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IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES OF TURKEY

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Abstract

Climate change is one of the major problems worldwide. Global warming is falling out of balance endangering food, water and energy security and affects the temperature, precipitation and evaporation patterns. As the earth is getting warmer, the significant impacts on fresh water supplies with the potential for disruptive effects on these resources would be expected. Turkey is one of the countries being in the Mediterranean macro-climatic zones, predicted to be affected by many of these adverse effects of climate change especially in water resources. Water is a vital resource for life, so it is important to figure out the situation of Turkey in terms of water resources. This paper investigates the impact of climate change on water resources of Turkey. In this context, current situation and projected effects of climate change on water resources, and measures of adaptation to these impacts were investigated. Results show that in Turkey water is mostly used for human consumption, agriculture sector and industry sector, so basin level is the most appropriate scale for effective water management. In Turkey, adaptation to climate change is largely dependent on extending the knowledge of global warming and water scarcity, rising public awareness on water resources and selecting suitable production and water consumption techniques for all sectors under the different development scenarios.

Keywords: Turkey, water resources, climate change, adaptation

1 INTRODUCTION

The scientific studies of Intergovernmental Panel on Climate Change (IPCC) and other international institutions proved that climate is changing, and global warming is one of the most important problems in our age. Climate change have produced very serious and threatening consequences for all living and non-living beings in the world, such as increase of melting in glaciers, rise in sea level, extinction of plants and animal species, decrease in freshwater resources, disasters such as storms, temperature fluctuations and drought, and deaths due to these negative effects. Another negative consequence of poor nutrition and unhealthy environmental conditions is spreading of diseases among people and other living things. In addition to these negative impacts on the environment and health; the economic and social effects of global warming are also discussed.

The amount of greenhouse gas emissions in the atmosphere must be reduced for slowing down the global warming. According to the IPCC's 5th Assessment Report (AR5), problems such as drought, excessive rainfall, floods, erosion, water shortage and air pollution are becoming increasingly serious. The further negative impacts of climate change on ecosystem services is expected (Demirci 2015). In ecosystem services, water has a privileged place that enable the living beings to continue their lives. Sustainable management of water is one of the most important topics to be addressed in the context of adaptation to climate change.

The aim of this study is to evaluate the sustainable management of water resources in Turkey, in the context of climate change and defining the adaptation strategies to be implemented to get rid of the risks.

2 METHODOLOGY

The research method of this study is to collect the necessary data from related sources and to evaluate opinions and findings of different authors together. In this context different book, journals, articles, project reports, statistical data and web-resources were used as reference materials. The studies and best practices done in Turkey on water resources and climate change adaptation were evaluated. The article was discussed in three chapters. (1) First, the effects of climate change on water resources were emphasized. (2) Then the

problems encountered in water resources due to climate change in Turkey were identified. (3) Recent studies carried out under the heading of integrated water resource management and climate change adaptation in the context of Turkey were examined. Under this chapter especially the project results of Ministry of Forestry and Water Affairs of Turkey (MoFWA) was evaluated. MoFWA developed a Climate Change Impacts on Water Resources Project (CCIWR) for 25 basins to identfy the adaptation measures for water resources under the climate change scenarios with a basin management approach.

In this Project HadGEM2-ES model, MPI-ESM-MR model and CNRM-CM5.1 global climate model, RCP4.5, and RCP 8.5 emission senarios (Fig. 1) were used (MoFWA 2016). Reference and projected periods were selected as 1971-2000 and 2015-2100 respectively. In the scope of the project, climate change projections for all basins were prepared and changes in groundwater and surface water budgets for all basins were predicted. Total annual water demand in all basins were calculated (MoFWA 2016).

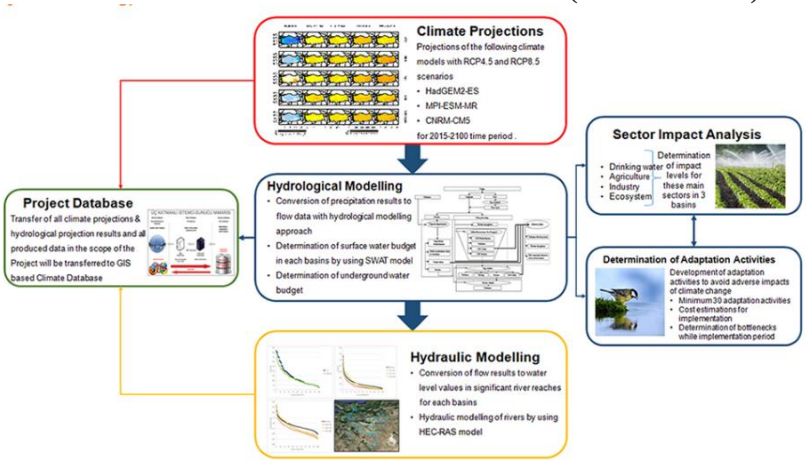

Figure 1. Climate change impacts on water resources project (MoFWA 2016)

According to water potential projections, vulnerability of sectors was analyzed in three pilot river basins (Büyük Menderes, Meriç- Ergene and Ceyhan river basin). Impact analysis studies were performed for drinking and tap water, agriculture, industry, ecosystem, tourism, textil and energy sectors (MoFWA 2016).

3 IMPACTS OF CLIMATE CHANGE ON WATER RESOURCES

Climate change was defined as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." in Article-1: Definitions of United Nations Framework Convention on Climate Change (UNFCCC 1992).

Because of the extreme human activities, today's climate change is called "anthropogenic" climate change (IPCC 2013). According to the data of the United Nations (UN), today the world population has reached 7 billion people. Approximately 50% of this population lives in cities. In 2025, this ratio will reach 65%. The rapid expansion of the cities creates a pressure on natural resources and on the carrying capacity of the surrounding areas of the cities. According to UN Habitat data, cities account for about 75% of world energy consumption and 80% of global greenhouse gas emissions that cause to climate change. Not only urban areas, but also rural areas are polluting the environment, causing climate change and damaging water resources (UN HABİTAT 2016; OECD 2017). Today, due to the migration from the village to the city and the concentration of human activities in the cities; the environmental problems, the increasing pressure of the population on the water resources and the climate change problem have reached a level that cannot be compared with the past.

Water is an indispensable resource in terms of ecosystem services. The climate system and the hydrological cycle are directly related to each other and any change affects both. Therefore, the amount and distribution of fresh water resources will be affected by climatic variables and climate change. The changes in climate cause disruption of the hydrological cycle (EEA 2017). Under normal conditions, the water cycle begins with evaporation from the land or from the oceans and continues to disperse the water vapor in various forms into the cloud form of the atmosphere. The water falls back to the surface as precipitation after this step. When the falling rain is absorbed by the soil or the rain goes to the ocean, the process is completed

and repeated. In the atmosphere, increasingly concentrated greenhouse gases cause following changes on the hydrological cycle and water resources:

- Changes in seasonal amount and distribution of precipitation,
- Changes in balance between snow and rain,
- Increased water loss and reduced soil moisture,
- Changes of vegetation cover in parallel with change in temperature and precipitation,
- Decrease in agriculture and pasture areas exposed to droughts and floods,
- Energy security problems,
- Reduction in amount and quality of water resources,
- Melting of ice masses and spatial contraction of ice cover,
- Risk of fire in many areas,
- Increase in floods in coastal areas,
- Loss of wetlands due to sea level rise,
- Negative impacts on coastal ecosystems,
- Decrease in water use efficiency and perspiration by CO_2 effect in plants,
- Changes of climate zones,
- Increased epidemics and pests due to the high temperatures (IPCC 2013; Venton 2007; EEA 2017).

However, for demonstrating all these effects for a given region, it is necessary to make long-term observations and measurements, and it is necessary to identify other factors affecting climate change and water cycle processes (EEA 2017). The number of migrating people due to climate change or other natural catastrophes is increasing day by day and finding the solutions to the problems become increasingly difficult. It is important to search for adaptation possibilities in the face of climate change and to develop integrated water management techniques (Lehman 2009; Sipahi and Tekin 2016; IPCC 2014).

4 WATER ISSUES LINKED TO CLIMATE CHANGE IN TURKEY

Turkey is geographically located between 26°-45° eastern longitudes and 36°-42° northern latitudes. Turkey connects Asian and European continents. Turkey is surrounded by seas on three sides and establishes a natural relationship between the Black Sea and the Mediterranean. The surface area of Turkey is 780.000 km^2 (Eroğlu 2007; SHW 2012b). According to the Turkish Statistical Institute (TURKSTAT) data, Turkey's population which was 56.47 million in 1990 reached to 80.81 million as of 2017 (TURKSTAT 2018). The population is estimated to reach about 93.50 million in 2050. Turkey is located between mid-latitude climate zone and subtropical climate zone. Because of topographical structure, Turkey has many climate zones, but Turkey is generally located within the Mediterranean macro-climatic zone (MoEU 2016).

Turkey has a semi-arid climate. The topographical characteristics, distance from sea and fluctuations in altitude create climatic variance within short distances. Mediterranean climate featuring hot, dry summers and mild, rainy winters is seen at the southern coastal side. Black Sea climate is mild, rainy in almost all seasons, and seen at the northern coastal fringes of Turkey. Central Anatolia features a steppe climate with little precipitation and daily and yearly temperature values differing significantly because of surrounding with high mountains (SHW 2012b).

In the analysis using the data for years 1960-2010 in Turkey, it was observed that the number of summer days, hot days and the nights increased, and the number of cool days and nights decreased. However, an increase in maximum and minimum temperatures and a decrease tendency in minimum and maximum temperature differences were observed. Moreover, when compared with the values measured in 1981-2010, a decrease of 13% in precipitation is seen with a precipitation rate of 564 mm in 2013. When we look at precipitation levels at regional level, it is seen that the total annual precipitation trends tend to increase in the north of the country and decrease tendency in Southeast Anatolia, Mediterranean and Aegean regions (MoEU 2016; SHW 2012b).

When it is evaluated together with the results of the outputs for all the scenarios, it is generally seen that the temperatures will rise by 2-3°C in average and the precipitation will significantly reduce. For Turkey, an important increase in the number of consecutive dry days and decrease in the number of days with frost is estimated. These predictions will show an upward trend until 2099 (MoEU 2016). Even in scenarios where a global increase in temperature of 1-2°C is predicted, the magnitude of the hazard is better understood in an environment where temperatures are expected to increase excessively. This will mainly affect arid and semi-arid regions under the threat of desertification (Southeast, Central Anatolia, Aegean and

Mediterranean) that do not have enough water (Öztürk 2002). This means for Turkey that the increase in the number, severity, frequency and the effects of the hydrometeorological disasters. In Turkey, the increase in extreme weather events have already began to be seen. Therefore, in Turkey flood management plans and early warning systems were prepared. In this direction, reforestation and erosion control studies are continuing (MoEU 2016).

Considering the issue in terms of precipitation in Turkey, it is observed that especially in the mountainous coastal regions receive abundant rainfall (1,000 to 2,500 mm/year). Inland areas away from the coast are getting less rainfall. In the Marmara and Aegean regions and Eastern Anatolia Platos, rainfall is 500-1,000 mm / year. The inner parts of Anatolia and Southeastern Anatolia receive only 350-500 mm of rainfall annually. The Salt Lake and its surroundings are the region with the least rainfall (250-300 mm/year) per year (SHW, 2012b). In the north of Turkey, total annual precipitation is increasing and in Southeast Anatolia, Mediterranean and Aegean Regions is decreasing. In Eastern Black Sea region, a significiant increasing trend was observed in number of days with heavy precipitation. In the Southeastern Anatolia Region, there is a significiant decreasing trend (MoEU, 2016). The amount of rainfall in Turkey is expected to decrease at 30% ratio in the Mediterranean and Aegean coasts and at 20% ratio in the shores of the Black Sea. 86.5% of the land is vulnerable to desertification in Turkey (Albayrakoğlu 2011). In this way, especially in areas of terrestrial ecosystems, where water and mass losses will be on the agenda, there will be other consequences such as a reduction in freshwater resources and a reduction in the flow rates of rivers. These studies prove that Turkey is under threat in terms of desertification, water scarcity and food security (MoEU 2016; SHW 2012b).

It is expected that the decline in the water potential of the Gediz and Büyük Menderes River Basins in the Aegean Region will reach to 20% by 2030. The increasing CO_2 concentration in the Seyhan River in the Mediterranean Region will affect the major crops such as wheat and maize with temperature and water pressure. In the Black Sea Region, eutrophication has been important problem since the 1980s. Depending on climate change, increase in sea water temperature taking place in Turkey, and even in fish migration routes of certain species of fish lost our coast which is the main source of livelihood of the people (Albayrakoğlu 2011). Due to climate change, the rise in seawater levels leads to erosion, flooding and salt water mixing into fresh waters. Turkey is not a sensitive area in this regard, but the increase in the level of seawater in the past century for the Mediterranean and Black Sea reached 12 cm. The loss due to coastal erosion in the Turkish coast is manifested as a 6% loss in Gross National Product (GNP) (Demirkesen et al. 2008).

While the climate change is continuing at this pace, if necessary water management measures are not taken, water stress problem all over the world will reach a more serious level in the future. At this point, it is important to identify the meaning of water stress concept. While most the world's water resources are salt-water resources, only 2.5% of the water resources are fresh water. While 70% of these freshwater resources are in the form of ice masses in Antarctica and Greenland, the remaining 30% (which corresponds to 0.7% of the world's water reserves) is in a form suitable for consumption (Greenfacts 2018).

These statistical values are important because they show that the world is experiencing shortages of available water. Between 1950 and 1990, the world population increased by more than twice, from 2.5 billion to 5.3 billion. This population is expected to reach 9 billion by 2050 (UN HABİTAT 2016). The fact that the unequal distribution of the world's water is an important problem. Assessment of the presence of water is usually done by the amount of water per capita. For this reason, population is an important criterion in assessing water potential. There are many different approaches to assessment the amount of water per capita. For example, according to the Falkenmark indicator, water stress differention proposed as shown in Table 1.

Table 1. Water stress differentiation proposed by Falkenmark (Brown and Matlock 2011)

Index (m^3 per capita)	Category/Condition
>1,700	No Stress
1,000-1,700	Stress
500-1,000	Scarcity
<500	Absolute Scarcity

Turkey is divided into 25 hydrological basins (Fig. 2). Twenty-five river basins of Turkey were classified as inland river basins with no coasts and river basins with coasts to Black Sea, Mediterranean Sea, Aegean Sea and Marmara Sea.

Figure 2. Hydrological Basins of Turkey (SHW, 2012b)

According to Falkenmark indicator, Turkey is in a position that "a country facing water stress" according to per capita water. The annual amount of usable water per capita is around 1,519 m^3. TURKSTAT forecasts the population of Turkey for 2030 as approximately 100 million people. In this case, the amount of usable water per capita for 2030 will be around 1,125 m^3/year. It should be emphasized that all these estimates assume that existing water resources and potential are transferred to the next generations, as they are now (SHW 2012b). Not only Turkey but also all countries should manage their water resources in a rational way for their future generations. The geopolitical consequences of climate change and its impacts on water resources; local political, social and economic factors as well as the magnitude of climatic differentiation should be considered together in water amanegement studies (Kibaroğlu 2008).

5 WATER MANAGEMENT STUDIES IN THE CONTEXT OF ADAPTATION TO CLIMATE CHANGE IN TURKEY

Turkey is surrounded by sea on three sides, with a fragmented topography and the presence of orographic features and water resources will be affected in varying degrees by climate change. Water need for drinking, agriculture, industry and energy sectors has increased exponentially since the second half of the 20th century in Turkey (Kibaroğlu 2008). In current situation, Turkey's sustainable and usable water potential is 112 billion m^3, its 98 billion m^3 of this amount is surface water, and 14 billion m^3 is underground water. Water consumption is expected to increase to the year 2030 (MoEU 2016; SHW 2012b).

In a study done by the European Environment Agency (EEA) for estimating the water stress level in the European Union and Turkey between the 2000-2030 periods, accordingly, as of 2030, it is expected to experience water stress at a rate exceeding 40% in the middle and western region of Turkey. This ratio is predicted to be between 20-40% in southeast and eastern regions. The studies carried out among the European countries reveals that Turkey has the highest risk of water safety. Scientific studies have shown that 20%, 35% and 50% decrease of surface waters in the basins, respectively, by 2030, 2050 and 2100. It is obvious that population and water use which will increase in the forthcoming period will significantly increase water stress (MoEU 2016; SHW 2012a). Developing a basin-based approache is considered as the most appropriate scale to ensure effective water management. River Basin Protection Action Plans (RBPAPs) should be prepared to provide integrated and controlled water management (Şen 2009; MoEU 2016; climatechangepost.com 2018; Gosling et al., 2011). Water stress level of the countries via the ratio of total withdrawals to total renewable supply in each area shown in Fig. 3 below. When an increase is seen in ratio, the conflict among the water users increase, too (Maddocks 2013).

Turkey is a developing country, which wants to attain to its socio-economic development goals. To support these goals, Turkey has prepared the integrated basin management plans and implemented them to protect water resources. The data on water resources have been collected from the stations of General Directorate of State Hydraulic Works (SHW). In this context, hydrological and meteorological variables such as river flows, groundwater and lake water levels, sediment loads, water quality, amount of precipitation, and evaporations are collected and monitored (SHW 2012b). Beside SHW, there are several public institutions and organizations in Turkey working on the development of land and water resources of 25 river basins. The most efficient solution for overcoming these problems and allow occurrence of water cycle is well-designed Basin Management Plans. Developing a basin-based approach and well-designed

Basin Management Plans are considered as the most appropriate scale to ensure effective water management (Eroğlu 2007).

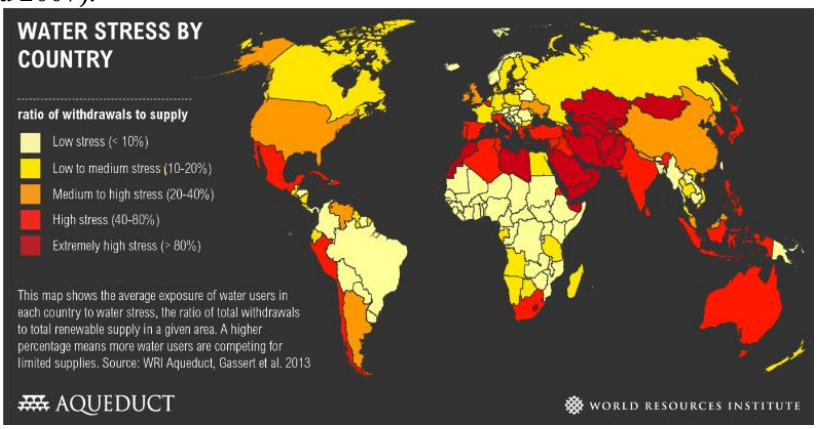

Figure 3. Water Stress Level of the Countries – 2013 (Maddocks 2013)

In the context of Environment Chapter, which was opened on 21 December 2009, Turkey has made negotiations with European Union (EU). Especially in water sector, studies for alignment with the EU acquis were carried out. Basin Management Committees were established in line with the EU Water Framework Directive (WFD). WFD also supports the River Basin Management process, action plans and other protection activities. In WFD, indeed climate change and adaptation were not stated directly (OECD 2017). However, considering the negative effects of climate change on Turkey, Water Management Coordination Committee (WMCC) was established in 2012 for coordination and cooperation on water issues with high-level participation of related Ministries. WMCC determines national level water policies. In addition, Basin Steering Committee established with the presidency of Undersecretary of MoFWA. In 2009, RBPAPs for 25 basins of Turkey were started and they were completed in 2013. Basin Management Committees carry out monitoring of the implementation of RBPAPs and Provincial Water Management Committees at local level with the national level support of Water Management Coordination Committee and Basin Management Central Committee (MoFWA, 2015). The National River Basin Management Strategy (NRBSM) (2014-2023) published in 2014 (Official Gazette dated 04.07.2014 and numbered 29050). The NRBMS has drawn the framework of national water policy in Turkey (MoFWA 2015).

Beside these studies, River Basin Management Plans were prepared between 2011-2013 considering water bodies and typology, classification, objective setting and economic analysis (MoFWA, 2015). With a basin management approach, MoFWA developed a Climate Change Impacts on Water Resources Project (CCIWR) for 25 basins to identfy the adaptation measures for water resources under the climate change scenarios. From the results of these studies, 138 adaptation activities were determined for Turkey and ClimaHydro Database were created by processing all results produced in the project.

In Turkey, because of potential climate change impacts on water resources, water stress will increase in both water resources and sectors because of expected precipitation decrease together with evaporation rate increase. According to these results, considering climate change, mainly three sectors are important for water resources of Turkey: water intended for human consumption, agriculture and industry. The adaptation activites under these titles were determined as shown in Table 2.

Table 2. Determined adaptation activities under CCIWR Project (MoFWA 2016)

Water Intended for Human Consumption	Agriculture	Industry
Decreasing Seepage Loss (Non-Revenue Water) Ratios	Product Design Compatible with Climate Change	Intra-Facility Control
Rainwater Harvesting	Effective Irrigation Techniques	Clean Production
Domestic Wastewater Recovery	Organic (ecologic) Agriculture	Industry Wastewater Recovery

At basin level, in agriculture sector, developing effective agriculture techniques and selection of products compatible with climate change are important. To decrease the use of water by population, the awareness about water resources should be developed. In economic sectors, water friendly and sustainable production systems should be introduced.

6 DISCUSSION

According to the IPCC Assessment Reports and other national and international scientific researchs, the effects of climate change in the Mediterranean Basin, in which Turkey is also taking place, will be at a level that would threat sustainable development and national security of the countries. Turkey is inevitably affected by the global warming. In Turkey, expected adverse effects of climate change are heat waves, increased forest fires and increased floods etc. Because of these negative effects of climate change, developing the measures for basin-based water management is very important for Turkey. According to the results of scientific researchs in Turkey, water mostly used for human consumption, agriculture and industry sectors. For this reason, the river basin scale should be taken as a basis for the management of water resources. River basin is the most appropriate scale, because the basin level includes all sectors, all resource users and all considered effects which have to be evaluated together. As stated above, Turkey is not a water rich country and has water stress considering the annual amount of usable water per capita, which is around 1,519 m^3. The amount of water foreseen to be used in 2023 will be equal to the amount of available water resources now, if these resources are transferred without any destruction. To reduce water stress, water protection and reuse of wastewater should be considered in a sustainable way to reduce water losses and fugitives. Sustainable use of water resources requires maintaining the integrity of the hydrologic system in Turkey. International water policy of Turkey is equitable and fair water use and avoiding significant harm to downstream countries. In Turkey, there is a great deal of efforts in adopting and implementing an integrated approach to water resources management. National studies are carried out towards establishing the legal, scientific and technical capacity and creating expertise in water, food, energy and ecosystem security. International studies are closely followed to understand the main reasons of water stress, which increasingly experienced with climate change. Turkey should maintain and develop these efforts in all aspects for its next generations.

7 CONCLUSIONS

Climate change causes threats to national security and it negatively affects the development of countries. Urgent measures for climate change should be taken. Water should be evaluated as natural resources at which adverse effects are already beginning to appear. Water is also important in terms of ensuring the economic development of countries as well as the continuity of the life of the living beings. The provision of food, energy and ecosystem safety is also water dependent. Climate change and water resources related studies have been carried out not only for protection and effective use of existing resources, but also for identifying the potential impacts of all kinds of activities on ecosystem in a chained manner and the probability of accelerating the climate change. Damages to water resources should be prevented before they occur. Necessary measures should be taken before these damages reach to the level that threaten our individual, national and global security. It should not be forgotten that the policies that are consciously prepared and applied in a steady manner would be a guarantee of a water safe future.

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