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CLIMATE CHANGE AND WATER RESOURCES MANAGEMENT

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CLIMATE CHANGE AND WATER RESOURCES MANAGEMENT

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CLIMATE CHANGE WATER AND RESOURCES MANAGEMENT

CONTENT

ABBREVIATIONS

ANA	Agência Nacional de Águas *National Water Agency of Brazil*
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
CDM	The Clean Development Mechanism
COP	Conference of Parties
EMBRAPA	Brazilian Agricultural Research Corporation
GCF	Green Climate Fund
GEF	The Global Environment Facility
GNP	Gross National Product GNP
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Center
OECD	Organization for Economic Co-operation and Development
REC	Regional Environmental Center
UNEP	The United Nations Environment Programme
WEAP	Water Evaluation and Planning System
WMO	World Meteorological Organization

EXECUTIVE SUMMARY

Climate change is one of the most serious issues of our time. It has negative effects on human life, nature, living things and economy. This report is prepared on water resources management and climate change, where international efforts are summarized and Turkey's position in the international agreements are addressed. The effects of climate change are discussed depending on the evaluations of Intergovernmental Panel on Climate Change (IPCC) that are based on various climate scenarios.

This report comprises of current information on the effects of climate change on water resources in the world and Turkey, with specific examples from Brazil, European Union and Central Asia. The effects of climate change on water resources were examined with regard to the change of hydrological cycle and water quality. Although the total amount of water in the world is unchanged by the hydrological cycle, temporal and spatial changes in rainfall regime, the change of precipitation type, and the variations in the amount of surface flow or recharge of groundwater sources are expected to cause serious problems. The effects of climate change on the quality of water resources depend on variations in physiological, chemical and biological parameters. The increase in dissolved solid content depending on the change in water discharge and deterioration of water quality are the most common effects.

In fact, the effect of climate change on water resources have further impacts on agriculture, energy, stock farming and tourism sectors. In the module, these effects are explained with specific examples from both Turkey and the world. It was confirmed that food and energy security are under threat as a result of decreasing amount of available water supply in some basins in Turkey. Because of variations in precipitation and evaporation, plant pattern in Turkey is expected to change and the frequency of sudden and extreme weather events and thus drought and flooding risks are expected to increase.

The major sectors affected by the climate change in Turkey are drinking and utility water, agriculture and industry sectors. Regarding adaptation to climate change, some suggestions are given, some of which are reducing losses and leakages in water distribution networks, widening of alternative water sources such as rainwater and treated waste water, using water-saving technologies, selection of suitable production patterns for agriculture and employing zero-discharge approach for the industry, as well as adopting clean-production applications.

1. GLOBAL WARMING AND CLIMATE CHANGE

Ever-growing world population and the economic development, which started by the Industrial Revolution are the major driving forces accelerating the use of natural resources. As a result of overuse of fossil fuels such as coal, oil and natural gas, global average temperature of air and oceans is increased, which triggers climate change.

Based on satellite data and surface and atmospheric temperature measurements on thousands of points on earth, scientists have shown that global average temperature is increased 0.9°C since 1880 (NASA, 2018). CO_2 concentration in the atmosphere increased 47% with respect to commencement of Industrial Revolution changing from 278 ppm to 410 ppm (NASA, 2019a). Fuel types causing high CO_2 emission are coal, oil and natural gas. According to a recent report of IPCC (IPCC, 2018), if the global warming level is increased at current rate, the global average temperature will increase about 1.5°C in the years between 2030 and 2052. The World Bank warns that if CO_2 emissions are increased at current rate, the increase in average temperature in 2060 will be about 4°C (WWF, 2019).

Climate change is a general term expressing the changes in several climatological factors such as temperature and precipitation from global to local scale. These changes occur as a result of global warming. For example, when considered from a wider perspective, the United States was much wet whereas Sahel region in the Central Africa was much arid in the 20th century. Such changes in California resulted in diminishing and melting of Sierra ice mass, which in turn caused water scarcity (WWF, 2019).

Land and ocean temperatures are increased and precipitation regime is changed. In general, wet regions are wetter during the winter season whilst arid regions become more arid during the summer. It causes increases in the frequency and intensity of extreme weather events such as rising of sea level, loss of ice sheets on mountainous areas on the poles, heat waves, floods and drought and also shifts in blooming periods of plants.

Satellite data of GRACE of NASA indicate the mass of Antarctica (upper region) and Greenland (lower) ice sheets has been lost since 2002 and the rate of mass loss has increased after 2009 (NASA, 2019c). The change in mass loss of ice sheets is 127 Gigatone/y for Antarctica and 286 Gigatone/y for Greenland. According to latest measurements in August 2018, the change in sea level rise was 87 mm (NASA, 2019d). The rate of change is 3.2 mm/y. There are two reasons for the sea level rise; addition of water from melting of ice sheets and thermal expansion of seawater by global warming (NASA, 2019d).

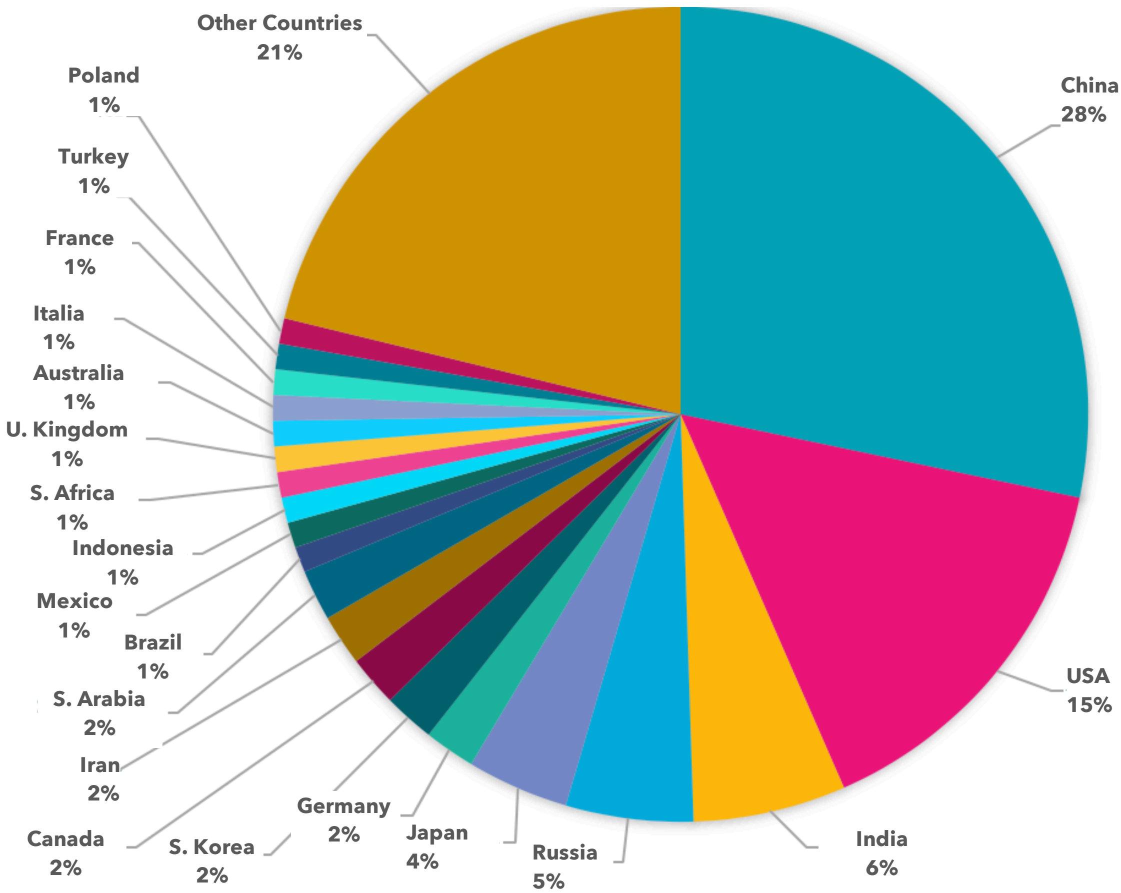
1.1. Country Emissions and Status of Turkey

In total CO_2 emissions associated with burning fossil fuels, the highest shares belong to China (28%), USA (15%), India (6%) and Russia (5%) (Figure 1) (Union of Concerned Scientists, 2018). Greenhouse emissions of developing countries such as Turkey are very low in comparison to industrialized countries. Total greenhouse emission of Turkey in 2016 has increased 135.4% with respect to 1990 and reached 496.1 Mt CO_2 equi. (TUİK, 2018). The energy-based emissions with a ratio of 72.8% comprise the largest share in 2016 emissions as CO_2 equi. This is followed by industrial processes and product use with 12.6%, agricultural activities with 11.4% and wastes with 3.3%. The largest increase since 1990 is recognized in the energy sector (Köse, 2018). Just like in the world, most of the greenhouse emissions in Turkey arises from the energy sector.

According to the United Nations Framework Convention on Climate Change, Turkey as a member of OECD, is categorized as a developed country. In the original text of UNFCCC which was open for signature in 1992, Turkey was listed in both Annex 1 (historical liability) and Annex 2 (financial liability). Turkey is the merely developing country in Annex 1. Therefore, during the course from COP1 held in 1995 to COP6 held in 2000, several attempts were made to be exempt from the annexes of UNFCCC. In 2000, the attitute was changed and Turkey suggested to be exempt from the Annex 2 and be a part of Annex 1 acknowledging its special terms (Republic of Turkey, Ministry of Environment and Urbanisation, 2019).

Countries listed in Annex 1 should propose absolute mitigation targets for greenhouse emissions and while those in the Annex 2 should provide financial assistance to the developing countries for their efforts to cope with climate change. Turkey who did not sign the Convention due to such liabilities, was dropped out from the Annex 2 by resolutions adopted during the 7^{th} UNFCCC Parties Conference (COP7) held in 2001 in Marrakech but special terms that made Turkey different from countries listed in Annex 1 were recognized by other countries party to the Convention. As a result, liabilities of Turkey to propose absolute mitigation targets for emissions and assist to other countries lost validity. Turkey approved the UNFCCC in 2004 as the 189th state party. Turkey is listed in Annex 1 of the Framework Convention that includes the developed countries (İklim Haber, 2018).

Figure 1: *CO_2 emission rates of countries (2015)*



In Kyoto Protocol which was effectuated in 2005, Turkey officially became a party in 2009. During COP16 that was held in 2010 in Mexico, it was confirmed that status of Turkey is different from other Annex 1 countries and special terms of Turkey were recognized once again by other countries party to the UNFCCC. In addition, Turkey's access to the aid mechanisms of the Framework Convention was approved. In meetings organized in Doha and Lima, Turkey's access to Global Environment Facility (GEF) and UNFCCC mechanisms was warranted. However, since Turkey is listed in Annex 1 countries, Turkey cannot benefit from the Green Climate Fund (GCF) and Clean Development Mechanism (CDM) (İklim Haber, 2018).

Turkey signed the Paris Agreement in 2016 that was accepted in 2015, however, the agreement has not been legitimatized in the parliament. Turkey submitted its "National Contribution" comprising the years between 2020 and 2030 to the United Nations Secretariat and informed that it will decrease the greenhouse emissions to 21 percent with the BAU (Business as Usual) method (Republic of Turkey, Ministry of Environment and Urbanisation, 2019). In the concept of Paris Agreement, Turkey demands to be listed as a "developing country".

In Turkey, where climate change and global warming are effectively contended with, the emission volume of energy sector has been increased two to three orders of magnitude and this necessitates the use of renewable energy resources. In this sense, the Energy Efficiency and Environment Department was established under the Ministry of Energy and Natural Resources by the Presidential Decree (dated 10 January 2019 and numbered 27) in order to work on climate change, environment and sustainability issues. .

1.2. Intergovernmental Panel on Climate Change

Being established by the United Nations Environment Programme (UNEP) and World Meteorological Organisation (WMO) in 1988, the Intergovernmental Panel on Climate Change (IPCC) is one of the leading organizations with 195 members that makes assessments on climate change. IPCC, based on published scientific, technical and socio-economic data, makes international assessments that set the scientific background for climate change. IPCC completed the 5th Assessment Report (AR5) in 2014. Since publishing the Fourth Assessment Report, three different working groups have produced reports on different fields. In 2018, IPPC issued a special report on 1.5 °C increase and its impacts (IPCC, 2018). 6th Assessment Report and Synthesis Reports will be published in 2022.

According to 1.5°C Special Report of IPCC (2018), if the global warming increase at current rate, it is highly probable that the increase will reach 1.5 °C in years of 2030-2050. The report also states that human-induced warming from pre-industrial period to the present time will be permanent for centuries and will give rise to long-term impacts on the climate system such as sea level rising and associated effects. However, emissions cannot be the sole factor for 1.5°C warming.

Risks expected for 1.5°C temperature increase are higher than those of current warming level but lower than for 2°C warming. These risks depend on the size of warming, warming rate, geographic location, development level, vulnerability level and adaptation options and their applications.

The climate models demonstrate the relations between the climate components (atmosphere, lithosphere, biosphere, hydrosphere and cryosphere) with measurable and observable methods. The Global Climate Models (GCMs) that are complex and comprehensive are operated based on scenarios proposed by IPCC. To obtain detailed projections, outputs of global climate models are introduced as the inputs to the regional climate models (General Directorate of Meteorology, 2018). According to climate models, strong differences are estimated in the regional climate characteristics as between current warming level and 1.5°C, and between 1.5°C and 2°C. The expected impacts are given in Table 1. Accordingly, average temperature increase in land and oceanic areas and extreme temperatures in densely populated areas are expected at high significance level. On the other hand, extreme rainfall in several regions and drought and insufficient rainfall in some regions are expected at a moderate significance level.

Table 1: *Expected impacts in climate characteristics (IPCC, 2018).*

Expected impact	Reliability
Average temperature increase in several land and oceanic areas	High
Extreme heat in densely populated areas	High
Extreme rainfall in several regions	Moderate
Drought and insufficient rainfall in some regions	Moderate

The impacts on bio-diversity and ecosystems including extinction of species expected from 1.5°C increase is lower than those from 2 °C increase. Projections reveal results of high significance level such that if the global warming is restricted to 1.5°C, the expected impacts on land, freshwater and coastal ecosystems will be much lower than 2°C increase (IPCC, 2018).

If the global warming is restricted to 1.5°C rather than 2°C, it is projected that the temperature increase in the ocean water and acidity of seawater will be decreased. Correspondingly, it is highly probable that risks on marine bio-diversity, fishery industry, ecosystem and associated services to the people will be decreased. Climate-induced risks on health, life, food safety, water supply, human safety and economic growth will be increased with 1.5°C increase and they attain serious extents by the 2°C increase.

IPCC states that results of published research indicate that the cost of net loss arising from climate change will be too much and increase in time. Scientists have accurate findings to assert that global temperature will increase tens of years because of greenhouse emissions from human-induced activities. More than 1300 scientists joined IPCC predict that temperature in the next century will increase in the range of 1.5 to 5.6 °C. According to IPCC, the extent of climate change impacts in various regions will change in time with respect to mitigation and adaptation ability of different social and environmental systems.

2. THE EFFECTS OF CLIMATE CHANGE ON WATER RESOURCES

Climate change and water are closely related. According to scientists, the most important impacts of climate change are breakdown of water cycle and deterioration of water quality. The volume of water resources in the world is constant by the water cycle, however, since the location and time of water resources change due to climate change, the management of water resources will be a hard task by means of quantity and quality. Considering that daily life and plans are arranged with respect to hydrologic systems, understanding the effects of climate change on drinking water sources, sanitation, and food and energy production is quite crucial.

Because our planet is warming, considerable harmful impacts are expected on water resources (Water Calculator, 2018). The extent of change in the following few ten years depends on the volume of greenhouse emissions and sensitivity of our planet (NASA, 2019e).

The impact of climate change on the quality of water resources can be monitored with physicochemical parameters, micro pollutants and biologic parameters. Basic physicochemical parameters include temperature, pH, dissolved oxygen, dissolved organic material and water-soluble nutrients. Micro pollutants are metals, pesticides, and inorganic or organic parameters such as pharmacological products. The biologic parameters are water quality indicators such as pathogen microorganisms, cyanobacteria and fish, green algae, diatoms. The impact of these parameters depends on the type of water mass (e.g. river, dam and pond) and water mass characteristics (e.g. retention time in water, size, shape, depth) (Delpla; Jung; Baures; Clement & Thomas, 2009).

Climate change indicators such as changing temperature, sudden weather events (e.g. flood, drought, storm) and increasing solar radiation result in changes in physicochemical parameters in waters. For example, oxygen density in water decreases by 10% for each 3°C temperature increase. The effects of climate change on the quality of surface waters and drinking water supply has been examined and it was noticed that drinking water supply can be interrupted due to floods and drought. Moreover, depending on the decrease of water volume, dissolved solid content might be increased and therefore drinking water resources may not meet the quality standards of drinking water (Delpla; Jung; Baures; Clement & Thomas, 2009).

The impacts of climate change on water resources at basin scale comprise the following (Demuth, 2017).

- ***Flooding***; Due to extreme weather events, during the winter season river flows, surface flow and flooding are expected to be much frequent.
- ***Drought***; Due to high temperature and increasing rainfall, drought is expected.
- ***Hydroelectrical power***; Variations in water discharge will lower the clean power production.
- ***Agriculture***; The need for irrigation water will be increased.
- ***Snow mass***; 25% decrease will modify the water supply.

- ***River flow***; Variation in water flow will affect water quality, water supply, fishery industry and recreation activities.
- ***Groundwater***; Due to hydrological changes (e.g. shallow water level) and increasing water demand some shallow wells will be dried up.
- ***Water use***; Agricultural and urban water demand will be increased.
- ***Water quality***; Due to sea level rise, salty water intrusion will affect deltas and coastal aquifers.
- ***Water stress in deltas***; Sea level rise will threaten water sets.
- ***Habitat***; Warmer river waters will stress cold-water fish such as salmons.

The relation between water, agriculture, energy and climate is quite complex. Climate change has the potential to threaten the security of water, food and energy systems. For example, electricity supply by hydroelectricity power plants may be at risk as a result of climate change, because decreased precipitation, extreme rainfall in some cases and the change of rainfall regime in time will cause difficulty in the management of hydroelectricity-producing dams. Similarly, food safety may be at risk as a result of soil loss triggered by the extreme rainfall and decreasing soil efficiency by salinization or difficulty to supply irrigation water due to lack of rainfall.

The lack of water quality and discharge data for several rivers and aquifers is a big disadvantage for the assessment of variations. The observed changes depend on several driving forces including population increase, changes in the land use, migration, urbanisation and climate change. There is limited information on renewable groundwater resources which exert a great role in water storage and the food production. Therefore, approaches should be regional rather than global and data for modelling must be collected at micro scale. Adaptation strategies should be improved at local scale.

Determination of impacts of climate change on water resources and endeavoring to achieve adaptation/mitigation are quite important for the security of life on our planet.

3. CASES FROM COUNTRIES

3.1. Brasil

Groundwaters

Although Brasil has a large water potential, distribution of waters among the regions is considerably different. At present, misplanning of land and water use is the chief reason for the shortage in spite of economic growth. For example, although the southern part of Brasil has a great water potential, it faces water shortage due to uncontrolled urbanisation. Water potential in Brasil particularly during the summer time is directly related to climatic factors. Delays in the starting of rainy season may affect agriculture and hydroelectricity production. The extreme events in the Amazon basin such as drought in 2005 and flooding in 2009 had seriously affected the economy and residents. It is stated that Brasil is sensitive to such climatic anomalies and will keep its sensitivity to extreme weather and rainfall events that are induced by climate change (Marengo; Tomasella & Nobre, 2017).

Variations in precipitation regime and order may also affect river flow. Studies yield that the São Francisco River will be the most affected river by such changes. Decrease in rainfall will lower the discharge and then seriously affect the irrigation and hydroelectric production. Actions in adaptation and reduction and monitoring plans on water resources are matter of urgency with regards to climate risks. Comprehensive studies are needed on climate changes and its impacts on water resources. Projections on climate change and uncertainties should be considered in the management of water resources and application of water policies.

Most studies carried out in Brasil focusing on surface waters, hydroelectricity production and agriculture were reviewed. Scenarios used in a study by the Sustainable Development Organization (Salati; Schindler; Victoria; Salati; Souza & Villa Nova, 2009) indicate that in all large basins of Brasil water excess will be decreased. In the study, for B1 and A2 scenarios HadRM3P regional model and the average of 15 climate models of IPCC were used. Thornthwaite-Mather Water Balance model and calibrated water balance were applied to 8 hydrographic regions in Brasil and the results showed that water excess in the 1960-1990 period was consistent with measured discharges at the ANA main station. It was stated that the decrease in water excess in the Sao Francisco River basin at northeastern part of Brasil was not significant. Decrease in water discharge in the Tocantins River basin is also expected. Considering the extreme sensitivity of northeastern region to the water deficit, climate change is expected to have serious agricultural impacts (Tomasella; Rodriguez; Cuartas; Ferreira, M.; Ferreira, J. & Morengo, 2009). Results of EMBRAPA study (2008) indicate that global warming will cause 7.4 billion US dollars loss in agriculture for the year of 2020 which may attain 14 billion US dollars in 2070. Results also showed that soya production will be most affected. According to the worst scenario, the losses may be up to 40% in 2070 which correspond to 7.6 billion US dollars. Due to increasing risks, coffee production in southeastern Brasil will be significantly affected but increased in the southern part. Production of corn, rise, bean, cotton and sunflower will be considerably decreased whereas sugar cane production will be doubled.

Regarding hydroelectricity production, A2 and B2 scenarios imply 1% and 2.2% decrease, respectively (Schaeffer; Szklo; Lucena; Souza; Borba; Costa et al., 2008). In the Sao Francisco River basin, which is the most affected region, the loss is expected to vary from 4.3 to 7.7%.

In a more detailed study, A1B scenario and ETA model (40 km resolution) and spherical HasCM3 model at boundary conditions were used for the Tocantins River basin and its sub-basins (EMBRAPA, 2018). Regarding 2080-2090 scenario, decrease in flow rate will be 30% as monthly average which will attain 60% during dry period. It is proposed that impacts will be much higher in the Araguaia River basin. Results of study showed that water deficit will not be same throughout the year and impacts will vary with respect to characteristics of hydrographic basin.

Groundwaters

Temperature increase arising from global warming has direct impact on hydrological cycle. Temporal and spatial distributions of total rainfall are altered (frequency of drought and flooding). This affects some hydrological parameters such as flow rate and infiltration. These variations affect the water storage underground and thus recharge of aquifers. In other words, climate change affects the water level in aquifers. This affects not only the water intended for human consumption but also regulation capacity of large rivers creating negative conditions for all water-consuming sectors (ANA, 2005).

According to ANA report (2005), recharge flow rate of renewable underground reserves in the country is about 24% of average flow rate of rivers within the country's boundaries and 49% average flow rate during the dry period. Considering that usable reserve is about 20% of renewable resources, the total usable groundwater reserve in the country is 8400 m^3/sec.

In Brasil, there are important aquifer systems with good water potential which are well distributed among the regions. Although surface water is abundant, underground reserves might be accessible at a certain extent; however, the fact is quite different. Groundwater is the major water resource used in most of regions and city centers. Groundwater used for human consumption, industry and agriculture are the principle water source in many part of the country.

As a result, it is noted that possible spatial and temporal effects of climate change on water resources in Brasil are not exactly known and such uncertainties pose an obstacle for the operational planning and management of water resources.

It is suggested that first action to be taken should be the establishment of investigation and monitoring programs for the assessment of climate change and related risks. Northeastern and southeastern regions are quite sensitive due to their dependency on the electrical energy. In these regions, climate change may increase the current risks as raise in the air temperature and changes in the land use triggered by increasing population, urbanisation, industrialization, agriculture and livestock production. Current problems in the Amazon basin are due to biodiversity loss and change in the hydrological cycle.

Scientific findings indicate that climate change may create serious problems in water resources in Brasil. Droughts and extreme rainfall in the last 10 years and flooding events in 2009 affected regional and national economies and caused serious social impacts.

In order to accurately manage water resources under climate change risks, it is necessary to have information regarding water volume and how it will change with respect to different scenarios. Therefore, improvement of current studies and mitigation of uncertainties are of great importance. There is much more information on surface waters in comparison to groundwaters. However, we have limited evidence how the ecosystems are resistant or flexible to variations in the change, that are essential part of the climate change scenarios.

In the following, some adaptation acts for water resources are listed:

1) Improving sewage and water supply infrastructure.
2) Lowering illegal use and leakage.
3) Taking collective protective measures in water use by industrialists and community.
4) Requesting precautions to avoid water waste during the approval of new building projects.
5) Retrieval of natural ecosystems in wetland areas.
6) Regarding flooding and landslide risks, remediation in description of risky areas.
7) Warning systems in weather forecasting and natural disaster preparedness.
8) Improving warning systems for flooding and landslide.
9) Encouraging the use of flood-resistant materials and design.

3.2. European Union

The effects of climate change on water resources in Europe are assessed considering 2°C increase. In the study, LISFLOOD water resources model developed by Joint Research Center (JRC) was used and land use change and changes in water consumption were considered. In the study, two 30-year climate windows were considered and they were compared with climate windows of 1981-2010 period (Bisselink; Bernhard; Gelati; Adamovic; Jacobs; Guenther; Mentaschi & De Roo, 2018).

Assuming that land use and water need (for 2006) are not changed, climate projections for the 1981-2100 period were studied with a hydrological model and 2°C increase period was considered in 5 different climate change projections. Accordingly, except for the Mediterranean region, it is expected that rainfall will increase in many parts of Europe and the highest precipitation will be on the Alps and Eastern Europe. Increase in rainfall is generally related to temperature increase which triggers convective storms during the summer months.

Impacts recognized on river flow and extreme events (flooding and drought) are listed in the following:

- In many parts of Europe, annual average (median) river discharge is increased. However, four-season flow decrease is expected for rivers in the Mediterranean region.
- As a result of climate change, extreme peak discharges are expected to increase in almost every part of Europe including the Mediterranean region. The largest increase on flooding damage is likely to occur in the inland countries during the summer time. In the coastal regions and Scandinavia, the frequency of flooding will be decreased. Due to ever growing of cities in the vicinity of large rivers and increasing flooding damage, special attention must be paid to flood risk management and planning.
- Particularly in the Mediterranean region (Spain, Portugal and Greece), drought in rivers during the summer time is expected to increase seriously. This, in turn, will affect the supply of cooling water needed for industry and energy production, irrigation water reserve, critical environmental flow conditions and hydroelectricity potential.
- According to climate change projections, the most extreme events are flooding risk during summer season in the eastern part of Europe (e.g. Poland) and Baltic countries and extreme drought in the Mediterranean region.

The changes expected in the hydrological cycle are directly reflected on water resources indicators. The southern Europe countries are expected to witness an increasing water drought:

- According to climate change projections, the number of days in a year during which river flows are below the critical level will increase in the Mediterranean region and decrease in the northern latitudes. Low flow conditions will be much more particularly in Spain and Portugal.
- According to climate change projections, groundwater resources will decrease in southern European countries but increase in northern European countries. In southern European countries, overabstraction of groundwater beyond

the limits of renewable capacity will cause critically deep groundwater levels and increasing pumping costs.

- According to 2°C temperature increase scenario, soil humidity stress conditions will increase that cause low agricultural yields in existingly stressed areas of the Mediterranean region.
- The southern Europe with high water consumption rate with respect to its present water potential will greatly suffer from temperature increase and waning of freshwater resources. In the same time, due to increasing evaporation the need for irrigation water will be increased.
- In the Mediterranean countries, particularly Spain, management of water resources will be unsustainable. During global warming conditions, water imported to the country will not be adequate to meet the domestic water demand.
- In some regions in the Eastern Europe, water resources from which domestic water demands are met will be waned.

Policy suggestions:

- In order to comply with decreasing water availability of Europe particularly in the Mediterranean region, water saving is inevitable. For this, irrigation yield could be increased, deficit irrigation could be applied, the yield of cooling processes in the industry and energy production could be increased and water resources in a given basin may be managed better between the years (e.g. irrigation water used in the summer time can be stored within dam of hydroelectricity power plants during the winter).

There is a need for synergy between agriculture and water policies.

- In order for users to make water saving, it is necessary to warn people regarding the importance of water and apply a reasonable water pricing. If water is free of charge or cheap, saving could not be possible.
- In some European countries, in order to prevent overabstraction of groundwater, it is necessary to apply control mechanisms. Water withdrawals should be well recorded.
- Since flooding damage is expected to increase particularly in the city centers, flood risk management, flood prevention and adaptation issue will be much more difficult to manage.

3.3. Central Asia

According to field observations in the central Asia, warming has taken place for a few ten years and its effects are felt in the daily life. However, there are no sufficient information regarding the impacts of climate change on the environment and human life. In the report founded by the Asian Development Bank, new climate and hydrologic models indicate that river water in the central Asia should be partly regarded as unrenewable source (Punkari; Droogers; Immerzeel; Korhonen; Lutz & Venäläinen, 2014). One third of river waters is derived from mountain glaciers which are rapidly melted due to global warming. In this report (Punkari et al., 2014) it is also stated that as a result of climate change flat areas will be much hotter and drier. It is proposed that in the future water deficit will be a serious problem for the national economy and environment. With decreasing volume of river waters, water demand will increase which, in turn, result in disagreements in the water management and conflicts among the people.

In the central Asia, global warming will cause thawing of permafrost in mountainous areas which may trigger landslide and mud flow. Each year such disasters are affecting residential areas and infrastructure. Since melted snow is the major water source in the basins, spring floods will be more frequent. The mountains and nature of central Asia have unique features. In the report, it is noted that climate change will destroy these ecosystems and biodiversity and negatively affect the rarely seen plant and animal species.

All the countries have strategies to provide climate change mitigation controlling the greenhouse emissions and protecting the plant cover. Particularly central Asian countries should have strategies for adaption to climate change. Most of present strategies have ignored the problems arising from the climate change and proposed incorrect results. In technical aid project founded by the Asian Development Bank, in order to determine possible impacts of climate change on the hydrology of the Aral basin, models were developed combining the field observations with satellite data. In this project, using the temperature and precipitation data of the past three-dimensional map matrix of the Aral basin was constructed. Climate change scenarios for the future were made by IPCC and several research institutes proposed projections. SPHY hydrologic model, using the past and estimated climate data, analyzed rainfall, snow formation/melt and mass balance of glaciers. Model outputs comprise detailed water discharge from all the rivers and variations in water budget and future tendencies were determined. Using the WEAP frame the change in water demand in each river basin was analyzed with a water allowance model. Results indicate that water demand will increase but river discharges will be significantly decreased.

It is noted that projections are based on climate models given in IPCC 4th Assessment Report (Randall et al., 2007). Simulations used belong to 5 different models of moderate level emission scenario. It was proposed that until 2050, the average temperature will increase throughout the year and annual average temperature increase will be around 3°C. Warming will be at maxima in the mountainous areas in the northern latitudes.

Although estimated variations in the annual rainfall until 2050 are relatively low, they vary from one model to another. It is noted that southwest part of the region which is currently arid will be more arid particularly during the summer time. On the other hand, the total annual rainfall on the northern parts and mountainous will increase about 5 to 10%.

In central Asia, impacts of climate change in some parts of Kazakhstan will yield positive results (Lioubimtseva & Hennebry, 2012). Growth season would be much longer and water reserve could be improved. However, in areas presently suffered from water deficit the conditions might be much harder with the increasing temperature and evaporation and decreasing rainfall. In the region, some parts of Turkmenistan, Uzbekistan and western Kazakhstan will be much arid. For example, Uzbekistan economy is based on wet agriculture feeding from Amu Derya River. Therefore, decrease in water resources is expected to have serious problems for the country's economy (Schlüter; Hirsch & Pahl-Wostl, 2010). In order to comply with proposed risks, like the Aral Lake water system, a coordination is necessary among the Asian countries.

In the report, snow masses, glacial and small glacial sheets in the mountainous areas of the central Asia are noted to be quite important for the freshwater reserve. Depending on rapid decrease in ice and snow cover, a decrease in the water reserve and hydropower potential and seasonal decreases in surface flows, discharged from snow waters from the Tien Shan and Pamir Mountains, are expected.

In addition to variations in the rainfall, increasing temperatures are also important factors. Large-scale irrigation systems are presently suffered from water deficit and due to increasing temperature water demand of irrigated plants will increase. Additionally, high temperatures will also affect the natural plant cover and evaporation will increase and therefore less water will be available for the rivers.

An assessment for the regions yielded that the increase in water demand in Syr Darya and Amu Darya basins for 2050 will be 3-4% and 4-5%, respectively. The common impact of high-water demand and low discharge will thoroughly increase the present water deficiency in these river basins. It is expected that in 2050, water deficit in the Syr Darya basin will be 35% of total demand while that in Amu Darya basin will be up to 50%.

The most cost-effective adaptation options for the central Asia are reported as remediation of agricultural applications, application of deficit irrigation, reuse of water in agriculture and decreasing the size of irrigated areas. In general, measurements applied to agriculture are expected to be more efficient than those of domestic water use.

4. WATER STATUS IN TURKEY

In a study in which world countries are ranked with respect to water scarcity index, Turkey has been ranked 78th among 147 countries (Table 2) (Lawrance; Meigh & Sullivan, 2002). Finland is in the 1st rank while United Kingdom with the same score to Turkey is ranked 11th. For the determination of water scarcity index, assessment is made for 5 different categories; resource, access, capacity, use and environment. In each category, scores of countries on the scale of 20 are computed using the indicators given in Table 3. Results of this study indicate that Turkey has the lowest scores from the categories of resource, use and environment. Resource assessment is estimated with respect to freshwater flow in the country, flow from other countries and population.

Table 2: *Ranks of various countries with respect to water scarcity index*

Country	Resource	Access	Capacity	Usage	Environment	Water scarcity Index
Finland (1)	12.2	20.0	18.0	10.6	17.1	78.0
United Kingdom (11)	7.3	20.0	17.8	10.3	16.0	71.5
Germany (35)	6.5	20.0	18.0	6.2	13.7	64.5
Congo Republic (75)	17.1	10.3	11.8	7.3	10.9	57.3
Turkey (78)	7.8	14.8	13.1	10.7	10.1	56.5
Nigeria (129)	7.4	7.5	8.5	10.4	10.1	43.9

Total annual consumable underground and surface water potential of Turkey is 112 billion m^3, of which only 44 billion m^3 is used (State Water Works, 2012). Total annual utilizable surface water potential of Turkey is 98 billion m^3 of which 95 billion m^3 is from domestic rivers and 3 billion m^3 is from river flow from neighboring countries. Together with the underground water potential of 14 billion m^3, utilizable underground and surface water potential of Turkey is 112 billion m^3 (DSİ, 2016). In a project conducted by former Ministry of Forestry and Water Affairs Directorate General of Water Management, water potential of Turkey is noted as 108.5 billion m^3 which is close to 112 billion m^3 as given in several other studies (former Republic of Turkey, Ministry of Forestry and Water Affairs, 2016).

Table 3: *Indicators used for the estimation of water scarcity index*

Index component	Data used
Resource	Freshwater flow within the country, water flow from other countries, population
Access	Percent of population accessing clean water, percent of population accessing sanitation, percent of population accessing irrigation (adjusted for water resources for per person)
Capacity	Income per capita (ppp), mortality rate under 5-year-old, the percent of participation to education, Gini coefficient for income distribution
Usage	Domestic water use (lt/day), share of industrial and agricultural water use (adjusted for gross national product share of sectors)
Environment	Indices relevant to water quality, water stress (contamination), environmental regulations and management, information capacity, biodiversity (endangered species)

According to Falkenmark index, Turkey is not a water rich country (Table 4) and regarding water consumption rate, Turkey is beyond the world average. In Turkey where impacts of global warming are seriously felt, significant water deficit is expected in all sectors particularly for urbanisation, industrial and agriculture.

Table 4: *Water status of Turkey with respect to Falkenmark Index*

Category	Amount of freshwater available for each person each year	Turkey
Water poverty	Less than 1.000 m^3	1120 m^3/person/year (2030)
Water shortage	Less than 2.000 m^3	1519 m^3/person/year (2008)
Water prosperity	More than 8.000-10.000 m^3	4000 m^3/person/year (1960)

Utilizable water potential per capita in Turkey was 4000 m^3 in 1960. Water potential that was lowered to 1600 m^3 in 2000 is proposed to be down to 1120 m^3 in 2030 considering the population increase (Figure 1) (former Republic of Turkey Ministry of Forestry and Water Affairs, 2009). This figure is an indicatorof the fact that Turkey will be a water-poverty country in the future. Sectoral distribution of water use in Turkey by 2004 is as follows: irrigation 74%, drinking-utility 15% and industrial use 11%. In 2030, these ratios will be 64%, 16% and 20%, respectively (Figure 2). These data indicate that water use in agriculture sector will proportionately decrease but water use in industry will be doubled.

Figure 2: *Water potential of Turkey per capita (former Republic of Turkey Ministry of Forestry and Water Affairs, 2009).*

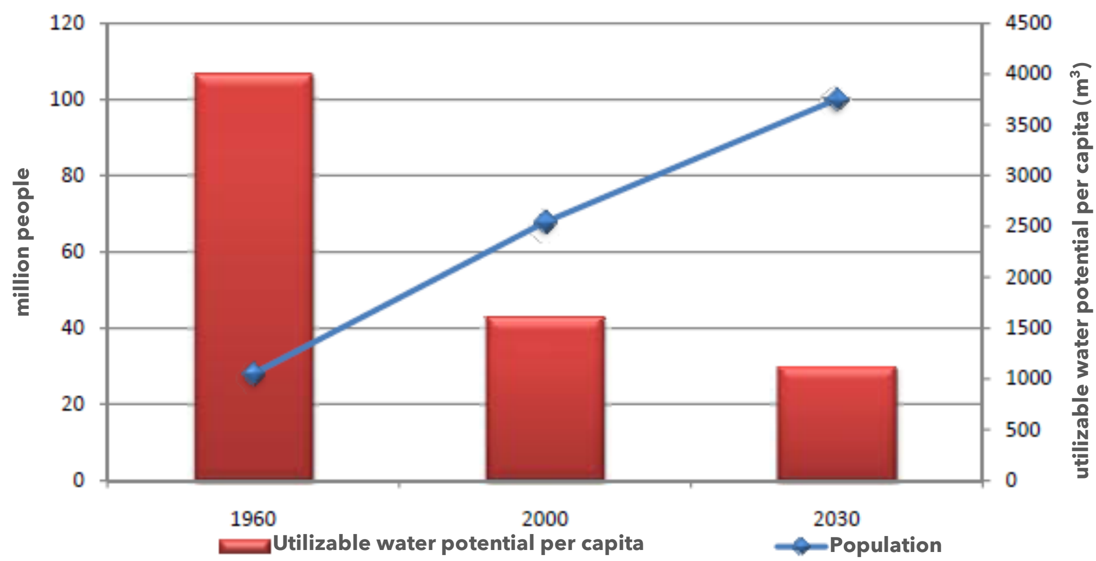
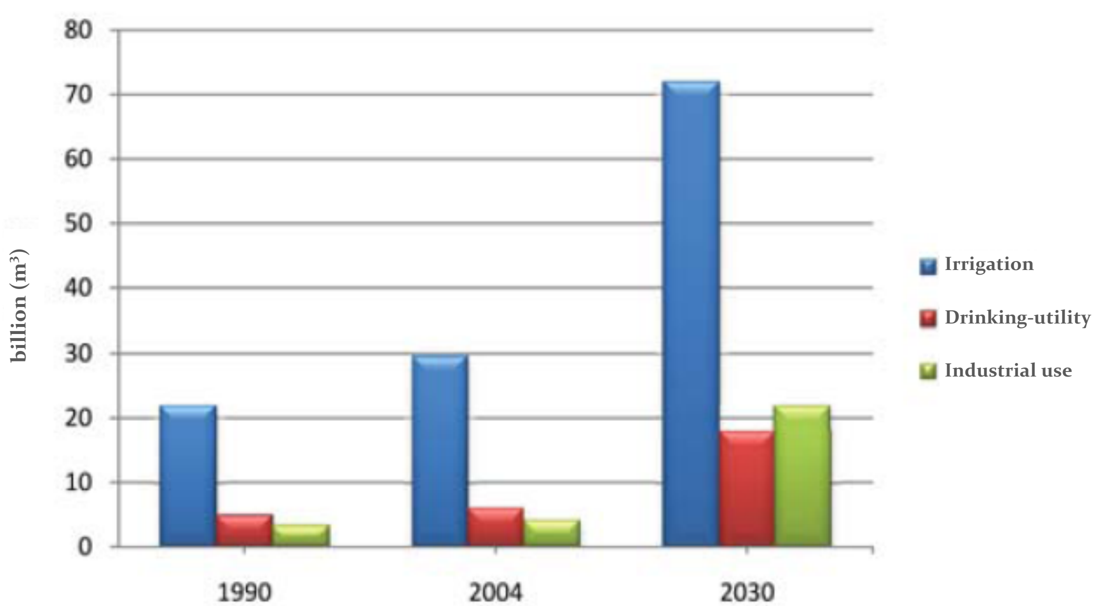


Figure 3: *Sectoral water use in Turkey.*



Turkey is divided into 25 hydrologic basins. Regarding water resources, Turkey is located in a semi-arid region and precipitation regime in the country show large seasonal and regional differences. Water demand in some river basins exceeds the potential of resources.

5. CLIMATE CHANGE IN TURKEY AND ITS EFFECTS ON WATER RESOURCES

Turkey is located in the Mediterranean-climate region. Turkey is surrounded by sea on three sides with an average altitude of 1100 m and hosts several sub-climate types. Such diversity in climate types is closely linked to its location in a transition region which is affected all the year round by various pressure systems and air masses derived from poles and tropical belts. In southern and western regions Mediterranean climate is dominated; summers are hot and dry while winters are cold and rainy. Along the Black Sea coast climate is much colder and rainy. In northeast Anatolia, continental climate is dominant; winters are long and severe while summers are short and cool. In the central Anatolian plateau, summer is dry and hot and winter is represented by cold steppe climate (Türkeş, 2008; REC Türkiye 2015).

As given in "Climate Change Guide: from A to Z", a book prepared by REC in 2008 and revised in 2015, according to observations between the years 1941 and 2003, particularly spring and summer (lowest during the night) minimum weather temperatures increased in many parts in Turkey. Significant decrease in precipitation and drought are more pronounced for the winters.

In Climate Change Guide 1971-2014 period was also evaluated by means of temperature and precipitation. The most remarkable historical climate change events in the last 42 years in Turkey are listed as follows:

- Temperature increased in every part of Turkey (Şen, 2013).
- For the same period, there was no significant change in precipitation.
- For the last 60 years, 10-m retreat on mountain glaciers (Sarıkaya, 2011).
- Sea level was in tendency to rise (Demir, 2008).
- Number of natural disasters was increased.

The results of modelling studies conducted by the General Directorate of Meteorology based on the IPCC A2 Scenario (average global temperature increase of 2-5 ^{o}C) and using the PRECIS Regional Climate Model developed by the Hadley Center for Climate Prediction of the Met Office of United Kingdom are given in Table 5 (REC Turkey, 2015).

Table 5: *Expected climate change parameters in Turkey from the results of PRECIS Model (REC Turkey, 2015). The results are projected for 2071-2100 period compared with the average values of 1961-1990 period.*

Temperature	▪ Average temperature increase of 5-6 °C except for coastal areas ▪ Temperature increase is higher in west during summer and in east during winter
Precipitation	▪ Decrease in average precipitation up to 40%. ▪ Decrease in precipitation in the west in total amount and %. ▪ Significant decrease in summer rainfall in central Anatolia and Black Sea regions. ▪ Rainfall increase in the Black Sea during autumn
Snow thickness	▪ Decrease in snow thickness up 300 mm on the Eastern Black Sea and Eastern Anatolia mountains

Findings based on future scenarios are summarized below (Demir; Kılıç & Coşkun, 2008):

- The temperatures for every season in every part of Turkey will be at an increasing trend (the increase in the summer time will be relatively higher),
- Precipitation in southern parts of Turkey will decrease and partly increase in the southern parts,
- Sea level rise will affect the low-elevated areas of coastal cities at river deltas,
- Water deficit and stress risks will increase throughout Turkey,
- Precipitation increase in the Eastern Black Sea region will increase the landslide risk,
- Weakening of snow cover will increase the avalanche risk,
- Drought and hot air wave risks will increase and become intensified

In parallel to global findings of IPCC, average surface temperatures in Turkey tend to increase. It is reported that rather than a general increase or decrease, there are irregularities in the precipitation regime and a significant difference between the volume of rainfall during dry and wet periods (Demir, 2008).

In another study suggesting a strong relation between rainfall and drought, using the Standardized Precipitation Index (SPI) and Standardized Precipitation Evapotranspiration[1] Index (SPEI), precipitation regime in Turkey (total, the minimum and maximum values), the length of arid days, arid periods and the intensity of drought for the 1971-2000 period are assessed. Results of this study yielded that the extreme rainfall and arid period temperatures arising from climate change will increase. Depending on changes in precipitation regime, number of arid days, the frequency of arid periods, and intensity of drought in Turkey may be doubled (Dabanlı, 2019).

In Turkey, increase in climate change-induced summer temperatures, decrease in winter precipitation, loss of surface waters, increasing frequency of droughts, soil deterioration, coastal erosion, flooding and overflow threaten

[1] Evapotranspiration, a term combined from the evaporation and transpiration, indicates total water loss of plants via water consumption and evaporation.

the water potential (Republic of Turkey, Ministry of Environment and Urbanisation, 2011).

The project so called "Impact of Climate Change on Water Resources" covering the period of 2015-2100 carried out by Republic of Turkey Ministry of Agriculture and Forestry in 2016 is a comprehensive study examining the impacts of climate change on surface and groundwater resources and adaptive acts (former Ministry of Forestry and Water Affairs, 2016). Within the scope of climate projections which comprise the first stage of this project, encompassing the whole Turkey, outputs of three spherical models comprising the base of 5th Assessment Report of IPCC and RCP4.5 and RCP8.5 emission scenarios and outputs of RegCM4.3 regional climate model were operated. RCP4.5 and RCP8.5 scenarios used are developed by IPCC and the most preferred scenarios.

With the aid of model simulations, projections of a total of 8 parameters and 17 climate indices representing extreme conditions were generated in a basin scale and the differences of studied parameters from the reference period of 2000 (accepted as the simulation of 1971-2000 episode) to the year of 2100 were estimated as seasonal and annual averages for 10- and 30-year intervals. It is noted that by the accomplishment of this project 3 spherical climate model results in 10 x 10 km resolution are obtained for the first time for Turkey. In the calculations it was assumed that equivalent CO_2 concentration in the atmosphere was 1370 ppm (RCP8.5 scenario) and 650 ppm (RCP4.5 scenario).

In the project sectoral impact analysis was made and a methodology was developed for analysis of the impact of climate change on drinking and utility water, agriculture, industry, ecosystem, tourism and energy sectors in Turkey. Taking into account the climate change projections specific to three basins that are selected as a pilot basin, the effect of water on sectors was analyzed and the exposure intensity of basins from each sector was categorized as "little effect, moderate effect, high effect, very high effect" (former Republic of Turkey Ministry of Forestry and Water Affairs, 2016).

It is noted that all simulations used in the project point to a significant warming in seasonal and annual scales during the 2015-2100 period. In the first years of 2015-2100 period, in some regions temperature changes are very little and even in some years cooling is recognized, however, in the following years the increase in greenhouse gasses increases the rate of warming. It was proposed that after year of 2050 temperatures of the winter season will be at least 1°C higher than the 1970-2000 period. It is reported that temperature increase during summer and spring seasons will be greater than that of winter and autumn months. Temperature increase through the 2015-2100 period decreases from south to the northern part of Turkey. The highest temperature increase is recognized in southeastern Turkey and along the Mediterranean coast. To the 2100's, temperature increases particularly in eastern and southeastern parts of Turkey are expected around 4-6°C (former Republic of Turkey Ministry of Forestry and Water Affairs, 2016).

Model simulations obtained from the ClimaHydro project point that climate regime in basins at northern Turkey will be much rainy with respect to the reference period. For example, RCP8.5 scenario shows that drought in the basins will be much severe from north to south since the 2050's and 10-year average of total annual precipitation in basin scale will drop to 150 mm. The lowest estimated precipitation for the 2015-2100 period throughout Turkey was found in the Konya Closed Basin. If variation in precipitation is examined as the percent of total annual precipitation in basin scale, the maximum changes are recognized in the decreasing order in Eastern Mediterranean, Western Mediterranean and Ceyhan basins. In RCP4.5 scenario, decreases in the total annual precipitation in these basins was 12-15% in the last ten years of the century while in the RCP8.5 scenario, precipitation is up to 20-25%. In the Euphrates-Tigris basin total annual precipitation in both scenarios is expected to decrease in the range of 3 to 8% (former Republic of Turkey Ministry of Forestry and Water Affairs, 2016).

The impact of RCP4.5 and RCP8.5 scenarios on each model is different for the Meriç-Ergene, Marmara, Northern Aegean, Susurluk, Gediz, Küçük Menderes and Büyük Menderes basins in western part of Turkey. For the RCP4.5 scenario, HadGEM2-ES and CNRM-CM5.1 model simulations show that climate regime in Marmara, Northern Aegean, Meriç-Ergene, and Küçük Menderes basins will be much rainy than the reference period while MPI-ESM-MR point that Eastern Black Sea, Western Black Sea, Marmara and Yeşilırmak basins will be much rainy (former Republic of Turkey Ministry of Forestry and Water Affairs, 2016).

Regarding the extreme weather events, an index of Warm Spell Duration Index (WSDI) was used which is one of the most important indicators of the temperature excess. WSDI indicates the calendar days in which the daily maximum temperature exceeds the 90th percentile of reference period. Except for the Southeastern Anatolian region, index results of RCP4.5 and RCP8.5 scenarios for the 2015-2040 period are generally consistent with the reference period and, as indicated by all earth system models, heat waves will increase in each 30-year period from southern latitudes of Turkey to the north. Based on the RCP4.5 scenario, particularly following the year of 2041, index values of the highest heat wave are proposed in Eastern and Southeastern Anatolia. In the last projection period, in southern part of the country index values of 80-120 days will be dominant. In the RCP8.5 scenario, much higher increases are proposed. Maximum and minimum temperatures are expected to increase to in the end of century which will be more pronounced for the Mediterranean and Southern and Eastern Anatolian regions (former Republic of Turkey Ministry of Forestry and Water Affairs, 2016).

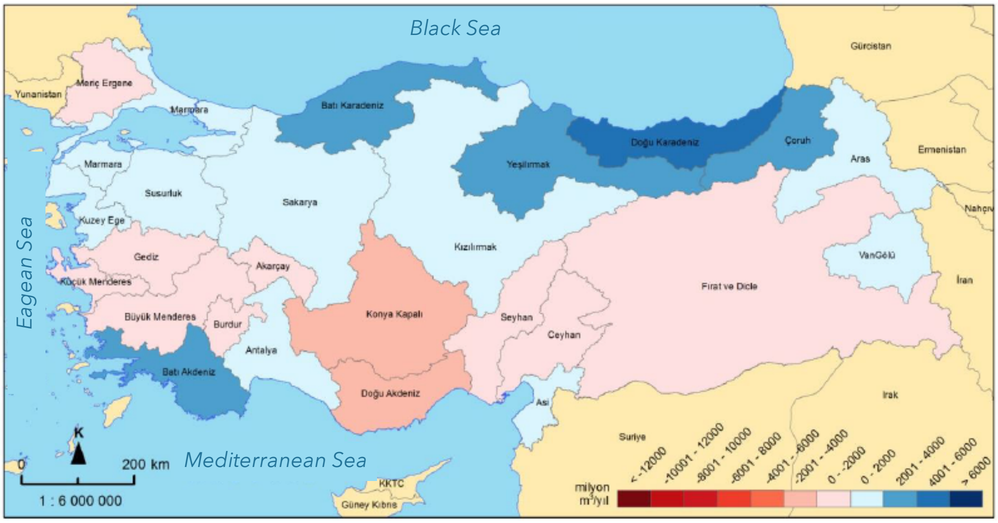
As a result of high daily temperatures, the frequency and intensity of heat waves in these regions are predicted to increase. Additionally, high night temperatures will increase the damage of heat waves since it may restrain the nightly relief of humans and animals. This will also increase the demand for energy that is used for space cooling during the night time. Increase in the evaporation rate together with expected rainfall shortage will increase the stress in water resources and agriculture. It is noted that a restoration is needed for the tourism sector along the Mediterranean coast (former Republic of Turkey Ministry of Forestry and Water Affairs, 2016).

In the project which also includes hydrologic projections, first time in Turkey water potentials of all basins are estimated with a mutual hydrologic model. Thus, precipitation values were converted to flow values and considering the present status of surface and underground water resources in all basins and estimated status for the projected periods, a water potential modelling/calculation study was carried out. Regarding the hydrologic projections, proposed change in the hydrologic reserve was assessed specific to basins and the Meriç–Ergene and Fırat-Dicle basins are found to be less affected ones through Turkey. The maximum impact of climate models/scenarios applied to the country is recognized in the Asi Basin. The most affected other basins, in the order of increasing rate of affection, are Burdur, Northern Aegean, Western Mediterranean and Akarçay basins in the western and central regions of Turkey.

Hydrologic projections also reveal that total flow in Turkey will decrease with respect to reference period. HadGEM2-ES climate model outputs based on hydrologic modelling yielded that median gross water potential for three sub-periods of the 2015-2100 period will decrease about 40-45% with respect to median value of reference period whilst hydrologic model projections using MPI-MSM-MR climate model suggested that the rate of decrease will be in the range of 15 to 20%. Regarding all the periods, the most significant water loss is expected in Euphrates–Tigris, Eastern Mediterranean and Konya Closed Basin (Figure 3-5). In RCP4.5 scenario of the Konya Closed Basin, HadGEM2-ES model suggested 10 to 30 mm water level decrease for the 2015-2100 period.

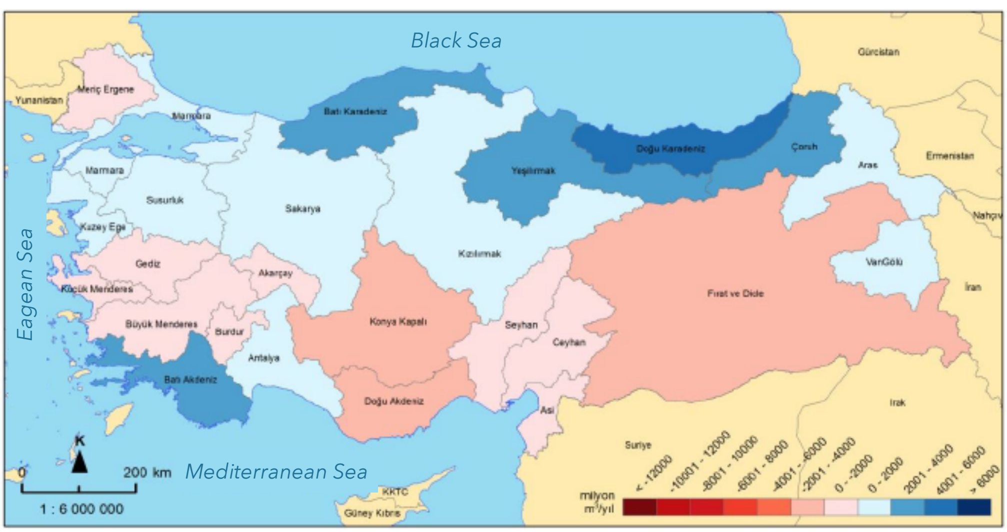
According to RCP4.5 scenario operated by the HadGEM2-ES model, Eastern Mediterranean and Çoruh basis are reported to have water excess for all the periods. Likewise, in all projection periods, net water volumes of the Marmara, Susurluk, Northern Aegean, Western Black Sea, Yeşilırmak, Antalya, Aras and Lake Van basins are found sufficient for the estimated water uses. It is noted that the Euphrates–Tigris basin by the starting of projection period and Eastern Mediterranean and Konya Closed basins during the 2041-2100 period are likely to face with a water deficit problem. Other basins may be experienced with low-degree water loss for all the periods. It is proposed that the years between 2041 and 2070 will be the most critical 30-year projection period by means of water availability.

***Figure 4:** Projections on water deficit and excess for basins (2015-2040) (former Republic of Turkey Ministry of Forestry and Water Affairs, 2016)*



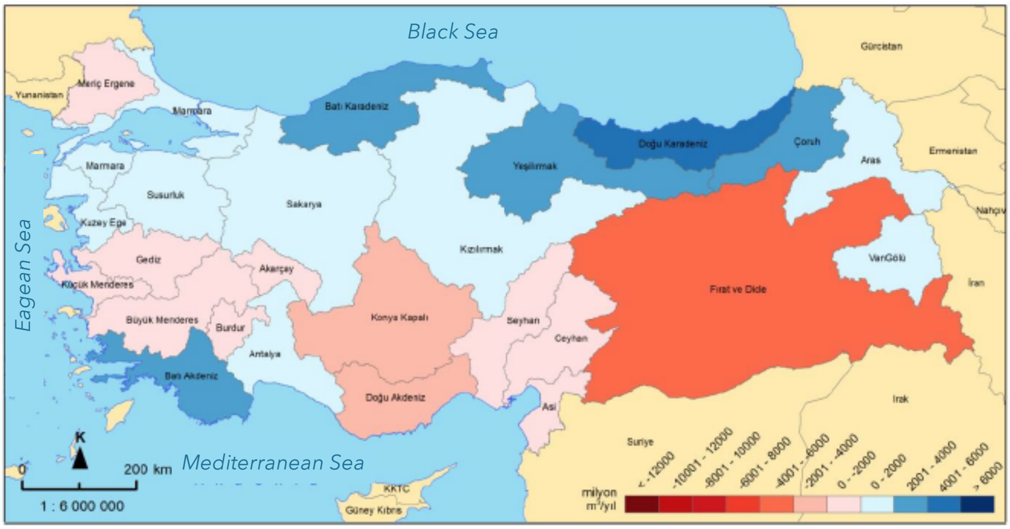
For the Fırat basin, 500 m^3/sec (water right committed to downstream countries) is taken into account.
For the Dicle basin, the average discharge to the downstream between 2011-2015 years is taken 342 m^3/sec (DSI data)

***Figure 5:** Projections on water deficit and excess for basins (2041-2070) (former Republic of Turkey Ministry of Forestry and Water Affairs, 2016)*



For the Fırat basin, 500 m^3/sec (water right committed to downstream countries) is considered.
For the Dicle basin, the average discharge to the downstream between 2011-2015 years is taken 342 m^3/sec (DSI data)

***Figure 6:** Projections on water deficit and excess for basins (2071-2100) (Republic of Turkey Ministry of Forestry and Water Affairs, 2016)*



For the Euphrates basin, 500 m^3/sec (water right committed to downstream countries) is taken into account.
For the Tigris basin, the average discharge to the downstream between 2011-2015 years is taken 342 m^3/sec (DSI data)

In the project snow projections are generally assessed. Both scenarios proposed that snowfall amount throughout Turkey will gradually decrease in the years of 2015-2100. As the warming increases precipitation occurs as snowfall which is hydrologically important since snow accumulated acts as a water reservoir and once melted during summer and spring months supplies water input to the river systems. Therefore, snow cover at high altitudes exerts a great control in the regional hydrologic cycle. Results of ClimaHydro project suggest that the decrease in snow cover particularly in particularly Eastern Anatolian region and Eastern Taurids Mountains may change the hydrologic cycle in the Euphrates–Tigris basins. Outputs of each of three models imply a water deficit of 2-12 billion m^3/y in the Euphrates–Tigris basin during the 2015-2100 period. Consequently, it is also noted in the report that Turkey needs to make a new assessment regarding the water rights committed to the downstream countries.

In a previous study on the Fırat-Dicle basin by Bozkurt and Şen (2013), GCM climate simulations were made for two 30-year periods (2041-2070 and 2071-2099) to examine possible climate changes in the basin. Outputs are in support of the IPCC results and suggest that the size of snow-covered areas will decrease since winter temperatures are likely to increase and early melted snow largely contribute to the surface flow with little penetration into the soil. To the end of this century, winter precipitation particularly on the mountainous parts of the basin is noted to decline in the range of 20 to 30%. All the simulations propose that in northern and mountainous parts of the basin precipitation will decrease while precipitation is expected to increase in the southern parts. Evapotranspiration will decrease with decreasing precipitation. The study which is based on a reference period of 1961-1990 proposes that surface temperatures throughout the basin will increase 1.5 to 5 ^{o}C. Due to heat waves, the basin which is already sensitive will suffer from extreme warming during the summer months. The total annual surface flow in the Eastern Anatolian Mountains is expected to decrease 25-55% and due to increasing warming the timing of surface flow is proposed to be 18-39 days earlier.

In the study of Bozkurt & Şen (2013), it is noted that due to drought in the winter season of 2007-2008, the agricultural production in 2008 in the Fırat-Dicle basin is significantly affected. In the future, the frequency of drought periods is expected to increase and climate change processes such as soils loss and desertification are noted to be dominant in the Fırat-Dicle basin. It is reported that due to geological changes rock-slope balance will be changed and the decrease in the snow cover will continue which might trigger landslide risk. Due to increasing transported material water quality will decrease and ultimately accessible water potential will decrease and the stress on water resources will increase. Due to change in time of surface flow, much more dam construction will be necessary to protect the water resources.

Ertürk et al. (2014) studied the impacts of climate change on groundwater resources in the Köyceğiz-Dalyan basin and stated that the quality of groundwater resources is getting decreased and ecosystem associated with groundwater resources is under threat. Diminished quality is attributed to decreasing feedback of groundwaters due to declining rainfall. Deterioration in the ecosystem is associated with variations in soil and water parameters. It is reported that plant existence and wild life in the region, coupled with increasing summer temperatures and evapotranspiration, will be in danger. In addition, the decrease in irrigation water will negatively affect the agriculture sector and increase the stress on water resources (Ertürk; Ekdal; Gürel; Karakaya; Guzel & Gönenç, 2014).

Regarding the lakes, the climate change has negatively affected the volume and quality of lake waters in Turkey (Yüksel; Sandalcı; Çeribaşı & Yüksek, 2011). For example, the area of Tuz Lake was 92562 hectares in 1987 but lowered to 32552 hectares in 2005; shrank about 35%. In the Beyşehir Lake, which is a freshwater lake, as a result of drought and agricultural irrigation water potential was decreased 23%. Likewise, water volumes and sizes of Eğirdir, Manyas, Ladik, Van, and Sapanca lakes have been seriously decreased.

The results of a project in which the impacts of climate change are assessed in a local scale indicate that water resources have been negatively affected (TEMA-WWF Türkiye, 2015). Because air temperatures in the Mediterranean region are above the seasonal averages, drought and degradation in water resources are evident. Some shifts were recognized in the marine ecosystem. As a result tourism sector might be badly affected. Moreover, diversity and amount of agricultural products will decrease which may cause disforestation and considerable damage on the agriculture sector, and decrease in biologic diversity linked to other sectors such as lumbering, hunting and natural life tourism.

The Konya case in the central Anatolia shows that agricultural production was damaged by the change in seasons and decrease in the volume of water resources and eventually food prices began to rise. Damage on the agricultural sector induced the domestic migration. In addition, wetlands, which have a critical importance to minimize the impacts of climate change, diminished and the frequency of natural disasters such as drought and erosion increased. In the Southeastern Anatolian region, Diyarbakır case was examined and observations indicated that water resources were decreased, winter drought is evident and as a result, energy demand for pumping water from deep wells increased. In Eastern Anatolian region, due to climate change winter tourism, agriculture, plant pattern and pasture livestock were negatively affected. The increase in the number and intensity of extreme weather events in the Black Sea region resulted in decrease in the population, production decline in tea and hazelnut and increase in the frequency of natural disasters such as landslide. Moreover, by the increase in seawater temperature Black Sea water has been recently threatened by the invasive species and fishery sector is negatively affected. Depending on the increase in the stress on water resources in the Aegean and Marmara regions, water supply to the cities has become a hard task and agriculture, livestock and fishery are adversely affected. According to impact assessment surveys, impacts of climate change on energy, agriculture and tourism sector were favored by 70%, 74% and 60% of the survey respondents (TEMA-WWF Türkiye, 2015).

In order for the tourism sector in Turkey not be harmfully affected by the climate change, necessary measures should be taken. For example, it can be said that recent water problems encountered in the Bodrum peninsula might be intensified because of climate change. A recent study (Koç, Bakış & Bayazıt, 2017) on the peninsula revealed that, as a result of revival of tourism sector during the summer months, the competition among the municipal, agriculture and industrial water use sectors increases. Maximum daily water demand of summer population is about two times higher than that of winter population. In the years between 2000 and 2060, daily water demand will increase 6-fold. With the commencement of Urgent Drinking Water Project in 2011 by DSI, drinking water will be supplied to the peninsula by the year of 2040.

In a study carried out in the western Mediterranean region where precipitation exerts a great control on agriculture (Erçin; Pilevneli & Çapar, 2019), it is noted that drought will have serious effects on the agricultural yield. Korkuteli, Milas, Acıpayam, Elmalı and Fethiye towns are represented by the highest level of water footprint of agriculture, and therefore, they are very sensitive to drought risk. In the region, the drought intensity is presently "low to moderate". The climate change will increase the vulnerability of agricultural sector to the drought 40%. The drought risk will be at maxima for the 2030-2040 period. Regarding drought intensity, two climate scenarios used (RCP 2.6 and RCP 6.0) show similar trends until 2050. During drought seasons, surface flow will be less and pollution in water resources will increase.

In a study carried out for the Thrace region (Konukcu; Albut & Altürk, t.y.), the rainfall and flooding frequencies since 1971 were estimated and hydrologic, meteorological and agricultural drought indexes were computed. Agricultural structure, production potential and associated problems were presented. The MapShed model was operated for the Naipköy Dam in the years between 1987 and 1997 and for the Kırklareli Dam in the years between 1970 and 1985. The variations in total nitrogen and total phosphorous concentrations in the Kırklareli and Naipköy Dams were examined separately by each model. The results showed that trophic level in both water masses will rise to hypertrophic[2] level. It was noted that nutrients should be avoided from water masses and remediation methods should be applied.

[2] Trophic level; Nutrition concentration of a water mass expresses the water quality which is identified based on chlorophyll-a, phytoplankton biomass and light transmission. For trophic classification system, OECD limit values are considered; lakes with total nitrogen of 750-1200 ug/L, less than 900 ug/L phosphorus, chlorophyll-a with the range of 100-150 µg/L and secchi depth of 0,4-0,5 m are called hypertrophic.

6. RESULTS AND SUGGESTIONS

How the stress on water resources will be minimized, and how the water resources will be sustainably transferred to young generations under several threats such as the current growth rate, varying water consumption habits and increasing water demand and how we adapt to negative effects of climate change on water resources are the most important humanity problems of the current century.

Drinking and utility water, agriculture and industry are the main sectors in Turkey. The main adaptation activities and precautions that these sectors can take against climate change could be lowering of losses and leakages of drinking and utility water, rainwater harvesting, the use of water efficient equipment for shower and siphon and recycling of domestic waste water.

In the agriculture sector, precautions may include selection of production pattern suitable for climate change, absolutely abandoning of wild irrigation, extensification of productive irrigation techniques such as drip irrigation, application of deficit irrigation when necessary, and application of organic agriculture and good agricultural practices. In agriculture, irrigation productivity and raising awareness of farmers are of great importance.

Precautions for the industrial facilities may include extensification of clean production applications, increasing on-site controls, extensification of zero-discharge approach and recycling of waste water and reuse as process water and other purposes.

Turkey has been applying integrated water management in basins which is an important step in the concept of adaptation to the climate change. Preparation of management plans for 25 basins should be completed taking into consideration the climate change and monitoring and improving works should be made. In addition to organization in the basis, management plans should be applied to the city districts and regions. All sector pioneers and stakeholders should take part in the decision processes of water management.

Because temperature increase in the 2015-2100 period is greater and possible effects of heat waves is much more than in other parts of Turkey, efforts to struggle with drought in Southeastern Anatolia should be increased. Forestation works should be accelerated and water use should be economized, and awareness of people must be raised regarding the expected impacts. In order to prevent possible unjust suffering, the impacts on agricultural products, livestock and public health should be scientifically examined and necessary precautions must be taken.

Eastern and Southeastern Anatolian parts of the Fırat-Dicle basin are under the threat of 4-6 C° temperature increase. The average annual precipitation will decrease in these regions; however the major problem is that precipitation mostly occurs as rainfall. The volume of usable water resources will significantly decrease during periods without rainfall. Because Euphrates and Tigris rivers are transboundary waters, information should be shared with riparian countries and cooperation must be made to overcome possible conflicts. The people in the Southeastern and Eastern Anatolian regions should be informed regarding precipitation time, precipitation type and river flow periods. Since plant pattern is expected to change, new agricultural products with high added value must be examined and necessary precautions should be taken for possible impacts on pasture livestock.

In Turkey, in the area of Asi basin the hydrological reserve will significantly change. In this basin negative impacts of variable rates of water discharged by the Syria are seriously felt. Worsening of these impacts coupled with climate change is inevitable. Therefore, a cooperation must be made with Syria and an action plan on this issue should be prepared in Hatay. Volumetric decrease in water resource will give rise to increase in pollution and decrease in agricultural production. Necessary studies must be made and precautions should be taken for the spread of disease by water.

The Eastern and Western Black Sea regions and the Çoruh basin are the areas of maximum precipitation and as a result of climate change in these regions much more precipitation is expected. In these areas, the frequency of natural disasters of flooding and landslide will increase and agricultural productivity will decrease due to over washing of soil. As a precaution, residential sites in the areas of flooding and landslide risk should be removed and other obstacles on the watercourses must be taken out. In order for the soil not to lose its productivity by washing, protection of soil cover is of great importance and therefore cutting trees should be well-controlled. It is necessary to warn people regarding the expected impacts and flood- and landslide- proof houses must be built. In front of steep slopes support mechanisms must be placed and warning systems should be established on the roads for possible loss of lives.

In Turkey, action plans prepared for several issues shed light into targets and policies used. For example, in the climate change action plan prepared for Istanbul, adaptation mechanisms to the climate change were determined. Adaptation of flexible working hours during the heat waves, the use of energy-efficient new municipal buildings, the use of big umbrellas during the summer months, high-standard isolation of buildings, and strategic, temporary, technical, ecological and managerial and environmentally friendly infrastructure investments are adopted. In the study, it was noted that stress on water resources in Istanbul will increase due to growing population and climate change (possible decrease in precipitation, possible increase in evapotranspiration) and therefore, as in the Melen project, water transfer from a distance will continue such as Western Black Sea where rainfall is quite high. In addition, in order to protect water resources in Istanbul, it is suggested that water consumption should be decreased and waste water treatment and recycling should be extensified. To stop the rainfall, decrease in Istanbul, the area of forest lands must be widened (Climate Scenarios Report, 2019).

For the expected water shortage in Turkey in the coming years, to meet the water demand from all the sectors serious precautions should be taken and rational plans should be applied. In Turkey, in order to improve a water management that is compatible with climate change, the following should be implemented: strengthening of public administration relevant to soil and water resources, extensification of fertile techniques in the domestic, industrial and agricultural water use, and initiation of an education campaign regarding the awareness that water is a valuable but nonrenewable natural resource. Lastly, it is of great importance to strengthen the nongovernmental organizations and ensure the coordination among the universities, public organizations and private sector which carry out research-development and training in respect of water resources.

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