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RESOURCES PROJECT**

Final Report

Executive Summary

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GENERAL DIRECTORATE OF WATER MANAGEMENT

GENERAL MANAGER

Prof. Dr. Cumali KINACI

DEPUTY DIRECTOR MANAGER

Hüseyin AKBAŞ

HEAD OF DEPARTMENT

Maruf ARAS

Ayşe YILDIRIM COŞGUN	Head of Division
Hülya SİLKİN	Expert
Mehmet AŞKINER	Expert
Seçil KARABAY	Expert
Tansel TEMUR	Expert Assistant

KEY EXPERT

Özcan ÇIRAK	Civ. Eng. (Project Manager)	Güler GÜL	Meteorologist
Ayşe DİKİCİ	Civ. Eng.	Muhsin KARAMAN	Survey Eng.
Amaç Bülent YAZICIOĞLU	Env. Eng.	Gökhan UZUNGENÇ	Civ. Eng.
Erdoğan Gül	Civ. Eng.		

TECHNICAL EXPERT

PROJECT ADVISORS

Emine GİRGIN	Env. Eng. MSc.	Prof. Dr. Selahattin İNCECİK	Climate Projections Team
S. Seda ABAT	Env. Eng.	Prof. Dr. Yurdanur ÜNAL	
Ceren EROPAK	Env. Eng. MSc.	Prof. Dr. İzzet ÖZTÜRK	
Assoc. Prof. Dr. Asude HANEDAR	Env. Eng. MSc.	Prof. Dr. Ayşegül TANIK	Hydrology Team
Prof. Dr. Erdem GÖRGÜN	Env. Eng. MSc.	Assoc. Prof. Dr. Ali ERTÜRK	
Evrin ATALAS	Civ.- Env. Eng.	Assoc. Prof. Dr. Alpaslan EKDAL	
Dr. Bertan BAŞAK	Env. Eng. MSc.	MSc. Aslı Özabalı SABUNCUGİL	
Gamze KIRIM	Env. Eng. MSc.	Prof. Dr. Turgut ÖZTAŞ	Hydro-geology Team
Merve AÇAR	Meteorologist MSc.	Assoc. Prof. Dr. Oral YAĞCI	Hydraulic Team
Kurtuluş KONDU	Civ. Eng.	Asst. Prof. Dr. Ahmet Özgür DOĞRU	GIS Team
Ferat ÇAĞLAR	Meteorologist	Asst. Prof. Dr. Caner GÜNEY	
Salim YAYKIRAN	Env. Eng. MSc.		
Mehmet KALFAZADE	Env. Eng. MSc.		

- ClimaHydro Database Applications have been developed by sub-contractor firm EXPERTEAM.

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1. Introduction

Climate change is the sudden, severe and important changes occurring in long term weather events, and due to the increase in human activities, they are felt more intensely presently. According to the Fifth Evaluation Report of Intergovernmental Panel on Climate Change (IPCC), majority of the warming in the atmosphere since the mid 20th century resulted from the increase in greenhouse gas concentrations arising from human activities (IPCC, 2014). As a result, global temperature has risen approximately 0.89°C in the last 150 years and it continues to increase. Because of increased greenhouse gas emissions, global warming has caused changes in the distribution of water resources in many parts of the world, and global and regional hydrological cycles have been greatly affected from the climate change (Brutsaert & Parlange, 1998; Solomon et al., 2007; Hagemann et al., 2013; Dufresne et al., 2013).

Climate change in Turkey has been evaluated in many different studies with its different aspects. Majority of both analysis performed and the future estimation works were focused on temperature and precipitation changes which are the most important climate parameters and extreme events. (Kadiođlu, 1997; Ően Z. , 1997; TrkeŐ, 1998; TrkeŐ, 1999; nol et al., 2006; nal & Semazzi, 2009) (Bozkurt et al., 2011; Demir, 2011; nal, 2012; nal et al., 2012; Toros, 2012; Ően et al., 2013; Kurnaz, 2014). (Karaca et al., 2000; Tan & nal, 2003; nal & nal, 2003; nal Y. , 2006; nal & Menten, 2006; nal et al., 2010) (nal et al., 2013). Climate projections demonstrate that the temperature increases will rise much more till the end of this century. Because of this, in terms of evaluating the impacts of climate change on water resources in Turkey, which is located in Southeastern Europe and Eastern Mediterranean, it is crucial that the future projections should be made with sophisticated models to obtain accurate results.

Even though climate change is considered as the increase in temperatures and global warming, the most important impacts resulting from climate change are the impacts that will take place due to the changes in the precipitation regime. Hydrological systems are affected from the climate conditions in the world both directly and indirectly. Changes in precipitations cause changes in the timing and severity of floods and drought, as well as the surface flow regime, amount of water leaking underground, plant patterns and growth rates (Ragab & Prudhomme, 2002).

Turkey is divided into 25 hydrological river basins having vital and social importance. Precipitation regime of Turkey, which is located in a semi-arid region of the world in terms of water, varies greatly in different seasons and regions, and it is seen that in some river basins

the water demand has exceeded the potential of the resources. However, impacts resulting from the climate change in Turkey such as increased summer temperatures, decreasing winter precipitations, loss of surface waters, more frequent droughts, deterioration of soil, erosion in coasts, flood and water deluges threaten the existence of water resources directly (T.R. Ministry of Environment and Urbanization, 2011). Because of this, Ministry of Forestry and Water Affairs, General Directorate of Water Management, Flood and Drought Management Department aimed to determine the impact of climate change on surface and ground waters and define the adaptation activities with the "Climate Change Impacts on Water Resources Project". Implementation area of the project is 25 river basins in entire Turkey and the projection period is between 2015 and 2100. Works performed within the scope of the project are listed in Figure 1.1.

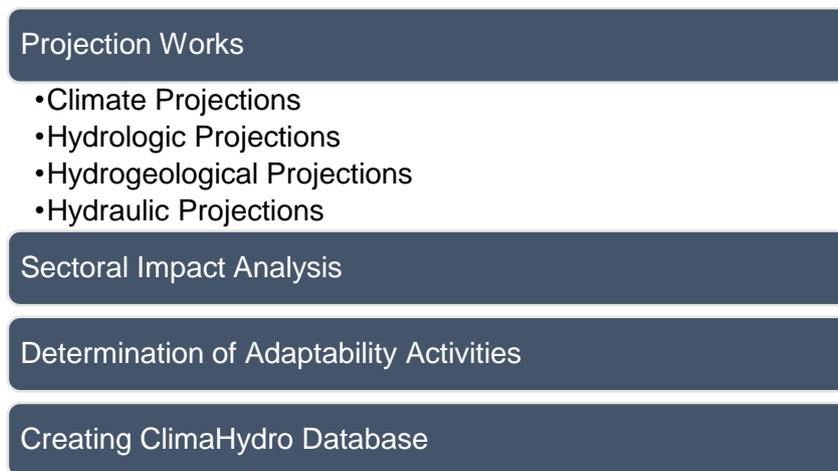


Figure 1.1 Works to be Carried Out in the Project

As part of the climate projections, the first stage of projection works, outcomes of three global models selected from CMIP5 archive and RCP4.5 and RCP8.5 release scenarios and RegCM4.3 regional climate model forming the basis of the 5th Evaluation Report of Intergovernmental Panel on Climate Change (IPCC) were studied including whole Turkey. Total 8 parameters and projections of 17 climate indices representing extreme conditions were formed in river basin scales through model simulations, and the differences of the studied parameters until 2010 were calculated as seasonal and annual averages for 10 and 30 years periods based on the reference period accepted as the simulations of 1971-2000. For the first time with this project, 3 global climate model with 10x10 km resolution results were obtained for Turkey.

As part of the hydrologic projections, the second stage of the projection works, for the first time in Turkey, the water potentials of all river basin in Turkey were calculated using hydrologic

model. Employing hydrologic models with the outcomes of the climate models, precipitation values were converted to flow values, and water potential modeling/calculation study was carried out considering the current situation of surface water and groundwater sources and the estimated situation for projected periods.

As part of hydrogeological works, aquifer environments on the basis of river basin were defined geologically and hydrogeologically; and current groundwater potential was calculated through groundwater observations and considering properties such as current and planned pit information in river basin scale. Groundwater potential amounts specific to water basis for the projection period were calculated adding current groundwater potential data and the precipitation, evaporation and temperature data changed due to climate change projections. Turkey's static groundwater reserve was calculated for the first time in this project. Calculating dynamic and static reserve together, the possible changes in groundwater levels were predicted.

In the last stage of projection works, hydraulic modeling approach was used to convert the flow values to the water level values along the principal river system and its side streams in the river basin. Afterwards, surface water capacities in the principal river system and its side streams in the river basin was determined.

As part of sectoral impact analysis works, a methodology was developed for the analysis of the impacts of climate change in Turkey on water intended for human consumption, agriculture, industry, ecosystem, tourism and energy main sectors. An evaluation systematic was developed allowing the digitization of exposure levels for the sectors. Considering the climate change projections in the three river basins elected as pilot river basins, impacts of water on sectors were analyzed, and the exposure intensity of the river basins from all sectors were determined in "low impact, medium impact, high impact, very high impact" categories.

As part of the determination of adaptation activities, considering all river basins, various suggestions for adaptation activities such as rainwater harvesting, pricing the water, enclosed irrigation system were developed for the elimination of the negative impacts of climate change on water resources. In total, 138 adaptation activities were examined, and at least three operations were evaluated in detail for each of the water intended for human consumption, agriculture and industry main sectors.

All results produced in the project were processed in the ClimaHydro Database equipped with GIS application. Therefore, it is ensured that the project outcomes are sustainable and can be considered in similar projects.

Project Final Report in which the impacts of climate change projections on the climate projection of our country until 2100 and the water potentials of water basis based on various parameters is composed of a single volume and 30 annexes, and contains all of the data and evaluation works produced during the 930-days project.

2. Methodology

Climate simulations at 50x50 km first and then 10x10 km resolution were obtained by using start and limit conditions (ERA-40 reanalysis data) (Uppala et. al., 2005) for the reference period within the scope of climate change projections. Afterwards, reference period climate simulations were performed with 10x10 km resolution of HadGEM2-ES, MPI-ESM-MR and CNRM-5.1 global climate models selected from the CMIP5 database. Comparisons were made with the simulations performed by using reference period simulation observation data of the global model, and the bias of the global model in the climate simulations was examined. Of three global models, simulations based on RCP4.5 and RCP8.5 representational concentration routes against the 4.5 W/m² and 8.5 W/m² climate forces in 2100, and climate simulations at 10x10 km resolution between 2015-2010 with RegCM4.3 regional climate model were obtained.

By using climate models' projection results, hydrological variants in the river basin drainage region scales were projected till 2100. Surface flow, soil moisture and evapotranspiration are the fundamental values produced by the hydrological model, groundwater and surface water potential was calculated in the river basins by using model outputs. Also, changes in the water usage in river basins during the 85-year-long projection period were obtained and such values were evaluated with hydrological variants produced by the model, and the projection for total annual water demand in river basins was made. SWAT model was used in hydrological modeling works, and such model was supported by the WEAP model in order to include it in the hydrological modeling process of lakes, ponds and reservoirs, and improve the hydrological model.

Within the scope of the hydrogeological projection works, first of all, locations and distribution of all groundwater environments within river basins were explored and environmental volumes were predicted; and the geo-hydraulic and hydrogeological environment characteristics were defined by using homogenized average values. In the study, "periodical groundwater feeding" and "periodical groundwater discharges" were calculated for each period by considering the impact of climate change between 2015 and 2100. Differences in found values were defined as the periodical ground water dynamic reserve of such hydrogeological environment for the

related period, and the hydrogeological, static and possible reserve values of the related hydrogeological environment for the mentioned period were determined. Based on the groundwater dynamic reserve values within the time periods determined in the hydrogeological environments in the river basin, periodical free/pressurized groundwater level (dynamic level) changes were predicted.

Flow values produced by the hydrologic model were transformed into flowrate and water level values during the principal river system of river basins with hydraulic modeling works. For the solution of hydraulic problems, Hec-RAS model, which is internationally accepted and often proven to be accurate in the literature, was utilized. In the model, surface water profiles were calculated by repeating the standard step method from one cross section to another and solving the energy equation. Within the scope of creating the model structure works, thalweg lines, stream rank lines, flood plains and cross sections along the principal river system and its side streams in the river basin were defined, and the integration of variants into the model was ensured.

Exposure, sensibility, impact, economical value, risk and adaptation capacity components and 10-year-long vulnerability levels of sectors were revealed in the sectoral vulnerability impact analysis developed within the project scope. This study was practiced for 4 main sectors as water intended for human consumption, agriculture, industry and ecosystem in 3 pilot river basins. Tourism was included for the Büyük Menderes River basin, energy was included for Ceyhan River basin and textile product manufacturing as the sub-industrial sector was included for Meriç-Ergene River basin.

In various regions and countries of the world, adaptation strategies and activities planned and implemented against climate change were examined, and over 100 adaptation activities were suggested for our country in the light of this information. Adaptation activities for the 3 main sectors (water intended for human consumption, agriculture, industry) that may be affected from water in our country were examined in detail in terms of advantages/disadvantages, cost/benefit, etc.in practice. Also, main sectors for the sectoral vulnerability analysis works were defined and river basins of Turkey were considered and grouped based on different geographical and climatic characteristics.

3. Climate Change Projections

3.1 Temperature Projections

Throughout Turkey, 10-year results of the HadGEM2-ES, MPI-ESM-MR and CNRM-CM5.1 model based RegCM4.3 regional climate model solutions belonging to the four seasons have been visualized for RCP4.5 and RCP8.5 scenarios; and the RCP4.5 scenario HadGEM2-ES model has been provided in Figure 3.1 as an example. In each three models, according to the RCP4.5 and RCP8.5 scenarios, the average temperature anomaly values of each three models show positive results for each four seasons compared to the reference period during the projection period (2015-2100).

It is seen that, all of the simulations based on the three global climate models and each of the two emission scenarios indicate an important warming over Turkey in the 2015-2100 projection period at seasonal and annual scales. In the first years of the 2015-2100 period, less temperature changes and even coolings have been seen in some years in some regions and in the upcoming years, the climate stresses caused by the increase in the greenhouse gases are likely to accelerate the increase in the temperature in a more predominant way. In both scenarios, each three models show that the temperatures of the winter season will progress at a temperature of at least 1°C more than the 1970-2000 period. Over Turkey, especially in the RCP4.5 scenario between 2091-2100 the temperature increases have been found as 3,4°C, 2°C and 2,5°C for RegCM4.3 coupled with HadGEM2-ES, MPI-ESM-MR and CNRM-CM5.1 models. In RCP8.5, which is a higher emission scenario, these temperature increase values are 5,9°C, 4,5°C and 4,3°C respectively. Although the temperature increases throughout Turkey are a bit above the RCP4.5 scenario until 2050s in the RCP8.5 scenario, the weathering gradually increases after 2050s. Temperature increases are higher in the summer and spring seasons compared to the winter and autumn seasons.

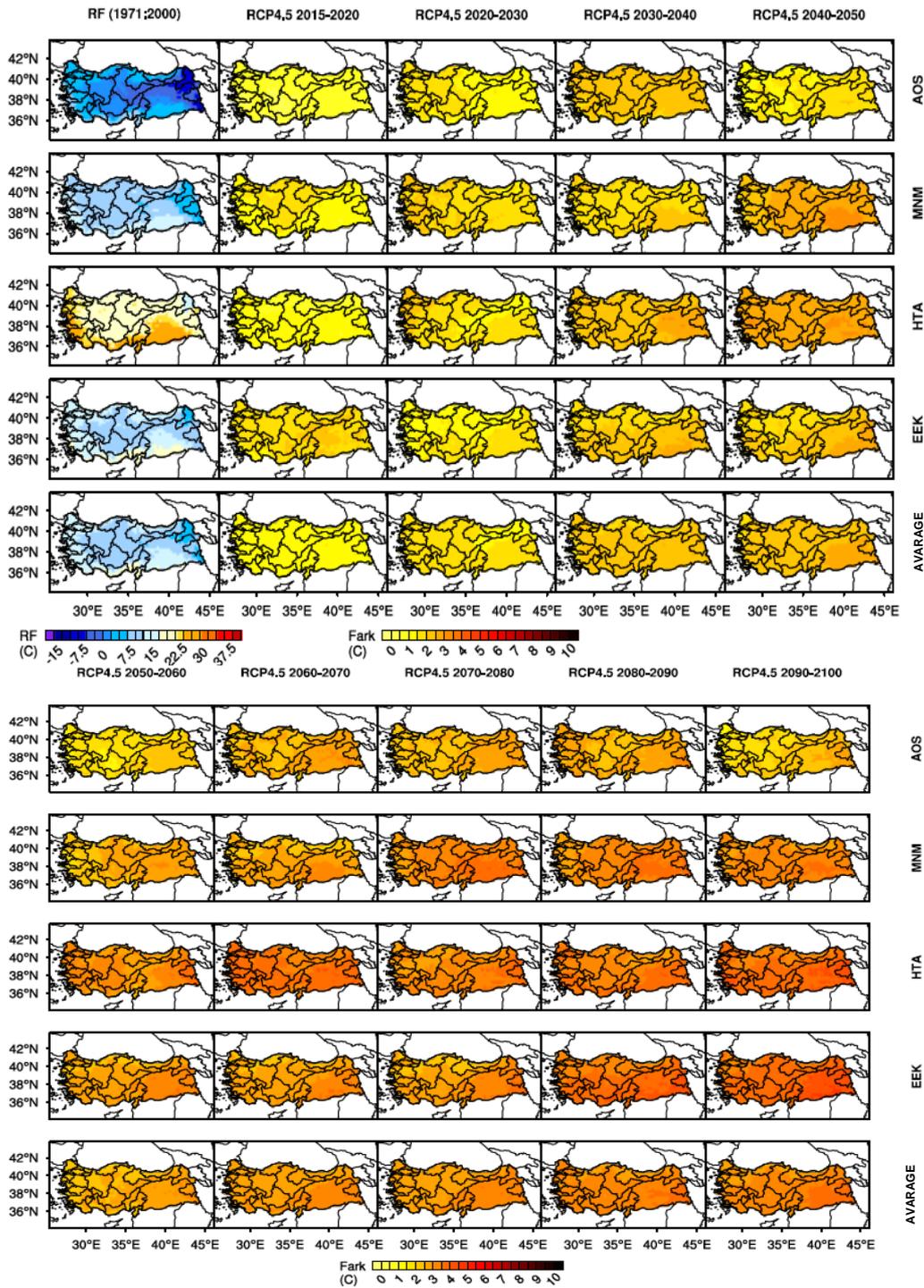


Figure 3.1 The Change of the Average Temperature Anomaly Values in 10-Year Periods and Seasonally for HadGEM2-ES Model RCP4.5 scenario

For each of the three models, the 30-year changes of the temperatures in 25 basins have been visualized, HadGEM2-ES model has been shown as example with Figure 3.2. According to this, it stands out that the temperature increases for both scenarios will occur starting from the southern latitudes of Turkey, enlarging to the north throughout the 2015-2100. For example, it

is seen that the highest temperature increases occur in the Southeastern of Turkey and across the Mediterranean. Especially within the topography where altitude is dominant, the temperature increases expected during the summer months on Fırat-Dicle Basin are higher compared to the other seasons and faster compared to the other regions. It is anticipated that the temperature increases will reach 4-6°C towards 2100s especially in the east and southeast of Turkey. The fact that the precipitation type more frequently turns into rain from snow in the winter months due to increasing temperatures, causes the snow-covered areas to diminish and the snow to melt earlier in the spring months. The diminishment in the snow-covered surfaces causes the albedo of the surface to decrease and therefore causes the sun radiation amount absorbed by the surface to increase and scales up the temperatures faster than the other regions.

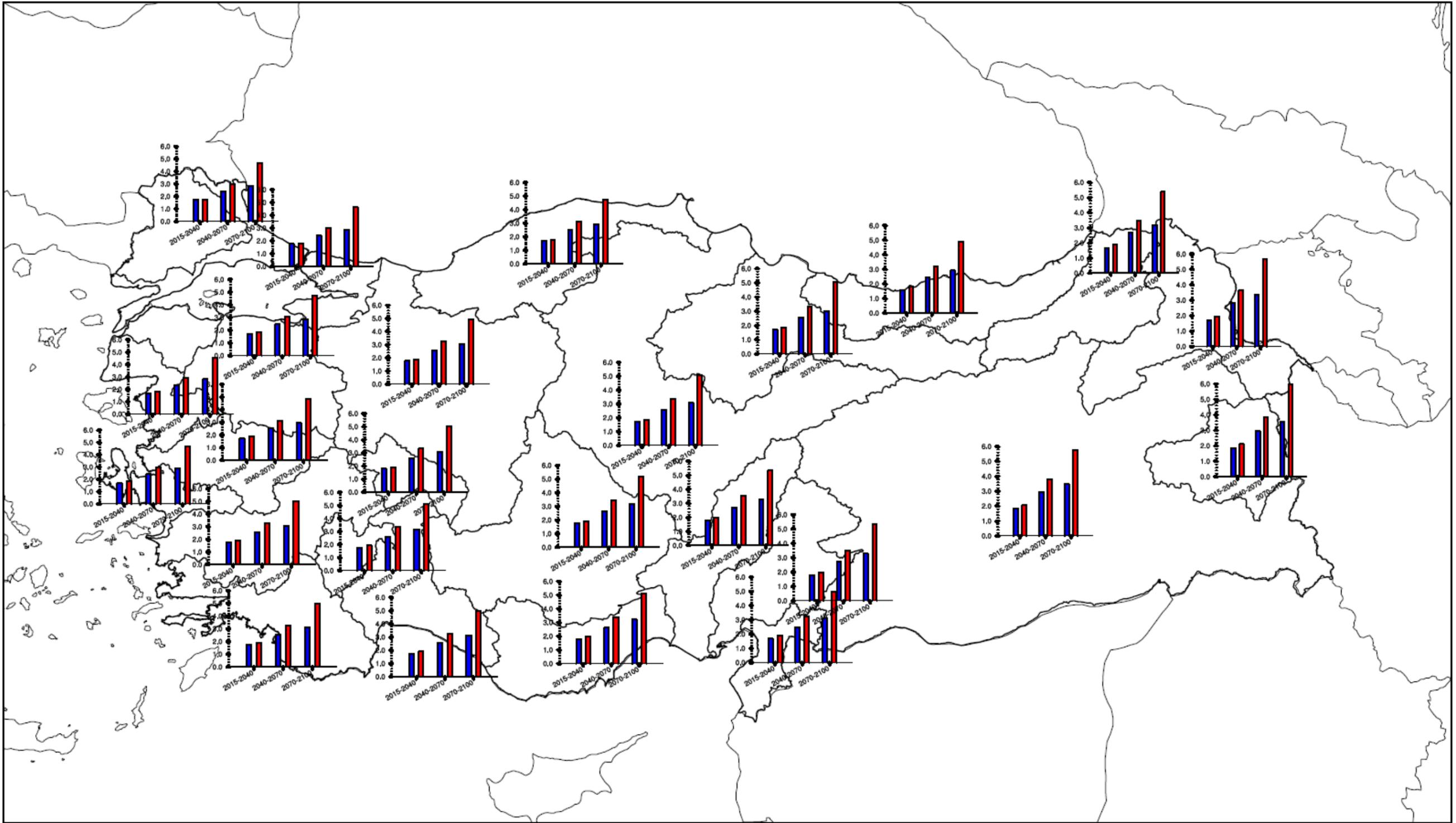


Figure 3.2 30-Year Averages of the Average Temperature Anomaly Values of the HadGEM2-ES Model on Basins throughout Turkey

3.2 Total Precipitation Projections

The 10-year results of regional, seasonal and yearly changes of precipitation throughout Turkey until 2100 under the RCP4.5 and the RCP8.5 scenarios of RegCM4.3 regional climate model solutions based on the HadGEM2-ES, MPI-ESM-MR and CNRM-CM5.1 models have been visualized. The RCP4.5 scenario MPI-ESM-MR model has been given as example by Figure 3.3.

For RCP4.5 and the RCP8.5 scenarios, precipitations of HadGEM2-ES, MPI-ESM-MR and CNRM-CM5.1 models show that throughout the projection period (2015-2100) regional precipitation increases and decreases will occur based on the ground system models. Generally, during the projection period, it is anticipated that precipitations based on the 10-year averages change between -50 mm and 40 mm for RCP4.5; -60 mm and 20 mm for RCP8.5. These changes occurring in precipitation can differ significantly from each other based on the considered periods and RCP4.5 and the RCP8.5 scenarios. For example, MPI-ESM-MR model indicates that along with the precipitation increases of 10,6 mm and precipitation decreases of regionally changing between 7,7 mm and 28 mm based on the 10-year averages throughout Turkey between 2015-2100. Besides this, as there is no consistency between the models in the 2015-2040 period; in the 2041-2070 projection period, HadGEM2-ES and MPI-ESM-MR models anticipate decreases in the precipitation for both emission scenarios. In case of RCP8.5, these precipitation decreases become intensified. In the last thirty years of the projection period, similar precipitation decreases are seen throughout Turkey.

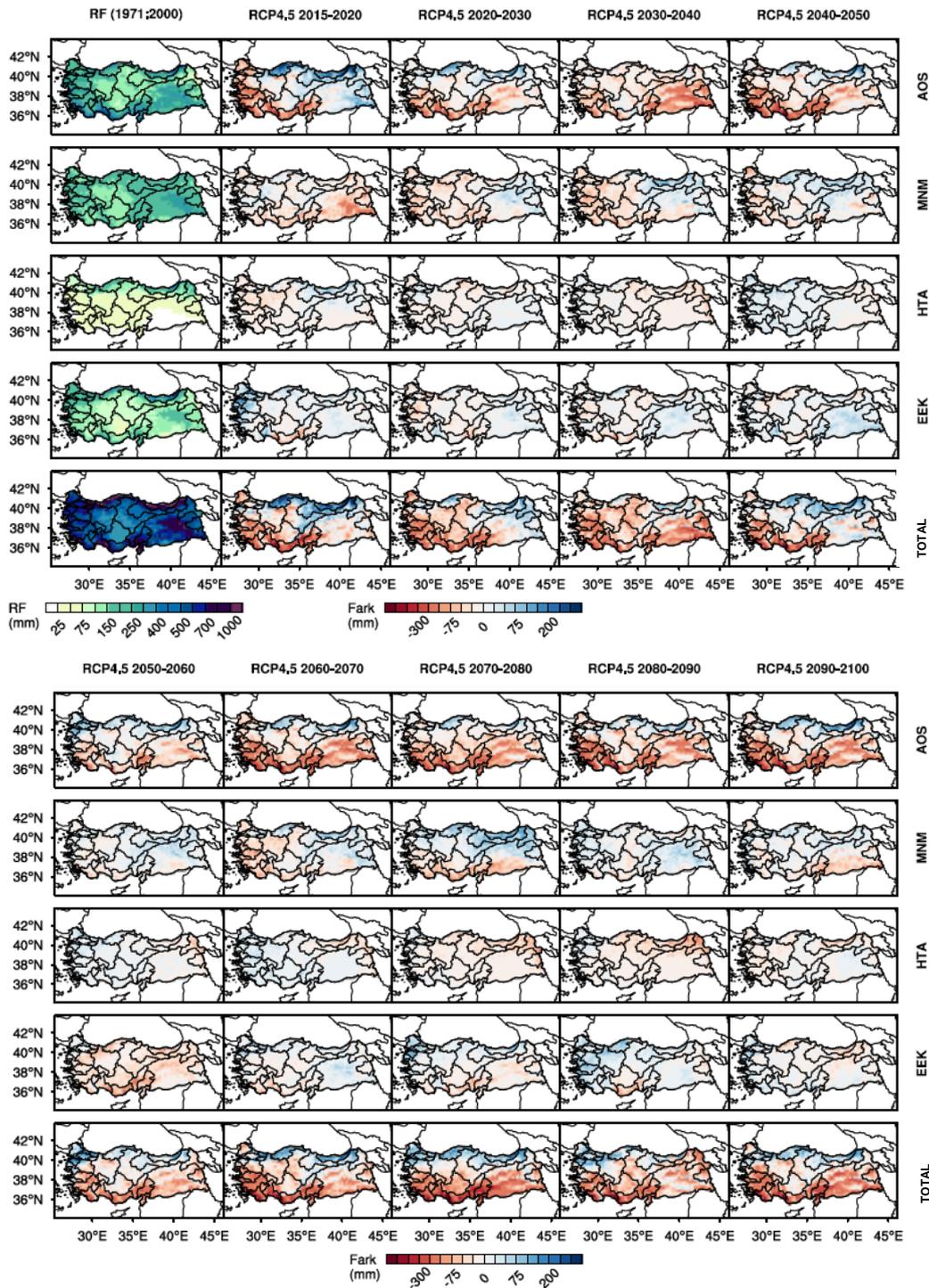


Figure 3.3 10-Year Period and Seasonal Changes of Total Precipitation Anomaly Values for MPI-ESM-MR Model RCP4.5 scenario

For each three models, 30-year changes of the precipitation have been visualized in 25 basins and MPI-ESM-MR model has been shown as example in Figure 3.4.

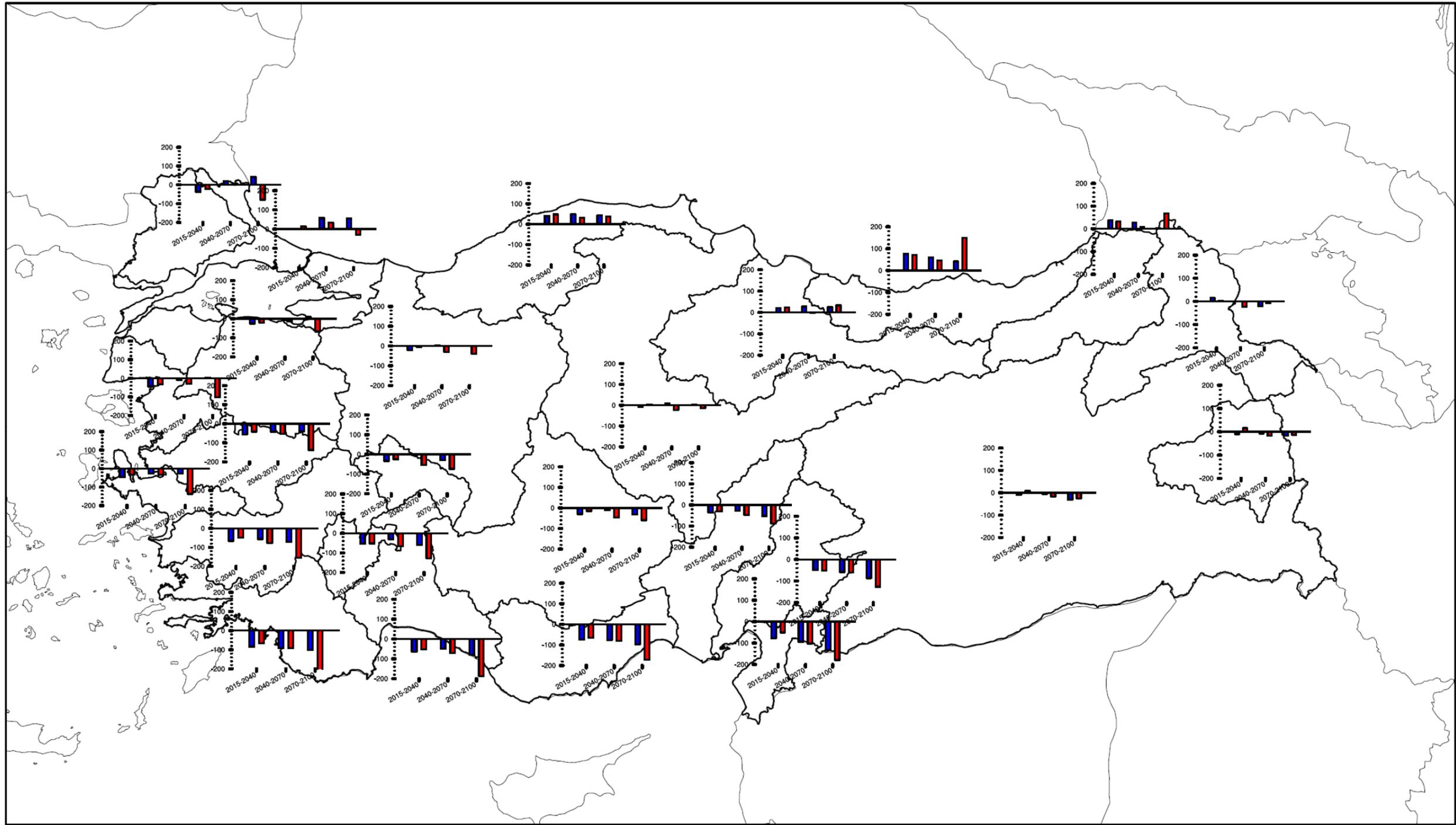


Figure 3.4 30-Year Averages of Total Precipitation Anomaly Values of MPI-ESM-MR Model on Basins throughout Turkey

Model simulations show that the climate regime in the basins taking place at the north of Turkey will show more precipitation than the reference period. For example; the RCP8.5 scenario suggests that as of 2050s, the drought in the basins will intensify towards south and the ten-year average of total yearly precipitations on basin basis will decrease to a level around 150 mm. The most severe drought forecasts belong to the MPI-ESM-MR model and the most temperate drought forecasts belong to CNRM-CM5.1 model. As the precipitation decreases based on basins are identified as the percentage of the total yearly precipitation, it is seen that maximum changes are in the Doğu Akdeniz, Batı Akdeniz and Ceyhan River Basins. In the RCP4.5 scenario, while the decreases in the total yearly precipitation in these basins are at a level of around 12% for HadGEM2-ESM, 15% for MPI-ESM-MR for the last ten years of the century, it reaches a level of around 20% for HadGEM2-ESM, 25% for MPI-ESM-MR in the RCP8.5 scenario. The yearly total precipitations in both scenarios in Fırat-Dicle Basin are expected to decrease between 3% and 8%. Throughout Turkey between the years of 2015-2100, the lowest precipitation values are produced for Konya Closed Basin. In Konya Closed Basin, according to the RCP4.5 scenario HadGEM2-ES model 30-year average results, decreases between 10 mm and 30 mm are identified in precipitation. The effect of RCP4.5 and RCP8.5 scenarios on the three different models show differences in basins located on the western Turkey such as; Meriç-Ergene, Marmara, Kuzey Ege, Susurluk, Gediz, Küçük Menderes and Büyük Menderes. According to RCP4.5 scenario HadGEM2-ES and CNRM-CM5.1 model simulations indicates higher precipitation values than reference period for Marmara, Kuzey Ege, Meriç-Ergene, Küçük Menderes Basins, MPI-ESM-MR model simulations indicates higher precipitation values for Doğu Karadeniz, Batı Karadeniz, Marmara, Yeşilırmak River Basins.

It is anticipated that throughout Turkey, snowfall amounts will gradually decrease between 2015-2100 in both scenarios. In the early part of the century, although snowfalls a little above or below the normal values similar to today's climate regime of Turkey were identified, they have rapidly decreased because the greenhouse gas emission scenarios were more predominant on the natural climate variability of the region. The fact that the type of precipitation becomes snow as a result of the increase in the temperatures is important in hydrologic terms. Yet, the accumulated snow serves as a water reservoir and especially at the beginning of spring and summer months, they melt down and provide water intake to river systems as a result of the increasing temperatures. Therefore, snow cover at high areas has an important role on the regional hydrologic cycle. Especially in Eastern Anatolian region and East Taurus Mountains, the decrease in the snow cover should be expected to change the hydrologic cycle of Fırat-Dicle Basin.

3.3 Climate Indices

In terms of extreme climate events, one of the most important indicators for temperature exceeds is the indices value belonging to heat wave (WSDI). WSDI shows the days on which the maximum temperature of each calendar day is more than 90% of the reference period. The heat wave (WSDI) climate indices comparison graphic of HadGEM2-ES, MPI-ESM-MR and CNRM-CM5.1 models is given by Figure 3.5. 2015-2040 WSDI results of RCP4.5 and RCP8.5 scenarios overlap substantially with the reference period except Southeastern Anatolian Region and all the ground system models similarly indicate that the heat waves will increase from the southern latitudes of Turkey towards the north in every 30-year period.

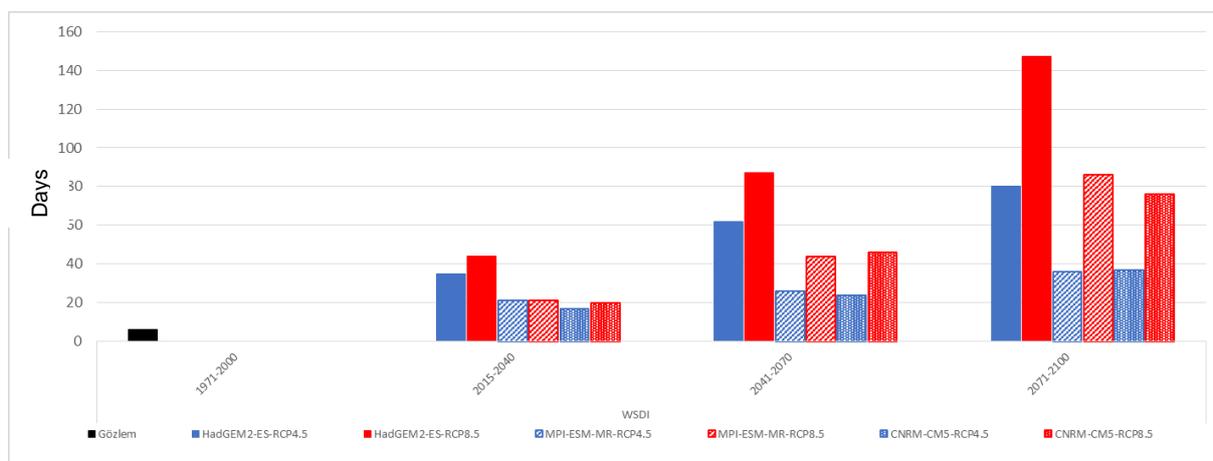


Figure 3.5 Heat Wave (WSDI) Comparison of HadGEM2-ES, MPI-ESM-MR and CNRM-CM5.1 Models

Especially after 2041, the highest heat wave values based on the RCP4.5 scenario are seen in the Eastern and Southeastern Anatolian Regions. In the last projection period, it is understood that these values, which vary between 80-120 days, will be predominant in the southern regions of the country completely. In the RCP8.5 scenario, greater increases are anticipated in these values. While the maximum and minimum temperatures are expected to increase towards the end of the century, it has been determined that these increases will be higher especially in the Mediterranean Region, Southern and Southeastern Anatolian Regions. The daytime temperatures being high will create increases in the heat wave frequencies and intensity in these regions. In addition to that, as the fact that the night temperatures being high will limit humans and animals in feeling relaxed, it will cause an increase in the harms that the heat wave will create. In addition, it will increase the energy demand to be used in the environment cooling at night in addition to daytime. The fact that along with the anticipated lack of precipitation, the evaporation rate increases will increase the stress in the water resources and agricultural sector. It suggests that in the Mediterranean coast there is a

requirement of a new structuring in the tourism sector. The behaviors of the CDD - which gives the number of the consecutive days on which the precipitation is less than 1mm – throughout Turkey also supports this situation. While the CDD shows increase in each of the three models, no significant change in the CWD, which gives the number of the consecutive wet days on which the precipitation is more than 1 mm, is identified.

R20mm shows the number of days on which there is blistering precipitation and gives the number of days on which the precipitation exceeds 20 mm. The comparison graphic of the R20 Heavy Precipitating Day values belonging to HadGEM2-ES, MPI-ESM-MR and CNRM-CM5.1 climate models based on the RCP4.5 and RCP8.5 scenarios throughout Turkey is shown with Figure 3.6.

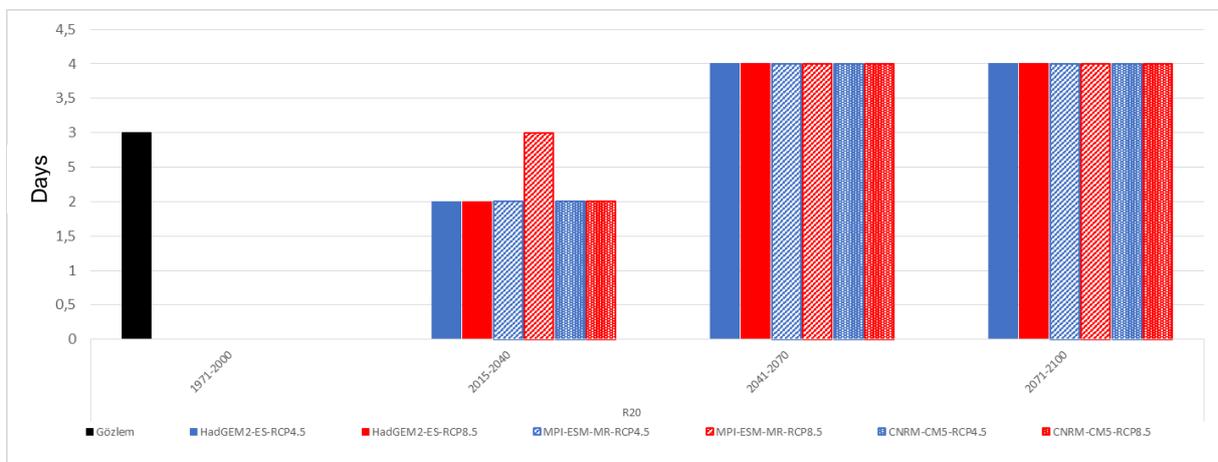


Figure 3.6 Comparison for HadGEM2-ES, MPI-ESM-MR and CNRM-CM5.1 R20 Very Heavy Precipitating Days

In Marmara Region, Aegean (especially southern Aegean) and Black Sea coast, Central Anatolia Region and Fırat-Dicle Basin, increases are seen towards the end of the century. Either the R20 (the days on which the precipitation is higher than 20 mm) or the R25 (the days on which the precipitation is higher than 25 mm) values which are the indices related to the number of days on which the precipitation is high do not show a significant change during the projection period in Turkey; it is anticipated by all the models and scenarios that there will be slight increases in the number of days on which take precipitation of more than 20 mm around Marmara, Western Black Sea, Southern Aegean and Lake Van. The fact that excessive precipitation possibilities increases in the Black Sea and Marmara regions where positive precipitation anomalies are seen between the years 2015 and 2100, may increase the frequencies of the formation of floods in city environments and correspondingly the economic losses. It is clear that due to the fact that the total yearly precipitations increase between 100-400 mm the precipitation regime in these regions will change or is currently changing.

4. Turkey's Water Resources and Projections

4.1 Water Resources

According to the DSI data, the total amount of the surface water and the groundwater is identified as 112 billion m³ in economic and technical aspects, for the various purposes of usage in Turkey. Hereunder, the usable surface water potential is a total of 98 billion m³ per year; 95 billion m³ from the inland streams and 3 billion m³ from the streams coming to our country from the neighbor countries. With the ground water potential determined to be 14 billion m³, the available surface and ground water potential per year is a total of 112 billion m³ and 44 billion m³ of it being used (URL-1).

Within the scope of the Project; up to date data acquired from many different resources like Activity Reports (DSI, 2013; 2012), Forestry and Water Council Working Group Reports (2013), Performance Reports (DSI, 2011/2012/2013), Basin Protection Action Plans (2010; 2014), Development Program Human Development Program (United Nations, 2013) and Turkey's Development Report (Ministry of EU, 2013) have been taken into consideration and it is aimed that the current situation of the water potential in Turkey is set forth in the best way. Within the scope of the project, the water potential of Turkey has been calculated as approximately 108,5 billion m³ which is close value to 112 billion m³ provided in many sources.

After the calculation of the usable water potential, the basic sectors, which will consume the water in each basin, have been set forth. The said water potential is distributed among 4 main sectors (water intended for human consumption, industry water, irrigation water and ecosystem services requirement). According to this, along with the population, industry and agriculture activities special to basins, the change of the ecosystem services requirements until 2100 is also foreseen. While the possible excess water or water deficit in the basins is being calculated, basin based population growth trends and the important common investment plans specific to basin have been taken into consideration. Similarly, with the progress of the changes in basin based industrial and agricultural activities, the necessities of the ecosystem services have also been taken into consideration.

4.2 Hydrologic Projections

The change in the gross and net water potentials throughout Turkey in 2015-2100 period is displayed in detail with Figure 4.1 on the basis of all the scenarios of the models. As the nation-

wide gross and net water potential forecasts of Turkey are observed, the lowest values for both scenarios in 30-year averages are produced with HadGEM2–ES model.

According to the results of each three climate models and two scenarios (RCP4.5 and RCP8.5), it is anticipated that the total flow in Turkey will decrease compared to the reference period. The lowest total flow forecasts for the results of both the RCP4.5 and the RCP8.5 scenarios are produced with the HadGEM2–ES model. With MPI-ESM-MR and CNRM-CM5.1 models, close results have been produced throughout all the periods. Along with the fact that the total flow forecasts made with the RCP4.5 scenario are a bit higher than the results of The RCP8.5 scenario draws attention; all the model forecasts remain lower than the reference period value (~186.000 million m³/year). Although 30-year yearly average forecasts are lower compared to the reference period, it is seen that the period value of each of the 30-year periods does not change too much for the same scenario of the same model.

In the simulations managed only with the HadGEM2-ES climate model outcomes, it is anticipated that the water deficit in at least 3 ten-year periods may be at a level of ~6.000 million m³/year. In the hydrologic modelling simulations carried out for HadGEM2-ES model and RCP8.5 scenario, there is an expectation of water deficit at a level of ~7.000 million m³/year (max: ~15.000 million m³/year) at least in 6 ten-year periods. The results that MPI-ESM-MR and CNRM-CM5.1 models have produced for both scenarios show similarity and it is anticipated that in the 2015-2100 period, the total water requirement of our country can be met and there will be no water deficit.

Within the scope of the evaluation of the model results throughout Turkey, a statistical analysis in the characteristic of a brief study. In the simulations performed with the outcomes of climate models and with WEAP supported SWAT hydrologic model, the status of the median gross water potentials forecasted for 3 sub-projection periods is compared with the median value of the reference period. According to this, with the hydrologic modelling base on the outcomes of HadGEM2-ES climate model, it is anticipated that the median gross water potentials for 3 sub-periods in the 2015-2100 period will decrease 40-45% compared to the median value of the reference period. Under the same conditions, it is forecasted that the decrease ratio of the median gross water potential obtained from the hydrologic model projections performed by the outcomes of the MPI-MSM-MR climate model will remain at the range of 15-20%.

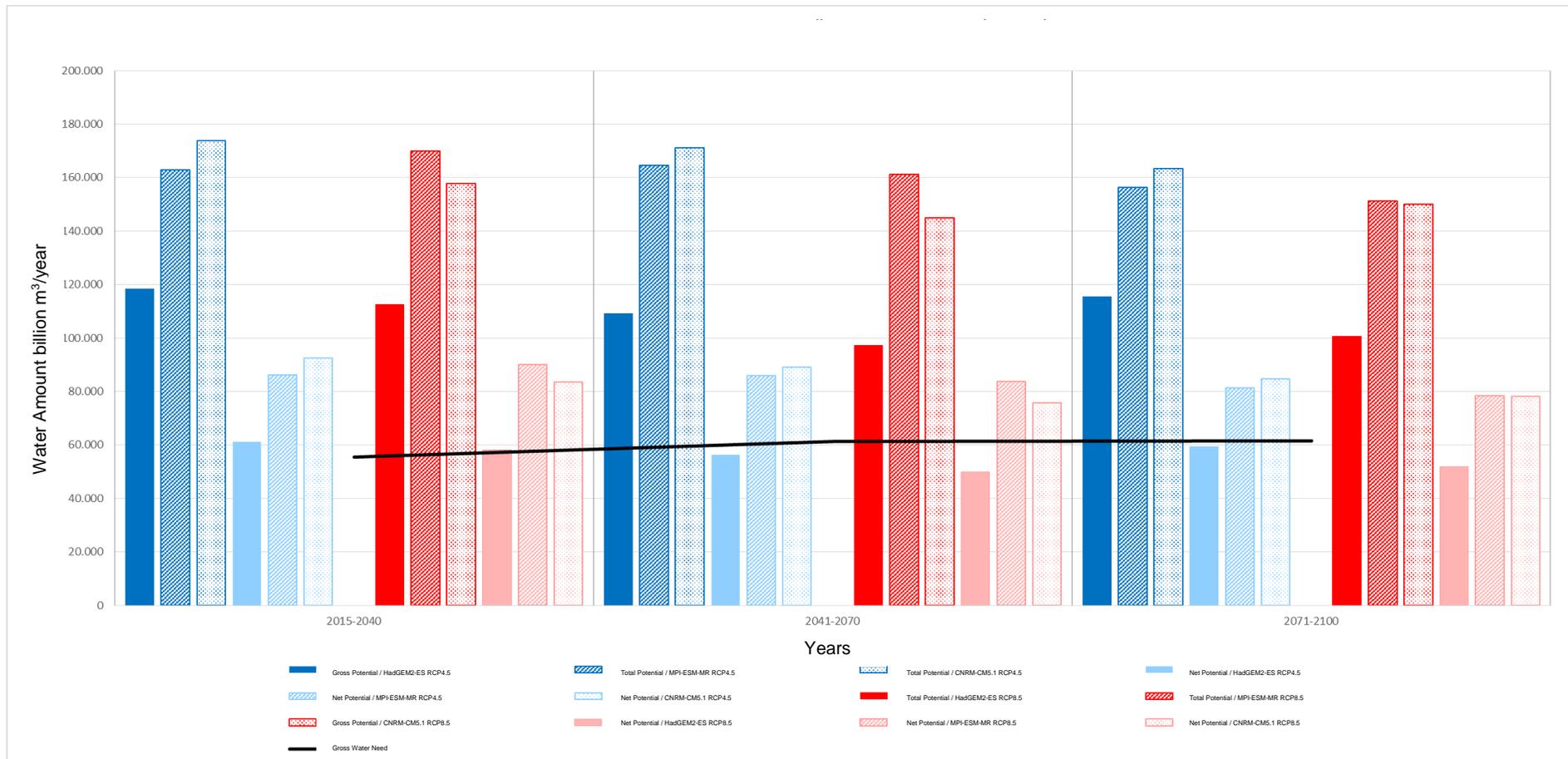


Figure 4.1 30-Year Comparisons of the Gross and Net Water Potentials According to the Climate Projections Scenarios for Turkey

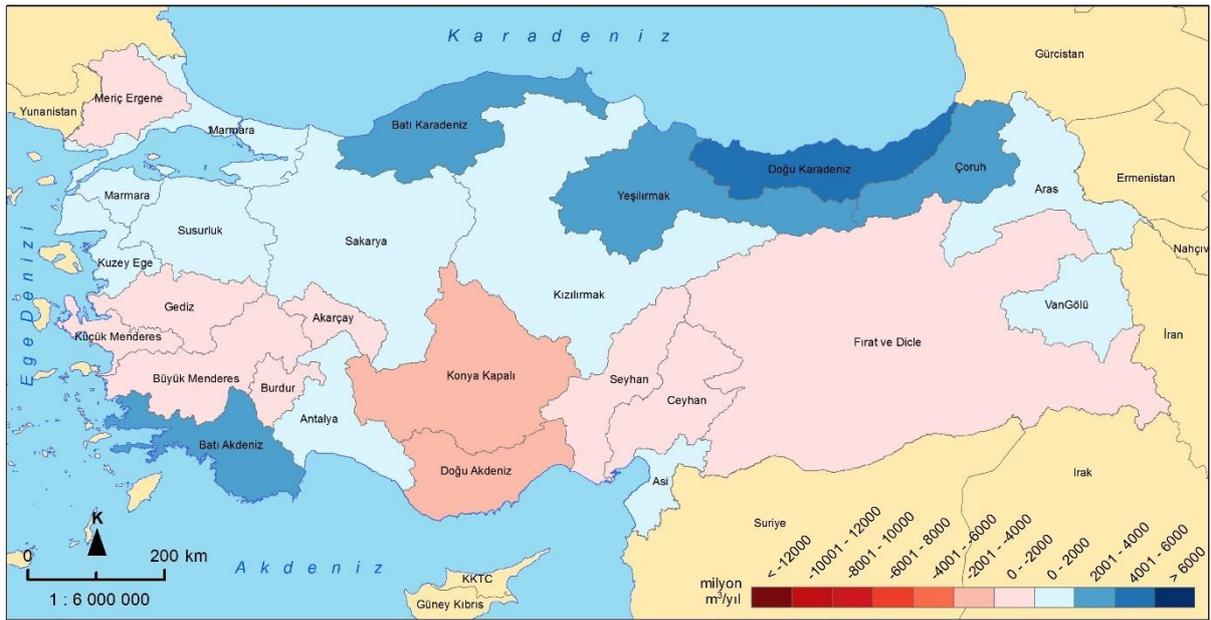
The net water deficit/excess situation of the river basins in Turkey for the 2015-2100 period has been prepared in thematic map format for three models and two scenarios separately; MPI-ESM-MR model and RCP4.5 scenario are shown as example in Figure 4.2, Figure 4.3 and Figure 4.4. The thematic maps showing the water excess/deficit may also be used in the future to determine the possible water transfer between the neighboring basins. In all the scenarios and projection periods, Fırat-Dicle Basin, which has the greatest water excess due to its magnitude, comes to the fore. On the other hand, even if not in all the periods, the basins where the most significant water deficit is observed are generally the Doğu Akdeniz Basin and Konya Closed Basin.

According to HadGEM2-ES model RCP4.5 scenario, the basins with water excess in all the periods are Fırat-Dicle Basin being in the first place, Doğu Karadeniz, and Çoruh Basins. Similarly, in all the projection periods; it has been observed that net water amount anticipated in Marmara, Susurluk, Kuzey Ege, Batı Karadeniz, Yeşilırmak, Antalya, Aras and Van Gölü Basins is sufficient for the estimated water usages. In Doğu Akdeniz and Konya Closed Basins, especially in the 2041-2100 period (in case no measures are taken) it is possible suffer sensible water deficit. In the other remaining basins, low-level water deficits may be observed in all the periods. Throughout the country, the most critical 30-year projection period in terms of water availability stands out as the period between 2041 and 2070 (mid period). The RCP8.5 scenarios of HadGEM2-ES climate model largely give parallel results with the RCP4.5 scenarios and as they describe more critical climate conditions they consequently points out to relatively more water deficit throughout the basins.

MPI-ESM-MR model generally points out to the fact that there will be relatively more water in the basins compared to the HadGEM2-ES model. According to this, in addition to the above-described Doğu Karadeniz and Çoruh Basins which are expected to significant scale of water excess; it is anticipated that in Batı Karadeniz and Yeşilırmak Basins there will also be substantial water excess. On the other hand, Fırat-Dicle, Konya Closed and Doğu Akdeniz Basins, which possibly will have water deficit, come to the fore in this scenario of the model. During all the projection periods, again Marmara, Kuzey Ege, Susurluk, Sakarya, Kızılırmak, Aras and Van Gölü Basins are the basins, which are expected to have sufficient water for all the usages and allocations. MPI-ESM-MR model RCP8.5 scenario shows substantial parallelism with the RCP4.5 scenario and for 2071-2100 period, it generally has not produced much critical results except the large-scale water deficit it anticipated for Doğu Akdeniz Basin. In addition, the said scenario points out to substantially increasing water deficits for Büyük Menderes and Seyhan Basins in only the 2071-2100 period. The forecasts of CNRM-CM5.1,

which is the other climate model, have produced quite close results to the outcomes of MPI-ESM-MR model.

The amounts of water that Turkey undertakes to release to the countries located at the river mouths from Fırat-Dicle Basin are taken into consideration for thematic maps showing the water deficit/excess situation of 2015-2100 period. The outcomes of each three models show that in Fırat-Dicle Basin, water deficit levels of up to 2-12 billion m³/year are expected in the 2015-2100 period. These data show that a new evaluation is required to be made regarding the amounts of water that Turkey has undertaken to release to the countries located at the river mouths of the basins.



For Fırat River Basin, the amount of 500 m³/s that Turkey undertakes to release to the countries located at the river mouths are taken into consideration.

For Dicle River Basin, the average flowrate value of 342 m³/s that releases to the river mouths between the years 2011-2015 is taken into consideration (DSI).

Figure 4.2 Thematic Map Showing the Basin Based Water Excess/Deficit According to the MPI-ESM-MR RCP4.5 scenarios of Climate Projections for Turkey (2015-2040)



For Fırat River Basin, the amount of $500 \text{ m}^3/\text{s}$ that Turkey undertakes to release to the countries located at the river mouths are taken into consideration.

For Dicle River Basin, the average flowrate value of $342 \text{ m}^3/\text{s}$ that releases to the river mouths between the years 2011-2015 is taken into consideration (DSI).

Figure 4.3 Thematic Map Showing the Basin Based Water Excess/Deficit According to the MPI-ESM-MR RCP4.5 scenarios of Climate Projections for Turkey (2041-2070)



For Fırat River Basin, the amount of $500 \text{ m}^3/\text{s}$ that Turkey undertakes to release to the countries located at the river mouths are taken into consideration.

For Dicle River Basin, the average flowrate value of $342 \text{ m}^3/\text{s}$ that releases to the river mouths between the years 2011-2015 is taken into consideration (DSI).

Figure 4.4 Thematic Map Showing the Basin Based Water Excess/Deficit According to the MPI-ESM-MR RCP4.5 scenarios of Climate Projections for Turkey (2041-2070)

4.3 Hydrogeological Projections

The first stage of hydrogeological studies is aimed at the distinguishing and description of hydrogeological environments. The hydrogeological environments separated and described throughout Turkey have the characteristics of granular environment and rock environment. An evaluation according to the free and pressurised characteristics of the environments described within the scope of the hydrogeologic projections has been made. The distribution of granular or rock structured hydrogeologic environments in Turkey is given by Figure 4.5 as example.

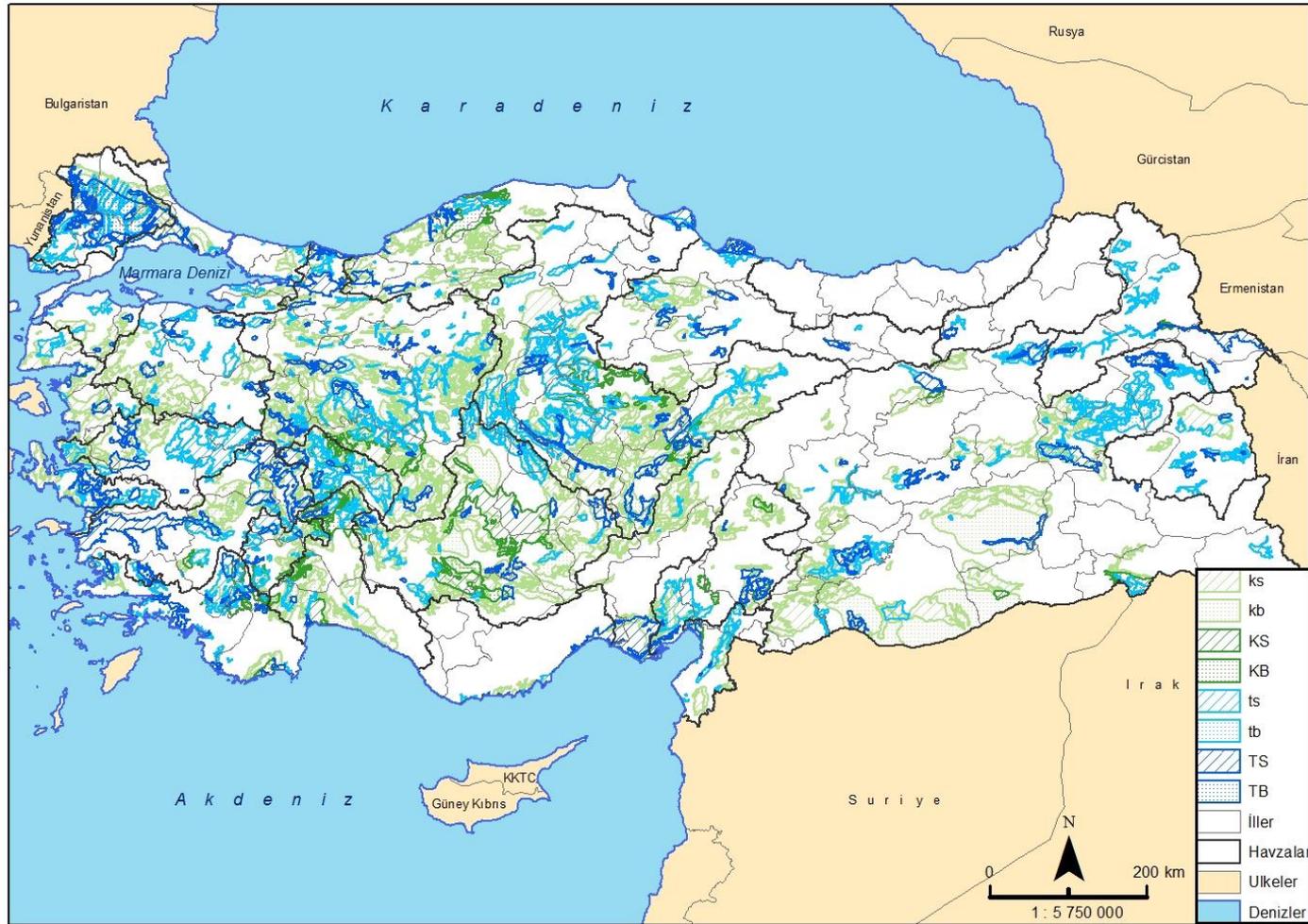


Figure 4.5 The Distribution of Free ± Pressurised Granular and Rock Environment Aquifers (TS, TB, KS, KB ; Aquifer) and Semi-Aquifers (ts, tb, ks, kb ; Aquitard) in Turkey.

The ground water potentials of the hydrogeologic environments whose characteristics throughout Turkey have been defined are determined as “dynamic, static, hydrogeologic, possible” ground water reserves. The calculations have been performed according to the “maximum ground water storage capability” by carrying out some environmental sizing acceptances with geo-hydraulic coefficients whose environmental representations have been homognized, entirely “*taking the original geologic-hydrogeologic character of each hydrogeologic environment as basis*”. The interbasin comparison of the dynamic, static and possible ground water reserve sizes - which are the expressions of the ground water potential of the hydrogeologic environments at the river basins in Turkey in different ways – is given with Figure 4.6 as example.

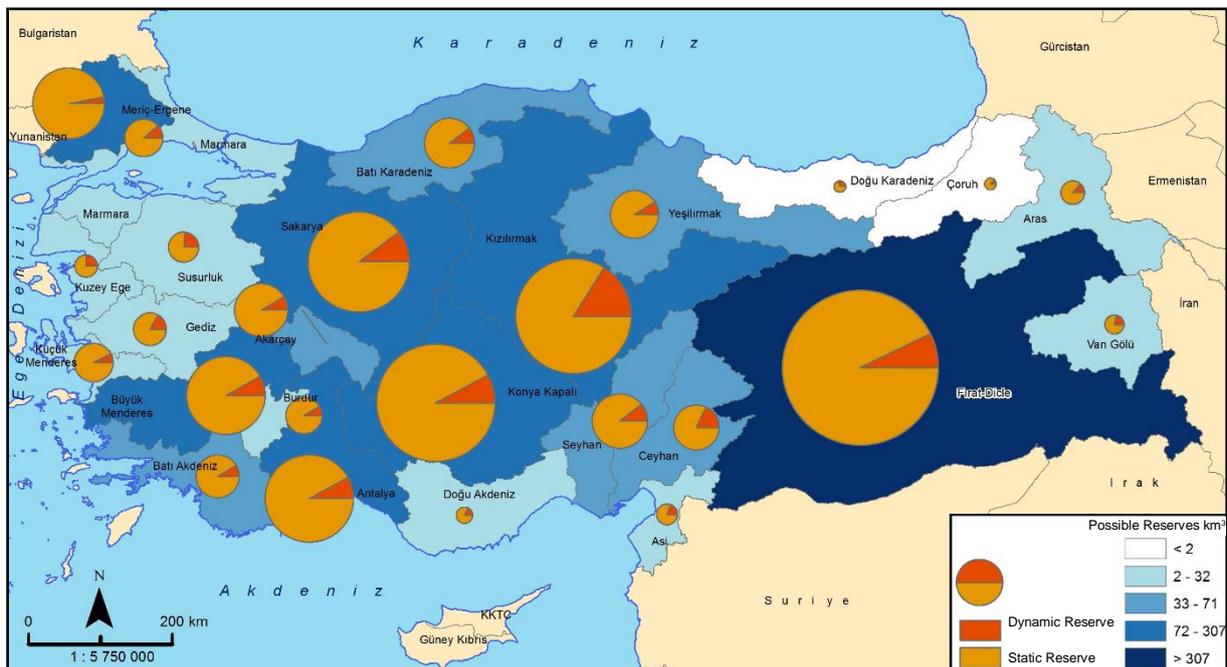


Figure 4.6 The Distribution of the Ground Water Potential of River Basins of Turkey in Terms of “Dynamic, Static, Hydrogeologic, Possible Reserves”

In parallel to the other study groups, in hydrogeological projections how the ground water potential of Turkey will show a change in the 2015-2100 period according to the two different scenarios of the climate change projections produced using the three global climate models is analyzed on the basis of different ground water reserve types and periodic ground water level change. From the performed study results, the ground water hydrogeological reserve, which expresses the total ground water potential of Turkey in overall, is presented with Figure 4.7 as example.

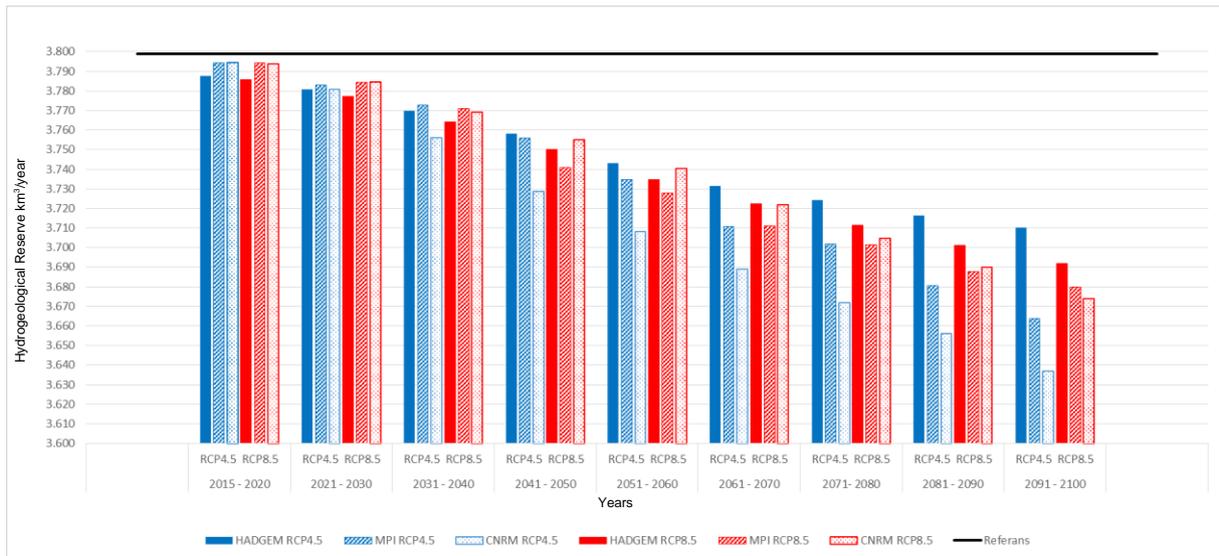


Figure 4.7 The Change Trend Foreseen in the Ground Water Hydrogeological Reserve of Turkey According to the Climate Models - Scenarios

As the change foreseen in the hydrogeologic reserve is evaluated specific to the basins, Meriç-Ergene and Fırat-Dicle Basins are among the basins which are least affected in Turkey overall. On the other hand, the striking maximum impact of the climate models-scenarios in overall Turkey is seen over the Asi Basin. In this context, the other most affected basins can be listed from most affected to least affected as Burdur, Kuzey Ege, Batı Akdeniz and Akarçay Basins which are in the western and middle parts of Turkey.

5. Evaluation of the Impacts of Climate Change on Water Resources Based on River Basins

Within the context of the project, the climate change projections of all the basins of Turkey and the impact of the said change on the water resources in the basins is analyzed. In this context, in the most general sense, the determinative river system in each basin is designated; the current use of the surface and ground water resources and the usage areas of the resources, the places where the composed domestic and industrial wastes are discharged and their amounts are analyzed. The hydraulic variables have been projected until 2100 at the scale of the drainage areas detected in the basin using temperature and precipitation projections based on the RCP4.5 and RCP8.5 scenarios of the HadGEM2-ES, MPI-ESM-MR and CNRM-CM5.1 climate models for the 2015-2100 period and the gross and net water potential change in each basin has been calculated. It is quite important for creating opportunities for the project outcomes to be taken into consideration in the determination of the water management strategies in all the basins and for the water deficit foreseen in the basin to be minimized.

In the RCP4.5 and the RCP8.5 scenarios for each of the three models, the 30-year changes of the gross water potential in 25 basins is shown with Figure 5.1.

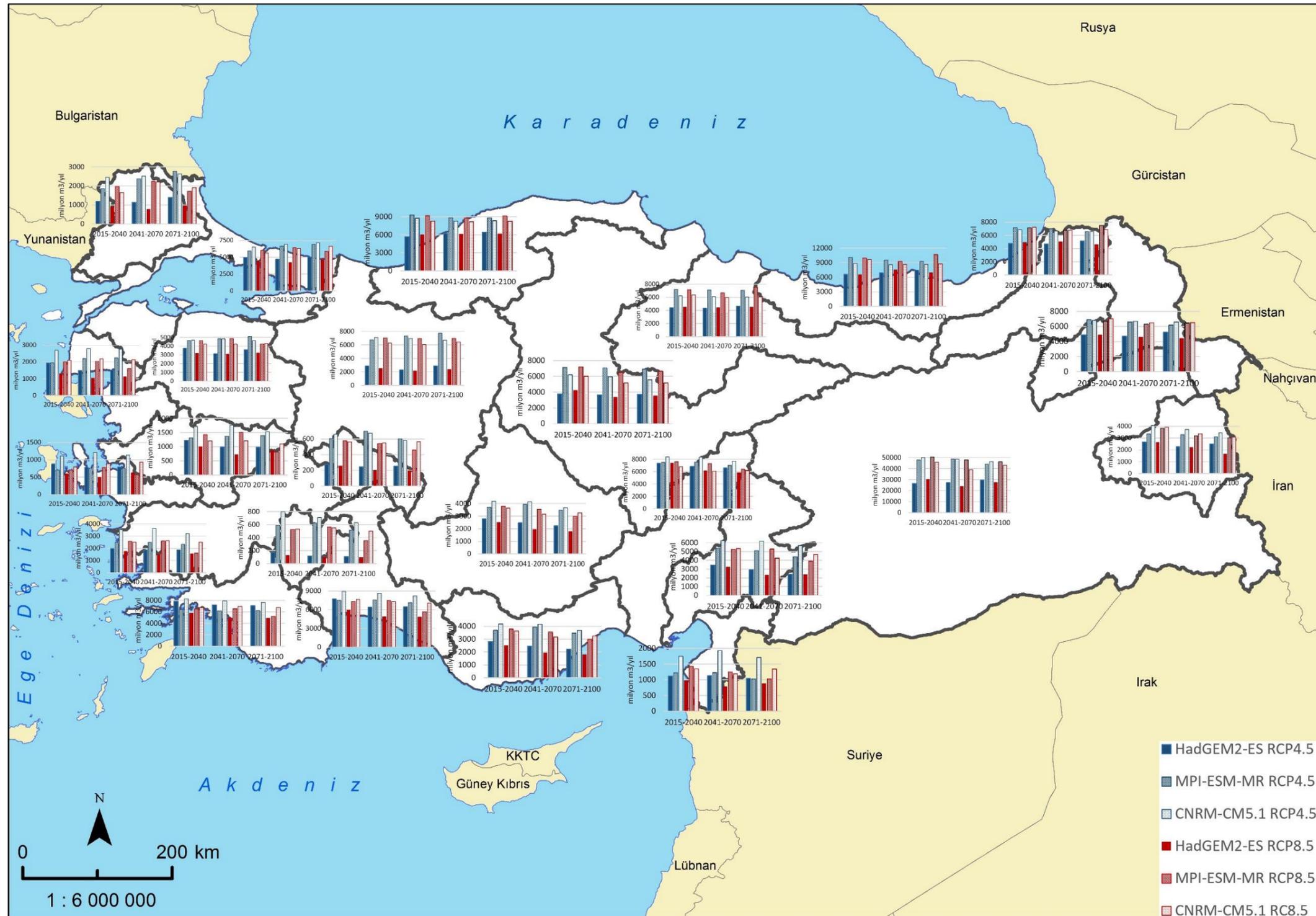


Figure 5.1 30-Yearly Averages of Gross Water Potential Values on the Basins for Turkey

In this section, the change of the average temperature, total precipitation, gross water potentials for 25 basins of Turkey are shown according to the reference period. Additionally, the amounts of water deficit/excess and hydrogeological reserves in the basin are given. All model results were evaluated over 30-year periods and possible extreme values were given in basin.

5.1 Meriç-Ergene Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **13,4°C** according to 1971-2000 observations, will **increase by at least 1,5°C, maximum 4,7°C** in 2071-2100 period.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **598,3 mm**. According to the 30-year projection results, there is no significant increase or decrease tendency for the total precipitation parameter and it is predicted that the basin will receive **13% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **northern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **1.838 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2070**, the gross water potential of the basin could **decrease up to 60%**. However, in the period 2071-2100, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **1.485 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **188 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **125 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **2%** and possible reserve by **3%**.

5.2 Marmara Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **13,9°C** according to 1971-2000 observations, will **increase by at least 1,5°C, maximum 4,6°C** in 2071-2100 period.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **679,2 mm**. According to the results of the projection carried out, there is an **increase tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **13% more** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall increases for this period will predominate in the **Black Sea coasts** of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **8.566 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2070**, the gross water potential of the basin could **decrease up to 50%**. Water transfer from the Batı Karadeniz, Sakarya and Meriç-Ergene Basins to the Marmara Basin is carried out so that the water need in the basin can be met at all times.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **53 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **29 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **6%** and possible reserve by **10%**.

5.3 Susurluk Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **12,5°C** according to 1971-2000 observations, will **increase by at least 1,6°C, maximum 4,7°C** in 2071-2100 period.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **640 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **10% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **southern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **6.157 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2070**, the gross water potential of the basin could **decrease up to 50%**.

Despite this, it is not expected that the annual available water amount for the projection period will meet the total water need.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **34 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **18 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **6%** and possible reserve by **11%**.

5.4 Kuzey Ege Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **15,9°C** according to 1971-2000 observations, will **increase by at least 1,5°C, maximum 4,6°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **eastern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **615 mm**. According to the 30-year projection results, there is no significant increase or decrease tendency for the total precipitation parameter and it is predicted that the basin will receive **15% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **southern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **2.379 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2070**, the gross water potential of the basin could **decrease up to 60%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **75 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **19 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **10 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **11%** and possible reserve by **21%**.

5.5 Gediz Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **14,6°C** according to 1971-2000 observations, will **increase by at least 1,7°C, maximum 4,9°C** in 2071-2100 period.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **589,7 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **20% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **southwestern and northeastern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **2.505 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2070**, the gross water potential of the basin could **decrease up to 75%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **1.445 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **40 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **21 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **11%** and possible reserve by **20%**.

5.6 Küçük Menderes Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **16,7°C** according to 1971-2000 observations, will **increase by at least 1,6°C, maximum 4,7°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the areas other than the coasts of Aegean.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **695,6 mm**. According to the 30-year projection results, there is no significant increase or decrease tendency for the total precipitation parameter and it is predicted that the basin will receive **20% less** rainfall

compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **eastern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **1.369 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2100**, the gross water potential of the basin could **decrease up to 70%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **315 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **56 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **32 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **3%** and possible reserve by **5%**.

5.7 Büyük Menderes Basin:

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **14,4°C** according to 1971-2000 observations, will **increase by at least 1,8°C, maximum 5°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **eastern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **592,4 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **25% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **western** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **4.028 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2070**, the gross water potential of the basin could **decrease up to 65%**. However, in the period **2071-2100**, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **2.480 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **228 km³**. The technically and economically

usable amount of this reserve, the possible reserve is calculated to be **138 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **4%** and possible reserve by **7%**.

5.8 Batı Akdeniz Basin:

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **16,2°C** according to 1971-2000 observations, will **increase** by **at least 1,8°C, maximum 4,9°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **northeastern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **731 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **28% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **southern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **9.403 million ³/year**. With the effect of climate change, it is predicted that in the period **2071-2100**, the gross water potential of the basin could **decrease up to 50%**. Despite this, it is expected that the total water need of the basin can be met until 2100 and there will be no water deficit in the basin.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **70 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **43 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **13%** and possible reserve by **22%**.

5.9 Antalya Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **14,2°C** according to 1971-2000 observations, will **increase** by **at least 1,8°C, maximum 5°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **inner** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **690,5 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **25% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **southeastern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **12.153 million ³/year**. With the effect of climate change, it is predicted that in the period **2071-2100**, the gross water potential of the basin could **decrease up to 60%**. Despite this, it is expected that the total available water potential in the basin will be above the total water need during 2015-2010, and there will be no water deficit in the basin.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **288 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **168 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **7%** and possible reserve by **12%**.

5.10 Burdur Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **12,3°C** according to 1971-2000 observations, will **increase by at least 1,9°C, maximum 5,1°C** in 2071-2100 period.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **508,7 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **25% less** rainfall compared to the reference period in **2071-2100**.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **606 million ³/year**. With the effect of climate change, it is predicted that in the period **2071-2100**, the gross water potential of the basin could **decrease up to 85%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **495 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **49 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **26 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **14%** and possible reserve by **26%**.

5.11 Akarçay Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **11,3°C** according to 1971-2000 observations, will **increase by at least 1,8°C, maximum 5°C** in 2071-2100 period.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **460,4 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **17% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **northern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **678 million ³/year**. With the effect of climate change, it is predicted that in the period **2071-2100**, the gross water potential of the basin could **decrease up to 70%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **545 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **105 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **57 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **11%** and possible reserve by **20%**.

5.12 Sakarya Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **11,3°C** according to 1971-2000 observations, will **increase by at least 1,7°C, maximum 4,9°C** in 2071-2100 period. It is expected that

temperature increases for this period will predominate in the **northeastern** and **southeastern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **477,8 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **8% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **southwestern and northeastern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **8.592 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2070**, the gross water potential of the basin could **decrease by 75%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **1.175 million m³/year** level.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **377 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **200 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **5%** and possible reserve by **10%**.

5.13 Batı Karadeniz Basin:

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **11,6°C** according to 1971-2000 observations, will **increase by at least 1,6°C, maximum 4,7°C** in 2071-2100 period.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **741,6 mm**. According to the results of the projection carried out, the amount of precipitation is above the reference period (1971-2000), and it is predicted that the basin will receive **8% more** rainfall compared to the reference period in **2015-2020**. It is expected that rainfall increases for this period will predominate in the **coastal** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **10.346 million ³/year**. With the effect of climate change, it is predicted that

in the period **2015-2020**, the gross water potential of the basin could **decrease up to 50%**. Despite this, it is expected that the total water need of the basin can be met until 2100 and there will be no water deficit in the basin.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **93 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **55 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **11%** and possible reserve by **18%**.

5.14 Yeşilirmak Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **11°C** according to 1971-2000 observations, will **increase** by **at least 1,8°C, maximum 5°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **southern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **510,2 mm**. According to the results of the projection carried out, there is an **increase tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **6% more** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall increases for this period will predominate in the **inner** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **6.432 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2070**, the gross water potential of the basin could **decrease up to 30%**. Despite this, it is expected that the total water need of the basin can be met until 2100 and there will be no water deficit in the basin.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **86 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **48 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **9%** and possible reserve by **17%**.

5.15 Kizilirmak Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **10,3°C** according to 1971-2000 observations, will **increase by at least 1,8°C, maximum 5,1°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **southern** and **northwestern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **448,7 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **6% less** rainfall compared to the reference period in **2041-2070**.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **8.011 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2070**, the gross water potential of the basin could **decrease up to 60%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **2.160 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **494 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **266 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **7%** and possible reserve by **13%**.

5.16 Konya Closed Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **11,1°C** according to 1971-2000 observations, will **increase by at least 1,9°C, maximum 5,2°C** in 2071-2100 period.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **397,6 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **16% less** rainfall

compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **southwestern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **6.532 million ³/year**. With the effect of climate change, it is predicted that in the period **2071-2100**, the gross water potential of the basin could **decrease up to 70%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **4.490 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **518 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **306 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **3%** and possible reserve by **6%**.

5.17 Doğu Akdeniz Basin:

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **16°C** according to 1971-2000 observations, will **increase** by **at least 2°C, maximum 5,1°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **inner** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **629,1 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **26% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **southwestern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **11.167 million ³/year**. With the effect of climate change, it is predicted that in the period **2071-2100**, the gross water potential of the basin could **decrease up to 60%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **4.695 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **10 km³**. The technically and economically

usable amount of this reserve, the possible reserve is calculated to be **6 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **10%** and possible reserve by **13%**.

5.18 Seyhan Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **12,3°C** according to 1971-2000 observations, will **increase** by **at least 2°C, maximum 5,3°C** in 2071-2100 period.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **545,3 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **15% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **southern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **8.711 million ³/year**. With the effect of climate change, it is predicted that in the period **2071-2100**, the gross water potential of the basin could **decrease up to 30%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **2.325 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **112 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **70 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **5%** and possible reserve by **8%**.

5.19 Asi Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **18°C** according to 1971-2000 observations, will **increase** by **at least 1,8°C, maximum 5°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **northern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **804,6 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **21% less** rainfall compared to the reference period in **2071-2100**.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **1.572 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2070**, the gross water potential of the basin could **decrease up to 55%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **270 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **16 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **9 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **29%** and possible reserve by **54%**.

5.20 Ceyhan Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **13,7°C** according to 1971-2000 observations, will **increase by at least 2°C, maximum 5,3°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **northeastern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **619,3 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **20% less** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall decreases for this period will predominate in the **southern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **8.165 million ³/year**. With the effect of climate change, it is predicted that in the period **2071-2100**, the gross water potential of the basin could **decrease up to 70%**.

However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **2.650 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **76 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **41 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **8%** and possible reserve by **15%**.

5.21 Fırat-Dicle Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **12°C** according to 1971-2000 observations, will **increase** by **at least 2,3°C**, **maximum 5,8°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **southeastern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **584,5 mm**. According to the results of the projection carried out, there is a **decrease tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **12% less** rainfall compared to the reference period in **2041-2070**. It is expected that rainfall decreases for this period will predominate in the **southern** and **inner** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **57.167 million ³/year**. With the effect of climate change, it is predicted that in the period **2041-2070**, the gross water potential of the basin could **decrease up to 60%**. However, in the same period, it is expected that the annual amount of water available will not meet the total water need, and the **water deficit** will be around **23.175 million m³/year**.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **899 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **473 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **2%** and possible reserve by **5%**.

5.22 Doğu Karadeniz Basin:

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **12,2°C** according to 1971-2000 observations, will **increase by at least 1,7°C, maximum 4,9°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **southern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **961,4 mm**. According to the results of the projection carried out, there is an **increase tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **15% more** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall increases for this period will predominate in the **northeastern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **15.336 million ³/year**. With the effect of climate change, it is predicted that in the period **2015-2020**, the gross water potential of the basin could **decrease up to 60%**. Despite this, it is expected that the total water need of the basin can be met until 2100 and there will be no water deficit in the basin.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **0,015 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **0,008 km³**. Under the effects of the climate change, no significant change is expected in the hydrogeological and possible reserves of the basin by the end of the century.

5.23 Çoruh Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **8,5°C** according to 1971-2000 observations, will **increase by at least 2°C, maximum 5,4°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **southern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **616,8 mm**. According to the results of the projection carried out, there is an **increase tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **10% more** rainfall

compared to the reference period in **2071-2100**. It is expected that rainfall increases for this period will predominate in the **northern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **6.600 million ³/year**. With the effect of climate change, it is predicted that in the period **2071-2100**, the gross water potential of the basin could **decrease up to 20%**. Despite this, it is expected that the total available water potential in the basin will be above the total water need during 2015-2010, and there will be no water deficit in the basin.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **1 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **0,7 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **5%** and possible reserve by **7%**.

5.24 Aras Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **6,1°C** according to 1971-2000 observations, will **increase by at least 2,3°C, maximum 5,7°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the basin except for the northern end.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **460,5 mm**. According to the 30-year projection results, there is no significant increase or decrease tendency for the total precipitation parameter and it is predicted that the basin will receive **5% less** rainfall compared to the reference period in **2041-2070**. It is expected that rainfall decreases for this period will predominate in the **central** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **4.886 million ³/year**. With the effect of climate change, it is predicted that in the period **2071-2100**, the gross water potential of the basin could **decrease by maximum 5%**. Despite this, it is expected that the total water need of the basin can be met until 2100 and there will be no water deficit in the basin.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **21 km³**. The technically and economically

usable amount of this reserve, the possible reserve is calculated to be **14 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **8%** and possible reserve by **13%**.

5.25 Van Gölü Basin

According to the climate change projections made for 2015-2100 period, it is expected that there will be a continuous increase in average temperatures. It is expected that the average temperature of the basin, which was **8°C** according to 1971-2000 observations, will **increase** by **at least 2,2°C, maximum 6°C** in 2071-2100 period. It is expected that temperature increases for this period will predominate in the **southeastern** parts of the basin.

According to the observations of 1971-2000, the average annual precipitation amount of the reference period of the basin was determined to be **527,6 mm**. According to the results of the projection carried out, there is an **increase tendency** in the total precipitation compared to the reference period (1971-2000), and it is predicted that the basin will receive **7% more** rainfall compared to the reference period in **2071-2100**. It is expected that rainfall increases for this period will predominate in the **southwestern** parts of the basin.

DSİ (Directorate General for State Hydraulic Works) data were used for hydrological model studies and the mean gross water potential of the basin for the reference period was determined to be **2.569 million ³/year**. With the effect of climate change, it is predicted that in the period **2071-2100**, the gross water potential of the basin could **decrease up to 40%**. Despite this, it is expected that the annual available water amount for the projection period will meet the total water need, and there will be no water deficit.

As a result of the hydrogeological studies carried out, the hydrogeological reserve of groundwater of the basin was determined to be **14 km³**. The technically and economically usable amount of this reserve, the possible reserve is calculated to be **7 km³**. It is estimated that at the end of the century under the effects of the climate change, the hydrogeological reserve of the basin will decrease by **9%** and possible reserve by **17%**.

6. Sectoral Impact Assessment

After the weighted index values of Sensitivity (S), Economical Value (EV) and Adaptation Capacity (AC) parameters for 5 main sectors, which are the water intended for human consumption, agriculture, industry, ecosystem services and tourism/energy/textile sub-sectors, were defined, it was accepted that these values wouldn't change during the projection period, and these were the values representing the river basin.

Values, which were produced after stages with many intermediate processes, varied between 1-4 scale, and they are simple enough for the decision makers and policy developers to understand and interpret easily, especially regarding the results instead of intermediate stages. Change range 1 indicates that the related sector would be affected from the change in the water potential the least, and it is emphasized that as the value increased, the sensitivity of the possible change in the water potential on the related sector increased, thus the potential of the sector to be affected from the possible change would increase. These tables are in the order of a matrix fundamentally, therefore lines indicate the vulnerability degrees between the sectors during the same projection period; whereas the columns explain the vulnerability of a sector during different projection periods. Vulnerability levels of sectors during the entire projection period according to both scenarios in Büyük Menderes River Basin is provided in Table 6.1.

River basin specific mappings for each sector, scenario and projection period were made by using these matrices. As an example, Figure 6.1 demonstrates the water intended for human consumption sector of Büyük Menderes River basin according to RCP8.5 scenario, Figure 6.2 demonstrates the energy sector's vulnerability levels of Ceyhan River Basin according to RCP4.5 scenario and Figure 6.3 demonstrates the industry sector's vulnerability levels of Meriç-Ergene River Basin according to RCP 8.5 scenario.

Table 6.1 Büyük Menderes River Basin Sectoral Vulnerability Analysis Results based on RCP4.5 and RCP8.5 Scenarios

Years / Sectors	Water intended for human consumption		Agriculture		Industry		Ecosystem		Tourism	
	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5	RCP4.5	RCP8.5
2015-2020	1	2	1	1	1	2	1	1	1	2
2021-2030	2	1	1	1	2	1	1	1	2	1
2031-2040	2	1	1	1	2	1	1	1	2	1
2041-2050	2	4	1	2	2	4	1	2	2	3
2051-2060	4	3	2	2	4	3	2	2	3	2
2061-2070	4	4	2	2	4	4	2	2	3	3
2071-2080	4	4	2	2	4	4	2	2	3	3
2081-2090	3	4	2	2	3	4	2	2	2	3
2091-2100	1	4	1	2	1	4	1	2	1	3

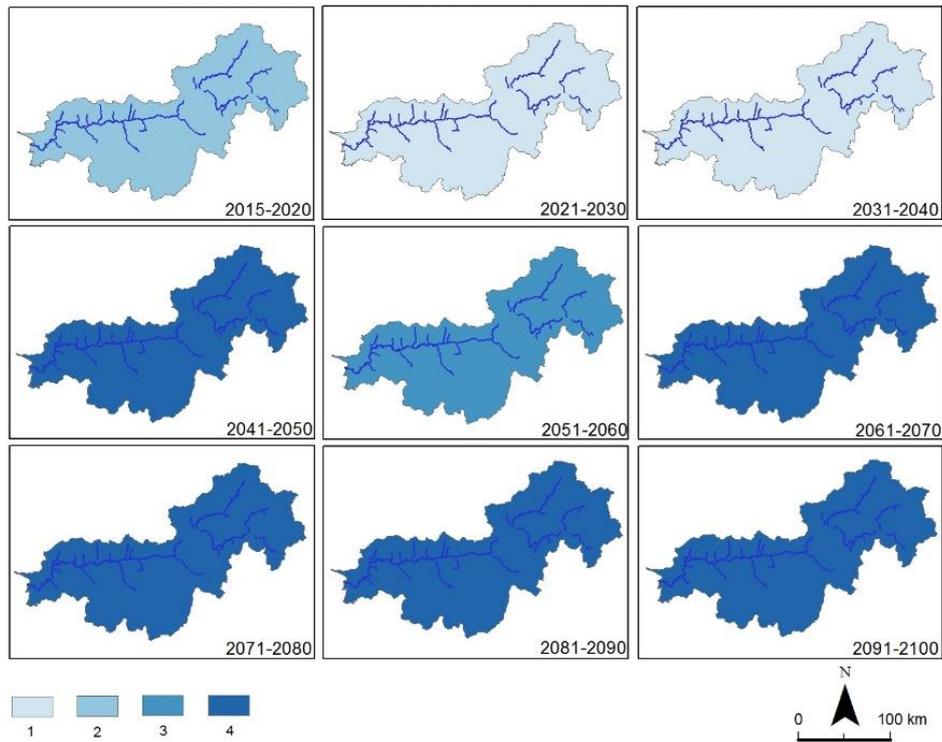


Figure 6.1 Büyük Menderes River Basin Water Intended for Human Consumption Vulnerability Analysis Results based on RCP8.5 Scenario

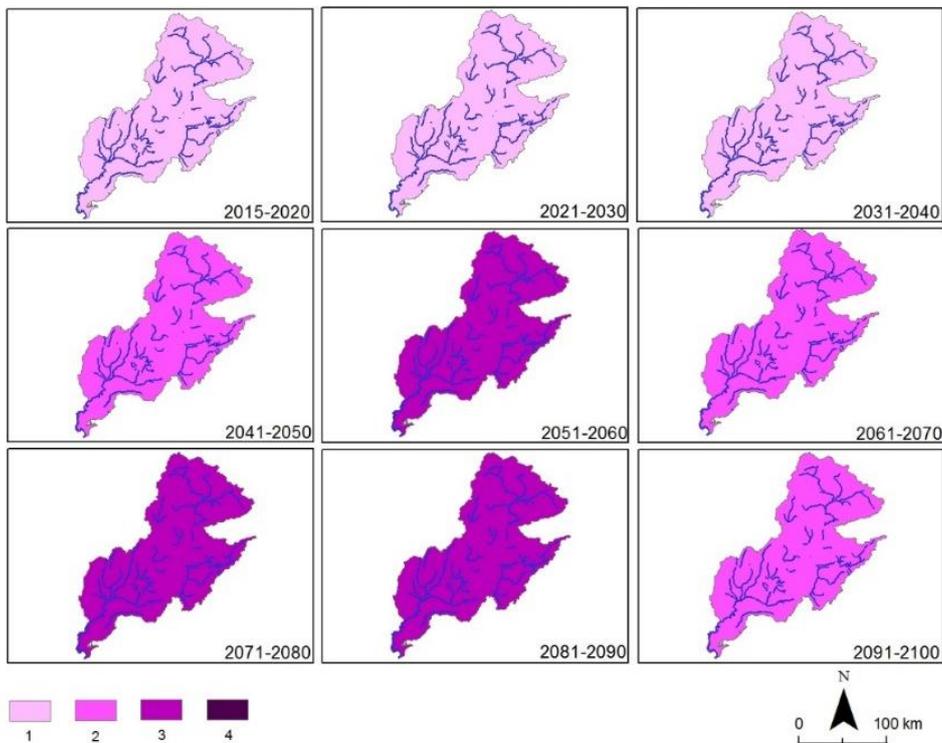


Figure 6.2 Ceyhan River Basin Energy Sector Vulnerability Levels based on RCP4.5 Scenario

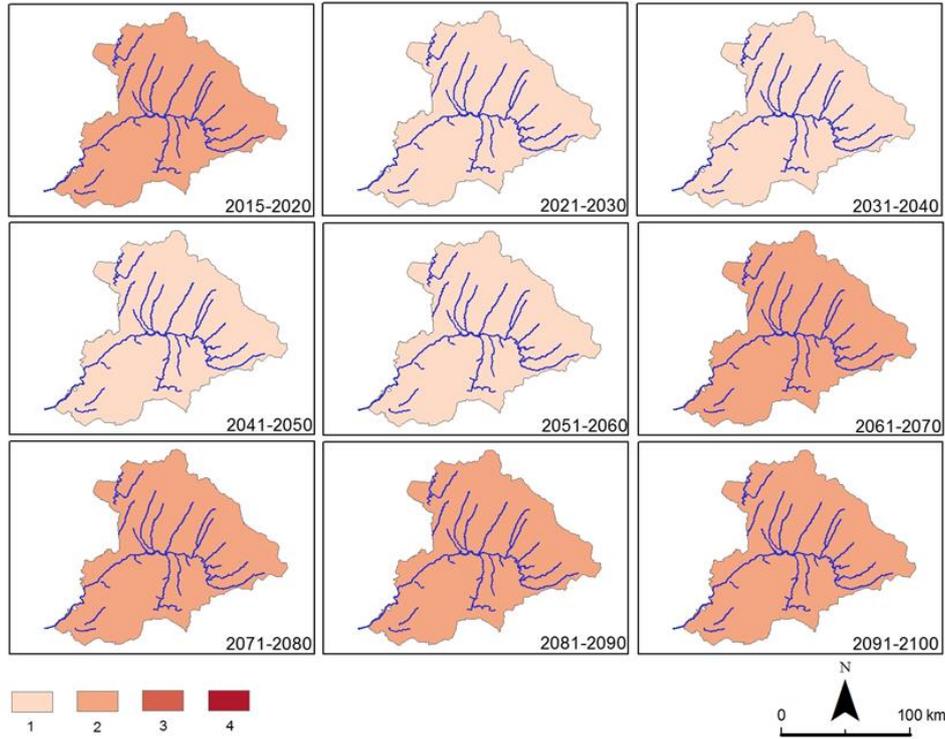


Figure 6.3 Meriç-Ergene River Basin Industry Sector Vulnerability Levels based on RCP8.5 Scenario

According to sectoral vulnerability analysis results, when the vulnerability analysis of the sectors examined in Büyük Menderes River Basin is considered, entire sectors except for the beginning of the projection period will be affected by the climate change, and it is predicted that the tourism sector will also have high vulnerability levels, initially the water intended for human consumption and industry sectors (Figure 6.4).

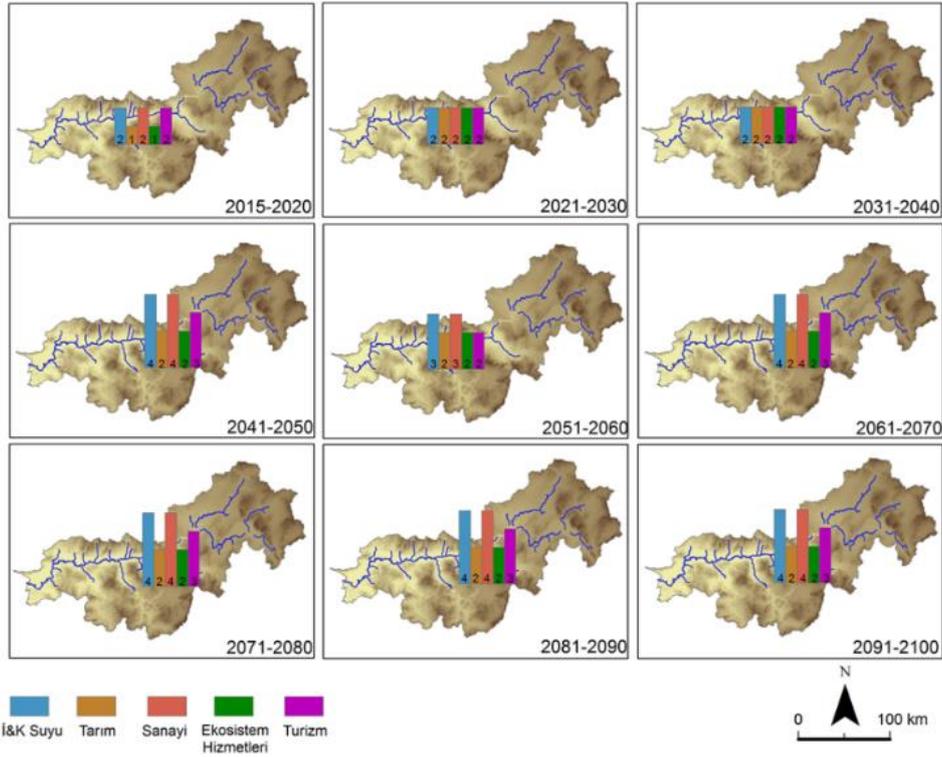


Figure 6.4 Comparison of the Vulnerability Levels of the Sectors in Büyük Menderes River Basin based on RCP4.5 Scenario

When the vulnerability analysis of the sectors examined in Ceyhan River Basin is considered, entire sectors except for the beginning of the projection period will be affected by the climate change, and it is estimated that the energy and ecosystem sectors will also have high vulnerability levels, especially the water intended for human consumption sector (Figure 6.5).

When the vulnerability levels of sectors from the climate change for a hundred years in Meriç-Ergene River Basin are examined, initially the agriculture and textile products sub-sector, then water intended for human consumption sector will be the sectors to be affected most (Figure 6.6). When sectoral vulnerability levels are evaluated in 10-year-long periods, according to RCP4.5 scenario the vulnerability of all sectors except for the agriculture and textile product manufacturing sub-sector is at low and medium levels. Industry and ecosystem services are under low impact during the projection period, whereas it is estimated that water intended for human consumption, agriculture and textile manufacturing sub-sector will be under medium impact and then under low and medium impact in the forthcoming periods.

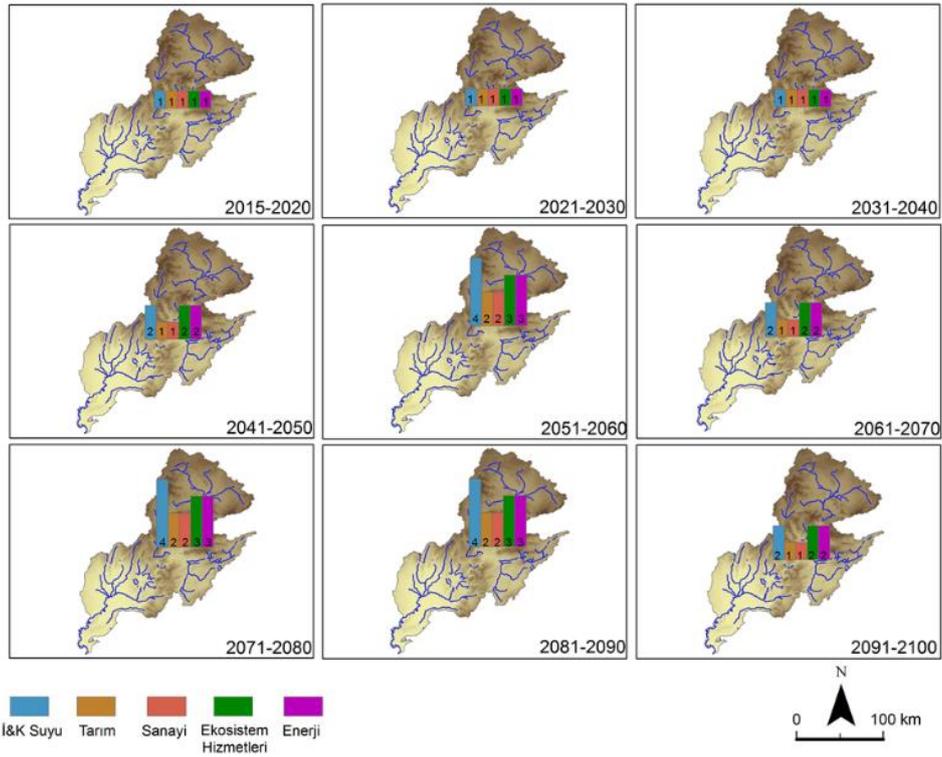


Figure 6.5 Comparison of the Vulnerability Levels of the Sectors in Ceyhan River Basin based on RCP4.5 and RCP8.5 Scenarios

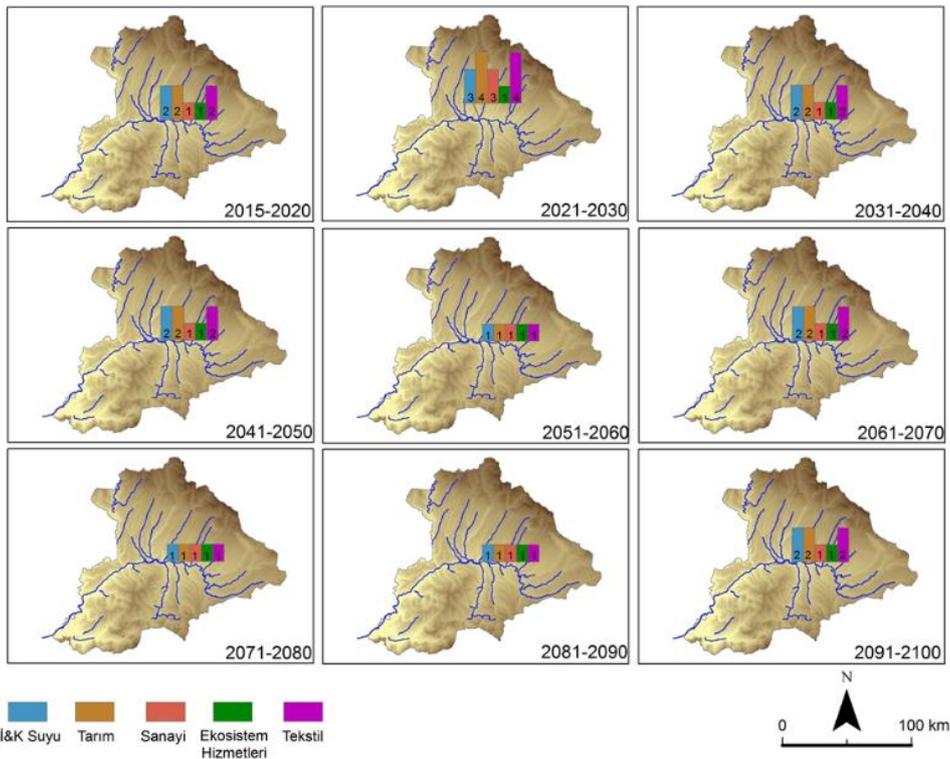


Figure 6.6 Comparison of the Vulnerability Levels of the Sectors in Meriç-Ergene River Basin based on RCP4.5 and RCP8.5 Scenarios

7. Adaptation Activities

Specific to adaptation activities, considering all river basins, various suggestions for adaptation activities are considered for the elimination of the negative impacts of climate change on water resources. In the studies to determine the adaptation activities, primarily the strategies developed in European Union (EU) are chronologically defined. The Green Document, the first official document prepared by EU Commission in 2007, stipulated all the countries of the world, mainly European countries to be prepared in their regions to be affected by the climate change, to determine their social priorities for main adaptation activities, and to determine the short-term measures. The document mainly explained the relevant legislation, the enforcement of the legislation and the funds to be used during implementation process.

After the Green Document, EU Commission issued the White Document in 2009. The purpose of this document is to form a basic framework to minimize the impacts of climate change and to ensure the common action of EU countries in this framework. The Document explains the basic ways to increase the resilience of the important sectors of Europe such as agriculture, bio-diversity, coastal ecosystems, decreasing the sensitivity to the climate change. Afterwards, the EU adaptation strategy formed as part of adaptation activities, the adaptation strategy of EU was published under the title European Strategy in the Adaptation to the Climate Change by European Commission. The main purpose of this strategy is to timely establish the mechanisms that will ensure Europe's preparedness to the current and future impacts of climate change. In 2013, the European Parliament and the European Council determined the adaptation targets to be met until 2020.

To help the adaptation activities to be carried out in our country, sectoral analysis and adaptation options in certain elected EU countries (Germany, France, Spain, Lower Danube River Basin) are studied in detail. In addition to these, examples of certain EU Countries (Germany, UK, France, Denmark, Italy) are included in the Adaptation Activities Report regarding certain adaptation activities implemented.

Along with EU, sectoral analysis and measures to be taken in 8 main sectors determined in the Climate Action Report in another developed country, USA, are included in the Adaptation Activities Report. Another guiding example mentioned in the Report is the technical report prepared by UNEP for the whole Africa continent and containing the sectors expected to be affected by the climate change and the measures to be taken. Following such an intense literature review, the Adaptation Activities Report contains the strategies, targets, plans and solution suggestions regarding adaptation with the climate change in Turkey. 138 adaptation activities are contained in the report as a result of these reviews.

As part of the measures to be taken against the climate change in 3 main sectors posing importance for our country (water intended for human consumption, agriculture and industry), following adaptation activities possible to be developed are examined below.

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

The sectors should use their share of the water consciously and controlled, and they should save according to the requirements of the era. For example, measures such as choosing the product design compatible with climate conditions in agriculture, starting to use modern irrigation techniques, preferring drip irrigation in the irrigation of green spaces, and using wastewater in irrigation as much as possible are the main measures decreasing water usage.

On the other hand, preferring clean production technologies in industrial use and taking intra-facility (on-the-site) control measures that will ensure decreasing water consumption are primary. Making savings in all domestic usages, mainly water intended for human consumption and/or using alternative water sources such as rainwater harvesting re-use of treated water and using grey water are the dominant studies of our days.

Along with creating awareness in the society, in parallel to the guidance of regional and local authorities towards encouraging the water savings and effective use of water, increasing the alternative water sources will minimize the use of clean water sources.

Technical visits were carried out in February-April 2016 in Büyük Menderes, Meriç-Ergene and Ceyhan River Basins in which sectoral vulnerability methodology developed in the project is applied. During these visits, we visited the sensitive areas characterizing the river basin, and provincial organizations of the institutions and organizations such as OSIB, ÇŞB, DSİ, Irrigation Associations, and discussed the adaptation activities suggested for the river basin against climate change, and the problems of the basin in this regard. Pursuant to the information obtained from the technical visits, estimated cost analysis for the adaptation activities to be applied primarily such as decreasing the seepage loss ratios, recovery of domestic waste waters and starting to use efficient irrigation systems in 3 pilot river basins was carried out.

Evaluating the global adaptation activities, 25 stream river basins of our country were classified to ensure easier implementation of the adaptation activities. This classification is especially recommended so as to prioritize the adaptation activities based on sectors, and ensuring easiness for the authorities and other regulatory bodies. Variable climate conditions and geographical properties are seen in the north, south, east and west parts of our country that is a bridge between the European and Asian continents. Therefore, it is obvious that there may be certain differences according to the regions and differences in the adaptation activities to be suggested among the sectors in which vulnerability analysis will be carried out.

Along with the various properties of the three seas surrounding our country, since some river basins have costs to an inland sea such as Marmara Sea, we thought it would be appropriate to classify river basins with coasts to different seas in terms of adaptation activities. According to the river basin classifications carried out using this method, 5 main river basin categories are obtained in the Figure 7.1.

- Inland river basins with no coasts,
- River basins with coasts to Black Sea,
- River basins with coasts to Mediterranean Sea,
- River basins with coasts to Aegean Sea,
- River basins with coasts to Marmara Sea.



Figure 7.1 Turkey's Coastal and Inland River Basins

Works in many countries were reviewed in detail, the scopes of the sectors considered in these countries were considered, and 12 main sectors are selected in Turkey. Along with the geographical properties, location, environmental problems, climate properties, land usage, urbanization level and technical and economic development level of the country, socio-economic structure and financial development level is also considered in the selection of these sectors. Additionally, adaptation activities specific to Turkey are determined based on the selected 12 sectors.

SECTORAL ANALYSIS

1) Health	7) Marine Environment and Fishery
2) Agriculture, Food Safety, Forest and Bio-Diversity	8) Tourism
3) Water Sources	9) Industry–Trade and Energy
4) Infrastructure (Building, Transportation and Energy)	10) Research and Development
5) Superstructures (Urban and River Basin Planning, Buildings and Settlements)	11) Information, Education and Training
6) Coastal Areas	12) Financing and Insurance

Sectoral vulnerability analysis should be developed and carried out specific to each river basin in total adaptation with the main principles of the methodology developed in this project so that adaptation activities can be effectively and productively carried out.

The steps to be followed with a master plan approach in terms of adaptation activities specific to each river basin are provided below.

- Sectoral vulnerability works based on the suggested sectors (site works and a detailed inventory)
- Determination and prioritization of the adaptation activities based on sectoral vulnerability,
- Sectoral planning of adaptation activities,
- Completion of benefit-cost analysis of the planned adaptation activities,
- Carrying out budget works based on price-cost analysis,
- Carrying out the implementations,
- Getting feedback from the implemented adaptation activities, and making revisions when needed.

8. ClimaHydro Database

The design of CWD is completed at the end of the works in the project. The designed system is developed on Oracle 11g (11.2.0) database server. As part of such database works, data tables regarding the outcomes of the project are formed, and the relations between tables are defined. The developed database application will allow the storage, search, analysis and visualization of the spatial and non-spatial data. Spatial data are in vector format, and are in spot, linear or area geometry structure. Such vector data is composed of the areal country boundaries and administrative organs, climate grids, river basins, water masses (seas, lakes, dams and ponds), drainage areas and linear stream networks. Such spot, linear and area geometric data are the spatial detail classes compatible with GIS data structure. Non-spatial data are the table generated by the other work groups in the project through their works.

As a result of the works carried out in this regard, the database contains more than 500 million records. The spatial (grid, drainage area, water mass) and temporal resolutions (monthly and annual) of the model results in the database vary according to the data group and parameters. Calculations are made pursuant to the search criteria determined by the client/user, and graphic visuals are generated in the application. Also, dynamic thematic map generation from search results is also available in the application. Therefore, ClimaHydro Database and its Web Application work is also a WEB GIS work.

The execution codes developed on data layer Oracle 11 g (11.2.0) database are developed using Microsoft Visual Studio 2013. Spatial data in the application are stored in Oracle 11g database in SDE data structure on ArcGIS Server 10.1 GIS server. ArcGIS Server 10.1 is also used in the publication of the spatial data as REST service. The spatial web services published as REST services are obtained by an API on the user side. This can be a web API, Silverlight or JavaScript API. ASP.NET MVC and ArcGIS JS API3.14 is used in the application. The rendering process for the map to be generated by the data obtained from the database may occur in the server or client. The spatial and non-spatial data are combined by the client in the application. The general structure of the system architecture of the application developed in the project is provided in Figure 8.1.

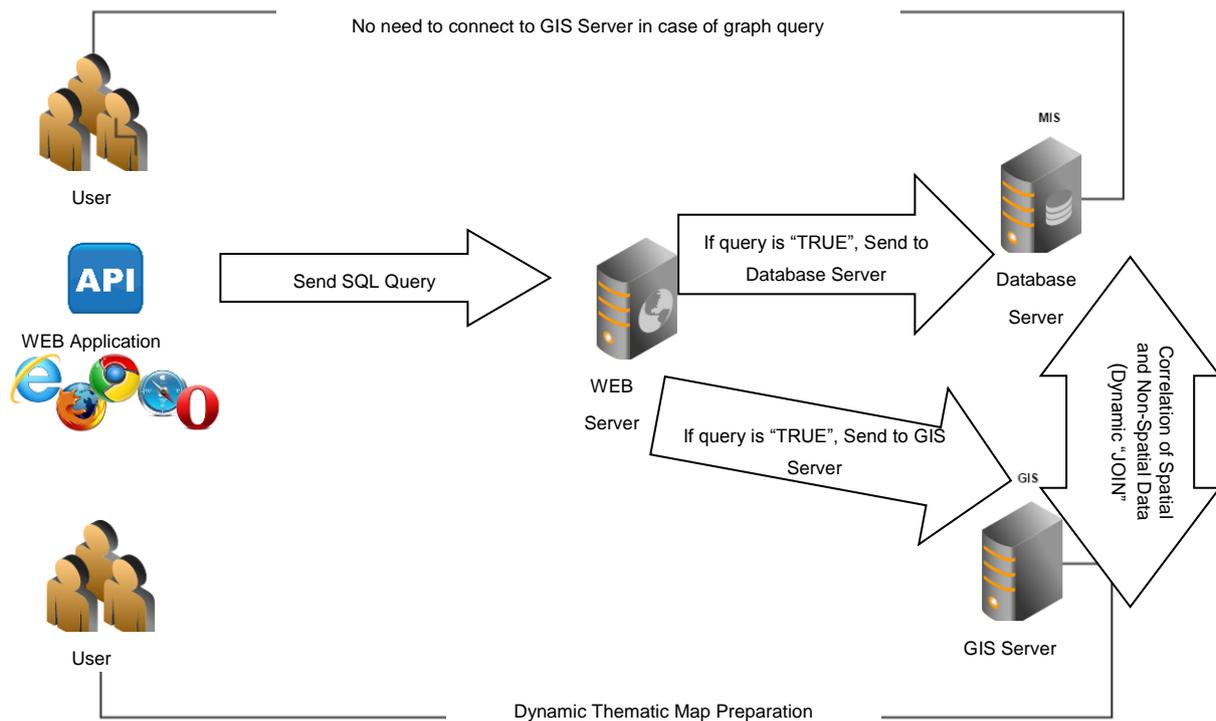


Figure 8.1 System Architecture of ClimaHydro Database

The results of the project can be monitored on the Project's Web Page on <http://iklim.ormansu.gov.tr/> link, and the application can be accessed through the same link.

9. Results and Evaluation

Before the "Climate Change Impacts on the Water Resources Project" was put into practice, many studies have been performed until today in Turkey to analyze the climate variability using various climate models. However, as these studies were not sufficient in terms of both the scope and the accuracy, there were crucial information deficiencies and uncertainties in determining precisely the risks and opportunities that are expected to occur in Turkey until the end of the 21. century due to global warming. For the first time in our country, the simulations included in the IPCC 2013 evaluation report and performed with the three ground system models in CMIP5 for the RCP4.5 and RCP8.5 emission scenarios have been scaled down dynamically to 10x10 resolution and applied successfully throughout Turkey and in 25 river basins in the 2015-2100 projection period with this project. With this project, it has become possible to increase the horizontal resolution to 10 km and obtain the details of the regional climate conditions developed as a result of the interactions with the topography. Especially in the regions where complex topography is predominant, in the simulations of the extreme/excess events, results with high accuracy have been obtained.

When the climate projections obtained within the scope of the project are analyzed in terms of temperature parameter; it is seen that all of the simulations based on the three global climate models and on both emission scenarios indicate a substantial warming over Turkey in the 2015-2100 projection period at seasonal and yearly scales. In the last 10-years term of the projection period, increases in temperature reach the maximum values as determined that 3,4°C for RCP4.5 scenario and 5,9°C for RCP8.5 scenario. For both scenarios, it draws attention that the temperature increases will start from the southern latitudes of Turkey and enlarge towards the north throughout 2015-2100, and that the highest temperatures occur in the Southeast of Turkey, which includes the topographies where height is predominant, and along the Mediterranean. Due to the increasing temperatures, the fact that the precipitation type in the winter months turns into more frequently rain from snow causes the snow covered areas to diminish and causes the snow to melt earlier in the spring months. The decrease in the snow covered surfaces causes the surface albedo to decrease and therefore causes the sun radiation amount absorbed by the surface to increase and increases the temperatures faster than the other regions.

When the climate indices - which are the indicators of exceeded temperatures in terms of extreme weather events – are analyzed, it is foreseen that the heat waves will increase from the southern latitudes of Turkey towards the north in each 30-year period, that especially after 2041 the highest heat wave values based on the RCP4.5 scenario are observed in the Eastern and Southeastern Anatolia Regions. While the maximum and minimum temperatures are expected to increase towards the end of the century, especially in the Mediterranean, Southern and Eastern Anatolia Regions these increases are identified to be higher. The fact that the daytime temperatures are high will create increases in the heat wave frequencies and severities in these regions. In addition to this, as the fact that the night temperatures being high will limit humans and animals in feeling relaxed, it will cause an increase in the harms that the heat wave will create. In addition, it will increase the energy demand to be used in the environment cooling at night in addition to daytime. The fact that along with the anticipated lack of precipitation the evaporation rate increases, will increase the stress in the water resources and agricultural sector. It suggests that in the Mediterranean coast there is a requirement of a new structuring in the tourism sector.

When the results of the climate projections are evaluated in terms of precipitation parameter, it is seen that the precipitation projections foresee regional increases and decreases throughout the projection period based on the ground system models. Generally, during the projection period, it is anticipated that precipitations based on the 10-year averages change between -50 mm and 40 mm for RCP4.5; -60 mm and 20 mm for RCP8.5. The model

simulations foresee that in the basins located at the north of Turkey, the climate regime will have more precipitation than the reference period. For example, in RCP8.5 scenario assumes that as of 2050s, the drought in the basins will become more severe towards the south and that the ten-year total average yearly precipitations per basin will reach around 150 mm. Most severe drought forecasts belong to the MPI-ESM-MR model, and the mildest drought forecasts belong to the CNRM-CM5.1 model. When the precipitation changes per basins are analyzed as percentages of yearly total precipitation, it is seen that the maximum changes are in Asi, Doğu Akdeniz, Batı Akdeniz and Ceyhan Basins.

Overall in Turkey, it is seen that the snowfall amounts will gradually decrease between 2015-2100 in both scenarios. Regardless of the fact that at the beginning of the century snowfalls of a little above or below the normal levels have identified similar to the current climate regime of Turkey, snowfall amounts have rapidly decreased due to the fact that greenhouse gas emission scenarios are more predominant on the natural climate variation of the region. The fact that the type of precipitation becomes snow due to the increase in the temperature is important in terms of hydrology. Yet, the accumulated snow serves as a water reservoir and especially at the beginning of spring and summer months they melt down and provide water intake to river systems as a result of the increasing temperatures. Therefore, snow cover at high areas has an important role on the regional hydrologic cycle. Especially in Eastern Anatolian region and East Taurus Mountains, the decrease in the snow cover should be expected to change the hydrologic cycle of Fırat-Dicle Basin.

Until today, the water potential calculations for overall Turkey have been performed without using the hydrologic model. This project, which aims to determine the impact of the climate change on the surface and ground waters on the basis of the basins, is a first due to the fact that all the basins have been solved with a common hydrologic model. Within the scope of the project, through hydrologic modelling study, possible changes in the water potentials based on the basins under the impacts of the climate change for the 2015-2100 projection period have been determined. Along with this, the main sectors which will consume the water in each basin have been taken into consideration and the water requirement has been projected and for the first time in our country, the periods in which possible water excess/deficit will be experienced in 25 river basins have been presented. This project is a detailed study in which how the dimensional and geohydrologic specifications of hydrogeological environments of Turkey will be impacted by the dynamic, static, hydrogeological and possible reserves and under the climate change impact of these components until 2100 is evaluated.

According to the model results, in the simulations which are run only with the outcomes of the HadGEM2-ES climate model, it is anticipated that at least in 3 ten-year periods the water deficit

may be at a level of ~6.000 million m³/year. In the hydrologic modelling simulations run for the HadGEM2-ES model and the RCP8.5 scenario, in at least 6 ten-year periods there is a water deficit expectation of ~7.000 million m³/year. The results produced by the MPI-ESM-MR and CNRM-CM5.1 models for both scenarios show similarity and they foresee that in the 2015-2100 period the total water requirement of our country will be possibly met and there will be no water deficit.

When the water potential change is evaluated specific to the basins, Fırat-Dicle Basin stands out in all the scenarios and projection periods with having the highest water deficit. On the other hand, even if not in all the periods, the basins where the most substantial water deficit is observed are in general Doğu Akdeniz and Konya Closed Basins. When the water deficit/excess situation is evaluated considering the amounts of water that Turkey undertakes to release to the countries located at the river mouths from Fırat-Dicle Basin, it is foreseen that water deficit at levels reaching 2-12 billion m³/year is expected in Fırat-Dicle basin in the 2015-2100 period. These data show that a new evaluation is required to be made regarding the amounts of water that Turkey has undertaken to release to the countries located at the river mouths of the basins.

The impacts of the climate change have begun to be seen and in the forthcoming 10-year periods this situation is expected to become more significant. Ensuring sustainable usage of the water resources on the basis of the basins is becoming a priority. In this context, to protect the water resources for our country, "Impact Analysis" methodology has been developed based on the sectors. Sectoral vulnerability analysis has been applied on the Büyük Menderes, Meriç-Ergene and Ceyhan Basins and impact levels in the main sectors in the forthcoming 10-year periods have been determined.

According to the results of the sectoral impact analysis, in each pilot basins, except the beginning of the projection period the water intended for human consumption sector reaches a quite high vulnerability level. Also in Büyük Menderes Basin, industry and tourism; in Meriç-Ergene Basin, agriculture and textile products sub-sector; in Ceyhan Basin, energy and ecosystem sectors stand out with high vulnerability levels.

The studies for struggling with climate change in our country are mainly aimed at reducing emission and with this project, an important step has been taken in the determination of the adaptation activities against climate change. In various regions and countries of the world, the sectors standing out in adaptation have been analyzed with adaptation strategies and activities put into practice and planned against climate change; and in the light of this information 25 river basins have been grouped, 12 main sectors have been identified for our country and adaptation activities specific to these sectors have been suggested. Taking into consideration

the results of the sectoral impact analysis developed within the scope of the project and the on-site monitoring made in the pilot basins, adaptation activities of top priority have been determined for these basins.

The information generated as a result of the studies carried out within the scope of the “ClimaHydro Database” project have been developed into a systematic and relational structure and the sustainability of the data has been ensured. The application is defined as a WEB CBS development work due to the fact that it performs dynamic thematical map production in addition to visualization on graphics. ClimaHydro Database application constitutes an important primary resource for the studies to be performed in the continuation of this project in terms of dynamically questioning the results provided as 10 and/or 30-year periods in different frequencies in the reports within the scope of the project.

9.1 Suggestions

The evaluation of the results obtained in this project and sustainability of the project outcomes, the points to consider in the subsequent projects and the subjects required to be completed are summarized under the following main topics:

- The project outcomes should be put into information and use of the related public and private bodies, maximum benefit should be gained from the project results.
- It should be ensured that the sectoral impacts of the climate projections and the hydrologic modelling forecasts on overall Turkey and in 25 river basins take place in the related Master Plans as basic input and that they are reflected to the Water Resources and Drought Management Plans.
- It should be ensured that the project outcomes constitute basic input to the preparation of Climate (Change Impacts) Resistant Water Management Master Plans of especially the Metropolitans and Mega Cities.
- With reference to the climate projections and the hydrologic modelling forecasts, how the water quality in especially the accumulating structures (dams and lakes) which supply water intended for human consumption to Metropolitans will be impacted and the possible reflections of this situation to the treatment technology used in the Water Treatment Facilities, to the operating technology and to the output quality should be researched with new projects.
- Taking the Turkey Geology Map with scale 1/500.000 dated 2002 as basis, a new Turkey Hydrogeology Map should be prepared on the basis of “environmental permeability variation” of lithostratigraphic units.

- The Turkey Ground Water Reserves Inventory which has been brought to a very important stage within the scope of this project should be supported with the site data to be produced with the contributions of the related public bodies, the dynamic and static reserve information of the hydrologic model and the water budget on the basis of the basins should be updated and put into service of the users.
- Taking into consideration the current ground water reserves, starting especially with the ground water plains (aquifers) from where excess draft is performed, a National Ground Water Master Plan should be prepared. The said Master Plan should also include the enhancement strategies related to the aquifers which are contaminated for various reasons.
- Any kind of hydrogeologic data related to the ground water environments which are found insufficient in terms of quality and quantity during the project studies, to the periodic ground water observations and measurements, to the production structures and to their usages should be re-approached and a new “Turkey hydrogeologic data bank” should be created.
- Plain (aquifer) surveys should be re-performed in a way to cover all the Plains of Turkey.
- The legal, administrative and technical works should be planned for primarily avoiding and later on reducing the sea water attempt developed on the coastal plains where especially the country tourism and agricultural activities are very intense; and following the hydrogeologic researches, the methods for precautions should be realized.
- Hydrogeologic researches should be performed with support of the field works in order to analyse, evaluate, develop and protect the rocks and granular environment aquifers specified in overall Turkey in terms of their formal, geohydrologic, ground water potential, utilizability and technical interference specifications.
- Regional hydrogeologic researches which will set forth the availability potential of the ground water environments should be performed. The ground water protection zones - which will ensure that the groundwater is fed and that its quality is not impaired - and the measures included by these zones should be defined.
- Illegal ground water usages should be avoided, current boreholes inventory should be formalised, borehole drillers should be audited and scientific-technical principles should be made dominant on the drilling and usage conditions.
- It is considered beneficial to prepare a Master Plan in adaptation with the Integrated Coastal Area Management concept with respect to which parts of our country shall be

impacted from the glacial meltings and sea level increases due to climate change and which preventive adaptation strategies can be implemented.

- Within the scope of the effective usage of the water, the reduction of the supply network losses and leakages especially in the urban areas in accordance with the targets of the “Regulation Related to the Control of the Water Losses in the Drinking Water Supply and Distribution Systems” (OSİB, 2014) should be effectively audited, new water (resource) allocation should not be performed to the Municipalities where loss and leakage ratio over the standard is identified.
- In irrigation, the practices related to the extensification of the closed (sprinkling and drip) irrigation techniques should be continued.
- Extensification of the clean production technologies (Best Available Technology (BAT) practices) using small amount of water/chemical in the industry among all the OIZs (organized industrial zones) and important contaminant industries should be tracked and encouraged.
- Taking into consideration the Impacts of the project outcomes on the current Nature Protection and Wetlands in our country, project that will ensure the protection and the sustainability of the said areas should be developed.
- Taking into consideration the outcomes of the project regarding the transnational waters in Turkey, our practiced Foreign Policy strategy and water disemboque guarantees should be reviewed in this direction.
- The climate and hydrologic modelling components of the project should be updated at intervals of 5–10 years, and the practices should be reviewed according to the revised outcomes to be obtained.
- It is beneficial to test the simulations made within the scope of this project at more confined areas with non-hydrostatic climate models where the resolution can go below 10 km and to diversify the used regional models. Especially, it is suggested that on the regions where the topography is complex, solutions with higher resolutions should be produced and compared with different models and different approaches in dynamic scale reduction.
- Sectoral analysis studies have been carried out on the basis of specific sectors specific to 3 pilot basins according to the Project Technical Specification. However, in the Adaptation Activities report, the situations of various countries have been analyzed in detail and practicable sectors in our country have been suggested. It is crucial for the methodology developed in this project is implemented on the basis of the suggested sectors instead of the projects to be developed.

- It is suggested that the sectoral impact analysis should be detailed on the basis of the sub-basins as well as being performed throughout the basin.
- With performing the sectoral analysis on all the basins and sub-basins, the applicable adaptation activities should be determined and they should be prioritized for short, medium and long terms.
- Within a plan in which the prioritized adaptation activity suggestions stated in the final report, interinstitutional duties and responsibilities are set forth; the necessary planning and implementation processes should be carefully followed to be put into practice specific to sub-basins.
- Before practicing the prioritized adaptation activities, Cost /Benefit Analyses should be made and budgeted for each adaptation activity.
- With reference to the fact that our country is surrounded on 3 sides by the sea, it should not be forgotten that management of the coastal areas is crucial. 17 out of 25 river basins are coastal basins, and it is suggested for our country to make Strategic Planning regarding Integrated Coastal Zone Management and to accelerate these studies.
- In the Data Processing infrastructure of T.R. Ministry of Forestry and Water Affairs, the hardware to be used according to the requirements of the projects can only be configured to be used by that project team in the beginning of the project.
- In terms of the sustainability of this project and similar projects, using a cloud server which is physically located outside the Ministry and which can easily be reached by both the company executing the project and the Ministry personnel can be put into practice. At specific time intervals, the database on the cloud and the replications of the practices can be carried over to the servers of the Ministry by the Ministry personnel and the development and execution steps of the project can be performed more efficiently and rapidly.

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