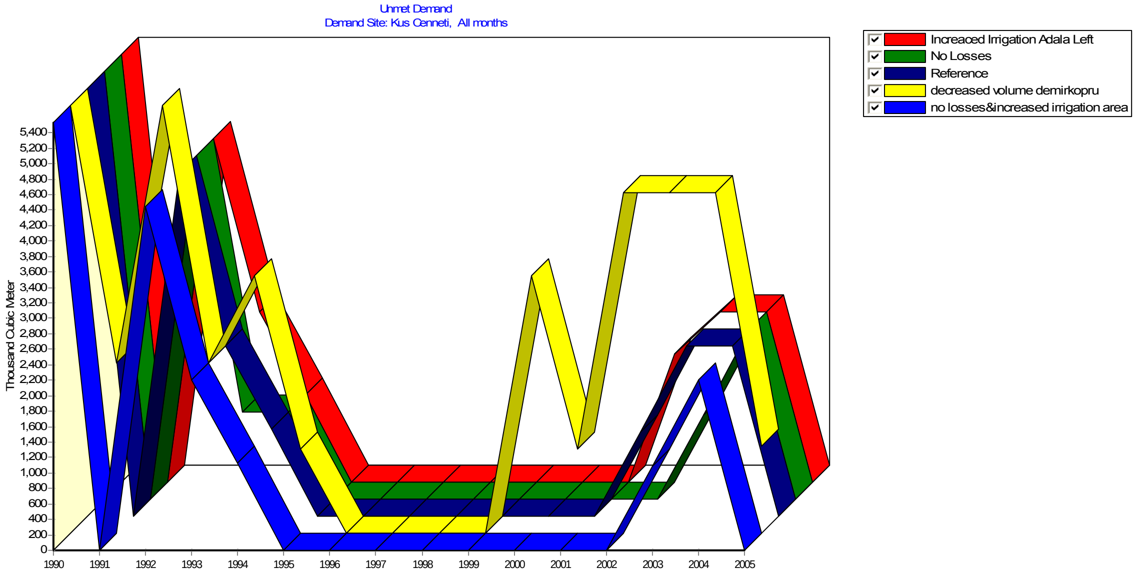


Figure 24: Yearly water shortage for Kuş Cenneti.

5 Conclusion and Recommendations

The overall objective of the project was to show the strength and weaknesses of the WEAP model in a setting with a Mediterranean climate and intensive irrigated agriculture. WEAP was setup in a relatively short time frame and was mainly based on information in the public domain and reports from earlier studies.

Chapter 4 presented the results of the WEAP model revealing some of the strong points WEAP offers to be used to support water managers. First of al is WEAP able to evaluate all aspects of the water system including water demand, water supply, streamflow, runoff and rainfall. Second, WEAP presents results of the analysis on many spatial and temporal levels: results can be shown for yearly means, monthly means, one year or one demand site. Furthermore WEAP is able to show results in many formats such as graphs, maps, and tables.

Another strong point resulting from the Gediz case study is the spatial scale of the model and the similarity between model results and the information needed by the decision makers. WEAP evaluates water resources topics on a relatively large spatial scale. Such a large spatial scale is an advantage for basin scaled planning because it clearly gives an overview of the effects for the whole basin, which is needed in a basin with spatial water delivery problems. Scale of the model and scale of the drought related management options suit each other very well in the Gediz case study. Scenarios are relevant and many policy scenarios can be modeled in this case study.

Figure 11 showed that the Rainfall Runoff method as included in WEAP does not take into account the all the complex processes in generating runoff from rainfall such as: snow-melt, groundwater vs. surface water runoff, channel flow etc. It is therefore that a more physical based model like SWAT should be included if rainfall-runoff processes are critical aspects of future projects.

This first version of Gediz basin was based on the so-called Water Year Method. To evaluate impact of climate change this method is less suitable and it is advisable to include the ReadFromFile function if climate change scenarios have to be evaluated.

The Gediz case study showed the importance of working together with the decision makers. Flexibility in adding scenarios and changing input data is a great advantage of the WEAP model. The Read From File function and the possibility to add Key Assumptions are of great help in supporting the flexibility of WEAP. Decision makers can influence the input in the model directly and these changes can be analyzed directly. This has contributed to a great confidence of the decision makers in the WEAP model.

WEAP can generate many management scenarios in a short time. This was demonstrated in the Gediz case study with three scenarios: (i) expansion of the irrigation area, (ii) reducing losses in irrigation canals, and (iii) modeling climate change. Furthermore WEAP has the option to incorporate an economic evaluation and a water quality evaluation.

Another advantage of the WEAP model worth mentioning is the ssupport of the model in terms of manuals, training and support of developers, that is excellent.

Overall it can be concluded from this first swift analysis that WEAP is able to support water managers and policy makers in their decision making process but that more refinement of the model is required to be applicable in Gediz basin.

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A Appendix Data

A.1 Precipitation and evapotranspiration in Gediz basin

month-year	Delta (mm)	Main valley (mm)	Mountain (mm)	Evapo-transpiration (mm)
Station	17186	17792	17750	11111
Jan-90	6.3	7.4	9.1	31.9
Feb-90	59	44.9	44.5	43.9
Mar-90	19.9	23.5	24.6	76.2
Apr-90	55	34.1	65.3	73.1
May-90	22.1	8.6	27.8	115.9
Jun-90	12.6	32.8	36.4	144.9
Jul-90	0	0	14	199.4
Aug-90	10.7	12.2	22.9	174.8
Sep-90	19.9	24.6	29.8	75.6
Oct-90	21.1	21.9	29.3	78.5
Nov-90	11.6	14.9	34.7	54
Dec-90	245	159.8	163.5	42.8
Jan-91	39.8	36.7	37.7	33.7
Feb-91	40.7	41	39.4	33.3
Mar-91	25.2	35.3	39.1	53.3
Apr-91	66.8	43.7	55.2	69.4
May-91	124.6	84.9	89.8	86.4
Jun-91	1.7	7.4	7	139.2
Jul-91	22.1	2.1	7.8	160.4
Aug-91	0.1	19.7	31.1	154
Sep-91	1.2	0.1	5.2	69.3
Oct-91	29.3	30.3	28.9	78.1
Nov-91	25.7	23.3	47	45.2
Dec-91	146.7	125.1	50	25.4
Jan-92	0.3	0	0.2	29.8
Feb-92	11.9	9.6	6.7	46.1
Mar-92	79.7	75.5	80.2	58
Apr-92	46.2	18.7	80.8	79
May-92	6.4	7.2	10.9	125.3
Jun-92	11.5	7.9	53.7	154.4
Jul-92	48.6	10	20.3	175.1
Aug-92	0.2	0.8	4.2	155.7
Sep-92	0	0	0	96.6
Oct-92	7.9	32.5	40.3	88.5
Nov-92	109.5	80.7	74.2	53.8
Dec-92	112.3	74.2	45.4	28.4
Jan-93	52.3	52.4	51.1	31.9
Feb-93	130.3	98.2	84.2	37.3
Mar-93	66.6	79.3	60.6	61.7
Apr-93	62.9	36.8	41.6	72.9
May-93	61	33.6	70.4	92.4
Jun-93	1.2	17.3	7.3	153.7

month-year	Delta (mm)	Main valley (mm)	Mountain (mm)	Evapo-transpiration (mm)
Station	17186	17792	17750	11111
Jul-93	0	0	0.2	196.4
Aug-93	0	0	0	178.4
Sep-93	0.2	2	0.3	110.6
Oct-93	4.5	10.6	17.7	94.9
Nov-93	121.8	74.5	78.4	51.2
Dec-93	151.9	56.7	86.2	29.2
Jan-94	73.8	53.7	68.8	30.9
Feb-94	81.4	51.3	57.4	28.6
Mar-94	82.1	86	47	58.7
Apr-94	67.2	20.4	42.5	86.1
May-94	28.5	45.6	52.5	129.4
Jun-94	4.3	52.7	23	176.6
Jul-94	0	0	7.2	208.3
Aug-94	0	1.8	14	194.5
Sep-94	0	24.1	5.8	94.5
Oct-94	53.3	26.3	51.2	68
Nov-94	87.3	96.4	71.1	44.9
Dec-94	115.4	68.2	74.9	25.9
Jan-95	203.4	121.7	92.3	23.3
Feb-95	29.8	17.9	14.2	36.1
Mar-95	180.1	109.4	107.6	56.4
Apr-95	84.1	69.9	68.1	71.4
May-95	40.6	24.6	15.1	114.6
Jun-95	0.3	2	12	148
Jul-95	5.2	3	33.4	197.8
Aug-95	19.3	6.5	10.4	160.2
Sep-95	19.9	22.1	32.5	74.9
Oct-95	5.7	20.9	74.6	0
Nov-95	104.8	61.9	58.2	31.1
Dec-95	82.9	46.2	59.8	29.1
Jan-96	12.6	12.1	20.6	24.3
Feb-96	163.7	105	99	20.2
Mar-96	39.7	43.6	57.5	40.9
Apr-96	89	72.7	55.3	54.5
May-96	27.7	8.7	55.9	94
Jun-96	0.4	10.8	8.1	146.9
Jul-96	0	8.4	5.5	157.6
Aug-96	3.8	1.1	0.7	128.6
Sep-96	39.4	53.5	60.2	61.6
Oct-96	18.3	13.7	22.2	53
Nov-96	63.6	47.4	32.9	34.9
Dec-96	110.5	80.3	125.6	19.3
Copy of 1996				
Jan-97	12.6	12.1	20.6	38.9
Feb-97	163.7	105	99	59.6
Mar-97	39.7	43.6	57.5	40.4
Apr-97	89	72.7	55.3	109.4
May-97	27.7	8.7	55.9	134.5

month-year	Delta (mm)	Main valley (mm)	Mountain (mm)	Evapo-transpiration (mm)
Station	17186	17792	17750	11111
Jun-97	0.4	10.8	8.1	153.6
Jul-97	0	8.4	5.5	122.6
Aug-97	3.8	1.1	0.7	86.8
Sep-97	39.4	53.5	60.2	0
Oct-97	18.3	13.7	22.2	25.3
Nov-97	63.6	47.4	32.9	18
Dec-97	110.5	80.3	125.6	29.1
Jan-98	12.6	12.1	20.6	31.2
Feb-98	163.7	105	99	42.6
Mar-98	39.7	43.6	57.5	69.2
Apr-98	89	72.7	55.3	94
May-98	27.7	8.7	55.9	146.9
Jun-98	0.4	10.8	8.1	157.6
Jul-98	0	8.4	5.5	128.6
Aug-98	3.8	1.1	0.7	61.6
Sep-98	39.4	53.5	60.2	53
Oct-98	18.3	13.7	22.2	34.9
Nov-98	63.6	47.4	32.9	19.3
Dec-98	110.5	80.3	125.6	34.4
Jan-99	12.6	12.1	20.6	38.9
Feb-99	163.7	105	99	59.6
Mar-99	39.7	43.6	57.5	40.4
Apr-99	89	72.7	55.3	109.4
May-99	27.7	8.7	55.9	134.5
Jun-99	0.4	10.8	8.1	153.6
Jul-99	0	8.4	5.5	122.6
Aug-99	3.8	1.1	0.7	86.8
Sep-99	39.4	53.5	60.2	0
Oct-99	18.3	13.7	22.2	25.3
Nov-99	63.6	47.4	32.9	18
Dec-99	110.5	80.3	125.6	-1995
Jan-00	12.6	12.1	20.6	31.9
Feb-00	163.7	105	99	43.9
Mar-00	39.7	43.6	57.5	76.2
Apr-00	89	72.7	55.3	73.1
May-00	27.7	8.7	55.9	115.9
Jun-00	0.4	10.8	8.1	144.9
Jul-00	0	8.4	5.5	199.4
Aug-00	3.8	1.1	0.7	174.8
Sep-00	39.4	53.5	60.2	75.6
Oct-00	18.3	13.7	22.2	78.5
Nov-00	63.6	47.4	32.9	54
Dec-00	110.5	80.3	125.6	42.8
Jan-01	12.6	12.1	20.6	33.7
Feb-01	163.7	105	99	33.3
Mar-01	39.7	43.6	57.5	53.3
Apr-01	89	72.7	55.3	69.4
May-01	27.7	8.7	55.9	86.4

month-year	Delta (mm)	Main valley (mm)	Mountain (mm)	Evapo-transpiration (mm)
Station	17186	17792	17750	11111
Jun-01	0.4	10.8	8.1	139.2
Jul-01	0	8.4	5.5	160.4
Aug-01	3.8	1.1	0.7	154
Sep-01	39.4	53.5	60.2	69.3
Oct-01	18.3	13.7	22.2	78.1
Nov-01	63.6	47.4	32.9	45.2
Dec-01	110.5	80.3	125.6	25.4
Jan-02	12.6	12.1	20.6	29.8
Feb-02	163.7	105	99	46.1
Mar-02	39.7	43.6	57.5	58
Apr-02	89	72.7	55.3	79
May-02	27.7	8.7	55.9	125.3
Jun-02	0.4	10.8	8.1	154.4
Jul-02	0	8.4	5.5	175.1
Aug-02	3.8	1.1	0.7	155.7
Sep-02	39.4	53.5	60.2	96.6
Oct-02	18.3	13.7	22.2	88.5
Nov-02	63.6	47.4	32.9	53.8
Dec-02	110.5	80.3	125.6	28.4
Jan-03	12.6	12.1	20.6	31.9
Feb-03	163.7	105	99	37.3
Mar-03	39.7	43.6	57.5	61.7
Apr-03	89	72.7	55.3	72.9
May-03	27.7	8.7	55.9	92.4
Jun-03	0.4	10.8	8.1	153.7
Jul-03	0	8.4	5.5	196.4
Aug-03	3.8	1.1	0.7	178.4
Sep-03	39.4	53.5	60.2	110.6
Oct-03	18.3	13.7	22.2	94.9
Nov-03	63.6	47.4	32.9	51.2
Dec-03	110.5	80.3	125.6	29.2
Jan-04	12.6	12.1	20.6	30.9
Feb-04	163.7	105	99	28.6
Mar-04	39.7	43.6	57.5	58.7
Apr-04	89	72.7	55.3	86.1
May-04	27.7	8.7	55.9	129.4
Jun-04	0.4	10.8	8.1	176.6
Jul-04	0	8.4	5.5	208.3
Aug-04	3.8	1.1	0.7	194.5
Sep-04	39.4	53.5	60.2	94.5
Oct-04	18.3	13.7	22.2	68
Nov-04	63.6	47.4	32.9	44.9
Dec-04	110.5	80.3	125.6	25.9
Jan-05	12.6	12.1	20.6	23.3
Feb-05	163.7	105	99	36.1
Mar-05	39.7	43.6	57.5	56.4
Apr-05	89	72.7	55.3	71.4
May-05	27.7	8.7	55.9	114.6

month-year	Delta (mm)	Main valley (mm)	Mountain (mm)	Evapo-transpiration (mm)
Station	17186	17792	17750	11111
Jun-05	0.4	10.8	8.1	148
Jul-05	0	8.4	5.5	197.8
Aug-05	3.8	1.1	0.7	160.2
Sep-05	39.4	53.5	60.2	74.9
Oct-05	18.3	13.7	22.2	0
Nov-05	63.6	47.4	32.9	31.1
Dec-05	110.5	80.3	125.6	29.1

A.2 Cropping pattern in the irrigation schemes

Menemen LB cropping pattern coverage (%)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cotton	50.0	52.8	55.5	58.3	61.0	63.8	66.5	69.3	72.0	67.0	58.0	67.0	70.0	66.0	62.0	58.0
Grapes	9.0	8.8	8.5	8.3	8.0	7.8	7.5	7.3	7.0	7.0	8.0	7.0	7.0	7.0	7.0	7.0
Others	41.0	38.5	36.0	33.5	31.0	28.5	26.0	23.5	21.0	26.0	34.0	26.0	23.0	27.0	31.0	35.0
Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Menemen RB cropping pattern coverage (%)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cotton	73.0	72.9	72.8	72.6	72.5	72.4	72.3	72.1	72.0	67.0	58.0	67.0	70.0	66.0	62.0	58.0
Grapes	22.0	20.1	18.3	16.4	14.5	12.6	10.8	8.9	7.0	7.0	8.0	7.0	7.0	7.0	7.0	7.0
Others	5.0	7.0	9.0	11.0	13.0	15.0	17.0	19.0	21.0	26.0	34.0	26.0	23.0	27.0	31.0	35.0
Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Ahmetli LB cropping pattern coverage (%)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cotton	30.0	33.1	36.2	39.3	42.4	45.6	48.7	51.8	54.9	58.0	51.0	41.0	52.0	49.4	46.9	44.6
Grapes	62.0	58.3	54.7	51.0	47.3	43.7	40.0	36.3	32.7	29.0	33.0	33.0	34.0	35.0	36.1	37.2
Others	8.0	8.6	9.1	9.7	10.2	10.8	11.3	11.9	12.4	13.0	16.0	26.0	14.0	15.6	17.0	18.3
Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Ahmetli RB cropping pattern coverage (%)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cotton	30.0	33.1	36.2	39.3	42.4	45.6	48.7	51.8	54.9	58.0	51.0	41.0	52.0	49.4	46.9	44.6
Grapes	62.0	58.3	54.7	51.0	47.3	43.7	40.0	36.3	32.7	29.0	33.0	33.0	34.0	35.0	36.1	37.2
Others	8.0	8.6	9.1	9.7	10.2	10.8	11.3	11.9	12.4	13.0	16.0	26.0	14.0	15.6	17.0	18.3
Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Adala LB cropping pattern coverage (%)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cotton	40.0	39.0	38.0	37.0	36.0	35.0	34.0	33.0	32.0	31.0	23.0	30.0	30.0	28.5	27.1	25.7
Grapes	48.0	48.4	48.9	49.3	49.8	50.2	50.7	51.1	51.6	52.0	52.0	60.0	53.0	54.6	56.2	57.9
Others	12.0	12.6	13.1	13.7	14.2	14.8	15.3	15.9	16.4	17.0	25.0	10.0	17.0	16.9	16.7	16.4
Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Adala RB cropping pattern coverage (%)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cotton	50.0	47.9	45.8	43.7	41.6	39.4	37.3	35.2	33.1	31.0	23.0	30.0	30.0	28.5	27.1	25.7
Grapes	33.0	35.1	37.2	39.3	41.4	43.6	45.7	47.8	49.9	52.0	52.0	60.0	53.0	54.6	56.2	57.9
Others	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	25.0	10.0	17.0	16.9	16.7	16.4
Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Alasehir cropping pattern coverage (%)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cotton	30.0	26.4	22.8	19.1	15.5	11.9	8.3	4.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grapes	50.0	55.4	60.8	66.1	71.5	76.9	82.3	87.6	93.0	93.0	94.0	94.0	94.0	94.0	94.0	94.0
Others	20.0	18.3	16.5	14.8	13.0	11.3	9.5	7.8	6.0	7.0	6.0	6.0	6.0	6.0	6.0	6.0
Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Sarigol cropping pattern coverage (%)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Cotton	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grapes	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	80.0	85.0	80.0	80.0	95.0	95.0	95.0	95.0
Others	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	15.0	20.0	20.0	5.0	5.0	5.0	5.0
Sum	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0