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Review Article

Assessing the Impact of Climate Change on Turkish Basins

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Abstract

Climate change, which is caused by the greenhouse gases released into the atmosphere by humans, disrupting the temperature, rainfall, and humidity balance on the earth, makes itself felt more and more every day. The effects of climate change are seen in oceans, habitats, briefly all over the world, from the equator to the poles. With the impacts of these effects, the polar glaciers are melting, the seawater level rises and soil losses increase in the coastal areas, while the severity and number of hurricanes, and floods increase in some parts of the world, while long-term droughts and desertification have started in some other regions. Climate change also affects water resources greatly, and it occurs as a decrease in water resources, forest fires, and related ecological deterioration. As a result of the decrease in the water flow in the river basins, water shortage started in the cities, agricultural production decreased and caused the expansion of arid or semi-arid areas. In this study, the impacts of climate change on Turkish basins were investigated and the measures to be taken were examined. Possible problems to be encountered in the future were mentioned and suggestions were made about what to do in the basins.

Keywords: Climate Change, Basin, Greenhouse Gases, Water Resources

Introduction

The total surface of the world is 510 million km² and about 71% (361.3 million km²) of it is covered with water. 96,5% (1365 billion km³) of these waters constitute saltwater in the oceans and seas, 0,9% is other saline water, and the remaining 2,5% (35 million km³) of fresh, usable water (Figure 1), while the total amount of this freshwater is 11 billion km³. 68,7% of the existing freshwater (24 million km³) is trapped in the aquifers at the poles and underground (UN-Water, 2020). This situation reveals that there will be major problems in meeting the water requirement that will increase in the future.

Approximately 500 thousand km³ of water is evaporated by solar energy every year and mixed into the atmosphere. While continents lose 70,000 km³ of water by evaporation, they receive 110,000 km³ of water through precipitation (UN-Water, 2020). Approximately 40,000 km³ of water flows and reaches the seas and lakes in closed basins through rivers, but only 9,000 km³ of this precipitation is technically and economically usable (UN-Water, 2018). Besides, the distribution of water falling to the earth by rains is not equal and does not have any order. While 1/3 of all precipitation falls to South America and the Caribbean, only 0.1% of the total falls to Australia (Sherwood and Fu, 2014). Different amounts of water distribution and different rates of population growth in the region create an unstable situation. In terms of the amount of water per capita per year, Iceland, the world's richest water country, is 68,500 m³/year per person, while Djibouti remains the poorest country with 23 m³/year (Sherwood and Fu, 2014; Rodell et al., 2018; UN-Water, 2018). When the water shortage that arises in this context is combined with the geographical conditions, it creates disputes between the riparian countries regarding the use of the international river. The increasing risk of conflict as a result of the decrease in available water makes it necessary to make legal arrangements in this regard. For this reason, in the last 50 years, many studies have been carried out by international institutions, international legal associations, non-governmental organizations, and academics in the international arena (Arnell, 1999a, 1999b, 2003; van Vliet et al., 2013; Sherwood and Fu, 2014; Rodell et al., 2018; UN-Water, 2018; Vano et al., 2010; Tramblay et al., 2020; Lehner et al., 2006; Smiatek et al., 2014; Amin et al., 2017).

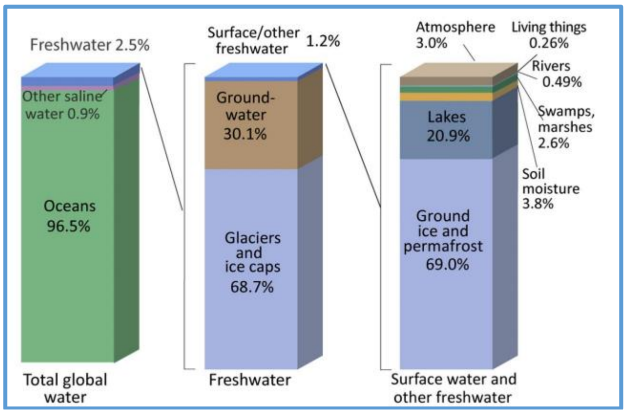

Fig. 1. Earth water potential (UN-Water, 2018).

In this study, the important impacts of climate change on Turkish basins were investigated and the measures to be taken are examined. Possible problems to be encountered in the future are mentioned and suggestions were made.

Climate change on basins

Climate change increases the importance of water resources; many regions of the world face the risk of desertification and in the future, water will be as valuable as oil (UNCCS, 2019; Ülker et al., 2018; Kibaroğlu and Scheumann, 2013; Timmerman and Bernardini, 2009; Akın and Akın, 2007; Gorguner et al., 2019; Kumanlioglu, 2020). With the impacts of climate change, a decrease in water resources, forest fires, and related ecological degradation will occur. As a result of the decrease in annual flows in river basins, water shortages will start in cities and water demand will increase. A decrease in water resources due to climate change will have a negative impact on agricultural production. Increasing the average annual temperature in addition to the expansion of arid and semi-arid areas will increase desertification, salinization, and erosion (UNCCS, 2019). The area covered by seasonal snow cover will decrease and the period covered with snow will be shortened. Changes in flow time and volume due to snowmelt will adversely affect the water resources, agriculture, transport, and energy sectors. Also, global warming will cause changes such as melting glaciers, rising sea level, and shifting climate zones (UNCCS, 2019; IPCC, 2014, 2019; Gorguner et al., 2019; Kumanlioglu, 2020; Yerdelen et al., 2021; Vazifehkhah and Kahya, 2019). Global climate change affects the current balance between systems and processes in the hydrological cycle. Since the atmosphere is one of the most important systems of the hydrological cycle, it is clear that the changes in the atmospheric conditions caused by climate change will cause significant changes in the hydrological processes of the basins, such as precipitation, evapotranspiration, and flow, both in space and time scales. These changes will not only be limited to the current long-term averages but will also be seen in the number, magnitude, and spatial distributions of extreme natural events. Studies on climate change show that climate change will play a restrictive role in water resources (UNCCS, 2019; IPCC, 2014, 2019).

The important impacts of climate change on basins depending on the regions where these waters are located; decrease or increase in surface water potentials, extreme floods, and drought, changes in times of seasons, changing rainfall regime, erosion problems caused by vegetation, and land use, differentiation in flow regimes of basins fed by snow water, increase in agricultural water needs and drought in transboundary water beds (UNCCS, 2019; IPCC, 2014, 2019; Güner Bacanli, 2017; Fawzy et al., 2020). Climate change has significant effects on the hydrological cycle, water resources, and the management and distribution of local-regional-global water resources. The aforementioned effects are expected to have consequences very slowly and over many years. Throughout the year, many changes occur in rivers and streams. The flow regimes of transboundary waters are changing and the number of natural disasters such as floods and drought is increasing. In addition, stream flows change, groundwater feeding increases or decreases depending on regional rainfall regimes (IPCC, 2019; Angelidis, 2010; WMO-GWP, 2016).

Evaluations made on a country basis indicate that the lands of Turkey will experience the direct negative effects of climate change more than the lands of other countries in the basin. By the end of this century, it is estimated that the annual surface runoff in Turkish soil will decrease by 26-57%. Since most of the rivers were located in this region, all other countries in the basin are expected to feel the stress of dwindling waters in the twenty-first century (Bozkurt and Sen, 2013; Ozkaya and Zerberg, 2019; Altın et al., 2020; Eris et al., 2020; Aziz et al, 2020).

Turkish Basins

Rivers constitute 22% of Turkey's land borders with a total length of 2753 km (Türkeş, 1996, 2003; Topaloğlu et al., 2012; Özdogan, 2011; Yilmaz and Harmancioglu, 2012). Some rivers of Turkey are only transboundary waters (such as the Euphrates), while others are both demarcated and transboundary (such as the Tigris). In a region with 900 m3 of water per capita, Turkey's limited water resources are seen as an inexhaustible treasure. The fact that Turkey is further north due to its position and the fact that the Euphrates and Tigris rivers flow out of Turkey gives the impression that Turkey is a very water-rich country (Bozkurt and Sen, 2013; Gorguner et al., 2019). Turkey seems to be a “trouble-free” and even “rich” country in its region with its activities on water resources, the use, and evaluation of these resources (Yuksel et al., 2011). However, compared to countries that are considered water-rich, Turkey cannot be considered rich, but rather in the category of countries with water shortages. According to the UN World Water Development Report 2020 (UN-Water, 2020), Turkey is one of the countries that have been experiencing drought since 2005 and it is likely to be among the countries that will suffer from economic water shortages from 2025. During this period, the Middle East will fully feel the drought in every aspect. 2040 will be a “critical year” for Turkey and the Tigris and Euphrates rivers will be the lifeblood of Turkey. Neighboring countries, Syria and Iraq, will suffer the most severe drought and will have difficulty growing crops in their fields.

The average annual rainfall is 643 mm and the total rainfall is 501 billion m^3 of water when the area of Turkey is taken into account with 779.500 km^2 (RTMAF, 2018). Approximately 274 billion m^3 of this water is returned to the atmosphere through evaporation from soil, water surfaces, and plants, while 69 billion m^3 of it feeds groundwater. 28 billion m^3 of this groundwater re-joins surface waters in rivers/streams. 158 billion m^3 of surface water formed by precipitation and 28 billion m^3 of groundwater that reaches the surface again in the form of a river, as well as 7 billion m^3 of transboundary water coming from neighboring countries, the gross water potential of Turkey is 193 billion m^3 (158+28+7=193) (Akın and Akın, 2007).

Turkey is hydrologically divided into 25 basins, five of which are within the scope of transboundary waters (Figure 2):

- Meriç-Ergene basin
- Asi basin
- Çoruh basin
- Aras basin
- Tigris-Euphrates basin

The average annual water potential of these basins originating from Turkey; Meriç-Ergene basin is 1.33 billion m^3, Asi basin is 1.17 billion m^3, Çoruh basin is 6.30 billion m^3, Aras basin is 4.63 billion m^3, Tigris basin is 21.33 billion m^3, the Euphrates Basin is 31.61 billion m^3 of a total of 66.37 billion m^3. This amount constitutes about 36% of Turkey's total gross water potential of 186 billion m^3 (Güner Bacanli, 2017; Topaloğlu et al., 2012; Büyüksalih and Gazioğlu, 2019; Kaya et al., 2019; Menteş et al., 2019; Bozkurt, 2013). The water potential of the Tigris and Euphrates rivers originating from our country is 52.940 billion m^3, which corresponds to 28.5% of the flow potential of our country and 62% of the total flow potential of 85.610 billion m^3 in Şattül Arab. Turkey is the country upstream with the Tigris, Euphrates, Coruh and Aras rivers, and downstream with the Meriç River. Turkey is the upstream and downstream country of the Asi River. Considering upstream-downstream relations and water potential, Turkey is generally seen to be an upstream country (Büyüksalih and Gazioğlu, 2019; Kaya et al., 2019; Menteş et al., 2019; Bozkurt, 2013). The average annual flow potentials are 50 billion m^3 of the Tigris River which is 21.33 billion m^3 from Turkey and 28.67 billion m^3 from Iraq, 35.61 billion m^3 of the Euphrates River which is 31.61 billion m^3 from Turkey, and 4 billion m^3 from Syria. In this case, the total current potential of the Tigris-Euphrates Basin is 85.610 billion m^3. 62% of this amount consists of currents occurring in Turkey, 5% in Syria, and 33% in Iraq (Bozkurt, 2013; Yılmaz, 2019). Other basins' water potential; Marmara basin is 8.33 billion m^3, the Susurluk basin is 5.43 billion m^3, the Northern Agean basin is 2.09 billion m^3, Western Agean basin is 8.93 billion m^3, the Gediz basin is 1.95 billion m^3, Eastern Mediterranean basin is 11.06 billion m^3, Eastern Blacksea basin is 14.90 billion m^3 (Türkes and Tatlı, 2011).

Fig. 2. Turkish Basins (Dogru et al.,2017)

The Impact of Climate Change on Turkish Basins Drought

Drought is one of the most important negative consequences of the effects of climate change on precipitation regimes. It is estimated that there will be more rainfall in regions that previously had rainfall, and more drought will increase in areas that previously had a drought. In other words, climate change will cause floods, hurricanes, and severe droughts in some regions. This situation will put many people at risk of hunger and thirst (UNCCS, 2019). The warming trend in the atmosphere will result in more evaporation, droughts, and erratic rainfall. Humanity will face a greater risk of experiencing periodic droughts as useful rainfall decreases due to irregular rainfall all over the world (Song et al., 2018; Huang et al., 2020). With climate change, many water-rich countries will start to become water-poor countries. The danger of thirst will increase as water sources gradually start to dry up (Huang et al., 2020). Many researchers in various parts of Turkey have conducted historical drought analyzes using different drought indices. (Dabanlı et al. 2017; Güner Bacanli 2017; Tosunoglu et al. 2018; Vazifehkhah and Kahya 2019; Turan, 2018; Ozkaya and Zerberg, 2019; Altın et al., 2020; Eris et al., 2020; Aziz et al, 2020). These studies have shown that the effect of drought in the basins increases every year, the basins start to dry up and the effects of drought will be more and more every year.

The average temperature of Turkey in 2021 was 14.9°C, 1.4°C above the 1981-2010 average of 13.5°C. There are positive temperature differences in Turkey's average temperatures since 1998 (except 2011). The hottest year is 2010 with 15.5°C and 2021 is the year. It was the 4th warmest year with 14.9°C. According to the 1991-2020 normal of 13.9°C, the anomaly is 1°C. When looked at the monthly temperature differences, it can be seen that the temperatures of all months are above the normal except March, September and October. In particular, May has been the first hot May in the last 50 years with a difference of 2.6 °C, while January and July have been the second hottest months in their own months.

Temperature projection was made for Turkey between 2016-2100 by the Turkish State Meteorological Service (Figure 3)(Turkish State Meteorological Service, 2022).

According to the RCP4.5 scenario, Turkey's average annual temperatures are expected to increase in the range of 1.5 – 2.6°C on average in the period 2016-2099. Average temperature anomaly is expected to be in the range of -0.9 to 4.1°C in the first half of the century, and average annual temperatures will increase by 1.4°C on average, while in the second half of the century it will increase by 0.6 to 4.1°C and increase by 2.2°C on average. The projection shows that the temperature values that will be seen in Turkey from 2035 will increase, the drought period will be more felt (Turkish State Meteorological Service, 2022).

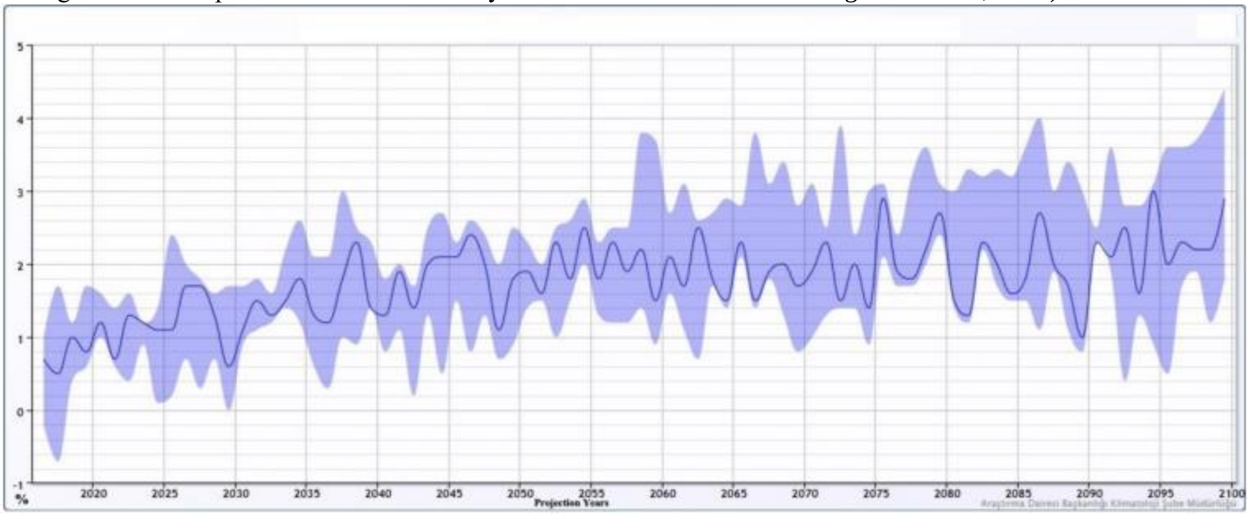

Fig. 3. Annual temperature projection of Turkey (Turkish State Meteorological Service, 2022).

In recent years, the drying up of Turkish lakes and dams in significant amounts reveals the dreadful effect of climate change. While Salt Lake's surface area was 92562 hectares in 1987, it decreased to 32552 hectares in 2005 and the surface area of the lake decreased by about 35%. Between 1995-2008, there was a 2-meter level decrease in Lake Van and the decrease of the water level in the lake caused the salinity and soda ratio in the lake water to increase. Lake Ladik, one of the three lakes in the world with floating islets, is drying up due to the extreme heat and irrigation purposes. The size of the lake, which was 1300 hectares, has decreased to 700 hectares due to the decrease in the water level from 6 meters to 1.5 meters (Turkish State Meteorological Service, 2022). Due to the effective drought, the excess amount of water used in agricultural irrigation, and the increasing energy demand, the low water level in the Atatürk Dam has approached 4 m. In Demirköprü Dam, it is seen that the water volume has decreased by 50% due to the lack of expected precipitation in recent years. The water capacity of the Avşar Dam, which was 73 million m^3, has decreased to 26 million m^3 (Büyüksalih and Gazioğlu, 2019; Kaya et al., 2019; Turkish State Meteorological Service, 2022; Aziz et al, 2020).

Yerdelen et al. (2021) examined the short and long-term drought cycles in Gediz Basin during the recording period of 1960–2016 and found that the change in the long-term drought cycles occurred on the northwest, east, and southwest regions by the beginning of 1980s, and by the end of the 1980s, respectively, and the change in the short-term cycles of drought occurred by the mid-1990s. The findings of this study showed a potential coherence between drought cycles, and NAO variability. All scenario simulations showed that surface temperature increased throughout the Euphrates-Tigris basin. In winter, the increase is relatively higher in the highlands. The annual increase in surface temperature in the highlands ranges from 2.1°C to 4.1C for 2041–2070, while between 2.6°C and 6.1°C for 2071–2099 is changing (Bozkurt and Sen, 2013; Ozkaya and Zerberg, 2019). Considering the changes caused by the decrease in the groundwater level and surface water amount in the Konya Closed Basin lakes in the last 35 years, approximately 50% of the surface areas of the 3 lakes studied have been lost due to drought in 35 years. Düden Lake, which dries up due to drought, is the most obvious example (Yılmaz et al., 2021).

Projected future changes in mean air temperature and precipitation climatology and inter-annual variability over the Mediterranean region were studied by Ozturk et al. (2015). The study concluded that the occurrence of frequency and intensity of high temperatures and heavy precipitation events will likely increase in the future period in the Mediterranean Basin. The Mediterranean Basin will be one of the regions that shall be affected most by the impacts of the future climate changes on hydrology and water resources. Yılmaz et al. (2021) investigated the projected droughts in the Upper Coruh Basin, and the future annual precipitation and the maximum and minimum temperatures were projected to change from−15.46% to 8.74%, 0.02 °C to 8.74 °C and −2.69 °C to 5.27 °C, respectively. The results showed that the frequency of hydrological drought durations will be higher under RCP4.5 and RCP8.5 during the period 2030–2059.

Because of global warming, climate change, and many human factors, water resources are decreasing every day. 36 lakes have dried up in 50 years in Turkey. When examined the lakes of Turkey that are completely dry according to the regions; Karagöl, Avlan, Girdev, Kurugöl, Keklicek, Manay, Tecer, Mamak ve Genceli lakes in the Mediterranean region, Acı and Işıklı lakes in the Aegean region. Tersakan, Bolluk, Musalar, Ilgın, Samsa, Yay, Seyfe, and Tuzla lakes in the Anatolian region, Yay lake in the Marmara region, Büyük, Küçük, Azaplı, Seki, Kuyucak, Akdoğan, Aygır lakes in the eastern Anatolia region (Turkish State Meteorological Service, 2022).

Rainfall

The impact of climate change on water resources is due to changes in rainfall characteristics. Rainfall is the main source of water balance variability in the time and place scale. Changes in rainfall due to climate can have important consequences for hydrology and water resources. Hydrological variability in a watershed over time is influenced by the variability seen in rainfall in daily, seasonal, annual, and ten-year cycles. The frequency of flooding is due to changes in rainfall intensity from year to year and differences in short-term rainfall amounts. There is also evidence that the frequency of torrential rainfall will increase with climate change (Menteş et al., 2019; Badalova et al., 2019; Turkish State Meteorological Service, 2022). The frequency of droughts also comes from changes in the seasonal distribution of rainfall. Increased temperatures cause reduced snowfalls. The reduction or complete cessation of snowfall will have important consequences for hydrological cycles (Menteş et al., 2019; Badalova et al., 2019). Climate change changes rainfall distribution. Rainfall shows the different distribution in different regions of the world. Rainfall increases in autumn and winter in the middle and high latitudes of the northern hemisphere, while rainfall decreases in tropical and sub-tropical regions in both hemispheres. It is estimated that the greatest rainfall changes to be observed overland with climate change will occur in some equatorial areas near the pole and Southeast Asia. With warming, more water will evaporate from the oceans and seas and the earth will be more humid. This will lead to increased rainfall. Rainfall on continents has increased by 1% in the last century (Badalova et al., 2019). In the 20th century, there was an increase of 5-10% in the precipitation falling on the continents in middle and higher latitudes. An increase of 2-4% was observed in the frequency of heavy precipitation. On the other hand, precipitation on land in subtropical areas decreased by 3% (Timmerman and Bernardini, 2009). In particular, there has been a decrease in the precipitation of some northern and western African and Mediterranean countries. In the last 10 years, there has been an increase in drought and heat intensity in some continents such as Asia and Africa (Tramblay et al., 2020).

Rainfalls across Turkey were below normal levels for many years and it was also below in 2021 (Figure 4) (Turkish State Meteorological Service, 2022). Total areal precipitation in Turkey in 2021 was 524.8mm, 9% below the 1991-2020 normal (573.4) and the 1981-2010 normal (574). While the areal precipitations throughout Turkey were above the normal levels in January, March, June, July, August, September and December of 2021, the highest rainy month was January with 94 mm and the lowest precipitation was July with 19 mm. May precipitation was at its lowest level since 1930. In 2021, an increase was recorded in the Eastern Black Sea Basin, compared to the normal ones, together with the basins located in the northwest of our country. The lowest precipitation was in the Konya Closed Basin with 371 mm and the highest precipitation was in the Eastern Black Sea Basin with 1141 mm. While the highest decrease compared to normal occurred in the Euphrates-Tigris Basin with 29%, this basin also received the lowest rainfall in the last 22 years. Based on regions, the Mediterranean and Central Anatolia Regions were around normal, and the Eastern and Southeastern Anatolia Regions received below normal rainfall. The highest increase compared to the normal way in the Aegean Region with an increase of 40% (Turkish State Meteorological Service, 2022).

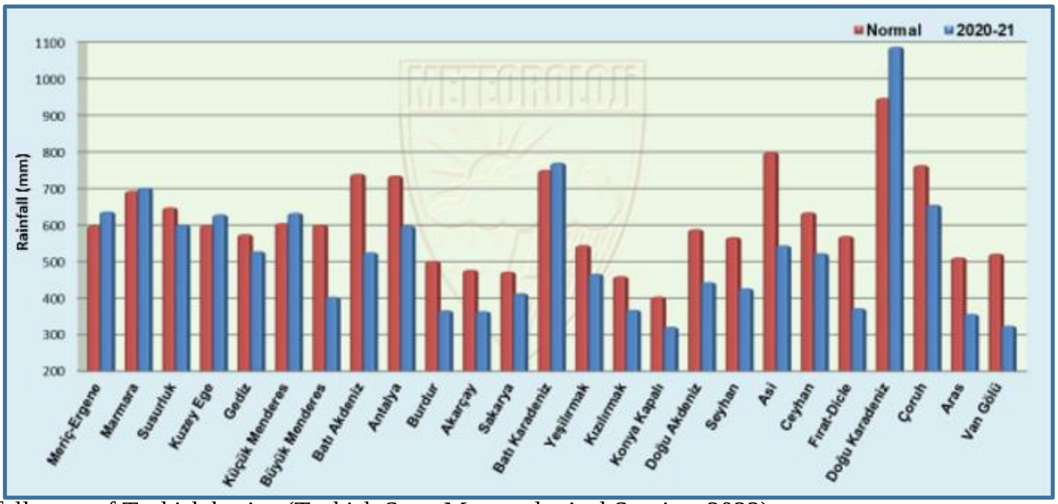

Fig. 4. Rainfall rates of Turkish basins (Turkish State Meteorological Service, 2022)

Climate projections were developed by the Turkish State Meteorological Service to reveal how climate change will affect the country in the future for the period 2016-2099. The projection shows us important consequences (Figure 5) (Turkish State Meteorological Service, 2022). Although a decrease in precipitation is generally expected, it is observed that there is no continuous increase or decrease trend, besides, precipitation irregularities tend to increase and there is a decreasing trend after 2040. According to the RCP4.5 projection, the annual total precipitation anomaly is expected to decrease between 3% and 6% on average in the 2016-2099 period. The average change in precipitation anomaly is predicted to be between 1% and 6% in the first half of the century (2020-2050) and between 5% and 6% in the second half of the century (2051-2099) (Turkish State Meteorological Service, 2022). This means that in the future, it will be seen fewer rainfalls and Turkey will be a water-poor country while now it is water insufficiency country.

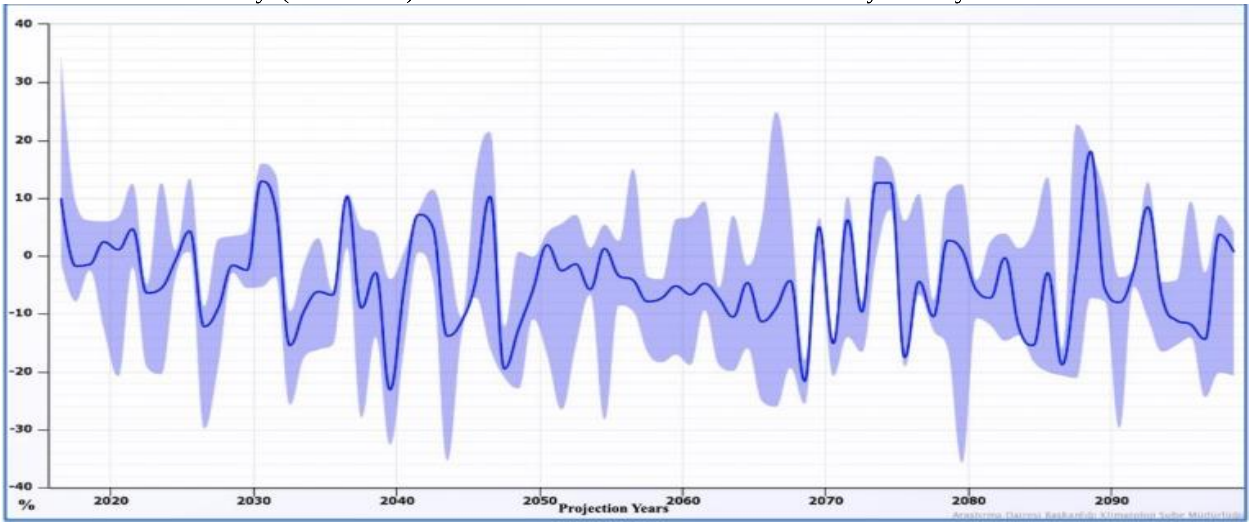

Fig. 5. Annual rainfall projection of Turkey (Turkish State Meteorological Service, 2022)

Gediz Basin has been experiencing water scarcity and competing use of water problems in recent years (Gorguner et al., 2019; Kumanlioglu, 2020; Yerdelen et al., 2021; Vazifehkhah and Kahya, 2019). It was assessed that there is a potential consistency between drought cycles and the North Atlantic Oscillation (NAO) variability. This relationship is very important in terms of estimating the water scarcity in the Gediz Basin and taking the necessary precautions. There is a broad agreement among the simulations, which indicate a decrease in the highlands and northern parts of the Euphrates–Tigris basin and an increase in the southern parts. Projected changes in the annual evapotranspiration indicate generally statistically significant decreases in the basin by the end of the century, which is most likely related with the projected decreases in precipitation (Bozkurt and Sen, 2013; Ozkaya and Zerberg, 2019). In the study conducted by Ejder et al.(2016), it was assessed that there are decreasing trends in stream flows and precipitation of Kocabaş Stream, and increasing trends in temperature. Şen (2019) studied the Upper Tigris River (UTR) drainage basin in Turkey for climate change impacted runoff estimations. It is observed that after 2021, precipitation decreases at about 12.5% and after 2030, it is 26%. Runoff projections indicate that they may decrease at about 30% especial after 2040.

Water Quality

Climate change will affect not only the quantity but also the quality of transboundary water resources and basins. Due to the increase in temperature and decreases in precipitation and flows, pollution concentrations will increase water quality problems. Drought and heavy rainfall put pressure on water quality. The amount of water that will decrease in rivers and lakes during the dry months will lead to higher concentrations of pollutants, and this will cause a decrease in water quality. Warmer waters mean less oxygenated waters. The decrease in dissolved oxygen levels, which is one of the most important determinants of water quality, brings serious pollution problems. The dissolved oxygen concentrations in warmer water are lower, and the increased temperature also encourages the proliferation of algae millennia that consume oxygen as they rot. The river water temperature increases slightly less than the air temperature. The least temperature rise occurs in basins fed by large amounts of groundwater (Bucak et al., 2017). Biological and chemical processes develop largely depending on the water temperature. Only higher temperatures will increase the concentration of some chemical species and a decrease in others. For example, nitrates are often taken to rivers by torrential rains after long periods of drought (Tramblay et al., 2020). During floods, for example, the quality of water coming into a reservoir is very low due to the soil and other pollutants it carries with it. It should be kept in mind that changing climatic conditions will bring water quality problems along with it, which will seriously affect human health and increase the need for water treatment, which will bring economic burdens (Vano et al., 2010). As the capacity and reserves of water basins will decrease with global warming, it will cause an increase in environmental pollution. Reduction of water will increase salinization and barrenization in agricultural areas, and excessive fertilizers and pesticides used to obtain yield will increase the amount of water and soil contamination (Webb et al., 2017).

In Turkey, with the rapid population growth, the decrease in the area per capita, the widespread use of industry, the mechanization of agriculture are the leading factors in the pollution of the environment and water (Bucak et al., 2017). It is known that today, pollution has reached significant levels in many water basins as a result of domestic, industrial wastewater and irregular agricultural activities that cannot be kept under control in Turkey (Yenici, 2010; Kaya et al., 2019; Menteş et al., 2019; Bozkurt, 2013; Yılmaz, 2019; Bucak et al., 2017).

Increased summer temperatures caused by climate change, reduced winter rainfall (especially in the western provinces), loss of surface waters, frequent drought, soil degradation, erosion in coastal areas, and frequent floods are threatening the existence of water resources and quality in Turkish basins (Republic of Turkey Ministry of Development, 2018).

When examined the water quality of the Turkish basins; the Marmara basin has the highest population and population growth, agriculture and industry are intensely carried out in this basin. As a result of the widespread use of fertilizers and chemical pesticides in the agricultural sector in the Marmara basin, it has been determined that almost all of the surface waters are at III or IV class level polluted or highly polluted in terms of NO_2N parameter. There is organic matter pollution in Büyük Çekmece and İznik Lakes, which are located in the Marmara Basin (Republic of Turkey Ministry of Development, 2018; Yuksel et al., 2011; Menteş et al., 2019). On the other hand, the high chromium-laden water threatens the basin. The zinc load is high in Ömerli Dam. Nitrogen and phosphorus loads have increased in Alibeyköy, Elmalı, Küçükçekmece, and Terkos Lakes as a result of industrial waste, domestic waste, and agricultural activities. In the Meriç-Ergene basin in the Marmara Region, the inadequacy of the treatment facilities and the nitrogen and phosphorus loads arising from the use of chemicals and natural fertilizers in agricultural areas are high. Industrial waste, domestic and agricultural residues reach the Meriç and Ergene rivers, causing contamination. In the same way, the Susurluk Basin faces the same risks in terms of contamination (Kaya et al., 2019). As climate change increased, water resources in the basin decreased (the rainfall regime changed) and industrial activities increased, and as a result of these effects, water quality in the basin decreased to an average level of III/IV.

Bakir stream, located in the North Aegean Basin, faces a certain level of contamination as a result of the activities of Soma lignite and olive oil production facilities. The load of sewage residual water is also low due to the low population density (Republic of Turkey Ministry of Development, 2018; Yuksel et al., 2011). The surface water of the Gediz River, located in the Gediz Basin, is contaminated. The river has IV class level water quality in terms of nitrogen, organic matter, and heavy metals from domestic waste, industrial waste, agricultural activities, and due to climate change (Republic of Turkey Ministry of Development, 2018; Yuksel et al., 2011). The Büyük Menderes River Basin`s water quality is generally poor; the waters of the basin are at the level of pollution of class III and IV. It is assumed that the cause of this is largely caused by domestic, industrial, and agricultural pollution. Especially around Denizli and Uşak provinces, the Buyuk Menderes River tributaries were more polluted than others. This situation is due to industrial density near Denizli and Uşak provinces (Eris et al., 2020). To improve water quality in the basin, domestic, industrial, and agricultural pollution need to be controlled, and the effects of climate change should be examined in detail.

The impacts of climate change on the hydrology of the Euphrates-Tigris basin were studied by Bozkurt (2013), Bozkurt and Sen (2013) by simulation studies and it was found that winter rainfall decreased in the mountainous areas and northern parts of the basin and increased in the southern parts of the basin due to climate change. A notable effect of warming can be seen on the snow water equivalent in the highlands, where each simulation points to statistically significant reductions ranging from 55% (lower emissions) to 87% (higher emissions). There is a statistically significant decrease (25% to 55%) in the annual surface flow of the main bodies of water. The annual surface flow changes predicted in all simulations indicate that the territories of Turkey and Syria in the basin are most vulnerable to climate change because they will experience significant decreases in the annual surface flow (Bozkurt, 2013; Bozkurt and Sen, 2013; Şen, 2019). Hydroclimatic changes in the Euphrates-Tigris basin under a changing climate were investigated by Yilmaz (2019), Ozkaya and Zerberg (2019), Şen, 2019. Simulations for the future were implemented using two different scenarios (RCP4.5 and RCP8.5) for the middle and end of the century, 2046-2065 and 2081-2100 in the study. At the end of the century, the pessimistic scenario (RCP8.5) showed that the temperature projections in Turkey reach 5°C, while the temperature increase in the GAP region is at 2°C. The RCP4.5 scenario shows a small increase in precipitation over this region for the middle and end of the century, while the RCP8.5 indicates a general decrease in the GAP region. Finally, perspiration-evaporation values may increase statistically significantly over the GAP region in the future, as in today's period. In this case, water loss by evaporation can reach higher amounts. The study found that human-caused climate changes will force the hydroclimatic conditions of the region and will affect the water quality of the basin. The fact that the projected increase in water loss due to evaporation indicates that the dispute between the watershed countries may become more difficult in the future (Yılmaz, 2019).

The effects of climate changes on the water resources and water quality of the Ömerli Basin were investigated by Kara (2014) through precipitation and flow analyses. In the analysis conducted, it was estimated that the rainfall values of the basin will be lower in the coming years and that the water shortage may occur in the future due to climate changes, as the duration and cyclicity of extreme events in the basin increases (Kara, 2014). Burdur Lake Basin, located in the Mediterranean region, faces serious contamination problems as a result of industrial, human, agricultural activities, and climate change. The surface waters of the Seyhan, Ceyhan, and Asi river basins in the Mediterranean region have reached class III and IV levels due to excessive pollution caused by industrial, human, and agricultural activities. The western Mediterranean, Antalya (Central Mediterranean) and Eastern Mediterranean basins are not yet facing serious water pollution problems (Tramblay et al., 2020; Bucak et al., 2017).

In the Konya closed basin, domestic and agricultural waste, combined with wastewater from industrial enterprises, reaches the Salt Lake through rivers and streams, leading to contamination of lake waters at Class III or sometimes even Class IV level. The waters of Eber Lake, located in the Akarchay (Afyon) Basin of Central Anatolia, face excessive pollution due to the effects of climate change (Republic of Turkey Ministry of Development, 2018). In the Yeşilırmak Basin, located in the central Black Sea region, class IV pollution is observed due to wastewater of the food industry and household residues. On the other hand, there is heavy metal pollution in Tokat and Amasya regions (Menteş et al., 2019). Due to pollutant parameters such as NO_2, O_2, Pb, and Cr in Göksu, Ankara, Karasu, Mudurnu, Seydisu, Kızılırmak streams, which are tributaries of the Sakarya River in the Sakarya Basin, III and IV class pollution has been observed. Heavy metal contamination of serious dimensions has been detected in this basin (Kara, 2014; Turkish State Meteorological Service, 2018). The harmful effects of climate change will be felt more in these basins in the future.

The lack of industrialization and population density in the other basins and the lack of agricultural fertilizer and chemical use indicate that serious contamination problems have not yet been seen in these basins.

Extreme Meteorological Events

Most of the natural disasters in the world are caused by meteorological disasters (UNCCS, 2019). Due to the climatic conditions in which Turkey is located, it is frequently exposed to the effects of disasters.

Meteorological disasters effective in Turkey are:

- Flooding
- Avalanche
- Extreme cold
- Storm
- Hail
- Lightning
- Drought-extreme heat
- Fog
- Excessive snow (Turkish State Meteorological Service, 2022).

2021 has been the year with the most extreme events, with 1024 extreme events (Figure 6). There is an increasing trend in extreme event trends, especially in the last two decades (Turkish State Meteorological Service, 2022). Most extreme events recorded in 2021 were storms (40%) and heavy rainfall/floods (28%) and other events were hail with 13%, heavy snow with 7%, lightning with 5%, forest fire %3, frost 2%, landslide 2%, and avalanche, dust storm, fog, severe cold and drought less than 1%. This shows us that as the effects of climate change increase, in the future the frequency and intensity of extreme natural events will be felt more in Turkey.

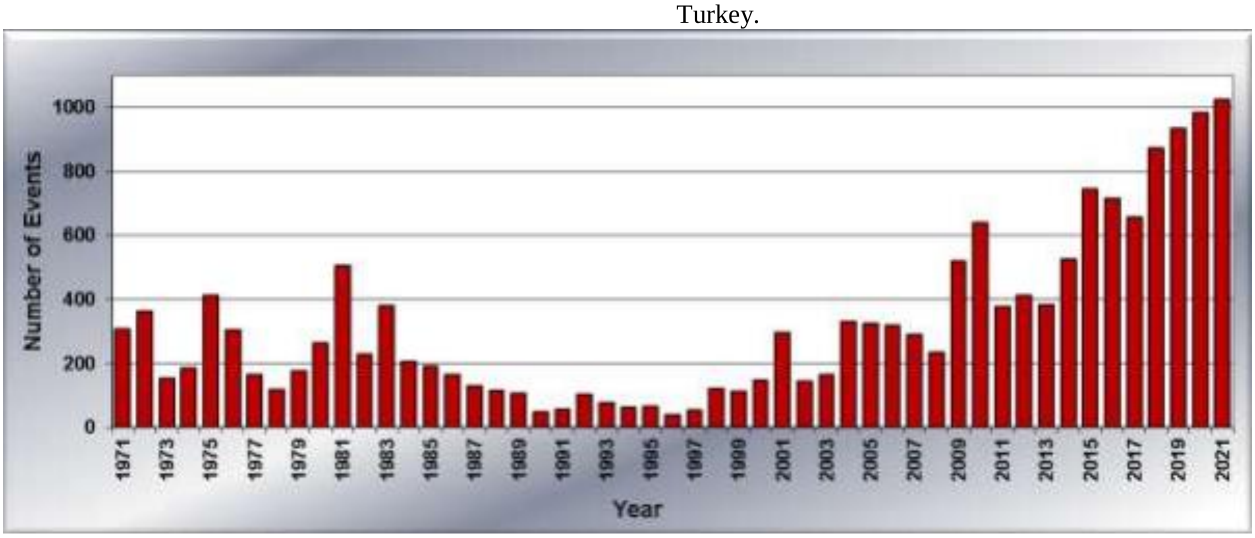

Fig. 6. Number of extreme events in Turkey (Turkish State Meteorological Service, 2022)

Results

In addition to being observed at the global level, the effects of climate change are also felt overtime at the regional and local level: for example, in some parts of the world, severe weather events such as hurricanes and floods and their numbers increase, while in some parts of the world, prolonged and severe droughts and associated desertification events may be more effective. This type of climate change can have unpredictable environmental, social, and economic consequences. Developing countries are among the countries that will be most exposed to the negative effects of climate change. These countries also need more energy services for their growth and development needs. Water scarcity of water-poor countries will inevitably be affected by the predicted negative aspects of climate change, such as high summer temperatures, forest fires, a decrease in rainfall and water resources, sea-level rise, drought and desertification, epidemic diseases, and the increase of pests in agriculture (Huang et al., 2020, Kibaroğlu and Scheumann, 2013; Song et al., 2018; Webb et al., 2017; Yılmaz et al., 2021; Bozkurt and Sen, 2013).

Climate change confronts many risks and uncertainties in the planning and management of water resources at the local, regional, and national levels. At the national level, especially in the arid and semi-arid zones of the world, it is important to create an effective, fair, and legally regulated water policy to meet the increasing needs of people with the available limited or scarce resources. If these resources are transboundary, the uncertainties and risks created by climate change should be taken into account in water negotiations between states regarding the use and allocation of water resources. However, it is observed that many bilateral or multilateral agreements on the allocation and sharing of transboundary water resources do not include natural changes that may occur in basins, such as seasonal/annual rainfall and flow differences, possible droughts, and flood conditions (Büyüksalih and Gazioğlu, 2019; Fawzy, 2020). In water negotiations, the parties should consider the physical conditions created by climate change and their socioeconomic effects as a critically important factor along with other factors that will determine water allocation (Yılmaz, 2019; Bozkurt, 2013; Bozkurt and Sen, 2013).

As a result of climate change, floods may occur in the river basins, resulting in serious social and economic problems. In such cases, the downstream country experiences the biggest problem in terms of agricultural and residential areas. In this context, a separate climate change agreement should be made between the upstream country and the downstream country to protect the rights of the downstream country regarding the effects of climate change (against floods). It is considered that signing a cooperation agreement that includes information sharing to reduce the effects of floods, whose number and intensity increase in transboundary water basins due to the effect of climate change, will be beneficial in terms of reducing the possible effects.

Discussion and Conclusion

The effects of climate change on food, energy, environment, and water security at national and regional levels may require rethinking Turkey's socio-economic development policies. Within the framework of Turkey's long-term policies, national policies for the effective use and protection of all natural resources, especially water resources, should be developed in line with the needs. Considering the transboundary nature of water resources, which are vital for food, energy security, and the continuity of ecosystems, coordinated policies with the content of cooperation with neighbors should be developed.

The use of water resources in the basins at the national level should be planned very well; attention should be given to water storage systems and necessary precautions should be taken. The effects of climate change on basin water resources should be modeled, the measures to be taken under different scenarios should be determined together with their costs and the results should be reflected in long-term water plans.

Risk maps on watersheds, including the number of floods caused by climate change, severity, and impact areas, should be prepared and surveys should be carried out for possible flooding. All work must be done together with the countries (upstream-downstream) through which the transboundary waters cross by bilateral agreements.

To minimize the adverse effects of climate change, necessary measures must be taken within the framework of basin water resources management. Within the scope of these measures, a water budget must first be made based on watersheds by modeling existing data from past to present. The number of meteorology and current observation stations should be increased to obtain healthy and adequate data and to make the right projects and projections. How basins will be affected by climate change should be modeled and benefit from future estimates in water resources related to drinking, irrigation, and energy projects.

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