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Full Length Research Paper

Evaluation of irrigation and drainage systems of (Southeastern Anatolia Project) GAP, the Turkey's largest integrated water resource development project

Kasim Yenigun* and Mustafa Hakki Aydogdu

Department of Civil Engineering, Faculty of Engineering, Harran University, Osmanbey Campus, anliurfa, Turkey.

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The Southeastern Anatolia Project (GAP), the Turkey's largest integrated water resource project, is among the world's most important regional development projects in terms of numeric size and influence. In the present study, irrigation systems and drainage requirements within the scope of GAP in the Euphrates and Tigris Basins are investigated. With the data collected, an attempt was made to determine the potential operational problems in terms of present requirements by investigating water resources, irrigation systems, and water distribution methods, efficient use of water control structures, valves, and water, and drainage requirements and systems based on field observations. In order to solve these problems and ensure that similar problems are not experienced in future projects, recommendations related to needs are made on subjects such as management and operation models that will achieve optimum use of resources, institutional and legal contents, social and cultural behaviors, environmental interaction potential, and economic requirements. A summary of wide-ranging research carried out in the study area, problems and recommendations are presented together.

Key words: GAP region, water resources, irrigation systems, drainage.

INTRODUCTION

Globally, the demand for water resources increases daily, but water resources are not being developed at a sufficient rate to meet this demand. Therefore, it has become necessary to use advanced engineering technologies, and to take measures of all kinds to achieve water savings. Projects and construction based on water resources, irrigation and drainage systems are long-term, high-cost, and for the most part publicly funded, and these need to be reflected in the water resource administration, with an approach in which all legal, administrative, social, technical, and economic activities related to water, from the basin to the farm are integrated.

Irrigation and drainage planning is important in terms of managers' efficient and effective use of irrigation systems, and in terms of objective evaluation, definition, and ultimately efficient management (Hassall and Associates, 2008).

According to studies carried out by the World Bank in 80 countries, making up 40% of the world's population, difficulties are experienced in access to water and in the procurement of water that meets health requirements. In addition to the insufficiency of water resources, this situation results from the inefficiency of irrigation systems, technological issues, irrigation infrastructure with inadequate delivery and distribution, and inadequate operation and maintenance conditions (Southernland Association, 2006).

Despite the increased use of water in other sectors, agricultural irrigation still accounts for the greatest consumption of water on a global scale. Along with this, there is gradually increasing pressure for more efficient use of water in agriculture and irrigation. Furthermore, irrigation is one of the most important factors in food

*Corresponding author. E-mail: kyenigun@harran.edu.tr, kyenigun@hotmail.com. Tel: +90 414 318 37 80. Fax: +90 414 318 3799.

production and rural income. It is for this reason that water management must be developed in order to achieve higher water efficiency and increase rural income. In water resource development and management services, it is necessary that, support and technical assistance should be given to users in rural areas on the level of the farm, with regard not only to design and application, but also to the determination and application of irrigation techniques. In order to make use of new developments and opportunities in water resource management, to manage the population increase and, institutionally, water resources more efficiently, countries must either bring about reforms, or find solutions that will meet the new needs. In this regard, education and the development of institutional capacity stand out as the most important factors (FAO, 2006).

Because of population increase, rapid urbanization, industrialization, and irrigation systems in many regions of the world on different continents, the demand for water and water resources is rapidly increasing on a daily basis. However, the water resources available to meet these needs are limited. As a natural consequence, capacity-increasing studies on water resources and on irrigation systems, which account for the greatest water consumption, are being carried out based on the principle of optimum use. Irrigation rates vary depending on country, geographic region and production design.

In regions such as the Middle East, where water resources are very limited, there are many differences in the irrigation systems used by countries depending on their economic, political, and social structures, and in the efficiency of their irrigation systems. For example, in projects in Syria, Iraq, and Jordan, in which open channel systems are employed, the irrigation efficiency ranges from 30 to 50%, while in Israel, which predominantly uses drip irrigation systems, it is approximately 90%, considerably higher.

Irrigation efficiency is around 40% in African and Latin American countries, and conveyance efficiency based on irrigation systems is not high. In studies carried out in Latin America and the Caribbean, in contrast with studies focusing on the procurement of new water resources, it has been shown that, along with the decrease in irrigation investments and despite the increased demand for water, equity and efficiency are improved with water policies and administrative reforms in water resource systems and irrigations (WCA, 2006).

In Europe, America, and Canada, on the other hand, because pipe irrigation systems are used, this rate is higher than in countries elsewhere, at around 85%. In Asian countries, the rate is not high, at 50 to 70%, although there is some variation depending on the country's location, the region within the country, and the irrigation systems in use. In Australia, "The contribution to the total net agricultural return of irrigated agriculture carried out using more than 70% of total water resources is around 50%. The achievement of feasible, sustainable irrigated agriculture is a priority" (CLW, 2006).

The operation and management modeling of irrigation systems is closely related to the high efficiency of operations. Sustainable development based on irrigation, which is one of the basic aims of GAP, stands out as a compelling sector (Yenigun et al., 2008).

In order for agricultural irrigation to be successful, its yields and the expanse of the area in which irrigation is planned must be taken into consideration, and it must be understood that irrigation yields need to be high.

When the matter is approached within this framework, there is general agreement among all relevant organizations that there is a need to determine the most appropriate operation, maintenance, and administration model for water irrigation in the region. For such a model to be successful, investigation is necessary of such subjects as institutional and legal contents, social and cultural behaviors, the potential for environmental interaction, and financial and economic needs. It is also necessary that technical suitability be determined, as well as the ability to achieve continuity (Khatibi and Suter, 1994).

The general model in the GAP region must have an institutional and organizational framework that supports the development of water needs and water irrigation in the most effective manner. Important factors include raising the net benefit to the maximum value, continuity, feasibility and flexibility. The model should have early feasibility and the ability to become more active by adapting to changing conditions over time. It is important to determine potential models for managing irrigation works, dividing the entire irrigation system into fundamental operational components, and to determine probable administrative units for each of them (GAP, 1994).

There are many studies in the literature on water resource planning, and the development, and sustainability of irrigation systems. Some of the related studies are evaluated in Table 1.

In the present study, water resources, irrigation systems, and drainage requirements are investigated within the scope of the Southeastern Anatolia Project (GAP) . The purpose of the study is to evaluate the goals of the planning of the distribution and use of the existing resources in terms of observational results, and to present recommendations. The observations, evaluations, and recommendations made in this study may form a base of experience for similar applications.

MATERIALS AND METHODS

Study area: Southeastern Anatolia project (GAP)

The area in Turkey's Southeastern Anatolian Region comprising the provinces of Adıyaman, Batman, Diyarbakır, Gaziantep, Kilis, Mardin, Siirt, anlıurfa, and ırnak is designated the "GAP Region." Bordered on the south by Syria and on the southeast by Iraq, and comprising vast plains in the lower Euphrates and Tigris basins, the GAP Region contains 20% of Turkey's 8.5 million ha of irrigable

Table 1. Summary of some related literature.

Literature	Study area	Method and conclusion of study
Warner, 2008	South-East Anatolian, Turkey	This article evaluated the Turkish hegemony in its hydraulic control and security strategies, and the international repercussions of that strategy. It suggests that Turkey's basin and regional hegemony is contested and constrained from different sides, not least at home. It also argues that the need to access capital in the international market to realize these ambitions necessitated a 'passive revolution' in Turkey which opened a window of opportunity utilized by the internationalized counter hegemonic moves against Turkey's dam projects in Southeast Anatolia, notably the ongoing Ilisu dam on the Tigris.
Unver, 2007	General evaluation	This study is the chapter of "Water Resources Sustainability" and it also advocates an integrated development approach based on the sustainable development of water resources on a regional scale. This is the area where sustainable socioeconomic development and integrated water resources management intersect and yield to a holistic formulation involving multiple sectors and multiple stakeholders. The water-based sustainable integrated regional development is covered in this chapter with its theoretical and practical aspects and through a contemporary example, the Southeastern Anatolia Project (GAP) of Turkey. This study is also deals with the prospect of using water resources for and within the broader framework of social and economic development on a regional basis and addresses the role that international organisations and the NGO community can play in overcoming for related barriers
Hu et al., 2007	Quzhou Experiment Station, China	This study evaluated the effect of spatial variability of surface soil saturated hydraulic conductivity on water drainage. The random field of surface soil saturated hydraulic conductivity was then coupled with a dynamic soil water movement model. Water drainage during a period of 3 months was stochastically simulated with a total water input of 354mm (including 270 mm of irrigation).
Karlberg et al., 2007	Pretoria, South Africa	This paper presents using saline water for irrigation increases water productivity by freeing up fresh water that can be allocated to domestic or other uses. The possibility of using low-cost drip irrigation with saline water to successfully irrigate a common garden crop, tomatoes, was tested in this study. Even at the highest irrigation water salinity (6 dSm $^{-1}$), a yield above the average marketable yield was achieved, indicating that low-cost drip irrigation works well in combination with saline water.
Fernández-Gálvez et al., 2007	Guadiamar valley, Spain	Drainage water was estimated by means of a simple infiltration model (bucket model) which computes on a daily basis the inputs and outputs of soil water through rainfall and evapotranspiration generated by a stochastic model of the local climate along a period of 50–100 years. The presence of a gravel rich horizon below 50 cm depth reveals an increase in drainage and the threat to ground water.
Mireri et al.,2007	Kisumu municipality, Kenya	This paper examines the environmental risks threatening sustainable urban agriculture in Kisumu municipality. The study sought to assess potential risks of contaminating urban agriculture produce and urban agriculture waste management. Household survey covered access to basic infrastructure and services, urban waste management and urban agriculture waste management.
Babajimopoulos et al., 2007	Thessaloniki plain, Greece	The mathematical model (SWBACROS) was applied to estimate the contribution of a shallow groundwater to the water needs of a maize crop. The model was applied with the top and boundary conditions defined by the observed irrigation/rainfall events and the observed water table depth.
Goncalves et al., 2007	Yellow River, China	The authors suggest that water saving and improved water use may be achieved in surface irrigation districts when a combined farm and system approach is adopted. Utility values increase from one scenario to the next but very little for the scenarios more demanding than scenario 4 that concerns improved irrigation deliveries and scheduling but not heavy changes in farm and distribution systems. Results also evidence the interrelations among improvements in the irrigation and drainage systems.

Table 1. Contd.

Pereira et al., 2007	Yellow River, China	Water saving in irrigation is a key concern in the Yellow River basin. Excessive water diversions for irrigation waste water and produce water logging problems during the crop season and soil salinization in low lands. Different models such as SRFR, SIRMOD and ISAREG were used interactively to define alternatives for the irrigation systems and scheduling that would minimize percolation and produce water savings.
Cancela et al., 2006	Terra Cha located in northeast Galicia, Spain.	This study refers to a region with temperate climate due to Atlantic influence and variable rainfall during the spring–summer season. Surface irrigation is traditionally practiced in this region, but this system is being progressively replaced by sprinkler irrigation. To assess the irrigation requirements and to select the most appropriate irrigation management practices, an irrigation scheduling simulation model was used after calibration/validation. Schedules refer to different soil water thresholds, and fixed (40 mm) and variable net irrigation depths, which range from 30 to 54 mm.
Ritzema et al., 2006	Worldwide	This article is about the new drainage materials were developed to replace the traditional drain pipes made from clay or concrete and drain envelopes made of organic materials or gravel. A shift from post-construction quality control to a total quality control system enables achieving a high quality of the installed systems even with the ever-increasing speed of installation. Nowadays, basically two modes are used: implementation by a (specialized) government entity or contracted to a specialized drainage company.
Lecina et al., 2005	Zaragoza, Spain	This report presents the surface Irrigated District V of the Bardenas Canal (Zaragoza, Spain) was evaluated, and alternatives were assessed to improve on-farm irrigation performance. The use of an average irrigation discharge of 152 Ls^{-1}, results in a relatively low irrigation time (about 3 h ha^{-1}). However, due to the low soil water retention, even this low irrigation time results in abundant deep percolation water losses. The optimization of the irrigation time would lead to average application efficiencies of 76%. As a consequence, the main effect of increasing the on-farm irrigation time is to increase the irrigation interval.
Isidoro et al., 2004	La Violada irrigation district, Spain	This article is about diagnosis of water management at the irrigation district level is required for the rational modernization of the irrigation schemes and the subsequent increase in the efficiency of water allocation and application. And study objectives were to: (i) evaluate the global irrigation performance in the 5282 ha La Violada surface-irrigated district (Ebro River Basin, northeast Spain), and (ii) estimate the water that could potentially be conserved under two scenarios of modernization and three increased irrigation efficiencies.
Lorenzo et al., 2004	Second Bangkok International Airport, Thailand	New innovative applications of PVD (Prefabricated Vertical Drain) and dual function geosynthetics in soft Bangkok clay have been presented in this paper in addition to the commonly practiced versatility of PVD as artificial drainage path in the consolidation of clay soils.
Causape et al., 2004	Ebro River Basin, Spain	This paper was focused on diagnosing the quality of irrigation and to prescribe recommendations aimed at improving irrigation management and reducing the off-site pollution from a 15,500 ha irrigation district located in the Ebro River Basin (Spain). Three hydrological basins were selected within the district where the main inputs (irrigation, precipitation, and groundwater inflows) and outputs (actual crop's evapotranspiration, surface drainage outflows, and groundwater outflows) of water were measured or estimated during a hydrological year.
Rosenzweig et al., 2004	Argentina, Brazil, China, Hungary and Romania, and the United States	It reports on methods of linking climate change scenarios with hydrologic, agricultural, and planning models to study water availability for agriculture under changing climate conditions, to estimate changes in ecosystem services, and to evaluate adaptation strategies for the water resources and agriculture sectors. For most of the relatively water-rich areas studied, there appears to be sufficient water for agriculture given the climate change scenarios tested. In Southeastern Brazil, future water supply for agriculture appears to be plentiful.

Table 1. Contd.

Sithole, 2003	mid-Zambezi	This paper focuses on irrigation, water management, and development in Chitsungo ward in the Zambezi valley. For practical purposes of policy-making, planning and implementing a people-friendly irrigation project, this paper highlights some of the overlooked cultural and social processes of change, together with the consequences and outcomes of such interventions.
Todorovic and Steduto, 2003	The Apulia region, Italy	This work describes the development, operational functionalities and spatial modeling applications of a Geographic Information Systems (GIS)-based irrigation management system, to be used by irrigation consortia and local governmental institutions. The irrigation water management system runs on different scales of both irrigation (from irrigation field to irrigation consortia) and administrative (from municipality to region) units.
Cai et al., 2003	Aral Sea Region, Central Asia	This report presents sustainability analysis for irrigation water management in the Aral Sea region. Sustainable irrigation water management should simultaneously achieve two objectives: sustaining irrigated agriculture for food security and preserving the associated natural environment. The current status of irrigation water management in the Aral Sea region demonstrates the Aral Sea disaster as a prime example for unsustainable irrigation development.
Bandara, 2003	Sri Lanka	In this research study, NOAA satellite data were used to assess the performance of three large irrigation systems in Sri Lanka during the 1999 dry season (from April to July): Polonnaruwa, Kirindi Oya and Gola Oya irrigation systems. Also the paper suggests that remote sensing measurements can help objectively analyze irrigation processes throughout the country and at a monthly time step.
Khanna et al., 2003	Southeast Australia	The design and management guidelines were developed using a two-dimensional computer simulation model (COBASIM) for contour basin layouts in the study. The computer model was used to simulate and analyze the performance of single- and multiple-basin layouts in response to key design variables including aspect ratio, inflow rates, microtopography, vertical interval between basins and number of interconnecting drainage outlets.
Pereira et al., 2002	Review	The paper proposes some concepts relative to water scarcity, concerning aridity, drought, desertification and water shortage, as well as policies to cope with these water stressed regimes. Conceptual approaches on irrigation performances, water use and water savings are reviewed in a wide perspective. The suitability of irrigation methods for using treated wastewaters and saline waters is analyzed.
Renault, 2001	General	The paper examines how a re-engineering approach can benefit irrigation management and canal operations and, hence, how the current, acute challenges to water management (e.g. competition, multiple users and protection of the environment) can be addressed. By comparing the irrigation and the industrial sectors, a re-engineering process includes re-thinking all the processes involved in irrigation management. For canal operations, the approach should focus on an improved physical assessment of the infrastructure.
Hiscock et al., 2001	Three low land rivers, eastern England	This study shows the flow records of the Rivers Bure, Nar and Wensum in eastern England have been examined with the aim of identifying long-term changes in flow behavior relating to variations in rainfall amount, land use, land drainage intensity and water resources use.
Christen and Spoor, 2001	Murrumbidgee Irrigation Area, South East Australia	Mole drains in flood irrigated agriculture can rapidly fail due to high flows of irrigation water entering the mole channel through the soil cracks formed during the moling process. This research study is taking place about improvement mole drainage channel stability of irrigated area. This paper also presents the trial results indicate that mole channels installed with angled leg plough have the potential for much greater stability on sodic and swell/shrink soils than moles installed with current straight leg mole ploughs.

Table 1. Contd.

Sarwar et al., 2001	Punjab province, Pakistan	The response of three water delivery schedules, representing various levels of flexibility, on crop production, water saving, soil salinization, drainage volumes and water table behavior was examined. A physical-based transient soil water and solute transfer model, Soil–Water–Atmosphere–Plant (SWAP), was used as a tool. In the present water deficient environment of the Indus basin, the benefits of the on-demand schedule and a fixed schedule are comparable.
Mohan and Arumugam, 1997	USA, Canada and Europe	This paper reviews recent applications of expert systems (ES) in the domain of irrigation management. The ES development has mostly been confined to USA, Canada and Europe, whereas in developing countries, the application of ES technique to irrigation is insignificant. The practical evaluation is a necessary step in the successful implementation of any ES in irrigation management. ESs of the expert system proper class are best suited to narrow domain problems where primarily heuristic knowledge is used to make decisions.

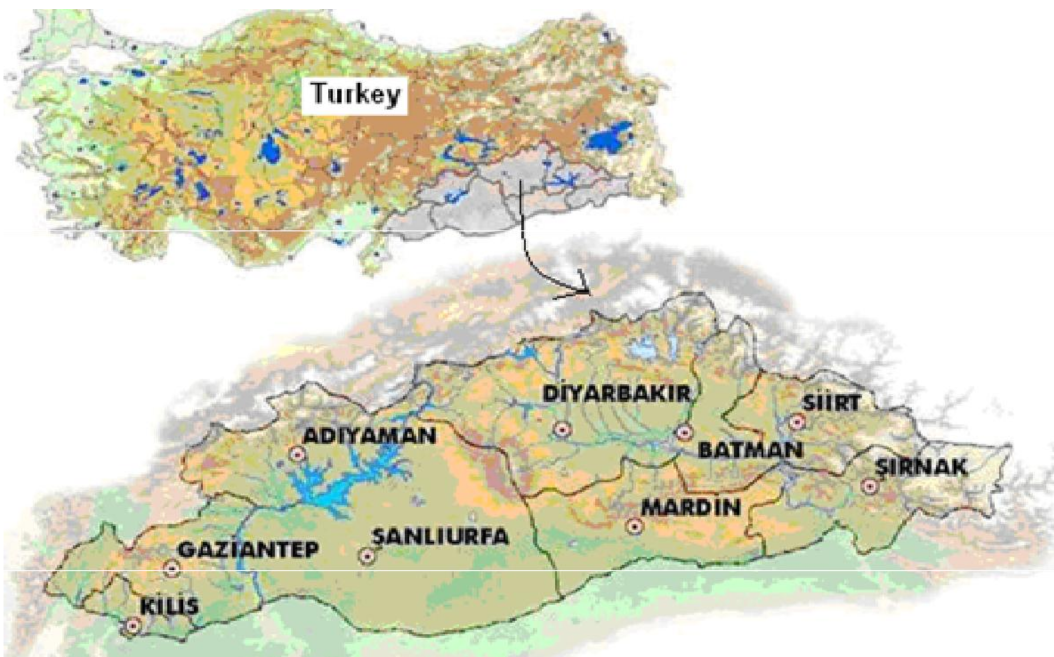

Figure 1. Turkey and GAP region (GAP, 2006).

land (Figure 1). Two of Turkey's major waterways, the Euphrates and the Tigris Rivers, pass through the GAP Region. With 22 dams and 19 hydroelectric power plants, irrigated agriculture in a 1,762,000-ha area is planned in the framework of GAP, as well as the production of 27 billion kilowatt hours of energy per year with a capacity based on 7476 megawatts (GAP, 2003).

GAP water resource development projects

Various studies have been conducted on the Euphrates and Tigris River Basins and on water resources from other small basins within GAP. The overall project principally consists of a package of thirteen large projects on the two large basins and their branches, and fifteen independent projects.

Hydrological data from the water resources of the Euphrates and Tigris Basins

After the application of various models in studies carried out to determine the water potentials of the Euphrates and Tigris Basins, hydrological data from the years 1937-1993 were collected for the Euphrates, and from 1946-1994 for the Tigris.

Regarding the total water potential of the Euphrates Basin, values tend to range from slightly below 30 billion m^3/year (approximately 90% of which is within the borders of Turkey) to several billion m^3/year above. As for the total water potential of the Tigris Basin, values generally range between several billion m^3/year above or below 50 billion m^3/year (approximately 20 billion m^3/year of which is within the borders of Turkey) (Shahin, 1989; Kolars and Mitchell, 1991; Star and Stoll. 1987; Beaumont, 1992; Kutan, 1996; Bilen, 1997, 2000; Akmandor et al., 1994; Foreign Affairs, 1996;

Table 2. Irrigations of Euphrates basin (DSI, 2006).

Name	Irrigation area (ha)	Water source	Irrigation method
Urfa- Harran	141 835	Atatürk Dam	Gravity
Mardin-C.pınar	185 639	Atatürk Dam	Gravity
Mardin-C.pınar	149 000	Atatürk Dam	Pumping
Siverek-Hilvan	160 105	Atatürk Dam	Pumping
Bozova	69 702	Atatürk Dam	Pumping
Suruç-Baziki	148 500	Atatürk Dam	Pumping
Çamgazi	6 536	Çamgazi Dam	Gravity
Gömikan	7 762	Çamgazi Dam	Gravity
Koçali	21 605	Çamgazi Dam	Gravity
Büyükçay	12 322	Çamgazi Dam	Gravity
Atatürk Dam	29 599	Çamgazi Dam	Gravity
Pazarcık	71 598	Kartalkaya Dam	Pumping
Hanca ız	7 330	Hanca iz Dam	Gravity
Kayacık	13 680	Kayacik Dam	Gravity
Kemlin	1 969	Kemlin Dam	Gravity
Birecik Dam	66 021	Birecik Dam	Pumping
Nusaybin	7 500	Yer alti Suyu	Pumping
Akçakale	15 000	Yer alti Suyu	Pumping
Ceylanpınar	9 000	Yer alti Suyu	Pumping
Hacıhıdır	2 080	Hacihidir Dam	Gravity
Dumluca	1 860	Dumluca Dam	Gravity

Özi , 1994; Özi et al., 2000a, 2000b).

With GAP facilities on the Euphrates and Tigris Rivers through which more than 53 billion m^3 of water per year flows within the country's borders, 29% of Turkey's total water potential has been brought under control (GAP, 2006).

GAP irrigation systems

In the GAP Region, more than 1.1 million ha of the planned irrigation is in the Euphrates Basin, while more than 0.6 million ha is in the Tigris Basin. Irrigations in the GAP area exhibit variation due to features such as dimensions, distribution method (pumping or gravity), hydraulic slope, and the number and condition of control structures (Tables 2 and 3).

The present irrigation total in the Euphrates Basin is 175,571 ha, while that in the Tigris Basin is 38,353 ha (DSI, 2006).

The main channel, backup channels, and discharge channels are of trapezoidal cross- section and with concrete lining. The smaller backup, tertiary, and distribution channels, on the other hand, are generally prefabricated canals placed on supports above ground level at heights that vary according to topography.

The control structures described as follows are generally used in diverting currents from the main channels to backup channels and from backup channel to tertiary channels:

1. As in the Urfa-Harran irrigation system, diverting from the large main channels to backup channels is generally achieved by regulators consisting of sluice gates and valves (radial and vertical). These are controlled manually or automatically.
2. Diverting from the main or backup channels to the tertiary (small backup) channels is accomplished by systems which consist of perpendicular valve combinations from constant head orifice turnout structures and backup channels. Essentially, a constant head orifice consists of a double-valve system located on constant level pools. Because these structures' foundation elevations are fixed, the required flow amount depends on the difference in constant water head forming between the main or backup channel and the constant head orifice pool.

One sample will be taken from each basin having characteristics representative of GAP irrigations in general, and more detailed information on them will be provided. Somewhat greater detail will be provided for the Urfa irrigation, from the Euphrates Basin, and the Çınar-Göksu irrigation, from the Tigris Basin. The criteria used in the selection of these two irrigations are as follows:

i. The existence of data on both channel systems, and of sufficient data on both irrigation networks chosen.
ii. In terms of size, the Urfa irrigation represents large networks, and the Çınar-Göksu represents small networks.
iii. Despite the existence of many control structures in the Urfa irrigation, there are none in Çınar-Göksu.

The irrigation systems and drainage requirements in the Euphrates and Tigris basins within the GAP were analyzed in general on the basis of projects. Based on the data collected in these analyses and on field observations from the point of view of existing requirements, an attempt was made to determine potential operational issues by examining water resources, irrigation systems, and water distribution methods, as well as water control structures, valves, the efficient use of water and drainage requirements and systems.

In order to eliminate these problems and ensure that similar problems are not experienced in future projects, recommendations are made regarding requirements on subjects such as administration and operation that will achieve optimum use of resources, institutional and legal contents, social and cultural behaviors, environmental interaction potential and economic needs. The

Table 3. Irrigations of Tigris basin (DSI, 2006).

Name	Irrigation area (ha)	Water source	Irrigation method
Tigris Right Side	52 033	Tigris Dam	Gravity
Tigris Left Side	74 047	Tigris Dam	Pumping
Batman Left Side	9 574	Batman Dam	Gravity
Batman Right Side	18 758	Batman Dam	Gravity
Batman Left Side	9 142	Batman Dam	Pumping
Tigris Right Side	200 000	Silvan Dam	Gravity
Tigris Left Side	57 000	Silvan Dam	Pumping
Garzan	60 000	Garzan Dam	Gravity
Nusaybin-Cizre- dil	89 000	Cizre Dam	Pumping
Silopi	32 000	Hezil Dam	Gravity
Devegeçidi	7 500	Devegeçidi Dam	Gravity
Silvan I. ve II.	8 790	Silvan Regulator	Gravity
Silopi-Nerdü	2 740	Nerdü Regulator	Gravity
Çınar-Göksu	3 582	Göksu Dam	Gravity
Garzan-Kozluk	3 700	Garzan Dam	Gravity

general evaluation framework is shown in Table 4.

RESEARCH FINDINGS AND DISCUSSION

Problem findings obtained in this study are summarized in Table 5. Solution recommendations for these problems are thus presented along with their evaluation.

Evaluations of water resources, water structures, and irrigations

A structural approach to water resources

Measures aimed at preservation should be taken, such as bringing dam lake areas under absolute protection, education of the people living in these areas, constant inspections in connection with the administrative structure to which the areas belong, and dissuasive sanctions. Building development, industrialization, and the discharge of wastewaters into the dam lake area must be prevented. Evaluation of the dam lake areas with regard to various usage goals and expected benefits is particularly important with regard to the system's sustainability.

Nighttime irrigations

The majority of farmers in areas where the irrigation systems are located carry out nighttime irrigation. In light of the fact that water not used by the farmers generally runs into drainage channels and that problems may arise with neighboring countries, different rates should be charged in nighttime and daytime irrigations.

The construction of reservoir areas on the main channel

The construction of these reservoirs will increase the start- up investment cost, and areas for their construction need to be designated. It is necessary to conduct additional studies and research in order to determine the profitability ratio between increased irrigation production and the cost of reservoir construction. Although alternatives requiring pumpage are theoretically possible, they are never of an acceptable value outside of situations where no other alternative is available. Over time, this alternative may become acceptable if farmers incline towards pressure irrigation systems.

The construction of regulation pools along the channel

In order to prevent fluctuations that might occur between source control and downstream distribution systems in irrigation systems operated by the conditional demand method, the use of regulation pools is of the utmost importance in order to prevent water loss. In irrigations in the GAP region in which distribution is carried out with open channels, water conservation will be achieved as well as increased irrigation efficiency in fields. For example, "In periods when water demands increase to maximum, in a distribution system in which the nighttime irrigation water demand is not of six hours duration, the unstored water loss will be 20 m^3 per hectare" (Halcrow-Dolsar, 1993).

Table 4. General evaluation scheme of irrigation and drainage at Euphrates and Tigris Basins within GAP.

Evaluation content	Proposal content
Evaluation for the water resources, hydraulic structures and irrigation	Structural approach to water resources Night irrigations Construction of water storage areas on the main canal Construction of balancing reservoirs along the canal Maintenance of irrigation system Increase of irrigation efficiency Upstream control structures and spillways Downstream control system Automation of control system Monitoring and measuring of flows Half-closed irrigation systems Run and contour lines Construction quality of irrigation system Appropriate usage of irrigation systems according to its technique Structures on the irrigation canal that are not in the scope of project Operation and maintenance of irrigation system
Determinations for the operation and maintenance of drainage system	Determination of drainage necessity Monitoring of ground water level Drainage design criteria Removal of drainage water Operation and maintenance of drainage canals
Determinations for the structural and institutional approach	Organization structure and integrated approach Collection of works done at database Organization of water union associations Billing of irrigation water Institutional organization structures

Table 5. General characterized problems at GAP water resource systems.

Evaluations for water sources, hydraulic structures and irrigations
Pollution of dam reservoir areas.
Information absence of local people.
Discharge of wastewater to the dam reservoir area due to settlements and industrialization.
Intensively daytime irrigation.
Conveying of unused water to drainage channels by the farmers.
Due to usage of conditional demand irrigation method, water loss and fluctuations occurs between upstream control and downstream distribution systems.
Low irrigation efficiency at irrigation systems.
Insufficient in field improvement services
Usage of inappropriate irrigation systems.
Faults depending on the farmer's education level.
The problem of using multiple ownership fields
Inferior quality of upstream control structures.
Lack of conveying the sufficient water on time to the downstream user's demand during the peak irrigation period.
Lack of automation at control structures.
Lack of sufficient number of appropriate flow monitoring and measuring structures.
Problems occurred due to surface irrigation methods (furrows and border strips) on some extent large areas.

Table 5. Contd.

Most of the irrigation project at Tigris Basin situated at the areas that has significant erosion risk.
Sediments are accumulating at the slope end of the field and damaging the crops while the farmers are making slope down irrigation.
Erosion of the soil in the upper elevations of the field and thus formation of rocky fields due to surface irrigation down the slope.
Cracks and thus percolation of water due to poor compaction of canal portions in backfill.
Inappropriate construction of joints in the lining of canal and thus occurrence settlement, cracking and sliding.
Insufficient concrete protection and/or low concrete quality due to hot and/or cold climate conditions.
Burning and abrasion in time due to hot and decrease at service life of the system.
Technically inappropriate construction of water intake structures such as constant head orifice and outlets on the main canal.
Slipping the fixed legs due to the fact that (because of) not to using plumbing "S" trap while getting water from the canals or getting water by means of breaking the canals.
Excessively water leakage and waste of water due to cracked at small channels, and effect of rising ground water level and salinization happens.
In case of unauthorized water intake structures on main canal, the main canal section getting smaller and flow regime changed.
Stone and sand at irrigation network together with exterior sediment are affecting the flow regime.
Waste materials and dead body of animals at irrigation systems are negatively effecting the flow regime and environmental health.
Determinations related to operation and maintenance of the drainage system
Mandatory determination of drainage requires.
Monitoring of groundwater
Detailing of drainage project criteria.
Mandatorily removal of drainage water.
Necessities related to operation and maintenance of drainage channel.
Determinations for the structural and institutional approach
As GAP Project has multi sectors, the lack of communication and repeated works make waste of supply and time due to insufficient and inactive coordination between the parties.
Disorganization of documentation happened due to many research and work done at different time by various institutes, establishments and persons, in the scope of GAP.
Social, legal, technical and institutional problems are occurs at existing water union associations and this effect the efficiencies badly.
Currently, water tariffs are low and irrigation fees are taken according to crop type.
Institutional organization problem

This means that the daily water loss in the Harran Plain irrigation alone (151,700 hectares) will be 151,700 × 20 = 3.034 million m^3. The construction of regulation pools will not only increase irrigation efficiency, but will also have a positive impact on the drainage problem.

Maintenance of irrigation systems

In order for the expected benefit to be achieved in irrigation projects conducted with large investments, and in order to avoid problems that have been encountered in other irrigation areas, it is necessary to determine and implement the operation, maintenance, and management model for irrigation systems that is most suitable to regional conditions.

Measurement results have shown that 50% of the water left to flow from irrigation channels to farming channels in Pakistan does not reach the farmlands (Kahlown et al., 2000).

Water losses in the upper sections of the channels vary according to the structure and condition of the main banks. In comparison with channels with lining, permeability is 2 to 10 times greater in soil banks that have been damaged (Kahlown and Kemper, 2003).

Among the factors causing these types of losses are damage to the channel conjunction areas, overflows over the banks, dead volume forming due to excessive digging in sections, and high rates of water less in the channels' upper sections (Trout, 1979).

Thus, given the distance between canals and the land, if the water is conveyed to field channels by siphon, it should be possible to achieve an irrigation efficiency of around 80%.

Irrigation efficiency and benefits that will be achieved if this yield is increased

The followings are among the most important reasons that irrigation yields in GAP systems are low: the fact that sufficient services for development in the field have not been offered; the irrigation system chosen; the irrigation methods employed; and farmers' education levels. In order for high-efficiency irrigation methods to be employed, the following may be recommended: immediate completion of the collectivization of the land and the contour, and completion of discharge structures into the ends of the canals by the General Directorate of State Hydraulic Works (DSI) in deficient places, and intermittent tertiary drains.

In DSI irrigations, the average irrigation efficiency has been 45% for many years. If irrigation efficiency increases to 60% at the first stage, then there will be a water saving of 15%. It is calculated that a water conservation of around 17% would lead to the opening of an additional 10% of land to irrigation. With the addition of this water conservation, the area would be approximately 16,770.6 ha.

Cotton agriculture is carried out in nearly all of the plain (92%). If the net income per hectare based on the existent product design is taken to be $1500, the contribution to the national economy that will be achieved with the irrigation of an additional 26,770.6 ha area is calculated as 26,770.6 ha x 1%, 500/ha/year = $40,155,900/year.

Thus, a 15% increase in the irrigation efficiency alone will achieve a savings of over 40 million dollars. If an irrigation efficiency of 85% is achieved, which is the DSI's agricultural criterion, this figure would be $107,216,253/year. It is reported that, with a change in the existent flora pattern and the development of fruit and vegetable agriculture, which brings a high income, this value would increase 5 to 15 times (Çevik et al., 2000).

When it is taken into consideration that water irrigation will be carried out on a 1,762,000-ha area, the yearly benefit that will be achieved for GAP's entirety by 15% water conservation and high irrigation efficiency will be $466,411,970/year.

It is possible to make the above calculations for other subjects, such as drainage and soil salinization. The purpose of these calculations is to demonstrate the importance of the selection and construction of irrigation systems that will affect water conservation and irrigation efficiency.

Source control structures and sluices

In the GAP systems, the planning of the source control structures in the main and backup channels used in distribution must be evaluated using alternative control mechanisms. Because source control mechanisms maintain the water at a constant level on the source side of the control or regulation structure, they form a constant water load in any backup or tertiary channel outlet in the source. In most irrigation projects, composite-type structures installed by DSI in the backup channels as control structure neither achieve sufficient control, nor have the potential to simplify automatic control. Structures used at the present time consist of vertically functioning valves and constant-threshold sluice gates located on both sides of these. Among the alternatives, fixed long threshold sluices (duckbill or diagonal sluices, diagonal side weir), radial control valves (Amil), and moving broad-threshold sluices (Romjin) can be cited as examples.

Downstream control system

The planning and implementation of downstream control systems along with source control systems and intermediate storage pools would be appropriate for the downstream regions of long distribution networks. If the consumers at the downstream use the water with a demand system, downstream control will achieve a more equitable distribution of the water. Reserve water volume collected in intermediate storage facilities may be used during peak irrigation periods according to demand, at a sufficient amount to meet the demands of downstream users.

Automation of control structures

It is important that control structures be automated and that control be centralized to the greatest extent possible. With priority given to the valves, local control can be set up hydro-mechanically or electro-mechanically. This solution has the potential to achieve great water conservation.

Within the scope of GAP, with the development of modeling and hydrometeorological prediction abilities for the Euphrates and Tigris Basins, studies aimed at systems analysis, modeling, and optimization in basins with multiple dams and multiple purposes should be carried out with goals as general as possible, such that they may be used for various purposes and with various criteria. In this way, with the aid of an integrated water resource planning and administration system that will be created, it will be possible to obtain and evaluate optimal solutions for the configurations of facilities that regulate the use of water resources in the GAP, according to the projected goals and criteria at various developmental stages.

The measurement and observation of flow

The construction of a sufficient number of appropriate flow measurement and observation structures, and the making and observation of sensitive flow measurements on all sides of the irrigation network are an indispensable part of a water administration, and in addition will contribute greatly to increased irrigation efficiency. The increase of irrigation efficiency indirectly leads to the increase of irrigation areas and rates.

Because there are sufficient pressure head in most irrigation networks, these measurement structures can be simple thick-edged sluices. In places where there is no pressure head, or where it is not possible to develop a pressure head, Parshall flumes may be recommended. In main structures, this should be automated by using pressure sensors or stilling pools, and if this is not possible then at the very least mechanical recorders should be used.

In the Euphrates Irrigation Association, with the GAP IBY (Turkish initials of GAP Irrigation and Maintenance) Project, the calibrated canal method has proven satisfactory for measuring flow. During the peak irrigation season of July and August, the general water usage efficiency was at an acceptable level, 80-86%, dropping to 50 to 60% at other times. Tertiary water administration results indicated that water distribution was controlled up to the level where the farmer achieved an 11% savings in water usage during the peak season (GAP, 2006).

Partially covered irrigation systems

Partially covered pipe systems should be used in GAP irrigation systems. “In approximately 94% of the total area, irrigation is carried out using surface irrigation methods (furrow and pan). In the remaining section, pressured irrigation (sprinkler and drip) is used” (DSI, 2006).

Low-pressure closed pipe systems have many advantages in comparison with open channel distribution systems. While the closed pipe system can be implemented on at a slope of less than 1%, the partially covered system can be used on steeper sections of field. Float valves are used in order to control downstream flows in the partially covered system. A system that operates on low pressure, enabling the use of cheaper piping and equipment, reduces the risk of erosion in farm outlets.

Gauges measuring water volumetrically can be installed on the pipes. Overflows, which may occur in open-channel systems, do not occur in this system. Thus, it contributes greatly to water conservation. The area covered by the distribution network ranges from 0.6 to 2% discharge and distribution losses correspond to 10 to 25% of the losses of classic concrete-encased channels. Despite the high cost of construction, the marginal value of maintenance and conserved water makes plain the most advantageous aspect in terms of costs.

When sprinkler and drip irrigation are used instead of traditional irrigation methods, efficiency can be increased from 60% up to approximately 85%. This amounts to approximately a 25% water savings (DSI, 2006).

Furrow lengths and contours

In many of the irrigation projects in the Tigris Basin, the areas are on hilly fields, which may be subject to a serious risk of erosion. Almost everywhere, farmers are observed to carry out irrigation down slope. Thus, sedimentation closes off the lower ends of the fields, and causes damage. In observations, it is shown how stony areas have formed as a result of soil erosion in the upper part of a field as a result of irrigation.

In order to prevent erosion, it is necessary for furrows’ maximum lengths for a given slope to be limited, or for the furrows to be dug more horizontally and parallel to contour lines on a slope so as not to lead to erosion. An alternative solution is field terracing.

Construction quality of irrigation systems

In irrigation systems’ constructions, particularly in open channels, it is of the utmost importance that the compaction of the embankment of the banks of channels passing in a fill be made in a way appropriate for project conditions. If this is not achieved, cracks in channel casing and subsequent water leakages and losses will occur.

In Pakistan, the agricultural sector is the largest consumer of water. Roughly 97% of river waters are used for agricultural purposes (Kahlown and Majeed, 2002). Irrigation systems in Pakistan are made up of channels, distributive conveyance, and field channels. Water conveyance losses in distribution and field channels (25 and 30%, respectively). The most significant cause of these water losses in concrete channels is, rather than lining thickness and the concrete mix and the lack of quality control (Kahlown and Kemper, 2004).

The fact that joint intervals in the lining are not made in accordance with technique in GAP irrigations causes water losses, and over time this can lead to settling, cracking, and slipping.

In addition, as a result of the aforementioned causes, plants grow out of cracks in channel lining and in particular in slopes, and between the joints, negatively affecting maintenance and repair and the flow regime of the channel.

The construction condition of concrete- lined channels is another important subject. Important factors affecting the irrigation channel covering system include the protection of lining in hot and cold climates, and the quality of the concrete. If the necessary care is not taken, then damage resulting from the heat or the cold may occur in concrete, as seen in Figure 2, and corrosion may

Figure 2. Oxidized and cracked concrete lining at Urfa Main canal.

Figure 3. Taking of water by breaking the small channels.

occur in the concrete over time, decreasing the service life of the irrigation system.

In terms of both the determination of the amount of water to be distributed to the irrigation areas, and in terms of water conservation, it is important that constant head orifice outlets, which are water intake structures, and outlets on the main channel be made in accordance with proper technique. This is a factor affecting efficiency in irrigation systems because of both construction and administration conditions.

The use of irrigation systems in accordance with proper technique and procedures

When water is being taken from canals, siphons should definitely be used. Instead of siphons which, in today's conditions are quite economical, attempts are made to take in water with expensive canals, which often break

Figure 4. Sliding of supports at canalette.

(Figure 3) . In addition to having a negative impact on the efficiency of irrigation systems, these canals cause the fixed bases on which they are mounted to slip, adversely affecting the canal network system.

In Figure 4, damage to the networks and slipping in the fixed bases resulting from uncontrolled irrigation due to the breaking of canals is shown. Water flowing and leaking because of damage to the canals significantly loosen the floor on the ground on which the canal bases are mounted, and settling occurs.

Structures made by people conducting irrigation on main irrigation channels

As seen in Figure 5, water intake structures on the Main Irrigation Channels constructed by water consumers outside the project should not be permitted. These structures both constrict the channel cross -section/width, and adversely affect irrigation efficiency by disrupting the channel's flow regime.

The operation of irrigation systems

Irrigation systems are high-cost investments. Management and maintenance services directly affect both the system's lifespan and efficiency for serving the expected goals.

As seen in Figure 5, stones and sand in the irrigation networks, depending on their amount, can adversely affect water flow in conjunction with sediment coming in from outside.

Within irrigation systems, materials such as bags, sacks, tires, and wheels as well as animal carcasses (Figure 6) are undesirable, but occasionally encountered. These may adversely affect not only the channel flow regime, but also human and environmental health.

Figure 5. Unauthorized water outlet at Urfa main canal.

Figure 6. An animal stuck to a gate of a hydraulic structure at Urfa main canal.

Determination regarding the management and maintenance of drainage systems

Determination of drainage needs

One of the most significant problems within the Southeastern Anatolia Project is the determination of drainage requirements and what needs to be done concerning this issue. These two rivers form a complex network of reservoirs and derivations in the GAP. In order for the water to be used productively, it is necessary to reconsider drainage requirements and drainage systems.

Monitoring underground water levels

It is necessary for observation studies on underground water table levels and salinization to be increased and developed. Research programs with the aim of establishing the activity of underground drainage systems in argillaceous soil in the region in general need to be accelerated. New, rapid, and reliable research programs must be created to determine the saline and water patterns within the soil after the initiation of irrigation. At present, the total amount of land with salinization or ground water problems is approximately 29,700 hectares.

Even during periods when there is no water need, excessive amounts of water reach the field because the water flow can not be impeded, and as a result, water resources are being wasted, and with the rising groundwater levels, salinization increases from year to year (Yesilnacar and Gulluo lu, 2008).

Drainage planning criteria

The drainage planning criteria used by the DSI within the GAP were developed for application in the western part of Turkey, where rainfall is more frequent. Revision of drainage projects for regions such as the Harran Plain, where a semi-arid climate dominates, may be beneficial. In techniques used to determine drainage flow discharge, soil is taken to be at field capacity in spring. This standard could be used for high-precipitation land, and in fact in projects such as Devegeçidi in the Tigris Basin, where winters are cold.

Removal of drainage water

The following are among measures that may be taken to reduce the amount of drainage water: Using this water for irrigation in planned method, diverting it to agricultural or foresting areas or collecting it in evaporation pools, or diverting it back into the Euphrates and Tigris rivers. The most reasonable of these is dependent on the development of policies that would achieve the greatest possible use of drainage waters in irrigation.

Within the scope of GAP irrigations, because open-channel and surface irrigation methods are in use, the amount of water returning from irrigation is not negligible. As a natural consequence, the reuse of waters returning from irrigations and of drainage waters is an important topic. In addition, it is expected that a water shortage will occur over time in the irrigation of all the areas projected to be included in the GAP.

In one study on this issue, it was determined that the water to be taken from the Ataturk Dam would not be sufficient to irrigate the entire Harran Plain, and the reuse of drainage water along with the use of underground water was planned. In this study, "A one-year water balance report was developed in which 1,595 × 10^6 m^3 of water irrigated a 145,713- ha region, and furthermore in which 44 × 10^6 m^3 of water was diverted to Syria. In order to meet the need, it was planned that 1,219 × 10^6 m^3 of water would be taken from the Ataturk Dam, 253 × 10^6 m^3 from underground water, and that 123 × 10^6 m^3 of water would be obtained through the reuse of drainage water. The quality of new irrigation water thus obtained will range from C2S1 to C2S2

(0.25-0.75 dS/m, SAR<8 to SAR <16)" (Sui Project, 1992).

The management and maintenance of drains

If drainage systems are expected to be beneficial with regard to the design purpose, it is imperative that maintenance be performed regularly. One factor that makes maintenance services difficult is the absence of entry structures that would direct surface waters into the drainage channels. In the current situation, incoming waters find their own way, carving out the drain slopes and causing siltation in the channel bed. Two methods may be used to prevent this. The first is to establish a strip between the channel and the land where plants constantly grow. The second is to build entry structures that collect surface waters and direct the flow inside the channel by means of a water-intake structure or pipe. In observations can be seen also slope flows and plant formations in the Urfa drainage channel.

Evaluations of structural and institutional approaches

Organizational structure and integrated approach

The GAP is a multi- sector project involving a large number of institutions and organizations. The lack of adequate and effective coordination between the interested parties naturally leads to disconnectedness between the institutions and organizations, insufficient communication, misunderstandings, unawareness of projects being carried out, the repetition of projects, and the waste of resources and time. For effective coordination, there is a need for legal regulation in terms of responsibility and authority.

The collection of studies conducted in a database

An extremely high number of studies and projects have been carried out in the GAP at different times by different institutions, organizations, and individuals. Studies that offer benefits from the point of view of requirements such as technique, management, maintenance, administration, and institutional and social planning should be collected in a database, which should be made available to individual, organizational, and institutional users who have need and/or will have need of it.

Irrigation associations

In many of the existent irrigation units, there are social, legal technical, economic, and institutional problems adversely affecting the efficiency of the irrigation systems. The institutional structure of irrigation associations needs to be strengthened in every way.

Charging fees for irrigation water

At present, irrigation fees based on production are extremely low and unrealistic. In addition, there are disruptions in the collection of water fees, and those fees collected fall far short of meeting the operational, maintenance, and repair needs within the irrigation association area. It is of the utmost importance to establish fees for water taken that will meet present-day needs realistically and based on volumetric value.

In this way, because the farmer will pay based on the amount of water used, he will be obliged to reduce his usage. Therefore, the amount of water going to drainage will be decreased, the rise and salinization of the underground water table will be prevented, and water and soil, two natural resources, will be conserved. Charging for irrigation water is of vital importance for GAP irrigations.

Institutional organization

Drainage system designs are inadequate because of the separate duties and responsibilities of the related institutions. At the operational level, on the other hand, there are additional irrigation associations. This many-headedness has a negative impact on the system in general, in many areas, from design to operation. All drainage channels within an irrigation project should be under the responsibility of a single organization. This organization should be DSI, and in order to achieve the expected benefits, reorganization and strengthening is needed in this area.

Conclusions

In the GAP, agriculture stands out as the most basic compelling sector. The benefits expected from agriculture are dependent on water resources and irrigation systems. As a natural consequence, this includes the implementation of advanced, efficient systems and models that achieve water conservation, and the rehabilitation of existent systems in a manner that will meet the needs. The GAP area is located in a semi-arid climate zone. Therefore, the conversion from open-channel irrigation systems to enclosed, pressurized irrigation systems will yield significant benefits from many perspectives. Aside from evaporation, water losses in the irrigation structures, operational errors, the determination and pricing of the water used, measurement of the system's efficiency, and the increase of irrigation productivity will result in a decrease in the amount of water going to drainage, and aid in the solution to problems related to this, and ultimately will achieve significant, positive contributions.

Absolute preservation of resources used for multiple purposes is necessary, as well as the prevention of pollution and of lake areas' filling with erosion. With this goal, absolute preservation zones must be established in the regions where the dam lakes are located, with the aid of a development plan aimed at preservation, and these plans must be actively implemented.

If irrigation systems and drainage requirements are considered as a whole based on optimization with an internally-integrated approach in terms of needs and feasible models, the benefits expected from the GAP will increase, and will have significant benefits not only for the regional and national economies, but also for the globalizing world economy.

Consumers' preservation of irrigation systems located in the GAP area is an extremely important subject. One of the most important duties with regard to this falls to the Irrigation Association. In particular, it is absolutely necessary to prevent water users from interfering in the system in ways not planned and contrary to proper technique. In connection with this, farmers must be educated as the necessary measures for water consumption are taken, and legal action must be taken against those who do not comply with these.

Water resource planning includes all activities that will achieve the most efficient use of water resources in the direction of the desired goals and in the framework of the projected criteria. The most essential parts are those dealing with system optimization. For this reason, the planning stage in projects must have continuity (especially with the assumption that a particular time frame is optimal). Therefore, planning must be dynamic, such that it can be continuously renewed (Yenigün and Gerger, 2006).

It is especially thought that the experience obtained in this study may be a guide and an example in other similar projects worldwide, because water is a unique vital element that is not exclusive to any region, and because water resources are not endless. Both the lack and excess of water create serious problems. It should not be forgotten that water, if not used according to procedure and in accordance with the purpose, will bring harm rather than benefit. The solution is the presentation of an optimum and feasible water model that takes into consideration the interactions of all components of the system.

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