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A study on the role and importance of irrigation management in integrated river basin management

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Abstract The purpose of this paper is to identify the role and the importance of irrigation management in integrated river basin management during arid and semi-arid conditions. The study has been conducted at Büyük Menderes Basin which is located in southwest of Turkey and where different sectors (irrigation, drinking and using, industry, tourism, ecology) related to the use and distribution of water sources compete with each other and also where the water demands for important ecological considerations is evaluated and where the river pollution has reached important magnitudes. Since, approximately 73 % of the water resources of the basin are utilized for irrigation; as a result, irrigation management becomes important for basin management. Irrigation operations have an effect on basin soil resources, water users, and environmental and ecological conditions. Thus, the determination of the role and importance of irrigation management require an integrated and interdisciplinary approach. In the studies conducted in Turkey, usually the environmental reactions have been analyzed in the basin studies and so the other topics related to integrated river basin management have not been taken into account. Therefore, this study also is to address these existing gaps in the literature and practice.

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Introduction

Integrated River Basin Management is not considered as a technical solution. Rather, it is an approach to water resources management that takes into account all of the factors linked to land and water resources, including social and economic activities. Its broad scope not only covers water resources but also environmental management aspects such as pollution control, development planning, and biodiversity conservation. The principles of Integrated Water Resources Management (IWRM) at the river basin level are succinctly described as the desired maximization of the 3 E's: Economics, Equity, and Environment (GWP 2000). Because the three objectives are not always achievable simultaneously, irrigation water management for agriculture involves tradeoffs more often than maximization (Molle 2008). Therefore, sustainable water resource management for irrigation is not only an objective on the farm level but also an overall goal at the regional level, which means in general at the basin scale. Recent approaches for sustainable irrigation water management at the basin scale are using the framework of an integrated water resource management by combining surface, groundwater, and unsaturated flow modeling as tools for the decision-making, the development of decision support systems, e.g., to improve planning and management in large irrigation schemes, the involvement of multiple decision tools to find conflict resolutions, or the integration of multi-discipline aspects into a web-enabled spatial Decision Support System (DSS). In recent years, much work has been conducted on integrated hydrologic-agronomic-economic-environment models in integrated river basin management. Examples include models designed to support improved irrigation efficiency (Cai et al. 2003), tracking hydrologic and institutional constraints (Dai and Labadie 2001), analysis of improved information at the basin scale to support the Water Framework Directive (WFD) (Van Ast and Boot 2003), insights into measures for reducing nitrogen pressure to support both the EU Nitrates Directive and the WFD (Fassio et al. 2005), nutrient management in the Rhine Basin (Van der Veeren and Lorenz 2002), and climate change assessment at the basin and regional scales (Krysanova et al. 2007). Many similar studies have been carried out in the world's various river basins. Some of them are the following: Analysis of the Colorado River Basin, in which the USA examined the economic value of competing water allocation measures throughout the basin (Booker and Young 1994), while a study of the Rio Chama (USA) examined economic values and tradeoffs between recreation and hydropower (Ward and Lynch 1996). An early celebrated analysis was conducted for the Missouri Basin, USA, that examined reservoir operation rules for Corps of Engineer projects (Lund and Ferreira 1996). More recent work for the Po Basin, Italy, conducted an integrated analysis of water regulation in connection with the WFD (Bazzani et al. 2004), while integrated analysis of the Syr Darya River, Central Asia, addressed basin-scale implications of irrigation-induced salinity (Cai et al. 2003). Hanley et al. (2006) estimated the benefits of water quality improvements for the Motray and Brothock catchments in Scotland. In the Murrumbidgee Basin, Australia, Xevi and Khan (2005) studied tradeoffs between environmental and farming uses of water; for the Rio Grande, USA, Ward and Velazquez (2008) described a basin-scale optimization to inform management choices affecting water quantity and quality. Two works have examined basin-scale tradeoffs and choices in Turkey, one for the competition for industrial and irrigation water uses in the Gediz Basin (Harmancioglu et al. 2008), and another for a series of hydroelectric and irrigation reservoirs in the Euphrates Basin in Turkey and Syria (Tilmant et al. 2008). While each of these studies has made considerable advances in basin-scale analysis, none of those studies take into consideration the principles and importance of irrigation scheme management in integrated river basin management. This paper's aim is to address these existing gaps in the literature. Current paper presents the role and the importance of irrigation scheme management in integrated river basin management. It describes the application and principles of irrigation scheme management in integrated management of Büyük Menderes River Basin, Turkey.

Material and methods

Material

The Büyük Menderes River is located in southwestern part of Turkey, in Western Anatolia between 37° 6′–38° 55′ northern latitudes and 27°–30° 36′ eastern longitudes. The territory of the basin, which represents 3.2 % of Turkey's surface area, includes parts of Aydın, Uşak, Denizli, Muğla, Afyon, Isparta, Burdur, and Izmir provinces. Figure 1 shows the basin and its location in Turkey. The Büyük Menderes River rises from springs which are originating at the limestone formations nearby Dinar and it flows 584 km to the West, irrigating 24.873 km^2 of southwest of Turkey before reaching the Aegean Sea at the Büyük Menderes Delta, which is located 115 km south of Izmir. There are many meanders along its course. The main tributaries of the Büyük Menderes River are Çine, Banaz, Çürüksu, and Akçay. Many of the small tributaries are dry during the summer period. The Büyük Menderes River is an important river system that includes wetland areas such as Lake Işıklı, Lake Bafa, and the delta of the Büyük Menderes River. It is also a very significant river basin from a biodiversity point of view. The Büyük Menderes River has its origin in the high mountains in the east of the river basin. These mountains have a height between 1000 and 1500 m. Approximately 80 % of the Büyük Menderes River Basin consists of soils that where formed in situ by weathering of the primary material. 15.5 % of the basin consists of soils that are formed by material which is either carried by river streambeds (alluvium) or with the fragmentation and carriage of geological material (colluvium). 4.5 % of the basin is not composed of soil, rather it consists of bare rock debris or settlement, riverbeds, lakes, etc.

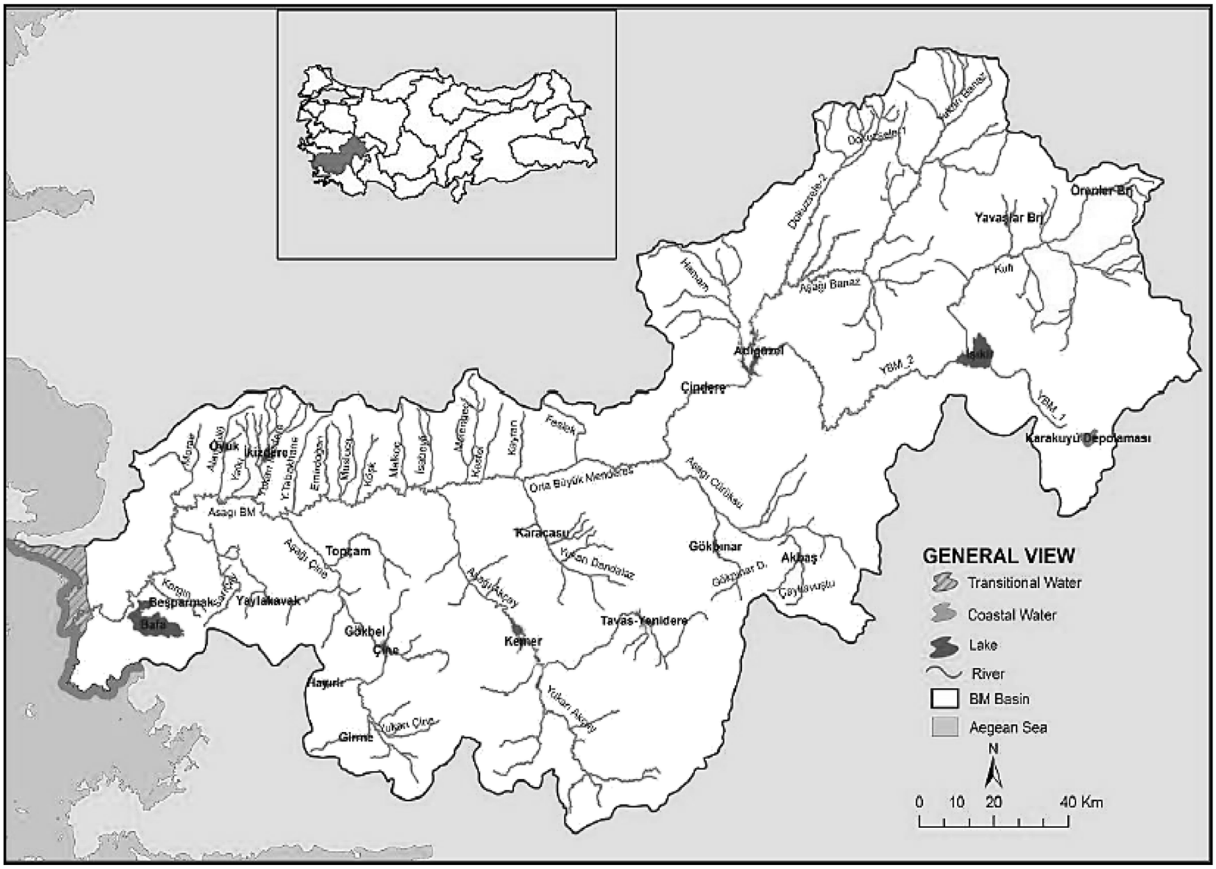


Fig. 1 Büyük Menderes River Basin and its location in Turkey

The coastal region of the basin is considered as Mediterranean climate, whereas at the upside of the basin, continental climate is dominating. At the places where sea effect is significant, it is observed that the weather is warmer than the other regions. The average annual precipitation in basin is 649.9 (263.9–733.1) mm/year. The annual average total evaporation is 2122 mm. In the Büyük Menderes Basin, 44 % of the land is covered by agriculture, 33 % is semi-natural, 20 % is covered by forest, 2 % is covered by urban and rural areas, and 1 % is covered by inland waters. Cotton is the main agricultural crop in the basin. Wheat, corn, barley, sunflowers, and vegetables are also cultivated, as well as olives, figs, chestnuts, and other fruits. The current irrigational water distribution schemes and irrigation areas, under operation, in the basin are shown in Fig. 2.

Methods

In this study, in order to determine the role and importance of irrigation management for integrated basin management, the topics and the subtopics which need to be studied have been provided in Fig. 3. The topics to be studied concerning irrigation management have been determined from field work and observations from the integrated river basin studies and reports from Büyük Menderes basin and other basins. Furthermore, talks with governmental organizations and irrigation organizations and the views of experts in the field have been utilized as well. In the studied irrigation networks, for determining the usage of water and efficient utilization of the area, the parameters for irrigation ratio, irrigation area sustainability ratio, and project irrigation efficiency have been utilized (Koç 2001a, b). Irrigation ratio is defined as the ratio of real irrigated area to project irrigation area for the year which is being studied; the irrigation area sustainability ratio is defined as the ratio of present net project irrigation area to the net project area at the beginning; the project irrigation efficiency is defined as the ratio of the net irrigation amount needed by crops in irrigation networks to the total water used in irrigation. The irrigation ratio shows whether the project

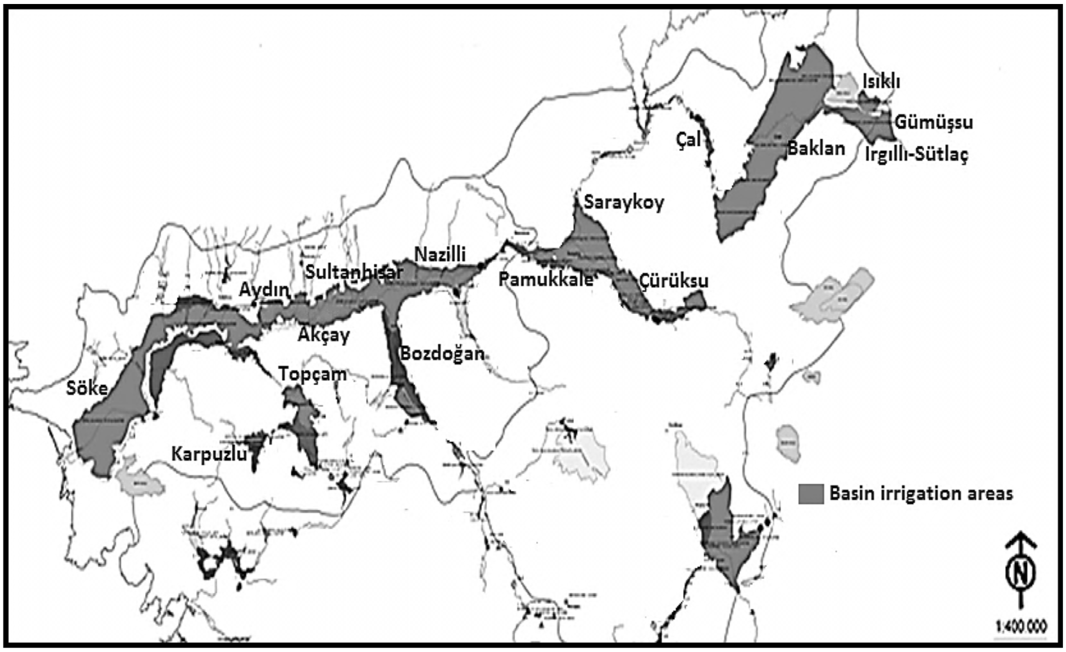


Fig. 2 Basin irrigation schemes

area is used for farming purpose or not; the irrigation area sustainability ratio symbolizes the physical changes of areas reserved for water farming in the basin and the irrigation area; while the project irrigation efficiency describes whether the water is used effectively in basin irrigation networks. The Water Framework Directive (WFD) of the European Union (EU) establishes a framework for community action in the field of water policy. It is one of the most substantial pieces of water legislation produced by the European Commission. The WFD is the major driving force for achieving good water status in the river basins of the EU Member States. Turkey has applied for membership in the European Union. If that application is approved, Turkey will need to conform to EU legislation in sectors such as agriculture, energy, economy, environment, and transportation. Conforming to, applying, and implementing measures required by the EU WFD will be essential.

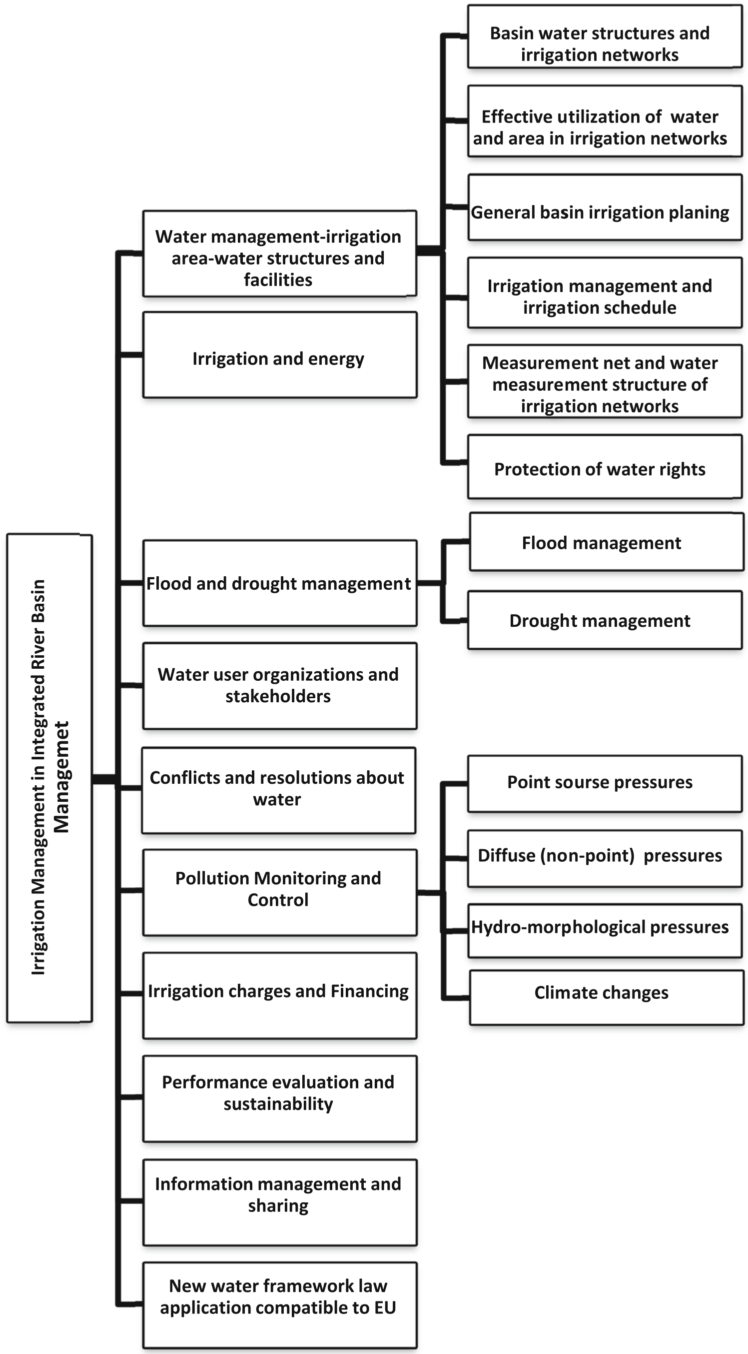
Results and discussion

Water management-irrigation area-water structures and facilities

Basin water structures and irrigation networks; In the Büyük Menderes basin, there are 18 water storage structures (dams) which are present and the total water storage capacity of these dams is 2.650 × 106 m^3/year. Eighty-two percent of the surface water resources are stored in these dams. Basin dams are operated for irrigation, energy, domestic uses, drinking, and flooding purposes, as dependent on the location of the construction and as per their purpose. The total net project irrigation area of the 16 irrigation networks totals as 169,096 ha, and in 2013, 159,846 ha of this area has been irrigated. The name of the irrigation networks; the net project irrigation areas; the actually irrigated areas, water sources, water distribution structures, and network types; and the operating organizations are given in Table 1.

Effective utilization of water and area in irrigation networks; In order to evaluate the effective use of water and the area of the examined basin irrigation networks, the irrigation ratio, irrigation area sustainability ratio, and project irrigation efficiency parameters have been utilized. The basin irrigation network *irrigation ratios* change between 37 and 146 %. The basin irrigation networks irrigation ratios change in a very wide and different interval. DSİ (2011) has reported that for the irrigation networks between the years of 1979 and 2010, the average irrigation ratio has changed between 32

Fig. 3 Irrigation management in integrated river basin management



and 117 %. The irrigation ratios that are obtained from the basin's irrigation networks show similarity with other irrigation networks in the country. In the basins, where the irrigation areas have a greater portion of cotton, vegetables, and citrus, it is observed that the irrigation ratios usually have higher values. The reaching to a level anticipated of irrigation ratio in the basin irrigation allows the efficient use of irrigation area allocated to agricultural use. Therefore, for achieving the desired level in the realization of irrigation ratio in irrigation projects, basin is an important component of integrated river

Table 1 Property of irrigation networks in Büyük Menderes Basin

Name of irrigation networks	Year of operation	Net project irrigation area (ha)	Actually irrigated area (ha)	Water source	Water intake structure	Type of water supply	Network type	Organization of water management
Aydın Irrigation	1991	18500	23292	Kemer Dam	Regulator	G + P	Canal + Flume	Irrigation Assoc.
Söke Irrigation	1981	26000	25841	Kemer Dam	Regulator	G	Canal	Irrigation Assoc.
Sarayköy Irrigation	1961	8245	12086	Adıgüzel Dam	Regulator	G	Canal + Flume	Irrigation Assoc
Pamukkale Irrigation	1946	8593	4226	Adıgüzel Dam	Pump	P	Canal + Flume	Irrigation Assoc
Nazilli Irrigation	1948	15000	16881	Adıgüzel Dam	Regulator	G	Canal + Flume	Irrigation Assoc
Sultanhisar Irrigation	1998	4740	3482	Adıgüzel Dam	Regulator	G	Pipe	Irrigation Assoc
Akçay Irrigation	1965	14900	14132	Kemer Dam	Regulator	G	Canal + Flume	Irrigation Assoc
Karpuzlu Irrigation	1985	2750	1308	Karpuzlu Dam	Sluice outlet	G	Pipe	Irrigation Assoc
Topçam Irrigation	1985	4300	1804	Topçam Dam	Sluice outlet	G + P	Flume	Irrigation Assoc
Çürüksu Irrigation	1986	9212	9003	Gökpınar Dam	Regulator	G	Flume	Irrigation Assoc
Işıklı Irrigation	1965	1650	1275	Işıklı Lake	Regulator	G	Canal	Irrigation Assoc
Gümüşsu Irrigation	1992	1600	1350	Işıklı Lake	Pump	P	Canal	Irrigation Assoc
Irgıllı Irrigation	1964	3920	1489	Işıklı Lake	Regulator	G	Canal	Irrigation Assoc
Sütlaç Irrigation	1996	2820	1279	Işıklı Lake	Regulator	G + P	Canal	Irrigation Assoc
Çal Irrigation	1996	1730	690	Işıklı Lake	Regulator	G	Canal + Flume	Irrigation Assoc
Baklan Irrigation	1991	45,136	35,190	Işıklı Lake	Pump	G + P	Flume + Pipe	Irrigation Assoc

basin management in terms of the effective use of land resources. The low rate of irrigation ratios causes investments in irrigation services for the country and basin to remain idle. In a study by Koç (2011b), it is reported that for the 27 irrigation networks, which are constructed by DSI in the Büyük Menderes and West Mediterranean basins, the average irrigation ratio changes between 15 and 97 %. Furthermore, while 76,282 ha of irrigation network is constructed in the basins, due to the fact that irrigation did not take place due to a variety of factors, an investment total of US$574,316,471.7 has remained idle.

Irrigation area sustainability ratios; Irrigation area sustainability ratios in basin irrigation networks achieve a value of 1.0. This situation shows that there is no decrease in the areas which are open to irrigation in the beginning. However, in order to not experience problems with irrigation area sustainability ratios in the future, it is essential to make sure that the necessary maintenance and repair work of irrigation networks be periodically carried out. In addition, it is essential to prevent field loss due to drainage and salinity problems, as well as to prevent wrong field usage caused by habitation and industry, along with elimination of the lack of facilities. The *project irrigation efficiency* for basin irrigation networks changes between 28 and 70 %. Plusquellec et al. (1990) has stated in their study that in large-scale gravitational irrigation, networks in Asia, Africa, and Latin America change between 26 and 70 %, but mostly the values are closer to 40 %, while the project irrigation efficiency is 20 % in Yemen, 28 % in Thailand, and 26 % in Mexico; in countries such as Cyprus and Israel, it can be 50 % or above, since sprinkler and trickle irrigation technologies are used. For the developing countries, the average total project irrigation efficiency is 30 %. In the USA, it changes between 30 and 80 % and the national average is 41 % (Anonymous 2002).

In his study, Koç (2005) has identified that for the four irrigation networks in Büyük Menderes Basin, the project irrigation efficiency has been found to be 40.5 to 58 %. DSİ (2013) has reported that in the country, the average project efficiency is 44.2 %. The basin irrigation networks which have been studied show compatibility with the values found in our country as well as in other countries. While the irrigation water conveyance efficiencies are high in the studied basin irrigation networks, due to the fact that field irrigation water application efficiencies are low, the project irrigation efficiency value decreases. In the study by Koç (2001b, 2001a, 2003), in order to determine the physical performance for operation-maintenance and management, he has used the irrigation ratio, project irrigation efficiency, and water utilization per unit area in the Nazilli, Akçay, Aydın, and Söke irrigation networks.

General basin irrigation planning; The values related to actually irrigated fields in the irrigation networks, cultivation areas according to crop pattern and ratios, crop-water consumption, moisture residue from winter, irrigation network conveyance efficiency, and field water application efficiency are compiled for many years (1997–2013). Thus, by taking the average of these values, irrigation water amount required for irrigation networks is determined (Koç 2014b). After the calculation of the required irrigation water amount, dam operation scenarios are prepared by calculating the necessary amount of water needed to be released from dams during irrigation season and basin water budget. Ikebuchi et al. (1982) reported that preparing a dam operation program depending on the needs is very important.

Water budget approach is made in river basins (Owen-Joyce and Raymond 1996; Hassan and the Buhutta 1996), irrigation networks (Perry 1996; Kijne 1996; Helal et al. 1984), and field levels (Mishra et al. 1995; Rathore et al. 1996; Bhuyian et al. 1995; Tuong et al. 1996). Gastélum et al. (2009) analyzed the problems of the Mexican Rio Conchos Basin, the largest tributary to the lower part of the Rio Grande/Rio Bravo Basin. They developed a decision support system (DSS) as a semi-distributed model, based on System Dynamics, to evaluate several allocation alternatives for the main basin's users: Irrigation District and Water Treaty. The DSS application showed that understanding the effects of multiple interacting variables is necessary to develop good natural resource management policies. General basin irrigation plans are prepared with the stakeholders (Irrigation Association, Energy Corporation) benefiting the irrigation services in the basin under DSI coordination. These plans are signed after the stakeholders come to an agreement on the general irrigation plan and then they are executed after the signature. Especially during the planning stage, the stakeholders' participation and perspectives are to be considered.

Irrigation management and irrigation schedules; Management of basin irrigation networks and preparation of the irrigation schedules are conducted by irrigation associations. After irrigation, water amount is allocated for each irrigation network during the preparation of the general basin irrigation planning, and once the process is determined, water distribution and application programs are prepared according to crop patterns, soil structure, canal capacity of the irrigation network, planned management method of the network, and user habits (Koç, 2014b). Oad et al. (2009) presented their ongoing research on efficient irrigation in the case of the Middle Rio Grande, where the irrigated agriculture has come under increasing pressure to reduce its water consumption. Their paper described formulation and implementation of a decision support system that can assist watershed managers to more efficiently plan and implement water delivery operations, using linear programming to find an optimum delivery schedule for irrigation canal service areas. Water distribution schedules prepared for irrigation networks in the basin are announced to the water users before the irrigation season. In addition, irrigation association personnel managing irrigation schedule performs water distribution according to the schedule and force sanctions on the ones who do not obey the schedule. Preparing irrigation schedule is important in order to use available water resources allocated to the irrigation networks effectively.

Measuring net and water measurement structures in irrigation networks; Measuring water resources for different sector elements in integrated river basin management (irrigation, flood, energy, ecology, storage, providing data) serve different purposes. In irrigation systems, measurement data are obtained at the exit points of storage facilities, at the station points on the main river bed, in the main canal entrance of irrigation networks, and at the end of the main drainage canal in order to control the general irrigation planning of the basin. These data help to detect the irrigation water returning drainage canals and to determine the irrigation performances (Koç et al. 2014). In the flood process, measurement data are collected from the measurement points intended for flood, from the important minor branches discharging into the river bed, as well as from the waterways in the settlements. This data is used to determine flood spreading area and the flood plain and to perform flood management. In energy management, in order to measure and record water amount allocated to energy facilities, measurement data from approaching canal entrance of run-of-river Hydropower Plant (HPP), tail water canal of dam HPP, entrance and exit of canal HPP, and river bed of run-of-river HPP are collected. In the ecological system, measurement data of bedsap of run-of-river HPP and entrance canal of ecology projects must be obtained in order to provide water to ecology projects, providing water reinforcements to the ecological areas and to maintain ecological life. In storage facilities, it is necessary to perform elevation measurement from dam and pond reservoirs in order to determine fullness ratio of storage facilities such as dam and pond and to postpone floods. In order for integrated basin management to be successful, it is essential to establish a system which can measure water accurately in basin irrigation networks and in the other water structures.

Protection of water rights; In the usage planning of basin underground and surface water resources, water requirements of all sectors (domestic, irrigation, energy, industry, environment, and ecology) should be taken into account, priorities should be determined, and water rights of the allocated resources based on sectors must be considered. In particular, no forfeiture should be created during the application phase of sector-based water allocation. Potentially, sector-based requirements (irrigation and energy) must be merged for the efficient use of water. In addition, water rights of all livings in the basin must be protected. In addition to the identification of water as a human right, the content of this right is important. In the direction of general irrigation planning in the basin, necessary observation and monitoring activities are performed in order to prevent forfeiture among the organizations and stakeholders in irrigation water shared in irrigation networks. Irrigation and other sectors' requirements in the basin are evaluated and applied with the integrated basin management.

Irrigation and energy

The data related to the names, operating companies, location of construction, Hydroelectric Power Plants (HPP) type, project production values and production values are presented in Table 2 for HPPs operating in Büyük Menderes Basin. Eleven of basin HPPs are canal HPPs, and three of them are dam HPPs. According to the project production values of the analyzed HPPs, energy production realization values change between 21 and 110 %. Total energy amount generated by 14 of HPPs operated and constructed in the basin is 463.26 GW h/year in the investigated year. Total production capacity of the investigated plants is 714.98 GW h/year and a production in the rate of 65 % is made. Koç (2014a) stated that total technical hydroelectric potential of Büyük Menderes Basin is 3.131 GW h/year, and 589.6 GW h/year of this amount is in operation phase, 267.5 GW h/year is in construction phase, and 414.3 GW h/year of the total amount is in planning stage. Basin energy facilities are closely associated with irrigation networks. First, the energies of the water released from storage facilities are stored and then the water is released back to the irrigation. Therefore, when general basin irrigation plans are prepared, the overlap of the water amount released from dams to irrigation and the flow rate of energy power plant must be considered. Energy per unit of water released from storage facilities in the basin irrigation networks is taken three times as Adiguzel, Entek, and Feslek/Basaran HPPs for the water released from Adiguzel dam and for the water released from Kemer dam; the energy is taken three times again in Kemer, Sirma and Akcay HPPs. Koç (2012) stated that the planning based on integrated basin management must be performed and integrated basin planning must include various professional disciplines and their representatives, as well as local managements and civil societies. Operating canal HPPs built in the basin and putting them into operation for irrigation is very important. In order to maximize energy production as well as to maximize irrigation, it is essential that irrigation schedules prepared should consider energy production conditions. Koç (2011a, b, c) stated in his study that selecting turbine flow rates based on the distribution of irrigation water used during irrigation season and irrigation canal capacities in operating canal HPPs maximizes the energy production of Canal HPPs.

Flood and drought management

Flood management; In integrated flood management, is aimed to obtain more revenue from the flood areas and minimize the losses caused by floods by integrating the development issues of water and soil resources in a river basin. The river basin is considered as a whole. The aim is not only to reduce flood damages but also at the same time the object is the utilization of the flood areas in the most efficient manner. Reducing casualties is the key priority in flood management. In his study related to integrated flood management in Büyük Menderes Basin, Koç and Bozkurt (2013) focused on dams and reservoirs, waterways, river bed and flood dikes, participatory basin management, canal improvements, floodplain regulations, location and design of facilities, estimation and early warning, as well as information and education about floods.

Dams built in Büyük Menderes Basin are the most important structures for controlling, routing, and reducing the damages of floods. Dams in the basin have the capacity to store approximately 85 % of the average annual flow of Büyük Menderes River. The size of the area, where the flood plains may be affected by the water that may flow out of the river bed during the flood from the existing river bed, must be determined with the help of advance studies. If these areas are determined previously, the type and time of the agriculture will shift to the outside of the processes when floods take place and as a result damages in the flood area will be prevented and the prevention of agricultural activities will be eliminated. Closed areas and concrete lined surface areas and locations of the facilities thought to be built on a sector basis in the basin should be evaluated in terms of integrated flood management to eliminate the negative effects that might be created by the possible floods should be performed. Facilities that will be built and the area that will be opened for settlement should be considered, so that they do not make a negative contribution to the severity and the duration of the floods. Flood condition of an area that will be opened for settlement should also be taken into account. Koç et al. (2010) stated that the location and importance of flood event in basin management should be told via meetings; also, it is necessary to inform them to ensure participation for not receiving any damage from this type of a catastrophic event.

Table 2 Properties of hydroelectric power plants operating in the Büyük Menderes Basin

Basin name	HPP name	City	Year of operation	Owner	Construction location of HPP	HPP type	Total power (MW)	Project production value (GW h/year)	Production for 2013 (GW h/year)	Realization ratio (%)
Büyük Menderes Basin	Feslek HPP	Aydın	2004	Bereket Energy Production Company	Nazilli Right Bank Irrigation Canal	Canal HPP	8.84	41.00	18.56	45
	Başaran HPP	Aydın	2006	Ekin Energy Production Company	Nazilli Left Bank Irrigation Canal	Canal HPP	0.60	4.27	0.91	21
	Akçay HPP	Aydın	2009	Akçay Energy Production Company	Akçay Irrigation Main Canal	Canal HPP	28.78	94.88	78.46	82
	Sırma HPP	Aydın	2009	Beyobası Energy Production Company	Akçay Irrigation Main Channel	Canal HPP	5.88	23.20	20.23	89
	Kemer HPP	Aydın	1958	EÜAŞ (Government)	Akçay Stream	Dam HPP	48.00	143.00	122.21	85
	Cindere HPP	Denizli	2008	Entek Energy Production Company	Buyuk Menderes River	Dam HPP	28.50	88.10	53.31	61
	Adıgüzel HPP	Denizli	1990	EÜAS (Government)	Buyuk Menderes River	Dam HPP	62.00	280.00	128.53	46
	Çal HPP	Denizli	2001	Limak Energy Production Company	Çal Irrigation Main Canal	Canal HPP	2.20	11.75	12.90	110
	Bereket I-II HPP	Denizli	1998	Bereket Energy Production Company	Çürüksu Right Bank Canal	Canal HPP	3.15	12.00	13.05	109
	Dodurgalar I - II HPP	Denizli	2004	Elta Energy Production Company	Dodurgalar I-II HPP Distribution Channel	Canal HPP	4.14	12.00	11.66	97
	Ege HPP I	Denizli	2009	Denizli Energy Production Company	Çürüksu Left BankCanal	Canal HPP	0.92	4.38	3.11	71
	Bekilli HPP	Denizli	1954	Bekilli Municipality	Çal Irrigation Main Channel	Canal HPP	0.33	0.40	0.33	83

Drought management; Necessary work should be done about the severity and duration of drought in the basins suffering drought. Since drought is a sneaky progressive process, it is essential to be prepared. Necessary work before and during the drought period should be integrated into an action plan. Koç (2007a, b, c) determined the severity and duration of drought periods in storage facility basins built in Büyük Menderes Basin by Standardized Precipitation Index method and reported that approximately 42 % of storage basins of Isikli, Adiguzel, and Kemer dams in the investigation period are rainy, 58 % of them drought depending on the severity and determined that 10 years between 1985 and 1994 in Adiguzel and Kemer dam basins to be drought period.

Since irrigation efforts are the largest utilization of the available water source, developments in the irrigation has a deep effect on all basin water usage and availability. Many basins in the world are operated as a closed basin and lack of water is experienced for almost 6 months. Büyük Menderes Basin shows closed basin properties between the dates April 1 (irrigation season starts) and September 30 (irrigation season ends) and all water in the basin are used for irrigation in these periods. Colorado in the USA, Indus in India and Pakistan, Murray-Darling in Australia, and many river basins in the Middle East and Central Asia suffer severe lack of water (Molle et al. 2001). In a case when the water coming from water storage basins does not meet irrigation water demand of basin irrigation network during drought period, management of the existing water resources to meet the demand gains in importance. Depending on the severity of possible drought, basin-based "Drought Strategic Action Plans" should be prepared and these plans should be carried out with a commission formed with relevant institutions and organizations (DSI, Irrigation Associations, Agriculture Organizations, Environment, Related NGO, and Meteorology). Water shortage that might occur depending on the severity of the drought in the basin should be announced to the users and they must be informed. Irrigation charge policies should be established, which encourages the users to use water-saving irrigation techniques and modern irrigation technologies in the basin. Irrigation charge methods (spatial, time, or irrigation number) focusing on the amount of water used in the basin irrigation network should be utilized. During the periods having lack of water, water should be allocated to the crops having economic and social priorities; the amount of irrigation water provided should be reduced by considering the climatic conditions or by increasing the irrigation intervals. In order to balance the water resources and the demand, crops that are currently produced should be replaced with the ones using less water or the existing planted acreage should be narrowed (Koç and Akar 2007; Akar and Koç 2005).

Water user organizations and stakeholders

The Water Framework Directive (WFD) agreed that the success is based on close cooperation with the people and the stakeholders in local level and including the people and the stakeholders to the basic decisions. To develop river basin management plans, which are the base of WFD applications, public participation is essential. Directive agrees that it is necessary to provide accurate information to the public about the planned measurements before taking final decisions about the measurements, in order to provide participation of the people and stakeholders in creation and updating the river basin management plans. Twenty-six irrigation networks which are operated and located in Büyük Menderes Basin are managed by Irrigation Associations created by water users (farmers). Operation-maintenance and management services of the irrigation networks in the basin are carried out by 28 Irrigation Associations, 2 Municipal, and 4 Irrigation Cooperatives. Total number of Water User Associations in the basin is 34.

Koç et al. (2006) reported in their study that transfer of basin irrigation networks into irrigation associations, namely the participation of the water users, have a positive effect on basin water users. Scott and Banister (2008) described the dilemma of water management development in Mexico, analyzing the current decentralization process. Although important advances have been made with irrigation management transfer, river basin councils, nascent user participation in groundwater management, and water as well as energy legislation, IWRM remains an elusive goal. This is principally due to inherent institutional and procedural contradictions in water resource allocation. Basin irrigation associations are responsible for making necessary organizations for distributing irrigation water allocated to the general basin irrigation planning, making necessary maintenance to keep irrigation systems operational, determining irrigation costs and providing collection services.

Conflicts and resolutions about water

Büyük Menderes Basin is an important basin where many projects with the aim of irrigation, energy production, creating drinking water, tourism, and ecology have been carried out. On one hand, the inter-sectoral race effects and the fact of not benefiting from the water sufficiently is seen. On the other hand, the drought processes and the lack of water as well as particularly the upstream and downstream relationship in the irrigation networks might increase conflicts related to water. However, while preparing general basin irrigation plans and during discussion of these plans with the related sectors, inspection and monitoring by the relevant public institution (DSI) will help for solving the possible conflicts. In particular, participatory management concept in all sectors will help to meet at a common point. To solve conflicts under different water users in a developing country, Randhir and Genge (2005) developed a conceptual framework for a watershed-based institutional approach including participatory integration and cooperative solutions. Water resources planning involves groups or institutions having differing objectives, responsibilities, and interests, and it requires collaboration for conflict resolution. Cai et al. (2004) discussed the characteristics and modeling requirements of conflict resolution in water resource planning. A method based on compound models is proposed for regional water resource planning involving multiple decision-makers. This method combines modeling techniques, such as multi-objective analysis, multi-criteria and multi-participant decision methods, and support plan generation and evaluation, individual and group preference elicitation, and negotiation taking aim at a consensus plan. Cap-Net (2008) reported that integrated water management, effective cost managements, transparent local management, and increased stakeholders' participation leads to cooperation between the private sectors, and it helps to reduce the conflicts.

In particular, to receive less water than planned for the irrigations located in the basin downstream and not receiving the planned amount on time may increase these conflicts. Particularly, not releasing water for ecology and environmental purposes from the systems operated together with hydroelectric power plants and irrigation or releasing insufficient water may also cause conflicts. The only option for solving the possible conflicts about water is to plan and manage the water and soil resources in an integrated way. Unless basin water resources is evaluated based on the sector, the possible conflicts will be eliminated during the planning phase; hence, only conflicts arising from physical conditions will exist. These conflicts will be resolved when the physical conditions return to normal levels.

Pollution monitoring and control

Pollution formed in Büyük Menderes river basin can be classified as point source pressures, diffuse (non-point) source pressures, and hydro-morphological pressures. This classification gives information about which water masses are at risk because of human activities.

> *Point source pressures*; Point source pressures are mostly caused by industrial effluent and urban sewage (both treated and untreated), geothermal energy wastewater, and to a small extent agricultural activities. Point source pressures are seen to be a very important risk category in Büyük Menderes river basin. For instance, the amount of domestic waste discharged from Aydin Province to Büyük Menderes river basin is 146,000 m^3/day and 85,000 m^3/day of this amount is treated. The volume of domestic waste is reported to be approximately 35,000 m^3/day. The waste coming from industrial sources is 150,000 m^3/day (EUTP 2008). Olive oil production facilities are the source of both point and non-point pollution sources. Some olive oil production facilities do not treat their wastewaters and their effluents become point pollution sources. Some facilities accumulate the wastewater in pools. These pools overflow with heavy rainfall, so these facilities cause the diffusion of pollution. There are almost 200 olive oil facilities in only Aydin Province Basin. Each facility produces approximately 8 t of olive oil per day. One ton of olive oil brings a pollution load equivalent to approximately 1000 people. Even though olive oil production season is 3 months in a year, the pollution load is very high. Koç (2010) analyzed the water quality of Büyük Menderes River by using six parameters in Modqual mathematical model method and stated that wastewater caused by local and industrial activities needs to be treated

before discharging into the water masses. Furthermore, he stated that fertilizer as well as pesticide usage in agriculture should be controlled firmly. In the basin, while there are geothermal power plants through active faults in the tectonic horizons located mainly in the north of water masses of Lower and Middle Büyük Menderes, works for opening new facilities are proceeding rapidly. These geothermal plants discharge sodium and boron into Büyük Menderes River Basin. Koç (2007b) stated in his work that boron pollution which is being discharged into Büyük Menderes River from geothermal resources and geothermal power plants varies between 27 and 0.2 ppm and also that this pollution threatens 130,000 ha of irrigation area. For example, boron and salinity concentration in the soil have been found to increase significantly after Saraykoy Geothermal Power Plant has started to operate. Citrus plants which are found in the Nazilli region are damaged to great levels and significant decline in the quality of these crops are observed. In addition, many other plant types which are sensitive to boron are affected negatively in the same way. Koç (2011a) found in his study about Lower Büyük Menderes Basin that river boron concentration varies from 0.10 to 0.43 mg Bl^{-1} and boron amount accumulated in the soil and leaking into the groundwater is 184,953 and 9154 kg B $year^{-1}$.

Diffuse (*non-point*) *source pressures*; Diffuse source pressures especially affect chemical quality of water. Enrichment of the surface waters, especially with phosphorus and nitrogen, in terms of nutrients can lead to eutrophication. This situation which creates negative effects on biodiversity as well as on water quality may reduce the amount of water masses available for supplying water and recreation. Nutrients enter into water via deposits from the atmosphere, point sources, as well as from land usage activities. Many rivers, lakes, and dam lakes in Büyük Menderes river basin are under risk because of diffuse source pressures. When diffuse source pressures are examined in sectorial basis for rivers, one of the main diffuse source pressures is confirmed to be agriculture. Urban pollution sources (wastewaters coming from places without a connection with the sewer system) is an important diffuse pollution source. In Koç's (2008) study related with the effects of salinity on underground water and irrigation water returning from irrigation in Aydın plain having 14,500 ha project area, he has stated that the salt amount accumulated in the soil and carried to Büyük Menderes river as a result of diffuse pollution is 211.609 and 246.565 t respectively. Hence, a total of 458,174 t of salt deposition affects the environment negatively.

Potential solutions to high soil salinity levels and waterlogging problems are investigated on a regional scale using calibrated finite-difference flow and mass transport modeling for a portion of the Lower Arkansas River Valley in CO, USA (Burkhalter and Gates 2006). Isidoro and Aragüés (2007) evaluated the salinity and ion concentrations in 31 river stations of the Ebro Basin, characterized the quality of waters for irrigation, and analyzed the influence of irrigation on river water quality. Due to the low salinity of most irrigation waters, maximum irrigation efficiencies are attainable in the Ebro Basin without compromising crop yields due to root zone soil salinization. Causapé et al. (2004) discussed salt and nitrate pollution of receiving water bodies caused by irrigation return flows. The objectives of this study were to perform a salt and nitrogen mass balance at the hydrological basin level and to quantify the salt and nitrate loads exported in the drainage waters and the groundwater. The off-site impact ascribed solely to irrigation in the analyzed basins was estimated in the soil drainage water. A low irrigation efficiency coupled to an inadequate management of nitrogen fertilization is responsible for the low-salt, high-nitrate concentrations in soil and surface drainage outflows from the studied basins. From the chemical analysis made of groundwater wells when these wells are opened for the first time, especially nitrate values were obtained. Since heavy agricultural activities are performed in the areas where groundwater masses are located, these agricultural activities are thought to cause possible nitrate pollution.

Hydro-morphological pressures; In the basin, concerns the release of water from storage structures like dam, ponds, and from water intake structures like regulators to the existing irrigation areas and settlements. Since water transfer is not in question neither from Büyük Menderes river basin to another basin nor from another basin to Büyük Menderes, there is no such pressure in the basin. Many streams are at risk because of water withdrawal and flow regulations. The most important water withdrawal category is intended for agricultural irrigation. The water allocated for home and industrial use from the surface water in the basin is 150 hm^3/year, the amount allocated for irrigation is 2.061 hm^3/year. Obstacles in front of the river (regulator) harden the fish migration and changing the cross-sectional area also affects the aquatic ecosystem. In Büyük Menderes River Basin, 27 tributary and 3 lakes are affected from morphological changes. Dam lakes are not included in this number. Morphological pressures can affect rivers. In some areas where surface waters are not adequate, groundwater wells were drilled in order to supplement the irrigation water and home and industrial water supply. For the purpose of drinking water supply, there are documented groundwater wells opened by the related municipalities and many unlicensed wells opened for various purposes around the basin. Total safe groundwater reserves in the basin is 697 hm^3/year and the water amount allocated from these reserves for drinking and usage is approximately 143 hm^3/year, the amount allocated for irrigation is approximately 197 hm^3/year. The states of groundwater masses are at potential risk in terms of the amount. No comprehensive study is made about the actual groundwater usage. However, by considering that the intense usage of groundwater and the increase of this usage, feeding and withdrawing relation should be determined by the conducted studies.

Climate changes; There are strong evidences that there will be a reduction in the amount of water in Büyük Menderes River Basin as a result of climate change. Depending on the climate change scenario, annual rainfall in Büyük Menderes River Basin is expected to decrease approximately 10 % until 2050 and approximately 20 % until 2100. Potential evaporation-transpiration is also expected to increase significantly due to an increase in temperature. As a result, the flow in Büyük Menderes River is expected to reduce approximately 20 % until 2050 and approximately 40 % until 2100. However, there is no appropriate method available to determine the amount of effects of the basin on the water budget (EUTP 2008). Agricultural production is affected by changes in climate, in particular through increased variability in rainfall and a higher frequency of extreme events (floods, droughts, storms, heat waves, etc.). Water management is an essential part of adaptation strategies, which help to cope with consequences of increased variability of rainfall (Ragab and Prudhomme 2002). Adaptation strategies to climate change have been explored using a linked field-scale basin-scale modeling framework for a basin in Sri Lanka. An integrated approach was followed concentrating on enhancement of food security and preservation of environmental quality (Droogers 2004). Because of these changes, water quality and ecology can be affected seriously. Climate change will cause a decrease in river flow; this will lead lower flow velocity, lower water levels, and increase of the areas where the bed often dries. When this issue joins with the increase in air temperature, it is possible to have negative and serious effects on physical and chemical water quality parameters and on ecology. Climate change will also have a significant effect on irrigation and agriculture activities; this will lead to changes in nutrient and pesticide loads.

Irrigation water charges and financing

Irrigation systems consist of work resources related with management-operation and maintenance (MOM) organization: personnel, equipment, materials and equipment, energy, transportation, and other elements. In addition to the possibilities to reduce expenditure needed for fulfilling irrigation MOM services, the opportunities of determining and increasing MOM revenue that will be used to finance MOM costs should be carefully examined. Irrigation charges that will be collected from the users constitute the main element of MOM revenue in basin irrigation networks. Therefore, determining irrigation charges constitutes a significant portion of financing of basin irrigation MOM organizations.

Water charges applied by irrigation association in irrigation networks in Büyük Menderes Basin show variations according to crop patterns between the costs based on unit irrigated area and crops pattern-unit area-unit time (hour). Generally, pumping irrigation networks use charge method based on crop pattern-unit area-unit time (TL crops type/1da/1 h) (Koç 2007a). Unit irrigation water cost shows variation in gravitational and pumped irrigation areas. Different MOM costs in gravitational and pumped irrigation areas may cause differences in unit irrigation water costs. Unit irrigation water costs show variations especially in pumped irrigation areas. Various qualifications and MOM costs for pump unit has an effect on unit irrigation water costs. Koç et al. (2005) stated in their study that the method based on unit water usage of the crops and unit cost of the water is needed, particularly the charges determined by irrigation organizations in pumped irrigation areas are lower than they are supposed to be.

Financing policies determining institutional arrangements related to irrigation MOM organizations are related with four main components. Those components can be stated as allocating the sources for MOM organization of irrigation networks, using these sources to fulfill MOM services, obtaining the sources from the users and inspecting those sources used. Components other than the third financing element have limited effect in terms of improving MOM costs. Irrigation MOM financing policies have the potential to increase necessary resources for MOM, improving operating efficiency of irrigation facilities, causing the irrigation managers to feel more responsibility for water users, more necessity and creating a cooperation with water users for MOM, increasing water usage efficiency by individual water users, improving irrigation investment decisions and financial position of the government (Koç 2001a). In order to determine financial performances of irrigation network of Büyük Menderes Basin, Koç (2007a) performed a study showing that financial self-sufficiency ratio, which is an important indicator of financial sustainability, varies from 0.99 to 1.51.

Performance evaluation and sustainability

The use and process of the water for irrigation purpose require periodic evaluations in terms of usefulness and effectiveness. The interest in the performance for irrigation sector is felt as a pressure developing on the water resources in the world with the idea of increasing sustainability of irrigated agriculture systems (Koç and Akar 2005). Any investment mandates the acquisition of information about resource management which has a result related with efficiency increase. In order to determine MOM performance of irrigation systems, irrigation MOM organization, physical, economical, and management organization activities should be investigated (Koç 2001a, b). Indicators related to irrigation area, irrigation facilities, and irrigation water utilization of MOM organization should be evaluated with irrigation network physical activity; revenue and expenses of MOM organization, indicators about determination, and collection of irrigation water charges and financial sufficiency ratio of MOM organization should be evaluated with economic activities. Furthermore, indicators related to MOM personnel and irrigation groups should be evaluated with institutional activity of MOM organizations (Koç et al. 2007). Lorite et al. (2003) developed a simulation model for the analysis and evaluation of the irrigation management of an irrigated zone in Córdoba, Spain. The simulation model is used together with an indicator of functional conditions and allows a first evaluation of the irrigation area. Distributed eco-hydrological modeling (Singh et al. 2006) can provide a useful tool to evaluate the performance of irrigation systems at different spatial and temporal scales. The Sirsa district, India, has been selected for a case study with typical problems of canal water scarcity, poor groundwater quality, rising and declining groundwater levels, and sub-optimal crop production. Vishnudas et al. (2005) have presented an analytical framework that helps to understand the different aspects and elements of sustainable watershed management and their interactions. Each element has been examined as to how it affects sustainability in relation to the other elements. The framework helps to reveal the important factors contributing to land and water management and the livelihood of the people. Determining and monitoring MOM performances of irrigation networks located in Büyük Menderes Basin is important in terms of efficiency and sustainability of the systems. Hussain et al. (2007) provided an overview of the issues in and approaches to measuring and enhancing the value of agricultural water in large irrigated river basins. They developed a framework and a set of indicators for valuing agricultural water by looking into various dimensions and underlying key factors that influence the value of water at micro, meso, and macro levels. In their study made in three irrigation networks in Büyük Menderes Basin, Koç et al. (2007) evaluated irrigation MOM performance according to WAM method and stated that the performances of the irrigation networks are in "fair" class. Koç et al. (2006) statistically evaluated a survey on five different subjects in four irrigation networks in Büyük Menderes Basin and determined irrigation MOM performance and stated that user participation created a positive impact on the performance. Using 80 % of basin water resources in agriculture and performing a large part of the irrigation services through irrigation networks mandate the performance evaluation in irrigation networks. Irrigation systems MOM organizations should be evaluated physically, economically, managerially, and environmentally, and it should question itself according to the obtained performance values. Performance evaluation offers the opportunity to compare irrigation networks with themselves, within the basin and the ones in the other basins. However, just as it is the case in the country as a whole, failure to identify the necessary indicators for irrigation MOM performance evaluation in Büyük Menderes Basin and failure to have a performance evaluation method (framework) prevent the realization of this work. Furthermore, this type of a method must be developed in order to identify requirements that need to be fulfilled and to determine the location of irrigation facilities in integrated basin management.

Information management and sharing

Information management is defined as three basic information activities as acquisition, storage, and transfer. Information management is a process of sorting, storing the data obtained from internal and external resources, distributing to the related places in required times in order to evaluate, and checking the information for updating. Information and data about integrated river basin management and about irrigation management should be shared and stored with basin management and public irrigation agency (DSI). In necessary times, the information must be updated and used in a coordinated way among the related organizations. Information sharing is important in terms of sustainability of irrigation institutions and for their self-developments. Information sharing and usage are available between irrigation organization and DSI in Büyük Menderes Basin.

New water framework law application compatible with EU

The aim of Water Framework Directive (WFD) is to create a framework in a way to protect interior water, transitional waters, and groundwater. Directive is one of the most important sections of the water legislation prepared by Directive European Commission. WFD offers the most important element to reach sustainable water management in EU Member Countries for many years. They introduce a new perspective based on River Basin Regions (RBRs) in terms of directive water management requiring reaching *good water* phase till 2015 for all surface water and groundwater in the defined river basin regions and explain how it can be reached by creating environmental and ecological targets directed to all water masses. *Good condition* for surface water is determined as *good ecological condition* and *good chemical condition*. Good groundwater conditions means to be at least *good* condition in terms of both quantity and quality. The objectives of WFD can be summarized as follows: protecting *very good condition* of water masses having a very good condition; preventing all distortion in the current condition of the waters and reaching at least "good condition" level for all waters until 2015. These objectives and targets are reported to be stated clearly in river basin management plan in directive; river basin management plan also includes measures which are aiming to make sure of reaching these targets. Good water conditions will be reached by considering environmental, economic, and social factors. Implementation of WFD is challenging and it raises many other challenges within a tight schedule. In order to operate irrigation water used for agricultural purpose in the basin in terms of quality and amount, water should be compatible the WFD rules. For optimum use of irrigation water of irrigation networks within WFD and avoiding negative environmental impacts, implementation of effective irrigation water distribution programs, raising project irrigation efficiencies, and applying irrigation charges based on the amount and quality should be aimed. According to WFD, returning "good condition" water mass used in irrigation to the basin with the same condition after the usage can be accomplished by integrated river basin management practices. Therefore, the key factor of the relationship between WFD and irrigation water usage is to integrate river basin management practices. For the implementation of the WFD, especially for the correct management of the water resources and the involvement of the stakeholders in the decision process, Martín de Santa Olalla et al. (2005) described the development of a Bayesian Networks to solve environmental problems. The main problem in the application region is the risk of overexploitation of the local aquifer, brought about by a considerable increase of the surface area of irrigated arable land. The results offered by the tool show that the current situation is non-sustainable. The aim of Bazzani et al. (2004) is to analyze the problem of water regulation in agriculture in connection to the WFD. This is done by setting up and testing a simulation model based on the integration of a mathematical programming model at a farm level and an optimal regulation model at the level of irrigation boards. The model allows quantifying water demand and optimal regulation from the policy maker's point of view. When implementing both full cost recovery and the polluter pays principle, the results show likely major impacts of water pricing on farm income and employment. The optimal policy is a combination of pricing instruments related at the same time to crop mix, water consumption, and pollution. Altogether, economic, social, and environmental issues have to be carefully considered in order to design suitable water policies. Álvarez et al. (2005) described the implementation of the European Union's WFD through a National Irrigation Plan in Spain, especially the sustainable and integrated use of water resources. The results of a questionnaire were used as the basis for a water management model and for analyzing the ongoing monitoring of irrigation water use in this region. A management model is developed as an interdisciplinary approach, namely to promote long-term social and economic development and at the same time ensure long-term environmental protection. According to Water Framework Directive, Urban Waste Water Treatment Directive and Dangerous Substances Directive, Büyük Menderes River Basin Management Plan has been prepared together with the relevant institutions. The legal framework in the European Union (EU) is faced today with the new Water Framework Directive (WFD) that sets up new criteria for water management, regulation, and pricing.

Conclusion and recommendations

Since Büyük Menderes Basin irrigation networks use an important part of basin soil and water resources, determining the role and importance of irrigation management in integrated river basin management requires an integrated and multidisciplinary approach. Basin irrigation management is in a race with the users in drinking and domestic, industry, tourism, environment, and ecology sectors in terms of water usage. Basin irrigation management should be analyzed by using economic, social, and environmental views instead of sector-based approach. In addition, the participation of all stakeholders is important in order to provide improvement in sustainability of irrigation management. Since irrigation management is the place where the decisions taken in the integrated river basin management plan turn into practice, it is one of the important elements in the new vision of water.

This study carried in the basin has illustrated, first, the impact of implementation of irrigation water charges and irrigation financing in such an extensive irrigation network systems, and second, the links between environmental policy and agricultural policy, focusing on the possible evolution of national agricultural policy and WFD instruments.

Countries should take the necessary political decisions for an integrated basin water management and all legal and institutional arrangements should be performed for implementation. Planning works carried out without necessary legal regulations will only carry a report attribute for archives and it will not be valid in practice.

General basin irrigation plan in basin scale should consider the other subjects of the integrated river basin plan. While the researches performed in the developing countries consider technical, social, and economic limits, they should be in an approach increasing the awareness of the farmers for environmental reactions. Sustainable basin management should join sustainable usage and urban development and reduce poverty.

Many researches give the research results of the projects in the USA, Asia, Europe, and Australia. However, in the studies conducted in Turkey, mostly the environmental impacts in the basin are analyzed; the other subjects of the integrated river basin management have not been considered. Particularly, the role and the importance of irrigation management in integrated basin management are not investigated. Since fertilizers and other agro-chemicals in the drain water from the plant root region for refilling aquifers are the main polluters, it is the non-point polluter of surface and groundwater. Together, with the inadequate management of nitrogen fertilizer, low project irrigation efficiency is the main source of pollution. A reduction in pesticide and fertilizer use with a simultaneous decrease in water use will have a significant impact on water quality. The other conflict is the saturation and salinity. Pollution of crops food materials and pesticides has not been investigated sufficiently.

Areas opened to irrigation, the amount of irrigation water used, and project irrigation efficiencies in the studied basin should be evaluated at the end of each year. It should be monitored if there is any intervention with salinity, drainage, lack of facilities, construction, industrial, and tourism purposes in the irrigation areas, where agricultural activities are performed within the integrated basin plans. In addition, the ratio of the planned and realized basin water resources allocated to agriculture sector with respect to the basin general irrigation planning should be calculated and its compliance with planning should be investigated.

Since the energy of the waters released from storage facilities in the studied basin is taken primarily, to obtain optimum efficiency in energy and irrigation sector, planning should be made by considering turbine discharges, hours when energy requirements are higher, as well as the water amount that should be released for ecological purpose.

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