Sustainability of Effective Use of Water Sources in Turkey

Olcay Hisar, Semih Kale and Özcan Özen

Abstract Water is the most essential natural resource for sustainable development of human society as well as the most vital source for viability of human and natural systems. However, natural water resources had been threaten by increase of temperature due to global warming and improper usage, causing health problems both for human and aquatic environment. On the other hand, global water consumption has increased because of growth in population and increase of the per capita water use. To make adjustments to the water utilization, the need is allocating limited water resources and increasing local water use efficiency. Sustainability is a relative concept that must be applied in an environment undergoing multiple changes that are occurring over different temporal and spatial scales. Contrary to the popular belief, Turkey is not a water-rich country. Turkey depends on its water resource systems for survival and welfare. Therefore, new studies have been forced in the rehabilitation and sustainable usage of water sources recently in the world. In this paper, information about their current state and future projections is given based on many published data.

Keywords Water resources · Sustainability · Global warming · Climate change · Turkey

1 Introduction

Sustainable water resources systems are designed and managed to best serve people living today and in the future. The actions society take now to satisfy our own needs and desires should depend not only on what those actions will do for us but also on

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W. Leal Filho and V. Sümer (eds.), *Sustainable Water Use and Management*, Green Energy and Technology, DOI 10.1007/978-3-319-12394-3_11

how they will affect our heirs. This consideration of the long-term impacts on future generations of actions taken now is the core of sustainable development. While the word "*sustainability*" can have different meanings for different people, it always includes a consideration of the welfare of those living in the future. While the debate over a more precise definition of sustainability will continue, and questions over just what it is that should be sustained may remain unanswered, this should not delay progress toward achieving more sustainable water resources systems.

The concept of ecological and environmental sustainability has largely resulted from a growing concern about the long-run health of our planet. There is increasing evidence that our present resource use and management activities and actions, even at local levels, can significantly affect the welfare of those living within much larger regions in the future. Water resource management problems at a river basin level are rarely purely technical and of interest only to those living within the individual river basins where those problems exist. They are increasingly related to broader societal structures, demands, and goals.

The containment of sustainability criteria along with the more common economic, environmental, ecological, and social criteria used to evaluate alternative water resources development and management strategies may identify a need to change how we commonly develop and use our water resources. We need to consider the impacts of the change itself. Change overtime is certain; however, how the change will be like is the challenge. These changes will affect the physical, biological, and social dimensions of water resource systems. An essential aspect in the planning, design, and management of sustainable systems is the expectation of change. These includes changes due to geomorphological processes, the aging of infrastructures, shifts in demands or desires of the changing society, and even increased variability of water supplies, due to the changing climate. Change is an essential feature for the development and management of sustainable water resources.

Sustainable water resources systems are designed and operated in ways that make them more adaptive, robust, and resilient to an uncertain and changing future. They must be capable of functioning effectively under conditions of changing supplies, management objectives, and demands. Sustainable systems, like any others, may fail, but when they fail, they must be capable of recovering and operating properly without undue costs.

Given the ambiguity of what future generations will want, and the economic, environmental, and ecological problems they will face, a guiding principle for the achievement of sustainable water resource systems is to provide options to the future generations. One of the best ways to do this is to interfere as little as possible with the proper functioning of natural life cycles within river basins, estuaries, and coastal zones. Throughout the water resources system planning and management processes, it is important to identify all the beneficial and adverse ecological, economic, environmental, and social effects—especially the long-term effects—associated with any proposed project (Loucks and van Beek 2005).

Being one of the most important key elements influencing social health, well-being, the preservation of ecosystem, and the economic development of a country, water is a natural, yet limited resource. Due to global warming effects and its adverse impact on climate, many countries of the world will face serious shortages on this limited resource. Thus, planning, management, and preservation of water on a basin-wide scale are essential (Eroğlu 2007).

2 Current Situation of Water Resources

Population growth, industrialization, urbanization, and rising affluence in the twentieth century caused in a substantial increase in water consumption. While world's population grew threefold, water use increased sixfold during the same period. Water crisis is observed such that over one billion people around the world do not gain enough access to healthy drinking water. Moreover, half of world population does not have enough water and infrastructure for waste water. So, unavoidable water crisis could be foreseen in the whole world. On the other hand, according to a relevant research, contaminated waters cause 80 % of illness in developing countries and death of approximately 10 million people every year (Anonymous 2011).

While the population was 75 million in 2011, in 2012, it is 74 million in Turkey. Fifty-nine percent of the total population of Turkey, which is currently around 74 million, is presently dwelling in urban centers, whereas the remaining 41 % is living in rural areas. The amount of this increase in population was higher in provincial and district centers, while a decrease have occurred in villages and towns. The migration from villages to districts is thought to be effective in the realization of the situation in this way (TURKSTAT 2013).

Turkey is located on the crossroad of Europe and Asia. It has a total surface area of 779,452 km^2, of which 765,152 km^2 is land area and the remaining 14,300 km^2 is water surface. The climate of Turkey is semiarid with extremities in temperature. Climate and precipitation amounts exhibit great variance throughout the country: in the higher interior Anatolian Plateau, winters are cold with late springs, while the surrounding coastal fringes enjoy the very mild-featured Mediterranean climate. Average annual precipitation is 643 mm, ranging from 250 mm in the southeastern part of the country, to over 3,000 mm in the Northeastern Black Sea coastal area (Eroğlu 2007).

Natural precipitation, groundwater resources, freshwater rivers, streams, rivulets and lakes, dams and reservoirs, and marine and estuarine water resources are sources of water resources. Natural precipitation is the key source of water that feeds all the other water resources. Therefore, a decrease in rainfall will affect all the other water resources in a harmful way (Zakari 2013).

The average annual precipitation amount for Turkey corresponds to an average of 501 billion m^3 of water per year (Fig. 1). However, gross water potential of Turkey totals 234 billion m^3 because of discharge groundwater and surface runoff into neighboring countries or the various seas surrounding Turkey, drained surface water in closed basins and evaporation (Eroğlu 2007).

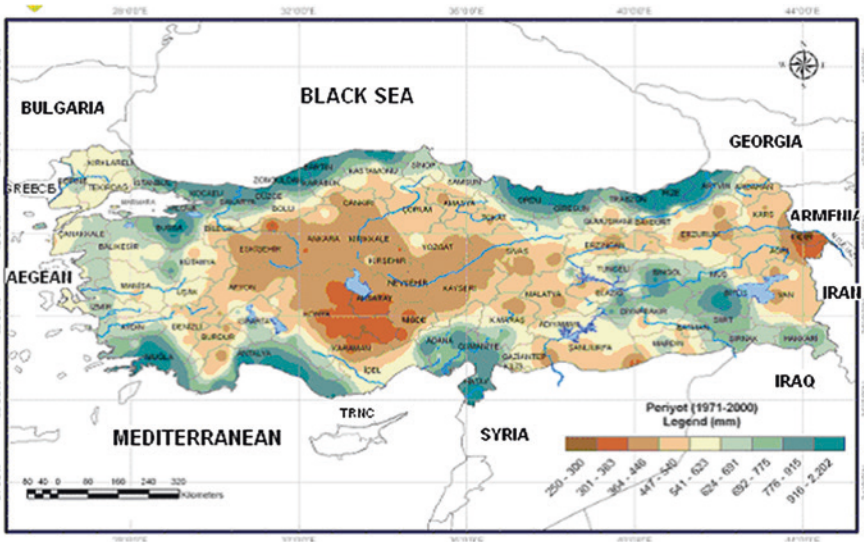

Fig. 1 Geographical distribution of mean annual precipitation (Şensoy et al. 2008)

Rivers are one of the main sources of freshwater. Seventy percent of total easily accessible water is provided by rivers. Moreover, 40 % of the world population depends for its freshwater on 214 transboundary rivers flowing through minimum two or more countries. For example, the Danube and Nile flow through 12 and 9 countries, respectively.

Turkey's water resources can be considered in 25 drainage basins. Figure 2 shows the water potential by drainage basins. The most important rivers are the Firat River (Euphrates) and Dicle River (Tigris), both of which are transboundary rivers originating in Turkey and discharging into the Persian (Arabian) Gulf. The Meric, Coruh, Aras, Arapcayi, and Asi Rivers are the other transboundary rivers (Bayazıt and Avcı 1997). Water potential and water consumption by basins are in Fig. 2.

The Euphrates and the Tigris are two of the most famous rivers in the world. The combined water potential of the two rivers is almost equal to that of the Nile River. Both rise in the high mountains of Northeastern Anatolia and flow down through Turkey, Syria, and Iraq and eventually join to form the Shatt–al–Arab 200 km before they flow into the Gulf. They account for about one-third of Turkey's water potential. Both rivers cross the Southeastern Anatolia region which receives less precipitation compared to other regions of Turkey. Therefore, during the 1960s and 1970s, Turkey launched projects to utilize the rich water potential of these rivers for energy production and agriculture. Turkey contributes 31 billion m^3 or about 89 % of the annual flow of 35 billion m^3 of the Euphrates the remaining 11 % comes from Syria. Iraq makes no contribution to the flow. As to the Tigris, the picture is entirely different. Fifty-two percent of the total average flow of 49 billion m^3 comes from Turkey. Iraq contributes all the rest. No Syrian water drain into the Tigris.

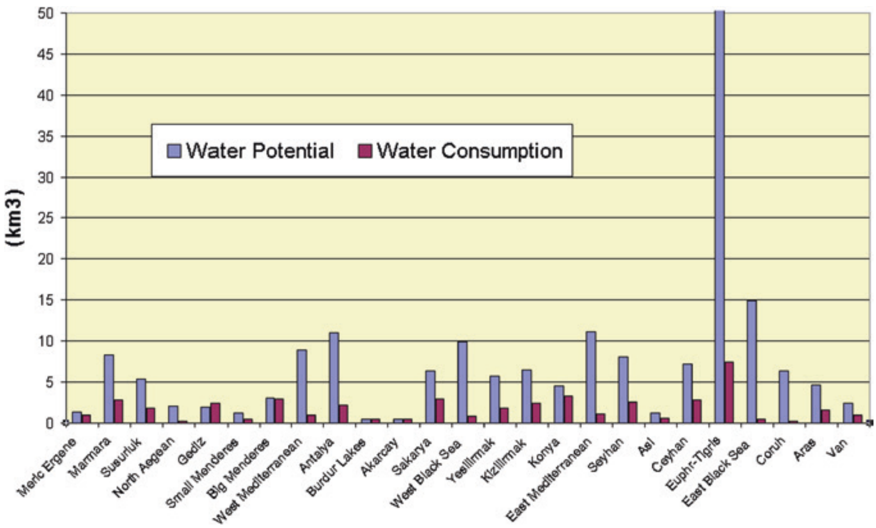

Fig. 2 Water potential and water consumption by basins (SHW 2009)

Southeastern Anatolia Project (GAP) is a regional integrated sustainable development project based on harnessing the water resources of the Euphrates and the Tigris rivers. It consists of dams, hydropower plants, and irrigation schemes and accompanying growth of agriculture, transportation, industry, telecommunications, health, and education sectors and services in this region. A total of 22 dams and 19 hydropower plants are to be constructed as components of GAP; 27,350 GWh/year will be produced (22 % of the country's hydropower potential), with an installed capacity of 7,500 MW and 1,700,000 ha will be irrigated (19 % of Turkey's economically irrigable land). Flow regulation and flood control will also be provided downstream (Anonymous 2011).

Swedish hydrologist Falkenmark (1989) points out that annual capitation of agricultural, domestic–urban, industrial water demand limit of minimum sufficiency is 1,000 m^3 in a country. So, under this limit means poverty in point of water. There are water famines especially in three regions of world at present time. These regions are Africa, the Middle East and South Asia. Similarly, covered by Water Basin Management Strategy in Turkey Aligned with the European Union and the Water Framework Directive, the countries that the amount of available water per capita exceeds 8,000–10,000 m^3 are defined "*water rich,*" less than 2,000 m^3 are defined "*have water scarcity*" and less than 1,000 m^3 are defined "*water poor*" (Akbulak 2011). The global distribution of physical water scarcity according to major river basin is presented in Fig. 3 (FAO 2011).

According to gross potential, water available per capita per year in Turkey as of 2009 was about 1,300 m^3. However, this amount is 3,000 m^3 in Asia, 5,000 m^3 in Western Europe, 7,000 m^3 in Africa, 18,000 m^3 in North America, 23,000 m^3 in South America, and 7,600 m^3 in overall the world (Türkkan 2006). Turkey is in

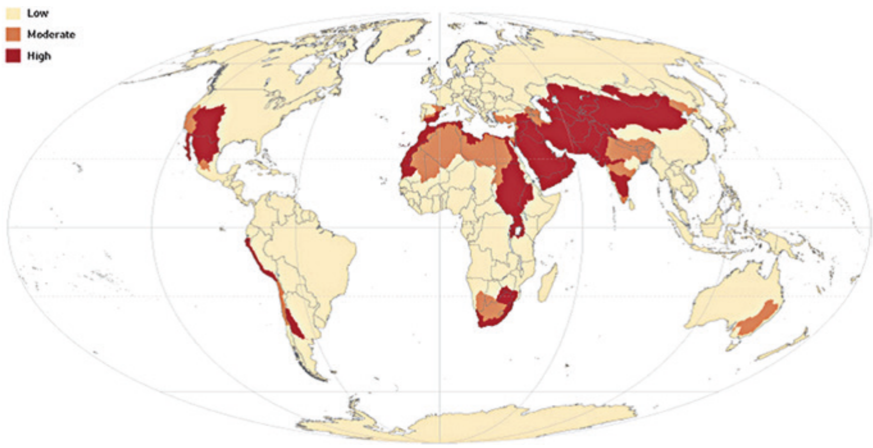

Fig. 3 Global distribution of physical water scarcity by major river basin (FAO 2011)

terms of per capita usable water potential in 182 countries 132nd ranks (Akbulak 2011). Actually, when capitation annual water amount is considered, the common aspect is that Turkey is not a rich country about water resources (Fig. 4).

The widespread nature of the risk of water scarcity may also limit the effectiveness of local solutions–such as acquiring more water from a neighboring country or basin–since many other localities will be trying to get control of the same resource (NRDC 2010). Turkey's policy regarding the use of transboundary rivers is based on the following principles:

- Water is a basic human need.
- Each riparian state of a transboundary river system has the sovereign right to make use of the water in its territory.

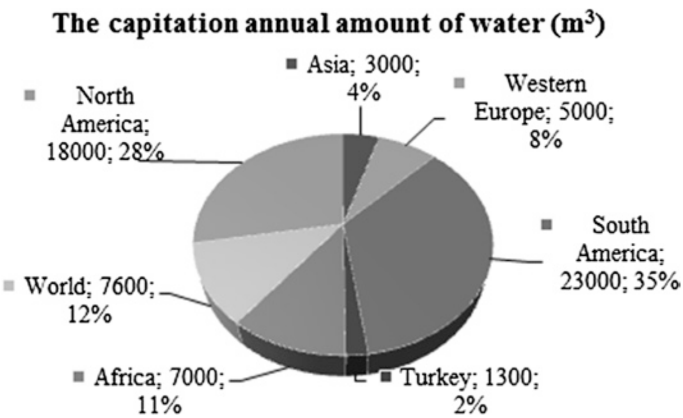

Fig. 4 The capitation annual amount of water (Türkkan 2006)

- Riparian states must make sure that their utilization of such waters does not give "significant harm" to others.
- Transboundary waters should be used in an equitable, reasonable, and optimum manner.
- Equitable use does not mean the equal distribution of waters of a transboundary river among riparian states.

As regards the Euphrates and the Tigris rivers;

- The two rivers constitute a single basin.
- The combined water potential of the Euphrates and the Tigris rivers is, in view of the Turkish authorities, sufficient to meet the needs of the three riparian states provided that water is used in an efficient way and the benefit is maximized through new irrigation technologies and the principle of "more crop per drop" at basin level.
- The variable natural hydrological conditions must be taken into account in the allocation of the waters of the Euphrates and the Tigris rivers.
- The principle of sharing the benefits at basin level should be pursued.

With respect to the utilization of the waters of the Euphrates and the Tigris rivers, Turkey has consistently abided by these principles and continued to release maximum amount of water from both rivers even during the driest summers thanks to the completed dams and the reservoirs in Southeastern Anatolia. For example, 1988 and 1989 as well as 2007–2008 water years were the driest years of the last half century. The natural flow of the Euphrates was around 50 m^3 per second. Yet, Turkey was able to release a monthly average of minimum 500 m^3 per second to Syria in conformity with the Article 6 of the Protocol signed by Turkey and Syria in 1987 (Bağış 1997). Article 6 reads as follows:

> During the filling up period of the Atatürk Dam reservoir and until the final allocation of waters of the Euphrates among the three riparian countries, the Turkish side undertakes to release a monthly average of more than 500 cubic meters per second at the Turkish–Syrian border and in cases where the monthly flow falls below the level of 500 cubic meters per second, the Turkish side agrees to make up the difference during the following month.

The motto of the Turkish government has always been that water should be a source of cooperation among the three riparian states. Turkey is eager to find ways of reaching a basis for cooperation, which will improve the quality of life of the peoples of the three countries. The point of departure should be to identify the real needs of the riparian states (Anonymous 2011).

In 2000s, total water supply (gross water consumption) is expected to be 3,973 km^3/year, and the net water consumption is expected to be 2,182 km^3/year (54 % of the water supply) in the world. This shows that water supply and net water consumption increased approximately threefold since 1950s. It is estimated that water supply and net water consumption reaches 5,235 km^3/year and 2,764 km^3/year, respectively. Nowadays, 59 % of the total water supply and 66 % of total net water consumption are carried out in the Asian continent, where major agricultural areas. It is expected that significant increase in water supply in the African and South American continent in the next year in spite of the decrease in water supply in the European and North American continent (Postel 1999; Shiklomanov 2000).

3 Use of Water Resources of Turkey

The trend of the water supply in Turkey is in Table 1. Quantity of water that supplying/will supply for today and the future was calculated by using population estimates (Table 2). Data related to the water consumption could not be reached. Nevertheless, water consumption can be calculated agreeably that 40–50 % of the supplying water lost in the distribution networks (Karakaya and Gönenç 2007).

When it comes to today, Turkey has water scarcity by the total potable water potential, which is totally 112 billion m^3 and 1,500 m^3/person. On the other hand, 73 % of total utilization in this potential, reaching to 44 billion m^3, have realized in the agricultural sector (SPO 2013).

Regarding to the utilization areas of water, irrigation is first rank (75 %), household usage including drinking water is 15 % and industrial usage is 10 %. Irrigation usage is 30 %, industrial usage is 59 %, and household usage is 11 % in developed countries. However, these rates are different in the less developed and developing countries. Irrigation usage is 80 %, industrial usage is 10 %, and household usage is 8 % in these countries. Turkey is closer to less developed and developing countries from the point of distribution of water utilization rates. When looking for hydroelectric use, Turkey has 433 billion kWh gross hydroelectric potential. It is estimated that the available part of this potential is 216 billion kWh and 33 % is realized. The Euphrates and the Tigris rivers are in the first and second rank in the available hydroelectric potential.

Table 1 The trend of water supply in Turkey (SPO 2001)

Years	Irrigation		Household		Industrial		Total Supply (10^9 m^3)
	Supply (10^9 m^3)	%	Supply (10^9 m^3)	%	Supply (10^9 m^3)	%	
1990	22,016	72	5,141	17	3,443	11	30,600
1992	22,939	73	5,195	16	3,466	11	31,600
1994	24,623	74	5,293	16	3,584	10	33,500
1997	26,415	74	5,520	15	3,710	11	35,645
2000	31,500	75	6,400	15	4,100	10	42,000
2030	71,500	65	25,300	23	13,200	12	110,000

Table 2 The trend of water supply for agricultural activities, industrial activities, and household uses (SPO 2001)

Years	Irrigation (m^3/person/year)	Household (m^3/person/year)	Industrial (m^3/person/year)	Total (m^3/person/year)	Total (L/person/day)	Population (10^6 people)
1997	432	88	59	579	1,586	62,411
2000	482	98	62	642	1,758	65,300
2030	801	283	148	1,232	3,375	89,206

Table 3 Aboveground waters (billion m^3) (Kıran 2005)

Flow	186.05
Consumable annual average amount of water	95.00
Actual annual consumption	27.50

Table 4 Underground waters (billion m^3) (Kıran 2005)

Drainable annual water potential	12.20
Assigned amount	7.80
Actual annual consumption	6.00

Quantity of the aboveground and underground waters and annual water consumption of Turkey are in Tables 3 and 4.

According to these tables, the potential of the aboveground and underground water resources is approximately 200 km^3. About 35 km^3 of these resources is allocated for consumption. It is expected to the amount of consumption reaches 110 km^3 in 2030 in consequence of the calculations considering the population estimates (SPO 2001).

4 Global Warming and Climate Change

All the countries and science world started to ponder about more productive use and development sustainability of available water resources because of *unconscious usage* of natural water resources and *global warming.*

The greenhouse gases in the atmosphere notably carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) prevent the heat radiated from the earth from being escaped into space. Human activities have led to an increase in the concentration of these greenhouse gases in the lower atmosphere which is resulting in global warming and its attended climate change. High solar radiation intensities and global warming, elevated air temperatures, reduced rainfall amounts and occurrence of droughts, unreliable and erratic rainfall events, poor rainfall distribution, extreme climate events–floods and storms, hurricanes and tornadoes are the indicators of the climate change (Zakari 2013).

Due to the human activities, there are now 40 % more greenhouse gases in the atmosphere and there were a few hundred years ago. The Earth has already warmed as the consequence of this, and scientists expect that the next 20–100 years, the world will warm a lot more (Fig. 5).

Global average temperatures are expected to increase by about 2–13 °F (1–7 °C) by the end of the century. According to this scenario, Turkey is among the risk group countries about the global warming (Fig. 6). It was also reported that the temperatures increase to 0.25 °C every 10 years in Turkey, there is fall average percentage 10 in rainfall, when a line is drawn from Samsun to Adana between 2071 and 2100 years, its west part will warm up 3–4 °C, its east part will warm up around 4–5 (Fig. 7). Daily rainfall amount will fall to 0.25 mm,

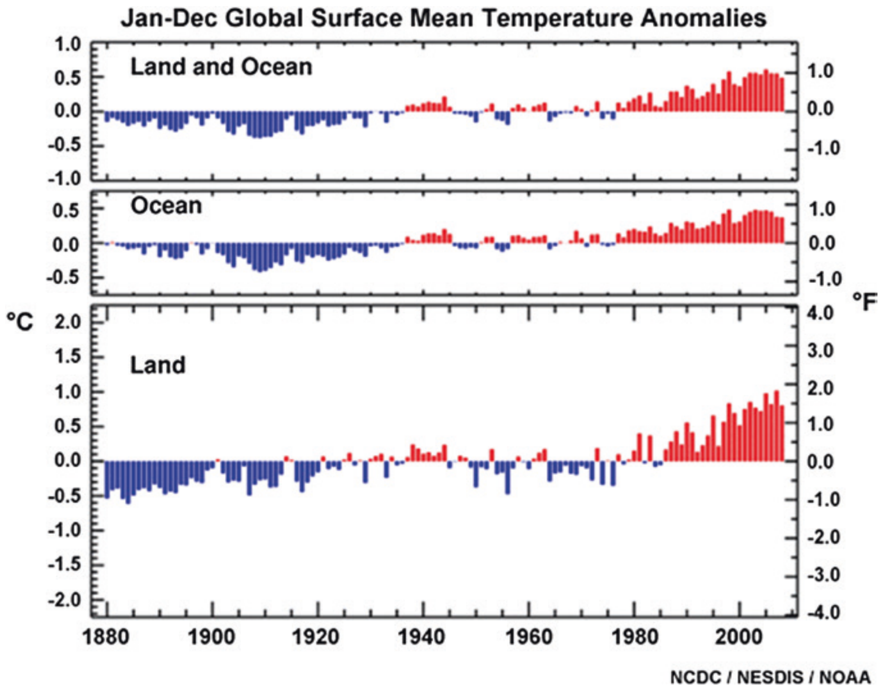

Fig. 5 Global surface mean temperature of land and ocean (NCDC/NOAA 2009)

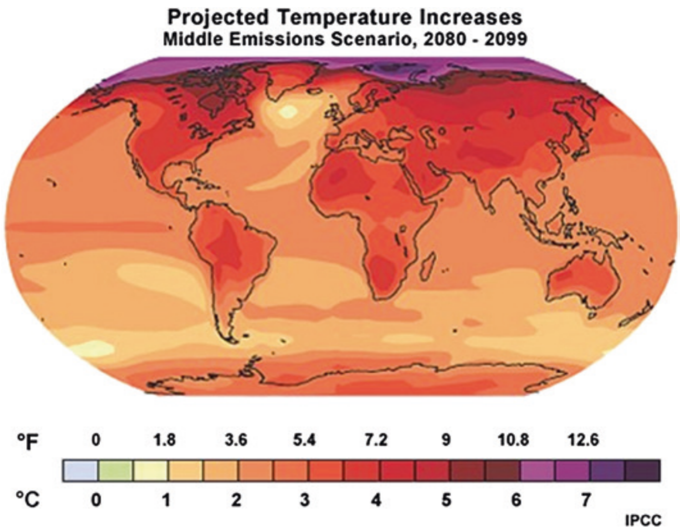

Fig. 6 Projected temperature increases (Gitay et al. 2002)

Fig. 7 Turkey map with a line from Samsun (in the North) to Adana (in the South)

vaporization and evaporation will increase, summer aridity will increase, there will be decline in fish species which live in interior waters depending on reducing in water resources (Atalık 2007). Again, it is made determined a lot of researches in parallel to report of IPCC (Bates et al. 2008); the negative effect of climate change to water resources will be pretty much in 10 years terms to come. Warming and sea level rise will continue and will probably occur more quickly than what we have already seen; even if greenhouse gases are stabilized, this will probably continue to occur for centuries, and some effects may be permanent.

One of the biggest problems of available resources is water pollution. Natural water resources are become dirty and unusable by industrialization, unplanned urbanization, agricultural activities, and polluting resources day by day.

5 Water Resources Management

Water resources management (WRM) is the wholeness that collects all the conditions and methods related to the determination and planning of need concerned with water resources, rational water use, detailed observation, and efficient protection under its framework.

In order to guaranty the supply of water in required place and at required time with sufficient amount and quality and to protect people and their activities from damaging effects of water resources, it is required to develop water resources development projects of different content and scope. A water resources project or system represent the group of measurements and activities that turn toward the aim of development or rehabilitation of water resources for serving into use of human beings and that contains structural or non-structural factors. Major targets of WRM of which the water resource is the basic elements can be listed as below:

- Determination of existing and future qualitative and quantitative characteristics of surface and groundwater resources, evaluation of supply possibilities,
- Determination, planning, and arrangement of community water demands,
- Formation of water balances, collection of factors that will provide continuity of these balances, and development of a long-term strategy for rational use of water resources,
- Monitoring of water resources in order to protect them from pollution and exhaustion,
- Planning water resources systems,
- Modeling of management,
- Designation of processes in water systems and operational conditions,
- Increase of assurance of water from quality and quantity point of views,
- Make it possible the multipurpose utilization of water resources, determination of priorities of these purposes, and reevaluation of allocations,
- Improvement of rational water use,
- Provide sustainability of natural potential of water resources and protect them,
- Provide effective utilization of technical elements (e.g., reservoirs and treatment plants) in order to protect communities from adverse effect of water resources,
- Benefit from managerial elements, economic instruments (e.g., pricing and penalties), laws, and regulations.

One of the most important WRM targets is planning and arrangement of community water demands after determination of existing and future qualitative and quantitative characteristics of surface and groundwater resources. Therefore, the extraordinary project of Turkey which related to inter-country transfers to make up for water deficits have been presented below as a case report.

6 The Northern Cyprus Water Supply Project

Cyprus is the third largest and third most populous island after the Italian islands of Sicily and Sardinia in the Mediterranean Sea (Carment et al. 2006). Also, it is the easternmost island in the Mediterranean Sea (Fig. 8). The island covers an area of 9,250 km^2 and a coastline of 648 km (Kleanthous et al. 2014). It is located in south of Turkey, west of Syria and Lebanon, northwest of Israel, and north of Egypt in the eastern Mediterranean.

As of 2010, requirement for domestic and drinking water of Turkish Republic of Northern Cyprus (TRNC) was 36 m^3/year and is expected to be 54 million m^3/year in 2035 (SHW 2011b). The population of TRNC was 294,906 in 2011. It is expected to be 349,650 in 2035 (TRNC-SPO 2013). Fifty-three percent of the population lives in the cities and 47 % lives in villages. The water is an indispensable resource for people and also it is important for developing social and economic activities (SHW 2011b) and critical to the functioning of human society and ecosystems (Alavian 1999).

Fig. 8 Geographical position of Cyprus Island

Cyprus, politically divided into a Turkish northern region and Greek southern region, now has an even greater problem. Completely surrounded by the Mediterranean Sea, the island is facing a water crisis that has been aggravated by several years of drought and an increased need for water. Progressive climate change has seen a decrease in precipitation levels in Northern Cyprus by more than a quarter over the past 96 years. Four years of drought, which ended in 2008, have made Cyprus the first EU country to run out of water (Anonymous 2009). For years, TRNC has water shortage and this problem must be solved as soon as possible. To solving this problem, it is decided to the most suitable solution was uninterrupted water and electricity transferring from Turkey to TRNC (Fig. 9).

The Northern Cyprus Water Supply Project *(in Turkish: KKTC Su Temini Projesi)* is an international water derivation project designed to supply water for drinking, domestic, and irrigation from southern Turkey to Northern Cyprus via pipeline under the Mediterranean Sea. This pipeline project is original, unique, and the first of its kind project in the world.

TRNC has limited natural resources. Therefore, supplying drinkable, domestic, and irrigation water from Turkey to TRNC will significantly contribute to the development of Northern Cyprus. Seventy-five million m^3 of water to be taken based on a constant flow rate will be transmission annually, from Alaköprü Dam, built on Anamur (Dragon) Creek in the city of İçel (Mersin), by TRNC Water Supply Project. Of the 75 million m^3 water which will be transmission to TRNC through 107 km line in total length, 37.76 million m^3 (50.3 %) will be used for domestic and drinking purposes and the remaining part 37.24 million m^3 (49.7 %) will be allocated for irrigation (SHW 2011a).

Cyprus has the water shortage with regard to the groundwater and surface water due to drought. The project aims to supply Northern Cyprus with water from Turkey for a time period of 50 years. Following the realization of the project,

Fig. 9 A scheme for The Northern Cyprus Water Supply Project

irrigated farming at an area of 4,824 ha in Mesaoria Plains, one of the largest plains and the most valuable agricultural land of the TRNC, will help improve the standard of living in the region.

The project will be carried out by the Turkish State Hydraulic Works (SHW). It consists of the construction of a dam and a pumping station at each on both sides as well as a pipeline of 107 km running mainly under sea. The construction will have four stages: Turkey side, Land Line, Sea Crossing, and TRNC side.

6.1 Turkey Side

Alaköprü Dam is being built in Anamur, İçel (Mersin) Province on the Anamur Dragon Creek at 93 m elevation (Fig. 10). It will have a reservoir holding 130.5 million m^3 water. Thanks to this project, Alaköprü Dam will meet the water requirement in time of forest fire in the forestland. Also, the electricity energy will be produced in Alaköprü Dam. A hydroelectric power plant which has 26 MW power will be built on Alaköprü Dam and it will produce 111.27 million kWh of electricity, annually. In this way, the hydropower plant will contribute to the economy. In addition to this, it will contribute to the region in terms of fishing and tourism.

6.2 Land Line

A pipeline of 1,500 mm diameter and 23 km length will carry 75 million m^3 water of Alaköprü Dam to Anamurium Equalizing Chamber, which will have a

Fig. 10 A scheme for transmission line in Anamur, Mersin, Turkey

reservoir holding 10,000 m^3 and connect to submarine pipeline in 1 km distance for transferring to Geçitköy Dam in TRNC side.

6.3 Sea Crossing

An 80-km-long submarine pipeline of 1,600 mm in diameter 250 m depth in Mediterranean Sea will transfer water from Anamurium Plant in Turkey to Güzelyalı Pumping Station in Northern Cyprus. The pipes will be made of high-density polyethylene (HDPE), a material commonly used to transport water. It will cross a channel as deep as 1,430 m, but the pipeline will be suspended 250 m below the sea surface and each 500 m section of pipeline will be fixed to the sea floor far below (Fig. 11). Earthquakes could destroy anchoring points or a tsunami could break the floating line. With all that, planning engineers considered potential hazards such as earthquakes, tsunami, and the high level of submarine traffic in the area.

6.4 TRNC Side

A pipeline of 3 km will elevate water from Güzelyalı Plant to the reservoir of Geçitköy Dam which is at 65 m elevation, close to the city of Girne. An 80-km-long submarine pipeline will be suspended in 250 m depth in Mediterranean Sea will transfer water from Alaköprü Dam in Turkey to Geçitköy Dam close to the

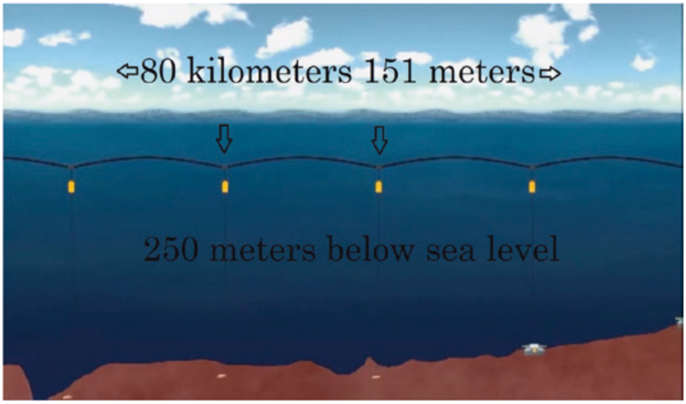

Fig. 11 A scheme for sea crossing of the project

city of Girne in Northern Cyprus (Fig. 12). Geçitköy Dam will have a reservoir holding 26.52 million m^3 water. Also, Güzelyalı Pumping Station will have 5 MW power and Geçitköy Pumping Station will have 16.40 MW power (TSMS 2011).

The pipes will be laid on the sea floor and will be immersed to the seabed by filling with the seawater after combined over the sea by the vessels. The pipes will be suspended 134 pieces suspender under the sea. Such a suspended submarine pipeline of this size does not exist in the world (Anonymous 2013). The pipes to be settled under the sea are smart pipes and the pipeline will have sensors and transmitters mounted to signal any possible faults for repair. The results of experiments showed that the fatigue life of the pipeline system is 125 years and the creep life is more than 1,000 years (Fig. 13).

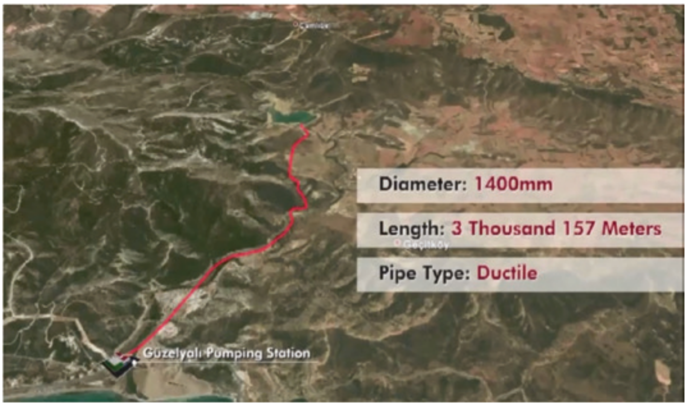

Fig. 12 A scheme for pipeline in Guzelyali Pumping Station and Geçitköy Dam in TRNC

Fig. 13 The HDPE pipes used in the project

Gruen (2000b) pointed out the preconditions for the successful importation of water. He stated that a plan for importation of water must meet four criteria to win general acceptance:

1. It must cause no appreciable harm either by reducing the supply to established users or by causing environmental damage.
2. It must prove to be technically feasible.
3. It must be politically acceptable. Facilities must be physically secure, and the agreement must be structured to insulate the scheme as much as possible from disruption or cancelation in case of political changes in the policies of the supplier country or of transit countries.
4. It must be economically viable.

The source of the water in Turkey, the Dragon River, has an annual capacity of 700 million m^3, about 1/10th or 75 million m^3 of which is to be piped to Northern Cyprus on completion (Anonymous 2013). So, the authors think that there is no risk for Turkey about reducing the resources and amount of supplying water to TRNC.

For solving the water shortage problem in Northern Cyprus, various measures and projects are planned and carried out to increase the amount of water supply and use it more efficiently. One of these projects have been planned to import water from Turkey by a tanker or through the use of large water bags. The purpose of this project is to import freshwater from Turkey by a tanker to meet the demand for potable water by households. The project does not aim to provide water for agricultural use or for recharging the aquifers which badly affected by the seawater intrusion. The first load of water was transported by water bags in 1998 by the Nordic Water Supply, the Norwegian producer of navigable plastic bags. Water bags of

10,000 m^3 capacity could potentially transport 3 million m^3 of water in the first year from Soğuksu River of Anamur in Turkey. Increasing of the water bags capacity to 30,000 m^3 would enable 7 million m^3 of water to be transported annually. This amount is the maximum that the system can allow to be pumped from Nicosia to Gazimagusa and then on to the main reservoirs. Bıçak and Jenkins (1999) explained in detail the total estimated costs for all parts of water import by water tanker are as follows: (1) The cost of water transportation was just US$0.4 per m^3. (2) It increased as US$0.79 per m^3 when substructure investments added. (3) Leakage of 30 % in the distribution system would increase total cost to US$1.13 per m^3 (Priscoli and Wolf 2009). This project aims to only freshwater importing but there is also a great need for agricultural use. So that this amount of the imported water is not enough for providing the water demands not only potable use but also agricultural use in Northern Cyprus due to the volume of water to be transported is limited by the capacity of the tankers. Therefore, when economic reasons were taken into account, the sustainability of this project was not possible.

Another important project purposes to prevent the excessive use of water by way of converting traditional irrigation systems to modern irrigation techniques. Through this project, a large amount of water will be preserved, salination will be prevented, and the quality and efficiency of agricultural harvest will be better. However, this measure will not supply water for potable use. Therefore, all of these measures are not adequate for sustainability of water sources.

There is another option for supplying demand for water desalination. Desalination is a general term for the process of removing salt from water to produce freshwater (Greenlee et al. 2009). Freshwater is defined as containing less than 1,000 mg/l of salts or total dissolved solids (Sandia 2003; Greenlee et al. 2009). Current desalination methods require large amounts of energy which is costly both in environmental pollution and in terms of money (Karagiannis and Soldatos 2008). We believe that there is variability in the cost of water desalination. The water desalination cost comprises of two main categories: The investment costs and the annual operating costs. The investment costs include all the costs related to the installation and appropriate method for the system such as drilling, desalination, and other equipment cost, buildings and installation and commissioning (Karagiannis and Soldatos 2007). Water desalination costs look like location specific and the cost per cubic meter ranges from installation to installation. Because, the water desalination cost depends upon a lot of factors which are the energy source, the desalination method, the capacity of the desalting plant, the level of feed water salinity, and other location-related factors. Karagiannis and Soldatos (2008) stated that the large desalination systems in many countries which could reach a production of even 500,000 m^3/day use mainly thermal desalination methods. In these cases, the produced freshwater cost ranges between US$0.50/$m^3$ and US$1.00/$m^3$. For medium size systems (12,000–60,000 m^3/day), the cost of seawater desalination shows the higher variability between US$0.44/$m^3$ and US$1.62/$m^3$. The cost can be higher which are between US$2.24 m^3 and US$19.11/m^3 in seawater desalination units having a capacity from a few cubic meters to 1,000 m^3. These small systems use mainly renewable energy sources and for this reason, as well as due to lower economies of scale the cost is so high. Seawater desalination plants have a cost which varies between US$0.44/m^3 and US$3.39/m^3 and only when the desalination unit is very small (2–3 m^3 daily production), the cost can increase to approximately US$6.9/m^3. These facts indicate that desalination requires great amounts of energy and this is high-priced way for supplying and sustainable use of water.

The water supply project was approved by Government decree No. 98/11202, dated May 27, 1998. It is being undertaken by a consortium of Turkish and European firms headed by Alsim-Alarko Holding of Istanbul, one of largest conglomerates and experienced construction companies of Turkey (Gruen 2000a). To maintain the sustainability of water import project, the impacts of each step should be evaluated and adverse effects should be mitigated as far as possible. For this objective, the environmental impact assessment (EIA) study is required as a decision aiding tool. For this project, there is also an EIA study carried out by Alsim-Alarko. Alsim-Alarko prepared the feasibility report and HSW approved it on 1999 (Rende 2007). The EIA study is a systematic procedure for classifying and estimating all potential impacts of the project (Lattemann and Höpner 2008). EIA report of this project shows that there is not a high-risk hazard and only a few moderate-risk hazards which are as low as can be implemented at a reasonable level. As a result, the EIA report pointed out the project is feasible. We would like to state that this project will continue to the Southern Cyprus if Southern Cyprus makes a request for supplying water.

Turkey has the capacity to contribute to the establishment of an enabling environment by realizing this project for socioeconomic development of the people in Cyprus which in turn could enhance peace and security in the region. We believe that this project will help to improved management of local demand.

The total investment cost of the project is budgeted at approximately US$320 million consisting of US$20.6 million for structures in Turkey, US$285.5 million for the submarine pipeline, and US$12.2 million for the structures in Northern Cyprus (Anonymous 2012). In case we are calculated the cost of water obtained using water pipeline, it costs US$4.2/m^3 water/a year. This value compared to whole desalination process is acceptable when the cost of maintenance is taken into account. Finally, a solution is still required to the water shortage problem in the island. 500 million m^3 of freshwater is annually flowing from southern of Turkey into the Mediterranean Sea (Bıçak and Jenkins 1999). Once the substructure is completed, it would be possible to export water to the Southern Cyprus firstly and then to the other Mediterranean countries. The benefits and impacts of water supply project should be considered on the scale of regional management plans. These facts indicate that the use of submarine pipeline between Turkey and Northern Cyprus is highly competitive to other methods of supply such as desalination and transfer by plastic bags. The authors point out the best solution is to construct a pipeline between Turkey and Northern Cyprus. Moreover, water shortage and worsening of water quality should be improved by successful water resources management strategies that require combining advanced technologies.

7 Conclusion

While water management and climate change adaptation plans will be essential to lessen the impacts, they cannot be expected to counter the effects of a warming climate. One reason is that the changes may simply outrun the potential for alternative such as modifying withdrawals, increasing water use efficiency, increased water recycling enhancing groundwater recharge, rainwater harvesting, and inter-basin or inter-country transfers to make up for water deficits. However, we use the isolated treatment of any component of water sources system results in suboptimal solutions. For that reason on integrated approach is inevitable for the rational management of water resources.

We believe that there is a great deal of effort in adopting and exercising an integrated approach to water resources management in Turkey. For this purpose, it has been taken into Water Frame Directive of European Union. The two main titles of this directive are as follows:

- "Usage of Sustainable Water" (80/68/EEC) topic (Efeoğlu 2005). To provide continuity of available resources is emphasized and to constitute necessary substructure about financial support is mandated.
- "Aquatic Ecosystem and Prevention of Waters." In other words to prevent pollution in available resources and to avert damage to nature stability is aimed.
- In addition, the two provisions are taken place in regulation of management of resource in 9th development plan of 2007–2013 years. These are as follows:
- "Environmental Protection and Development of Urban Groundwork" title of plan is 159 provision.
- 162 provision points out the agreement on the topic that "United Nations Climate Change Frame Engagement" was approved by the Turkish National Assembly in May 24, 2004.

Some foundations of Turkey unequivocally recognize the value of water resource information as a foundation for integrated management of resources. In this respect, they have lately had some initiatives and will hopefully achieve fruitful results in setting out to:

- implement better instrument for data collection;
- employ modern technology for data transmission, processing, and archiving;
- implement national water information system;
- take advantage of satellites and remote sensing applications for data transmission; analyze and present data using advanced computer models and Geographic Information Systems (GIS).

Acknowledgment The authors wish to thank anonymous reviewers for their insightful comments and constructive suggestions.

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