Planning of Drought Management by Integrating Science and Policy

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ABSTRACT

Drought is a vital phenomenon, particularly in closed basins where water resources are scarce to meet the demands. In Turkey, Konya and Akarçay Basins are among the closed basins which are susceptible to droughts at the highest level. In this study, drought, climate change, hydrological analyses and sectoral studies were performed to prepare drought management plans. The studies show that these basins will possibly experience more severe droughts in the future. By considering the results of these scientific studies together with the institutional capacities, the necessary policies to mitigate droughts for these basins were determined.

1. INTRODUCTION

Droughts occur as a result of natural (climatological) processes and it can affect specific areas for specific time intervals. Although, drought is a natural disaster, such as floods and earthquakes, it has a much longer onset and effecting period. The duration of a significant drought event can be expressed in terms of years. Drought emerges slowly but the consequences it causes can be serious and costly. In order to mitigate the impacts of droughts, drought vulnerability of the affected region must be very well assessed.

Turkey has been quite often exposed to the effects of this natural disaster. Although, spatio-temporal analyses are not sufficient for earlier droughts, it has been known that the serious droughts occurred in 1804, 1876 and 1928 caused loss of agricultural products and livestock as well as the migration of desperate farmers. It is estimated that the drought event occurred in 1876 caused loss of 200.000 lives by causing famines and diseases. In the republic era, in 1928, 1973, 1989, 1990, 1993, 1998-2001, 2008 and 2013, serious droughts were also observed (Yağcı, 2007; SYGM, 2015b).

Especially for the Mediterranean countries, adverse effects of the global climate change are observed and drought is becoming a serious problem. Mediterranean countries such as Turkey are expected to observe temperature increases and precipitation deficiencies in near future which may increase severity and frequency of drought events (IPCC, 2014).

Having limited amount of water resources and vast agricultural land as well as being a closed basin make Konya Basin and Akarçay Basin where the most vulnerable area of Turkey against droughts. Drought Management Plans for these basins have been prepared to mitigate the negative impacts of possible droughts and keep water scarcity at the minimum level by determining measures to be taken before, during and after the drought periods (SYGM, 2015a, SYGM, 2015b).

Drought risk assessment, climate change analyses, determination of water budget, sectorial vulnerability assessment are vital to prepare a comprehensive drought management plan. All these steps are the essential tools to determine the necessary measures at all stages of droughts and to prepare a drought management plan.

The purpose of this study is to discuss the essentials of a drought management plan by addressing the experiences obtained from the preparation processes of Konya Basin Drought Management Plan and Akarçay Basin Drought Management Plan.

1.1. Drought and Drought Management

"Drought" means the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems. (UNCCD, 1994).

An efficient drought mitigation can only be possible with an effective drought management which can be operated efficiently by a drought management plan. Drought management plans must include actions to be taken at pre-drought, during drought and post drought phases as well as the responsible actors who are responsible from taking these actions.

Drought management plans are the important elements of integrated water management of any water basin. In order to determine measures at all phases of a drought, meteorological, hydrological and agricultural drought characteristics, vulnerability of ground and surface waters against droughts, drought effects on different parties and water users, possible effects of global climate change on future droughts have to be considered while determining the measures in the drought management plan.

There are 25 main hydrologic basins in Turkey. Konya and Akarçay Basins are the driest ones (Figure 1.1) which makes them the most vulnerable against droughts. For this reason, the first drought management plans were prepared for these basins.

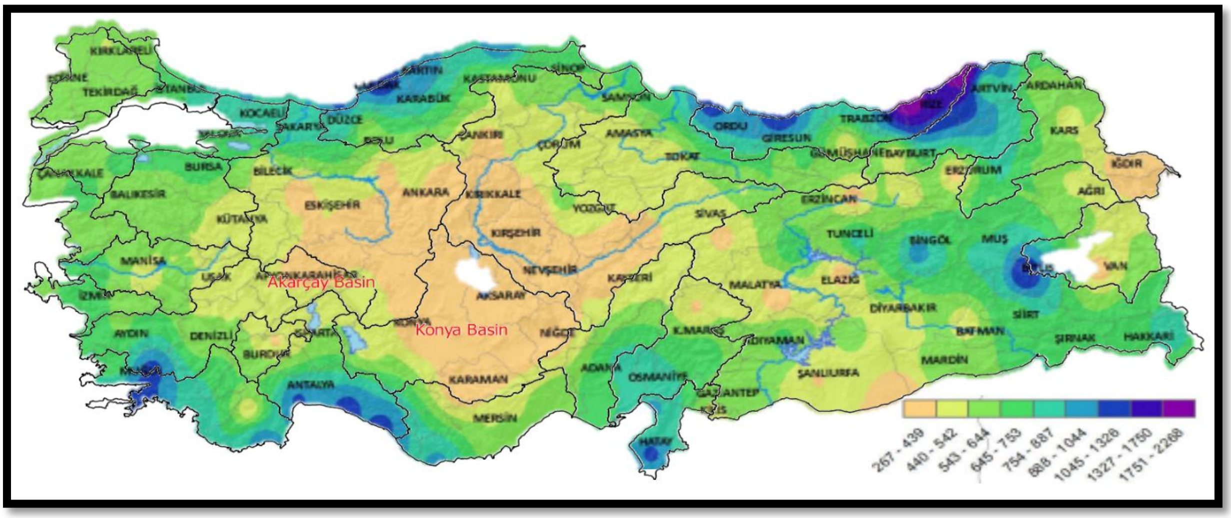

Figure 1.1 Mean Annual Precipitation (mm)

1.2. Konya Basin

Konya Basin is a closed basin, which is surrounded by Sakarya and Kızılırmak River Basins in the north, Kızılırmak and Seyhan River Basins in the east, Eastern Mediterranean Basin in the south and Antalya and Akarçay River Basins in the west. The basin is the fourth biggest basin among 25 basins in Turkey, and has a surface area of 50.073 km². Most of the basin is covered with large plains having an altitude ranging between 900-1050 meters that constitutes the Central Anatolian Plateau. Since the basin is surrounded by high mountains, the basin does not have any other inputs than precipitation. The precipitation amount is more in the south and southwest of the basin in comparison with its north and east. The annual average precipitation height of the basin is 384 mm. approximately 15% of the annual average precipitation creates surface runoff and constitutes the surface water resources of the basin. Konya Basin covers some of the areas of Aksaray, Ankara, Antalya, Isparta, Karaman, Konya, Mersin, Nevşehir and Niğde cities (Figure 1.2).

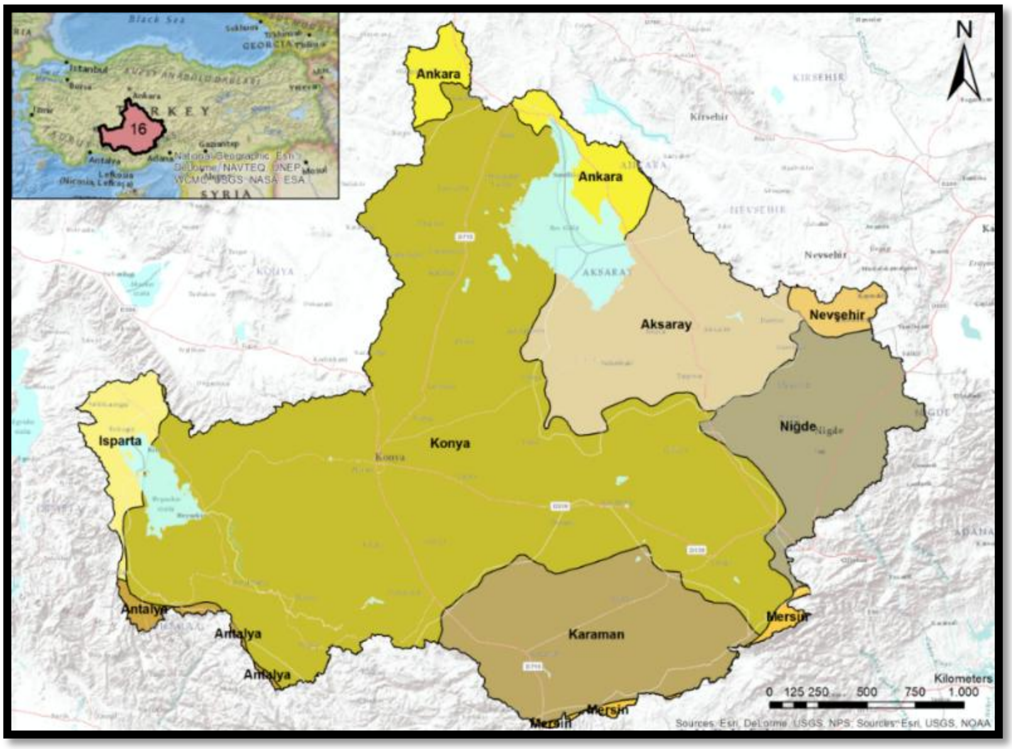

Figure 1.2 Konya Basin

1.3. Akarçay Basin

Akarçay Basin is also a closed basin which has similar characteristics with Konya Basin. It is one of the smallest basins of Turkey with the surface area of 7994 km^2. The basin is surrounded by middle height mountains and the rest of the basin is composed of expanded plains which are merged with narrow throats. The annual average precipitation height of the basin is 436 mm. Akarçay Basin covers some of the areas of Afyonkarahisar and Konya cities (Figure 1.3).

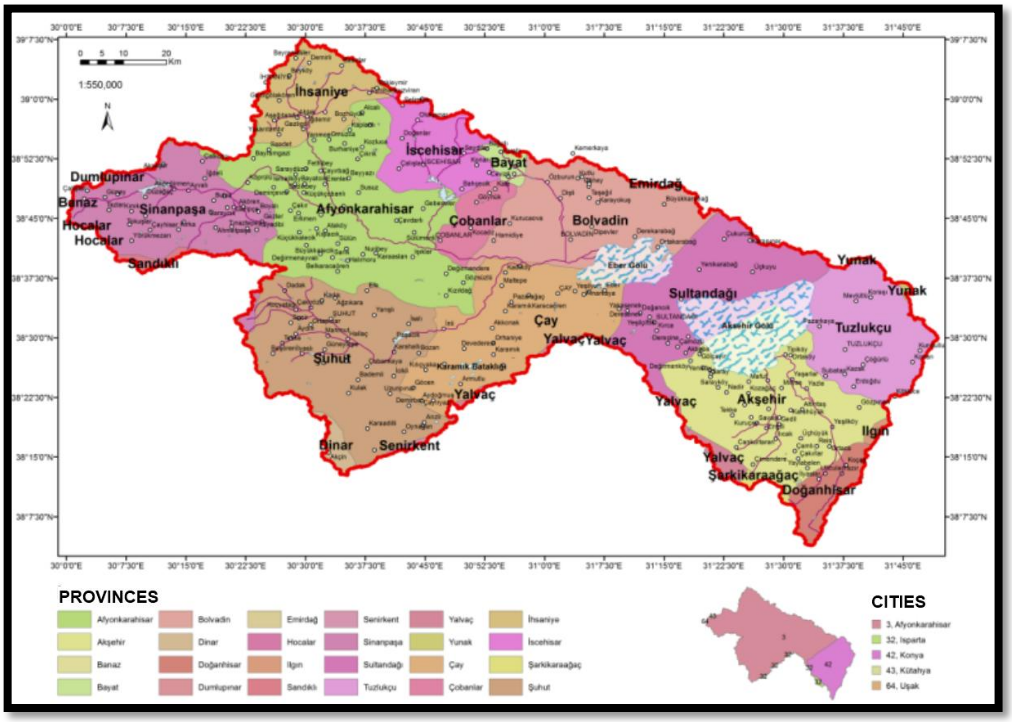

Figure 1.3 Akarçay Basin

2. METHODOLOGY

2.1. Climate Modelling

In order to estimate local effects of global climate change, downscaling approaches were developed which downscales the global estimates of climate into local scale (Wilby et al., 2002; Tripathi et al., 2006; Okkan & Inan, 2014). There are two main downscaling methods in the literature namely dynamic and statistical downscaling (Wilby et al, 2002).

In this study, both of these methods were utilized together. For dynamic downscaling method, the most appropriate global circulation models were determined. The outputs of the climate model were statistically downscaled to meteorological observation stations. The differences between the outputs of dynamic and statistical downscaling were eliminated using appropriate methods (such as bias correction) and for further studies, the outputs of dynamic downscaling method was utilized.

The global models –MPI-ESM-MR, HadGEM2-ES and GFDL-ESM2M– used in the project are the general circulation models developed by Max Planck Meteorology Institute (Germany), Met-Office Hadley Centre (England) and NOAA Geophysical Fluid Dynamics Laboratory (USA), respectively. Those global models have been previously evaluated by centers developing Regional Climate Models, particularly by

Abdus Salam International Theoretical Physics Center (ICTP), and are used within the scope of this project since they produce the accurate model results for the Mediterranean region.

2.2. Drought Analyses

Drought has been characterized for its meteorological, hydrological, agricultural, geographic and economic aspects and analyzed under different definitions. This characterization and definitions include the evaluation of many different drought variables and parameters as well as the possible adverse impacts of droughts. Extreme events occurred as a result of deficiency or excessiveness of variables such as precipitation, temperature, moisture, evaporation, transpiration and wind speed are taken into account in drought analyses (Türkeş, 1990).

Meteorological drought means the decrease in rainfall compared to long term averages for a certain duration. In order to determine meteorological droughts, different statistical methods and threshold values are used for different areas. For example, for a certain location, if the total of 21 days precipitation is below 1/3 of normal levels or there is no rainfall for 15 days, the situation can be evaluated as meteorological drought. (Türkeş, 1990).

Hydrological drought is deficit of water in hydrological respect where decreases in surface and ground waters are taken as the basis of drought. Hydrological drought and its severity can be measured by water level measurements of water environments (such as rivers, lakes, reservoirs, groundwater, etc.). Because of the linear time dependent relation between precipitation deficiency and water deficit in lakes and reservoirs, hydrological drought is not one of first indicators of drought. Even after the end of meteorological droughts, hydrological drought may affect the region for a long period with certain lag times, depending on the physiographical conditions and soil characteristics of the region. (Türkeş, 1990)

Agricultural drought means the inadequacy of soil water in the root zone which hinders plant growth. Especially at the growth period where the plant is highly vulnerable to water deficiency, if the soil moisture is not adequate, agricultural drought occurs (Wilhite & Glantz, 1985). Agricultural drought may occur just after meteorological droughts at rainfed agricultural areas, it may also occur as a result of hydrological drought at irrigated areas.

As drought severity, duration and vulnerability of communities increase, and if a drought risk management plan is either not available or not working properly, socio-economical drought may occur as a result of the consequences of meteorological, hydrological and agricultural droughts. (Wilhite & Glantz, 1985)

In order to determine and classify the complicated process of droughts by means of their severity, duration and geographical distribution, several climatological, meteorological or hydrological drought indices appears in literature. Drought indices can identify the drought occurrence, evolution and severity in a very explicit manner. Each one of them has its own characteristics and in general similar indices produce similar results. Eight of the most common drought indices were utilized in this study (Table 2.1).

Table 2.1. Drought Indices Used in Drought Analyses and Their Field of Study

Index / Drought Type	Meteorological	Agricultural	Hydrological	Climatological	Agro-hydrological
Percentage of Normal Precipitation (PNI)	*	*			
Standardized Precipitation Index (SPI)	*		*		
Palmer Drought Severity Index (PDSI)	*	*			
Palmer Hydrologic Drought Index (PDHI)			*		
Palmer Moisture Anomaly Index (ZNDX)					*
Aydeniz Index				*	
Erinç Drought Index (Im)		*		*	
Aridity Index (AI)	*	*		*	

2.3. Modelling of Water Budget

Drought related changes in precipitation and temperatures hydrologically triggers the changes in streamflow. Therefore, significant changes in water potential is an expected result of droughts. Changing of water potential during droughts effect many water users and sectors including municipal water, agriculture and energy. Reservoirs which were planned and constructed in accordance with observed streamflow situations may not be operated efficiently under the conditions influenced by the climate change. Therefore, it is vital to estimate drought related changes and explain the uncertainty in the water budget. Otherwise, characteristics and dimensions of additional measures (such as new storages, interbasin water transfers, etc.) taken against the thread may not be appropriate enough. These inappropriateness, as a result, may cause waste of both natural and financial resources.

In this project, a regional analysis is performed by using three different global climate model outputs and dynamical and statistical downscale methods. The impacts of the changes in the hydro-meteorological parameters on streamflow are analyzed using parametric rainfall-runoff models. The water budgets of the basins are determined by using internationally recognized parametric water budget models (HEC-HMS and Thronthwaite Monthly Water Balance Model). The models are operated with hydro-meteorological data created in monthly time-scale with annual periods for the years between 2015 and 2020 and with 5-year periods for the years between 2020 and 2050 and thusly future streamflow values are estimated.

The results obtained at this stage and the current situation of surface and subsurface water resources are used in projecting water potential for future and calculating the water budget.

3. RESULTS

All of the studies mentioned in Chapter 2 were conducted for both Konya and Akarçay Basins to serve Konya and Akarçay Basins Drought Management Plans respectively. However, for this chapter, only the results obtained in Konya Basin study were presented in order to explain the nature of the work briefly and explicitly without increasing the size of the text.

3.1. Potential Effects of Climate Change

In order to assess the potential effects of global climate change, climate modelling and projection has been made. The projections up to 2050 were considered for three different global circulation models and two different scenarios. The results suggest that the total precipitation has a decreasing trend between 6 to 15 percent and the average temperature has an increasing trend between 1 to 2.5 °C.

3.1.1. Changes in Average Surface Temperature

The estimated surface temperature changes until 2050 in accordance with GFDL-ESM2M global circulation model and RCP 4.5 scenario for Konya Basin are shown with respect to months in Figure 3.1. The results suggest that, especially for summer session, temperatures will increase around 1.5 to 2 °C.

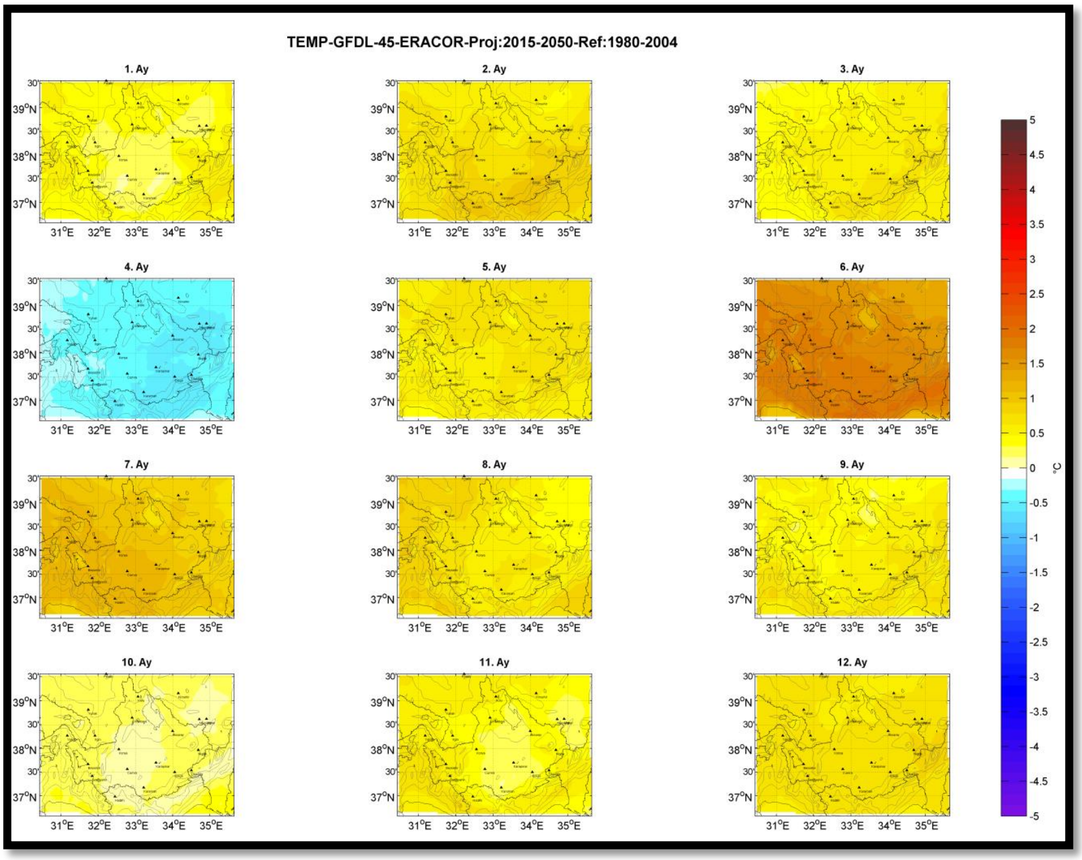

Figure 3.1 Expected Changes in Average Surface Temperature in Konya Basin in accordance with GFDL-ESM2M global circulation model and RCP 4.5 scenario

3.1.2. Changes in Precipitation

Expected changes in the precipitation in accordance with three global circulation models and two different scenarios are shown in Figure 3.2.

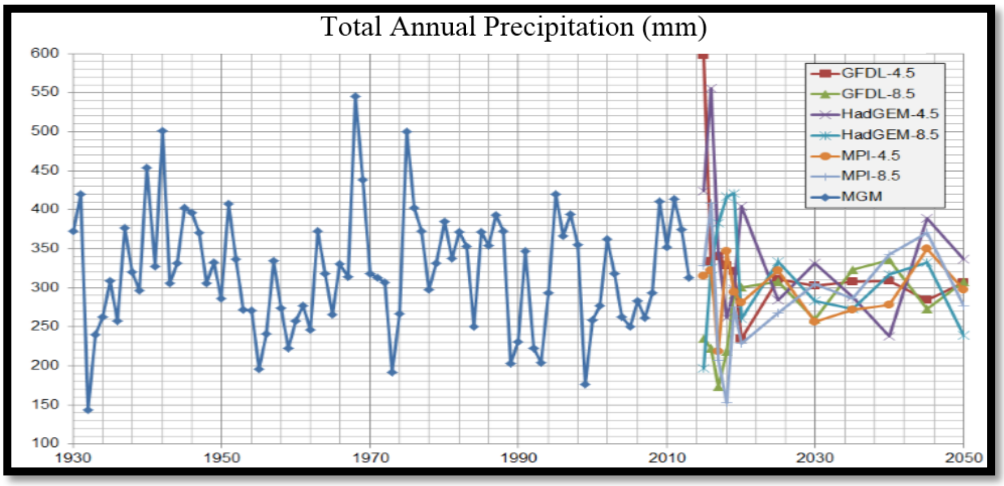

Figure 3.2 Expected changes in the precipitation in Konya Basin

The estimated winter precipitation changes until 2050 in accordance with HAD-GEM global circulation model and RCP 4.5 scenario are shown with respect to months in Figure 3.3. The main actor of the water budget of the Konya Basin is the winter precipitation which seems to have a decreasing trend according to the future projections.

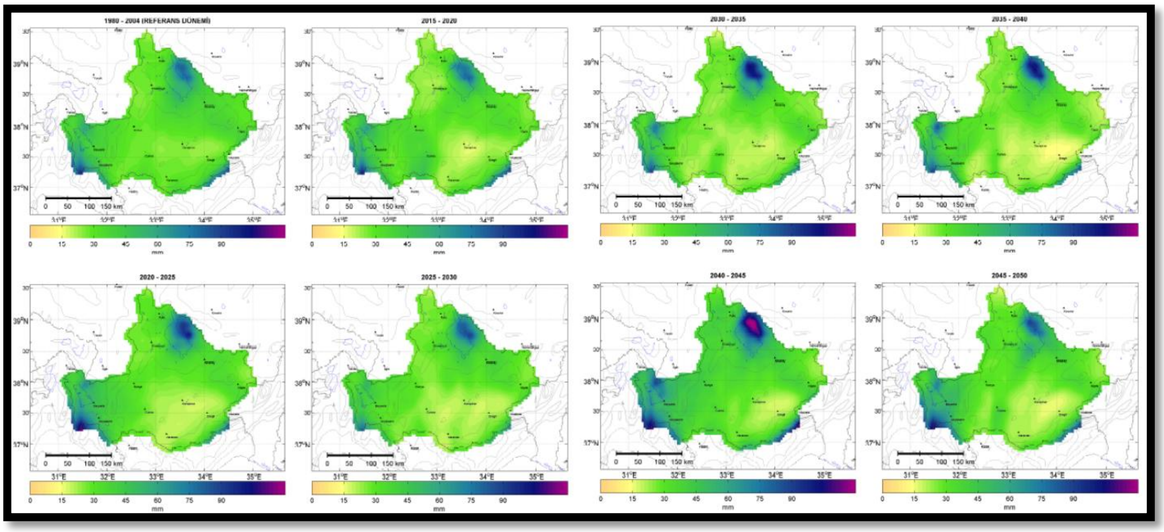

Figure 3.3 Expected Winter Precipitation Changes in Konya Basin in accordance with GFDL-ESM2M global circulation model and RCP 4.5 scenario

3.2. Drought Analyses

Past drought events of Konya Basin were determined as it was mentioned in Section 2.2 by using 19 meteorological observation stations' long term data by using several drought indices. The results of all indices were used to determine common drought periods of the basin. The results indicate that 1972-1974, 1984-1985, 2000-2001, 2004-2005, 2004-2008 and 2013 are the common drought periods of Konya Basin. Spatial distribution of drought periods which were determined using PDSI are shown in Figure 3.4.

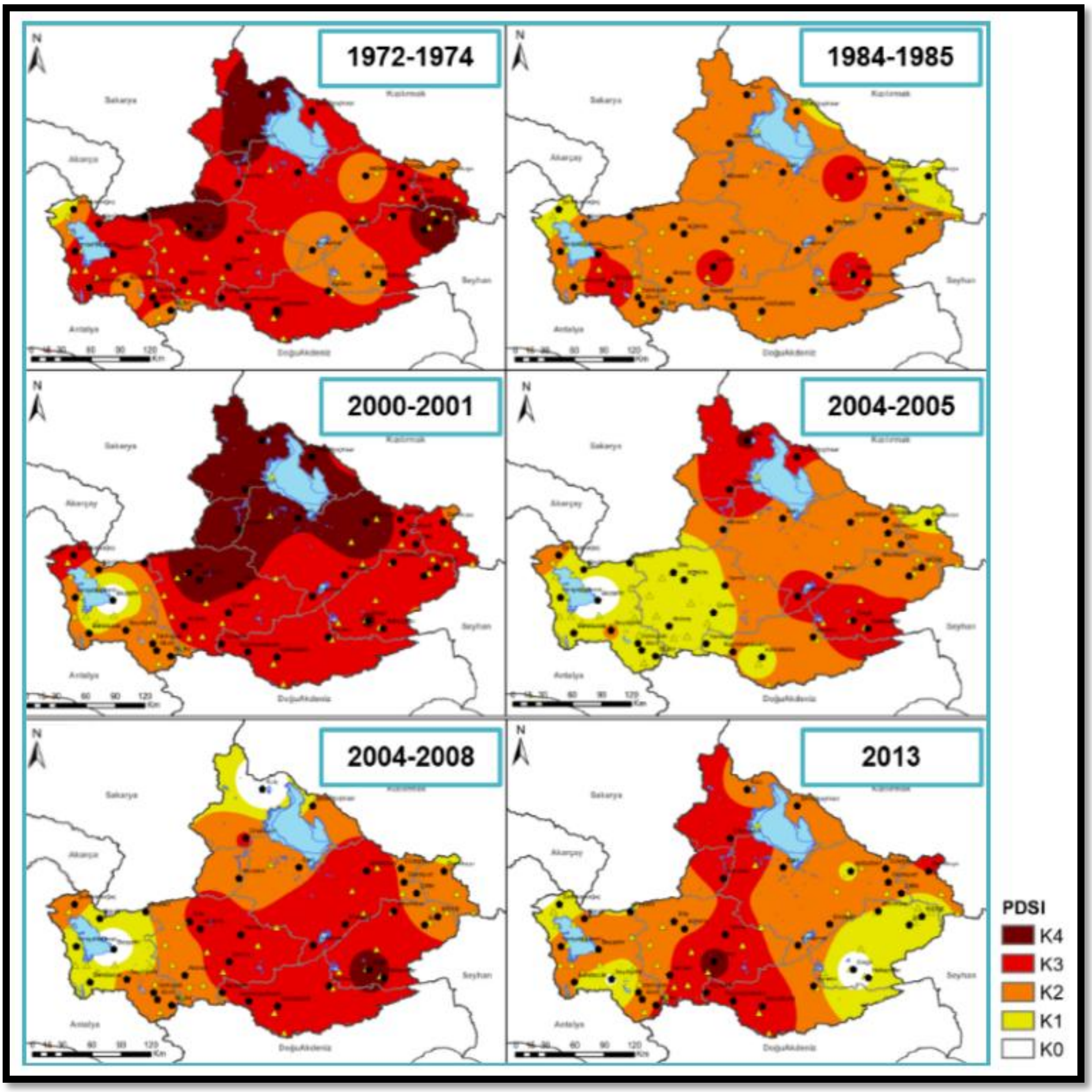

Figure 3.4 Common Drought Periods of Konya Basin (PDSI)

The results obtained from climate modelling study (Section 2.1) were used in calculating drought indices (Section 2.2) and potential future droughts were estimated. The results suggest that probability of occurrence of extreme droughts may increase around 12% to 46% until the year 2050.

3.3. Determination of Changes in the Water Budget

Groundwater and surface water potentials of the basin were calculated using annual precipitation data recorded at 1974-2013 period. The utilizable water potential of Konya Basin is assessed as 4.679 hm³/year. 57.2% (2.676 hm³/year) of the potential is surface water resources and 42,8% (2.003 hm³/year) of the potential is groundwater resources. The water balance diagram of the basin is shown in Figure 3.5.

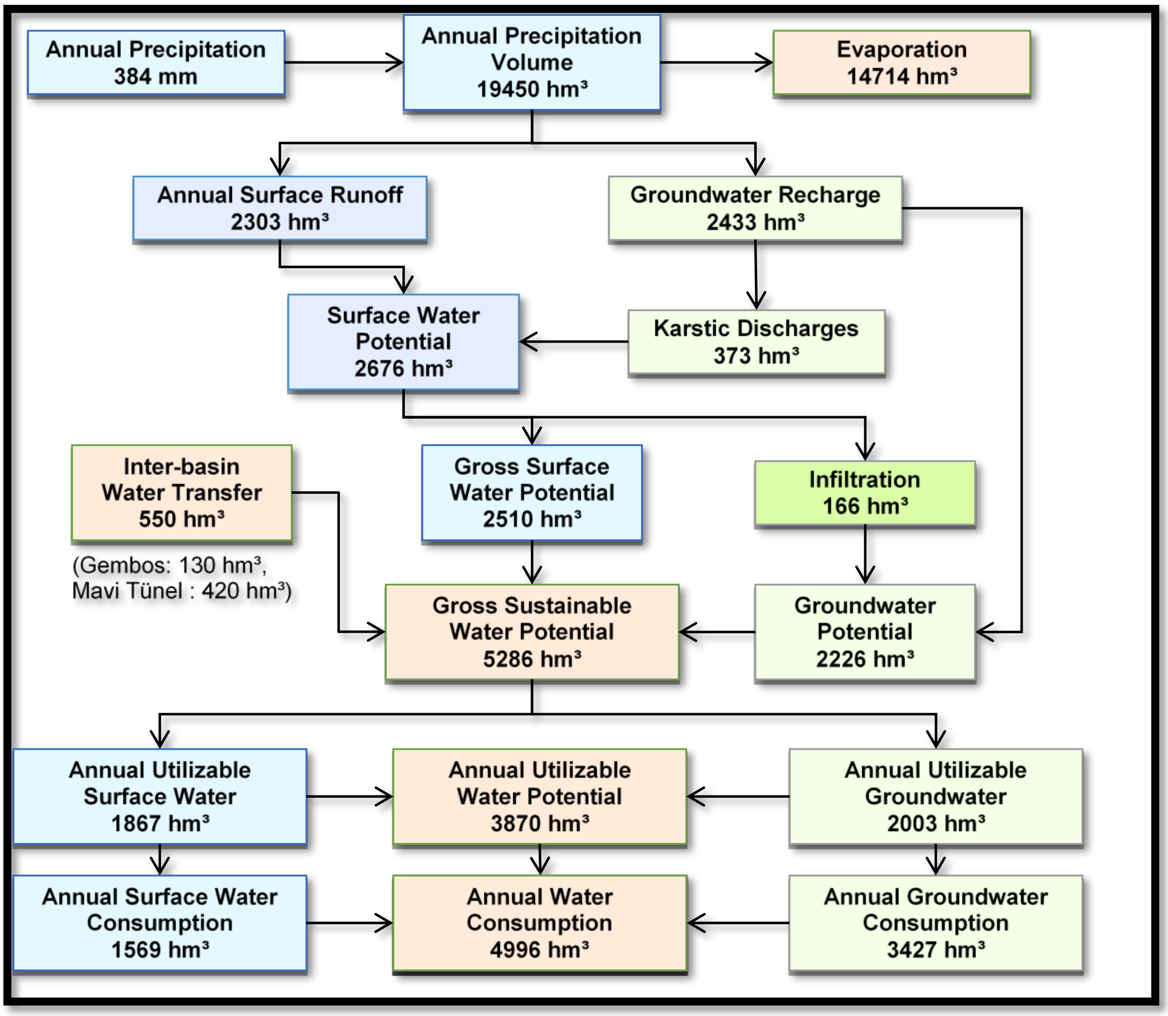

Figure 3.5 Konya Basin Water Balance Diagram

Before starting the hydrological studies, climatologic outputs of HadGEM2-ES model (Section 2.1) with RCP 4.5 and RCP 8.5 scenarios were corrected with the ground data of the meteorological observation network and Era-Interim data. Potential changes in the water potential of Konya Basin as a result of the expected changes, obtained as the output of the climate model HadGEM2-ES (Section 2.1), are presented in Figure 3.6 and Figure 3.7. The figures are depicted as box-and-whisker plots to summarize large number of qualitative data. In those figures, the upper and lower lines show the maximum and minimum values, respectively, the lower box shows the median and the first quarter, and the upper box shows the median and third quarter, while the black points show the mean and the dashed line shows the interannual variations of mean values. Significant decreasing trends were observed for both surface water (Figure 3.6) and groundwater potentials (Figure 3.7) for the years 2035 and 2040.

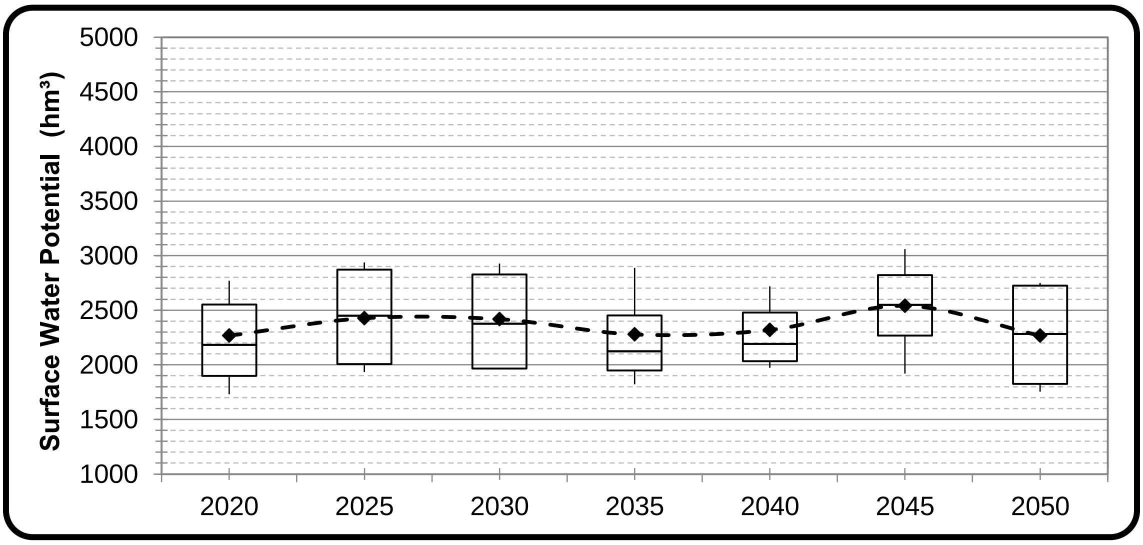

Figure 3.6 Expected Changes in Surface Water Potential of Konya Basin (2020-2050)

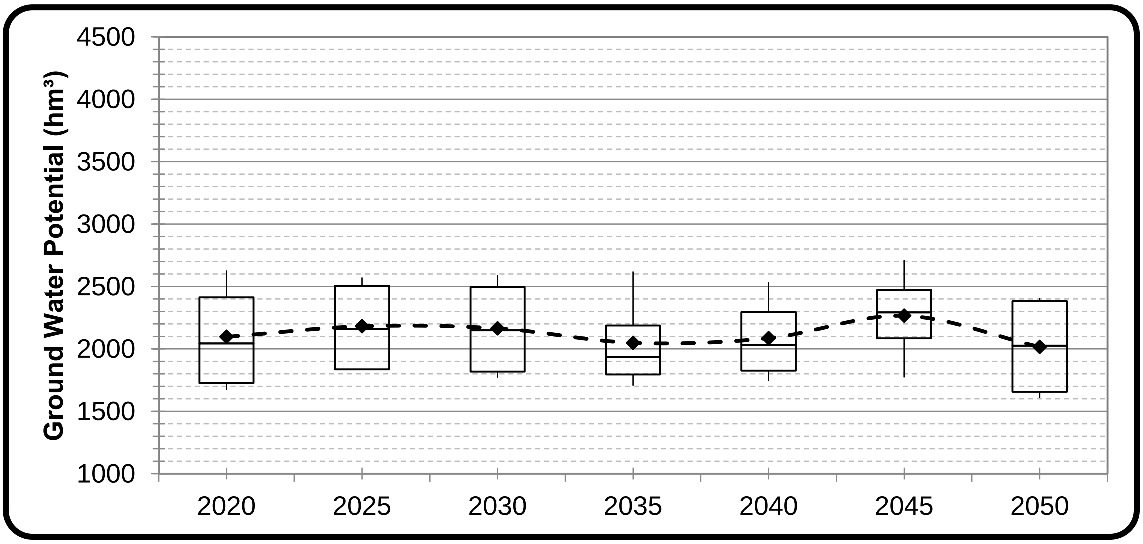

Figure 3.7 Expected Changes in Groundwater Potential of Konya Basin (2020-2050)

3.4. Drought Vulnerability Analyses

Vulnerability (sensitivity, susceptibility) assessment is an innovative analysis method, which has been developed to create a bridge for the determination of measures using the results of the impact assessment by focusing the attention of the decision makers on the reasons creating the vulnerability instead of the analysis of negative impacts that may occur as the result of a triggering event such as drought (natural disaster).

The basic components of vulnerability assessment are: the thread created by drought on the inspected region, the sensitivity of the region to drought, potential impacts based on experiences, and the adaptation capacity of the region to the drought conditions.

For four main sectors in Konya Basin (Agriculture, municipal water, industry and ecosystem) sectoral vulnerability assessments were conducted.

Required water is supplied from surface or groundwater resources. Almost all of the surface water resources and substantial amount of the groundwater resources are consumed in agriculture and the remaining is used to meet potable and industrial water demand. It is determined that 4.749 hm^3 water is used for irrigation, 180 hm^3 water is used as potable water and 67 hm^3 water is used as industrial water, corresponding to a total of 4.996 hm^3 water use in the basin. In accordance with this data, 95% of the water provided to the consumers in the basin is used in irrigation. The amount of water used as potable water and industrial water are 4% and 1%, respectively.

It is estimated that 4.356 hm^3 water will be used for irrigation, 400 hm^3 water will be used as potable water and 142 hm^3 water will be used as industrial water, corresponding to a total of 4.898 hm^3 in the basin in 2050. In accordance with this estimation, it is predicted that 89% of the water provided to the consumer in the future will be used for irrigation, 8% for potable water and 3% for industrial water.

The main reasons of the decrease in groundwater table in the last two decades are inability to supply agricultural demand from surface water resources and agricultural practices have not been performed compatible with the water budget of the basin.

Precipitation is not sufficient to recharge groundwater resources and the decrease in groundwater table. Water restrictions would be obvious in the future considering further impacts of climate change in the region, unless an effective basin management plan implemented for the basin.

Water budget deficiencies and decreases in groundwater table are forecasted for the 2015-2050 period considering trends in population growth, changes in water demand of water-consuming sectors and changes in water potential (surface- and ground-water) according to global climate models.

The vulnerability of the irrigated-agriculture lands, which is a sub-sector of agricultural sector, is assessed in the light of expected deficiencies in the water budget and decreases in groundwater table. Mean annual decrease of water table is 0.99m in Konya Basin (Table 3.1)

Table 3.1. Decreases in Ground Water Levels in Sub-Basins of Konya Basin

Sub-Basin	Sub Basin No	Well No	Name of the Well	# of years measured	Decrease Total (m)	Decrease Average (m/year)
Beyşehir (16/1)	16/1-a	52770	Doğanbey	3	5.20	1.73
	16/1-b	49340	Taşağıl	3	1.79	0.60
Konya-Çumra-Karaman (16/2)	16/2-a	8185	Hatip	34	39.00	1.15
	16/2-c	181	Fethiye	19	16.50	0.87
	16/2-c	52267	Arıkören	19	22.00	1.58
	16/2-c	9431	A.Hüyüğü	28	14.10	0.50
	16/2-d	52268	Eğilmez	31	37.40	1.21
	16/2-d	52258	Gülfet Yayla	39	31.60	0.81
Karaman-Ayrancı-Akçaşehir (16/3)	16/3-a	30642	Erentepe	15	13.00	0.87
	16/3-a	28719	Güneysınır	15	23.30	1.55
	16/3-b	20122	Sudurağı	16	39.00	2.44
	16/3-c	30270	Höyükburun	12	17.00	1.42
	16/3-c	13314	Akçaşehir	29	31.00	1.07
Ereğli-Bor (16/4)	16/4-b	52259	Yeniköy	13	14.00	1.08
	16/4-b	9749/A	Y. Zengen	13	2.00	0.15
Sultanhanı (16/5)	16/5-b	52266	Eşmekaya	16	17.20	1.07
Altınekin	16/6	221	Tutup	40	22.20	0.56
	16/6	46392	Meydan	13	17.55	1.35
Cihanbeyli-Yeniceoba-Kulu (16/7)	16/7-a	53704	Sığırcık	8	4.55	0.57
	16/7-a	53706	K. Kartal	8	2.00	0.25
	16/7-c	53707	Kulu	5	5.00	1.00
			Average	18	16.79	0.99

The potable water sector constitutes less than 5% of the total water need of Konya Basin, however it is vital for human life. The potable – use water sector is used for meeting the needs of public and households, commercial, public institutions, schools, hospitals, charity institutions and some small – medium scaled industrial facilities.

95% of the water use in the basin is currently being used by the agriculture sector. It is calculated that this value will decrease and become 85% in the future. Since the water resources are limited, the vulnerability of potable and use water sector to drought conditions is directly proportional with the water need of the agriculture sector.

3.5. Drought Management Plan

In order to prepare a drought management plan, all of the above mentioned scientific studies and the results obtained have to be put together by considering the following steps.

First of all, all of the stakeholders (especially the water users) must be involved in the process from beginning to the end. Their needs have to be identified and should be addressed in the plan to make the drought management plan usable and successful. For this purpose, at each stage of the preparation process of the plan, stakeholder meetings must be conducted and different water users must be visited in the field. (Figure 3.8)

Figure 3.8 Stakeholder Meetings and Field Studies (Konya Basin)

Since a drought management plan brings together a large number of data, it is necessary to create a database that will allow these data to be stored, compiled, and shared with stakeholders when necessary. Drought database of Konya Basin is shown in Figure 3.9.

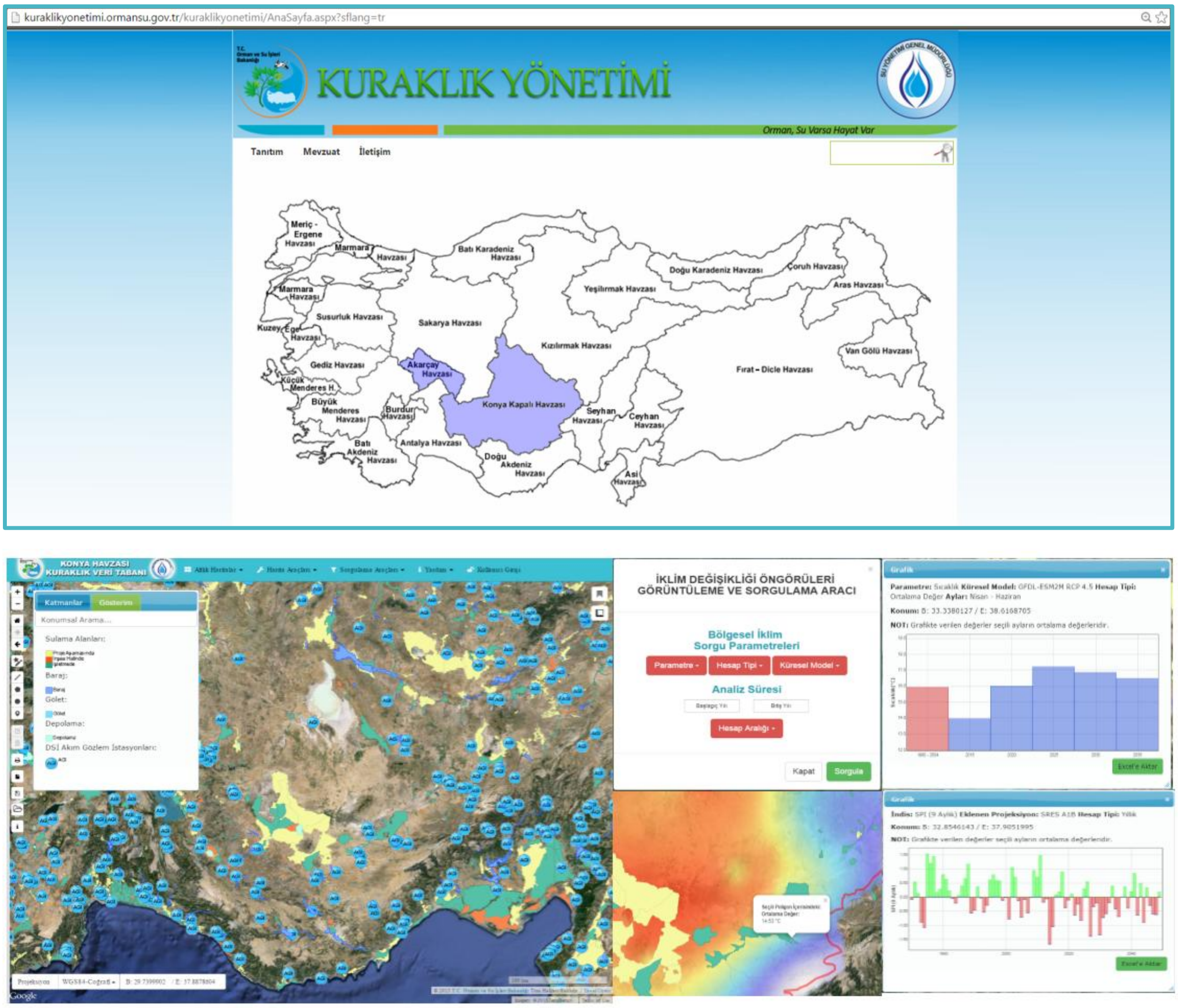

Figure 3.9 Drought Database

Numerous scientific studies that can be a base for a drought management plan need to be carried out. Past droughts must be analyzed to determine the drought characteristics of the basin and possible changes in the future climate of the study area must also be considered to have an idea about future drought conditions. Determination of potential changes in the water budget would certainly help identifying priorities and vulnerabilities of different sectors.

Making use of all of the scientific information obtained, necessary measures to mitigate droughts must be defined by stating at which state of drought the measure will be taken, who will take the measure and how the measure will be taken.

Examples of drought measures defined in this manner in Konya Basin Drought Management Plan are shown in Figure 3.10. The measures are grouped under eight main goals of drought mitigation:

1. Improve Water Availability, Monitoring and Drought Impact Assessment
2. Increase Public Awareness and Education
3. Enhance Mechanisms to Provide Water Supplies to Sub-basins That Are Under Risk of Water Shortage During Droughts

4. Coordinate and Provide Technical Assistance for Planning Efforts for Development of Water and Soil Resources by Local Administrations, General and Regional Directorates of Ministries
5. Reduce Water Demand, Encourage Water Use Efficiency and Conservation of Water Resources and Water Quality
6. Reduce Drought Impacts on Konya Basin's Economy, People and Ecosystem
7. Develop Interagency Stakeholder Coordination
8. Evaluate Potential Impacts from Climate Change

No	Priority	Recommended Measure	Primary and Related Goal	Level of Measure	Lead Agency	Partner Agencies	Period	Actions to be performed
1-16	H	Providing information about monthly drought condition in the basin	1,6	D0 → D4	SYGM	MGM, DSİ, GTHB, HYH	Continuous	Providing continuous information about drought conditions in the basin on a monthly basis by SYGM authorities over the drought web page and web-based geographical database of the basin.
1-17	H	Performance of questionnaire and inventory works for the determination and assessment of sector-based impacts of droughts	1,3,6	D0 (6-months); D1, D2 (3-months); D3, D4 (1-months)	HYH	SYGM, GTHB, AFAD, KOP, DSI, BST, GTB, OSB, BLD, Sul. Bir. & Koop.	Continuous	Periodical measurement, assessment and inventory preparation of drought impacts by every institution in their area of duty and reporting them to HYH.
1-18	H	Training of technical personnel, who will carry out the drought monitoring and impact assessment activities	1,2	Before drought	SYGM	DSİ, MGM, GTHB, AFAD	Continuous	Arrangement of common and regular trainings within the scope of a training program to be prepared by institutions for the technical personnel, who will carry out the drought monitoring activities in Konya Basin.
Goal 2: Increase Public Awareness and Education								
2-1	H	Provision of information, training, technical aid and infrastructure support for the water users about the efficient use of water and ensuring water saving	2,5,6	D1, D2 → Raising Awareness; D3, D4 → Public Alerts	HYH	GTHB, MGM, SYGM, DSİ, KOP, STK, MEB, BLD	Continuous	Encouraging sector-based water users to quit excessive water consumption, imposing correct water use habits; performing studies on the provision of information and training, technical aid and infrastructure support by ensuring the just sharing of water among all sectors.
2-2	H	Carrying out applied agricultural training (farmer demonstration) project in pilot regions in the basin	2,5,6	Before drought	KOP	GTHB, DSİ, Sul. Bir. & Koop. Ür.Bir. Zir. Od., San. & Tic. Od. Tic. Borsa	2016-2021	Informing farmers by performing modern irrigation methods, good agricultural applications, and limited irrigation demonstrations in pilot regions in the basin in order to ensure effective use of water and soil. Project should take a minimum period of 5 years or more.
2-3	H	Informing the public on the progress of drought conditions in the basin and announcement of measures that can be individually taken	2,5,6	D1, D2 → Rasing awareness; D3, D4 → Public Alerts	HYH	GTHB, MEB, MGM, SYGM, DSİ, KOP, BLD	Continuous	Informing the public on the progress of drought conditions in the basin through local or national radios, televisions, press, meetings held at district level and trainings to be given at the schools; announcement of measures that can be individually taken; performance of information, awareness increasing and warning studies with increasing frequencies for increasing awareness in case of low and medium intensity droughts and for warning the public in case of extreme and exceptional droughts
2-4	H	Performing "Water Management Under Drought Conditions" workshops	2,5,6	Before drought	HYH	BLD, STK, DSİ, GTHB, MGM, SYGM, KOP, ÜNİ, Ar.Ens.	Continuous	Imposing the correct water use habits to the public by holding small meetings at quarter and village level; assessment of saving in water consumption in the province-district by holding medium-scale meetings at province and district level; determination of the program and contents of the additional training studies to be performed at small scale; holding large-scale workshops at basin level and assessment of the success of the program carried out in the provinces – districts and in saving that is ensured in water used.

Figure 3.10 Example of Measures Defined in Konya Basin Drought Management Plan

A drought model management system must also be established in order to be able to take specified measures and monitor the implementation and ensure efficient and well-coordinated management of droughts. Once the stakeholders' views on the prepared drought management plan have been received, the plan should be published and implemented. Finally, at regular periods and particularly after drought events the plan should be revised in order to provide more efficient drought management.

4. DISCUSSION and CONCLUSION

Konya Basin and Akarçay Basin are the driest hence the most vulnerable areas of Turkey against droughts. The water potentials of these basins fail to meet the water consumption, so water transfer projects have already been carried out. Such projects are also aimed at reducing the pressure on groundwater. In these basins, tremendous amount of agricultural activities are being conducted. For example in Konya Basin 95% of the water provided to the consumers in the basin is used in agricultural irrigation. Annual utilizable water potential of this basin was calculated as 3870 hm^3 where the annual consumption is 4996 hm^3. Thus, groundwater table of this basin is decreasing around one meter per year.

In drought periods, due to lack of sufficient water resources, further difficulties and faster decreasing of the groundwater table is expected to be experienced. In order to mitigate the risk of potential droughts, Drought Management Plans for these basins were prepared.

In this study, necessary measures are identified for pre-drought, post-drought and during drought stages to provide an efficient drought mitigation considering prospective drought risks. Implementation of these measures which were defined by considering water budgets of the basins and drought vulnerabilities will increase drought resistance and decrease drought related losses.

A series of scientific studies were conducted in order to define the measures which includes evaluation of drought characteristics and water potential. Climate studies were conducted to estimate future climatological conditions of the basin which may occur as a result of global climate change. Climate studies were conducted using different global circulation models and different scenarios. Drought analyses were made by using both the current conditions and the estimated future conditions of the climate. Sectorial vulnerability assessment was made by evaluating water budget of these basins by using current and the potential future water demand of different type of water users and sectors.

All of these works are essential to estimate the damage of future droughts on different parties which is also essential to establish a proper drought management mechanism and define proper measures against prospective drought risks. Measures are defined by considering the capacities of the related institutions and for each measure responsible institutions were clearly indicated.

However, all of the measures defined in this study are based on current data and some projections which may not include potential unanticipated changes. In order to include unanticipated changes in climatology and socio-economy, drought management plans have to be revised on certain periods especially after drought events.

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