SEPTEMBER 2021 M.Sc. in Civil Engineering SEDA EROĞLU

REPUBLIC OF TURKEY

GAZİANTEP UNIVERSITY

GRADUATE SCHOOL OF NATURAL & APPLIED SCIENCES

INVESTIGATING THE CLIMATE CHANGE IN TURKEY BY TREND ANALYSIS TECHNIQUES

M. Sc. THESIS
IN
CIVIL ENGINEERING

BY

SEDA EROĞLU

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M.Sc. Thesis

in

Civil Engineering

Gaziantep University

Supervisor

Asst. Prof. Dr. Ayşe Yeter GÜNAL

by

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September 2021

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Seda EROĞLU

ABSTRACT

INVESTIGATING THE CLIMATE CHANGE IN TURKEY BY TREND ANALYSIS TECHNIQUES

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September 2021
54 pages

Climate change is defined as the change in climate observed over a time period and it is referred directly or indirectly to human activity. It is believed to be the most serious threat to global environment with its potential impacts such as global warming, sea level rise and increased extreme weather events. The reasons of climate change can be mainly divided into two main components which are greenhouse gases and human factors. Increase in the greenhouse gas (GHG) concentrations in the atmosphere is the main cause of the climate change in the world. The other important factor for climate change is humans. Humans are changing the climate of the world by burning of fossil fuels, urbanization, deforestation, agriculture, and industrial processes. In this work, the components of climate change in Turkey were deeply investigated. Firstly, how climate changed over the past 50 years was analyzed in terms of average annual temperature, precipitation, evaporation, moisture, sea water temperatures, soil temperature and number of snowy days in Turkey. Then, these data is analyzed by statistical techniques and their trends are evaluated. Moreover, Van Lake basin is taken as a case study and variations in temperature, precipitation, flow and lake level parameters are investigated. Again, trends of those variables are evaluated. In addition to this, correlations of those parameters are obtained and their effects on each other are explained. It is observed that while temperature is increasing, precipitation, moisture and number of snowy days are decreasing in Turkey. Hence, it can be said that global warming shows its reflections in Turkey as well.

Key Words: Climate Change, Trend Analysis, Temperature, Precipitation, Flow

ÖZET

TÜRKİYE'DE İKLİM DEĞİŞİKLİĞİNİN TREND ANALİZİ TEKNİKLERİYLE İNCELENMESİ

EROĞLU, Seda
Yüksek Lisans Tezi, İnşaat Mühendisliği
Danışman: Dr. Öğr. Üyesi Ayşe Yeter GÜNAL
Eylül 2021
54 sayfa

İklim değişikliği belirli bir zaman içerisinde bir bölgenin ikliminde meydana gelen değişiklikler olarak tanımlanır ve insan aktivitelerinden doğrudan ya da dolaylı olarak etkilenir. Küresel ısınma, deniz seviyesinde yükselme ve olağanüstü hava olaylarında artış gibi etkileri düşünüldüğünde küresel çevreye karşı en büyük tehdit olarak görülmektedir. İklim değişikliğinin iki temel sebebi vardır: Sera gazları ve insan kaynaklı sebepler. Atmosferdeki sera gazlarında meydana gelen artış iklim değişikliğinin en temel sebebi olarak gösterilebilir. Bir diğer önemli faktör ise insanlardır. İnsan kaynaklı iklim değişikliğinin sebepleri arasında endüstrileşmedeki artış, fosil yakıt kullanımı, ormanların yok edilmesi ve şehirleşmedeki artış sayılabilir. Bu çalışmada, Türkiye'deki iklim değişikliğinin etmenleri detaylı olarak incelenmiştir. Bu kapsamda, Türkiye'de son 50 yılın sıcaklık, yağış, nem, buharlaşma, deniz suyu sıcaklığı, toprak sıcaklığı ve karla örtülü gün sayısı verileri incelenmiştir. Buna ek olarak, Van Gölü havzasındaki iklim değişikliği ve hidrolojik faktörler üzerindeki etkileri incelenmiştir. Bu kapsamda, sıcaklık, yağış, akış ve göl seviyesi verileri alınmıştır. Bütün bu veriler, önce kendi içlerinde trend analizi teknikleri kullanılarak incelenip, sonrasında birbirleri arasındaki korelasyonlar araştırılmıştır. Hava sıcaklığı, deniz sıcaklığı ve toprak sıcaklığı geçtiğimiz 50 yılda önemli derecede artış gösterirken; yağış, nem ve karlı gün sayısı belirgin ölçüde azalmaktadır. Dolayısıyla, elde edilen sonuçlardan küresel ısınmanın Türkiye üzerindeki yansımalarını kolaylıkla tespit edebilmekteyiz.

Anahtar Kelimeler: İklim Değişikliği, Trend Analizi, Sıcaklık, Yağış, Akış

''Dedicated to my family''

ACKNOWLEDGEMENTS

I would like to thank my supervisor, Asst. Prof. Dr. Ayşe Yeter Günal for her guidance and support throughout the study. I am thankful for his encouragement and motivation.

I would like to express my love and gratitude to my family for their support, always best wishes.

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LIST OF SYMBOLS

$\boldsymbol{r_s}$	Correlation Coefficient
$\boldsymbol{\alpha}$	Alpha
$\boldsymbol{\tau}$	Tau

LIST OF ABBREVIATIONS

IPCC	Intergovernmental Panel on Climate Change
GHG	Greenhouse Gas
CO_2	Carbon Dioxide
WMO	World Meteorological Organization
TDM	Turkish Directorate of Meteorology

CHAPTER I

INTRODUCTION

1.1 A Brief Introduction to Climate Change

Climate is generally defined as the average state of the atmosphere for a given time scale (hour, day, month, season, year, decade and so forth) and generally for a specified geographical region. The average-state description involves a wide range of variables depending on what is of interest and among them, temperature and precipitation are the most commonly used. It is significant to point out the difference between the weather and climate. Weather involves the description of the atmospheric condition at that specific time. On the other hand, climate is an average of weather conditions over a period of time including the probability for distributions from this average. There are mainly five components of a climate system which are atmosphere, ocean, land surface, ice and snow surfaces and biosphere. Atmosphere can be counted as the basis of all five of them and the other four components directly interact with atmosphere to determine the climate of the atmosphere [1].

Climate change is defined as the change in climate observed over a time period and it is referred directly or indirectly to human activity. It is believed to be the most serious threat to global environment with its potential impacts such as global warming, sea level rise and increased extreme weather events [2]. The Intergovernmental Panel on Climate Change (IPCC), in its Fifth Assessment Report, reveals an increase of average global land and ocean temperature by 0.85 °C from 1880 to 2012. The IPCC is highly confident that the period between 1983 and 2012 was the warmest in the past 800 years [3]. The reasons of climate change can be mainly divided into two main components which are greenhouse gases and human factors. Increase in the greenhouse gas (GHG) concentrations in the atmosphere is the main cause of the climate change in the world. The current atmospheric concentration of carbon dioxide (CO_2), the major GHG, is 411 ppm, higher than any time in the past 800,000 years [4]. The global mean surface temperature is now about 1.0 °C above pre-industrial levels and this situation has consequences for human and natural systems that are detrimental for health and livelihoods. Assuming greenhouse gas emissions remain at the same rate as over the past decade, global warming is projected to reach 1.5 °C between 2030 and 2052 according to IPCC [4]. It should also be noted that the rate of climate change increased in about the 1970s. According to the report of World Meteorological Organization (WMO), average global temperature between 2006 and 2015 is 0.87 °C above a pre-industrial baseline [5]. In the fifth assessment report (AR5), the Intergovernmental Panel on Climate Change (IPCC) stated that human-produced greenhouse gases such as carbon dioxide, methane, and nitrous oxide caused most of the observed increase in Earth's temperatures over the past 50 years [4]. The other important factor for climate change is humans. Humans are changing the climate of the world by burning of fossil fuels, urbanization, deforestation, agriculture, and industrial processes. Since the Industrial Revolution, atmospheric concentrations of greenhouse gases (GHGs) have increased significantly by human-caused factors as stated above.

Climate change can have severe effects on humans and environment. At 1.5 °C warming, temperatures will be much higher than the global average in some regions, with some regional extremes potentially reaching dangerous levels for ecosystems and societies. Climate change related risks set to affect population health greatly. For instance, climate change can influence the quantity and quality of food and water, increases air pollution, changes disease transmission dynamics [6], [7]. Rise of global temperature also affect biodiversity. Extreme temperatures caused by climate change can severely affect fertility in animals, plants and fungi. In addition, population extinct may occur due to fertility losses due to climate change [8]. Other effects of climate change may occur in agriculture, forestry and water resources [3]. A study which is held on the effects of climate change in Malaysia suggest that grain production is adversely affected by extreme temperatures and unexpected rainfall patterns [3].

Effects of climate change on water resources are among the most commonly discussed phenomena in the last decade [9], [10]. Climate alterations cause widespread impacts on hydrological systems, changing precipitation and extreme weather events characteristics [11], [12], [13], reduce ice masses in cold regions [14], affect evapotranspiration processes due to wind speed changes [15], influence humidity and radiative components [16] in the atmosphere. In short, water resources are affected by climate change in terms of both quality and quantity.

1.2 Literature Review

Detecting trends in hydrological and climate parameters have attracted a considerable interest among researchers during last decades. Trend detection plays a vital role in revealing how climate changed during a certain timeline and predicting the direction of climate change for future planning. It has become more popular with the recent improvements on trend detection methods to investigate both climate change and water resources and to detect changes and any trends on those parameters.

Trend analysis methods are mainly divided into two main groups which are parametric tests and non-parametric tests. While parametric tests are also called distribution dependent tests, non-parametric tests are known as distribution-free tests. As the name suggests, parametric tests heavily depend on the data set. Regression analysis can be given as an example on parametric trend analysis methods. On the other hand, non-parametric tests do not have the dependence on the data set and provide accurate results even in the absence of some part of the data set. Furthermore, the power and significance of the test result are not intervened by the actual distribution of the data set. Lack of getting strong statistical and visual results may be counted as disadvantages of non-parametric trend analysis methods. Hence, it can be said that non-parametric tests are more suitable to analyze trends in hydrological and climate parameters since those parameters are generally skewed and contamination by outliers is possible. The most commonly used non-parametric tests are Pearson correlation coefficient test, Spearman’s Rho test, Mann-Kendall test, Theil-Sen test and Sen’s T test.

Pearson correlation coefficient is the most widely used measure of correlation among researchers and refers to the linear relationship between the two variables or real-valued vectors. This method states how far the two sets of data samples from the best fit line. Spearman’s correlation coefficient is a statistical measure of the strength of a monotonic relationship between paired data. The Mann-Kendall Test is used to analyze data collected over time for consistently increasing or decreasing trends.

Multiple researchers have used non-parametric trend analysis methods to investigate the change in climate and hydrological parameters on different regions of the world. Rainfall and temperature parameters in northcentral Ethiopia is investigated in [17] by Mann-Kendall trend analysis method. Trend analysis of several hydrological data is held in [18] by using Mann-Kendall test. Multiple hydrological data in Ontario, Canada is analyzed by using Mann-Kendall and Spearman's Rho test in [19] Rainfall anomalies in Southern Italy region is analyzed in [20] by innovative trend analysis (ITA) method that is previously proposed in [21]. Trend analysis of several climate parameters are hold in [22] by using various parametric and non-parametric methods. ITA method is used to analyze trends in seasonal rainfalls in eastern China in [23].

Trend analysis of climate and hydrological parameters in Turkey has also been held by various researchers. Discharge-recharge characteristics of Tacin karstic spring is investigated in [24]. Water quality parameters of Kızılırmak basin are investigated by Mann-Kendall test and ITA method in [25] and a comparison of both techniques are held. Several climate parameters in Turkey have been investigated in [26] by using a proposed method called Multiple Sen-innovative trend analysis and partial Mann-Kendall test.

In this work, Pearson correlation coefficient test, Spearman's Rho test and Mann-Kendall test were employed to analyze trends in climate parameters of Turkey and both climate and hydrological parameters of Van Lake basin. Firstly, how climate changed over the past 50 years was analyzed in terms of average annual temperature, precipitation, evaporation, moisture, sea water temperatures, soil temperature and number of snowy days in Turkey. Then, these climate parameters were analyzed by the abovementioned non-parametric trend analysis techniques and their trends were evaluated. Moreover, Van Lake basin was taken as a case study to insert another degree of freedom to the study in terms of investigating the effects of climate parameters on hydrological parameters and variations in temperature, precipitation, flow and lake level parameters were investigated. Again, trends of those climate and hydrological variables were evaluated. In addition to this, correlation of those parameters was obtained to see if climate parameters directly or indirectly affect hydrological parameters in Van Lake basin.

Finally, the conclusion gives a brief summary and critique of the findings.

CHAPTER II

COMPONENTS OF CLIMATE CHANGE IN TURKEY

2.1 Introduction

In this section, components of climate change in Turkey were evaluated in seven main parts which are average temperature, precipitation, moisture, evaporation, seawater temperature, soil temperature and number of days covered with snow.

2.2 Temperature

In this section, the change in average temperature in Turkey was investigated. The temperature data is obtained from Turkish Directorate of Meteorology (TDM). Average annual temperature is determined by considering 249 different measurement stations in different places of Turkey according to TDM. Temperature values are taken for each year between 1970 and 2020.

Figure 2.1 Average annual temperature in Turkey between 1970 and 2020 [27]

Figure 2.1 demonstrates the average annual temperature in Turkey between 1970 and 2020. It can be seen that temperature has a tendency to increase through the years. To make it more analytical, it can be said that average annual temperature rises up almost 2 °C in 2020 when compared to 1970. Average annual temperature reaches its maximum value in 2010 and 2018 as it becomes 15.1 °C. On the other hand, average annual temperature takes its minimum value in 1992 as 11.4 °C. Considering all the data between 1970 and 2020, resulting average temperature is 13.2 °C.

Figure 2.2 shows the comparison between the average temperatures for each month in 1970-2020 with respect to average temperatures in 2019 and 2020. In general, it can be seen that average temperatures for each month of the year obtained between 1970 and 2020is less than the values in 2019 and 2020.

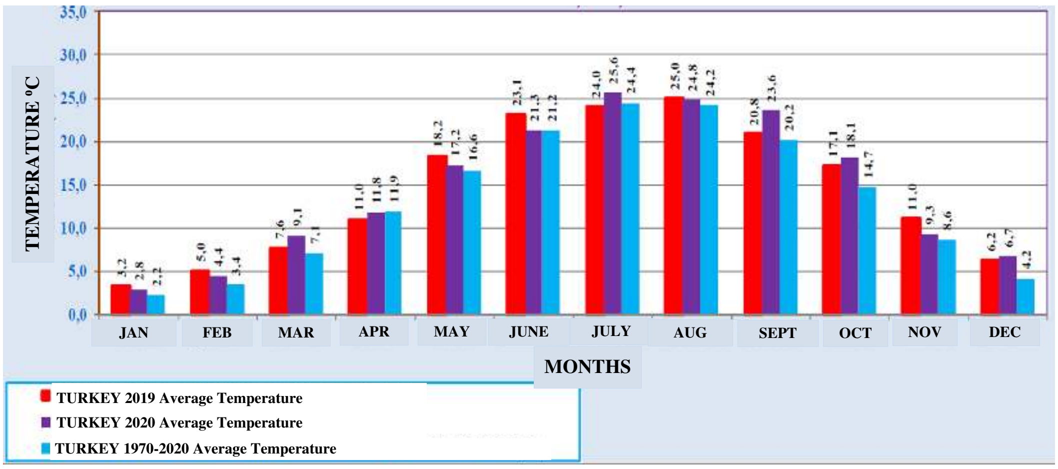


Figure 2.2 Average temperatures for each month in 1970-2020 with respect to average temperatures in 2019 and 2020 [27]

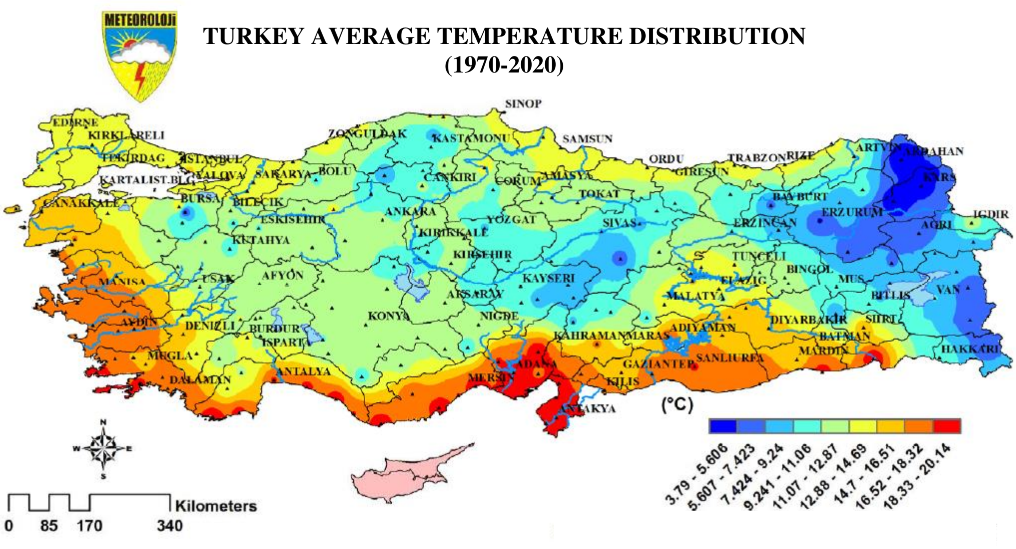


Figure 2.3 Average temperature distribution in Turkey between 1970 and 2020 [27]

In addition, average temperature is higher in 2019 than in 2020 for all months except the summer months. In summer months, 2020 temperatures are slightly higher than 2019 ones. In Figure 2.3, a graphical representation of the average temperature distribution in Turkey is given between 1970 and 2020. It is seen that highest temperatures occur in Southeast region of Turkey, Mediterranean and Aegean shores. On the other hand, the lowest temperatures are measured in Eastern region of Turkey.

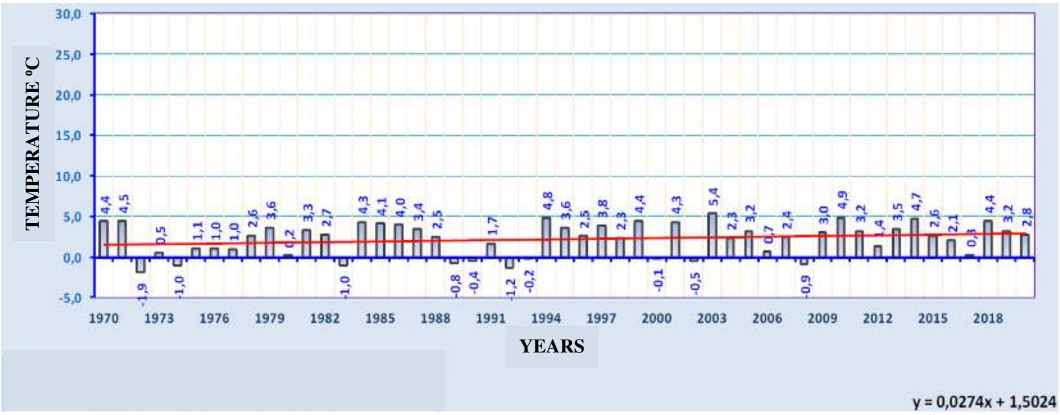
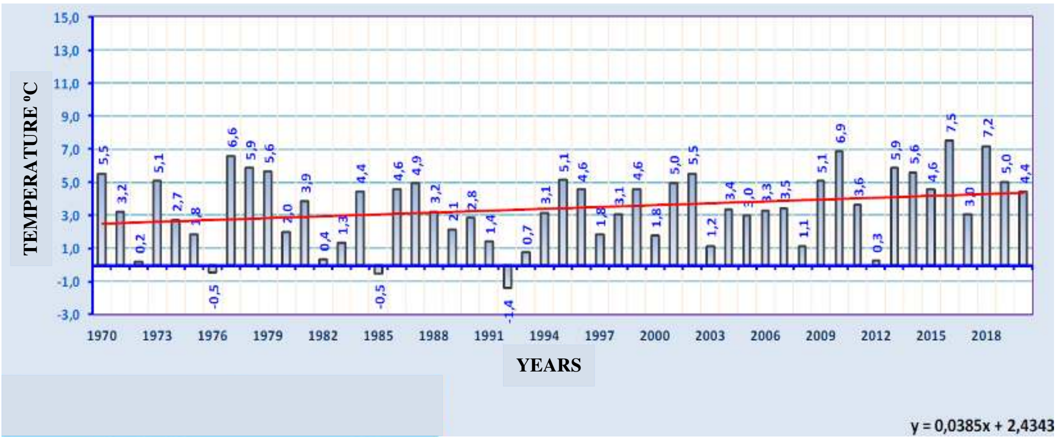


Figure 2.4 Average temperatures through the years between 1970-2020 for January [27]



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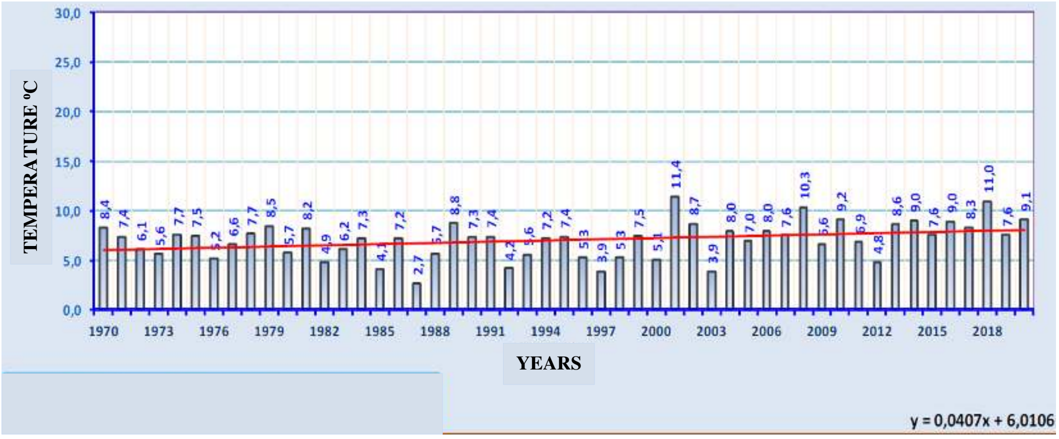


Figure 2.6 Average temperatures through the years between 1970-2020 for March [19]

Figure 2.7 Average temperatures through the years between 1970-2020 for April [19]

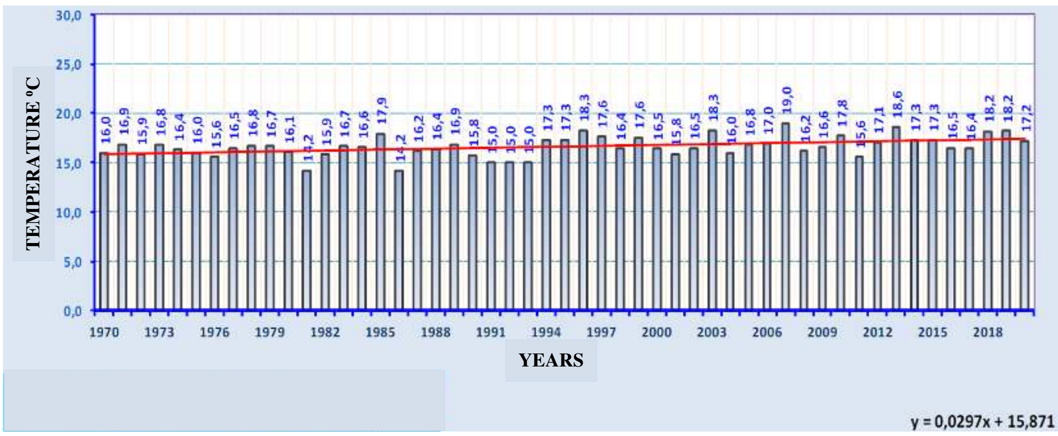


Figure 2.8 Average temperatures through the years between 1970-2020 for May [19]

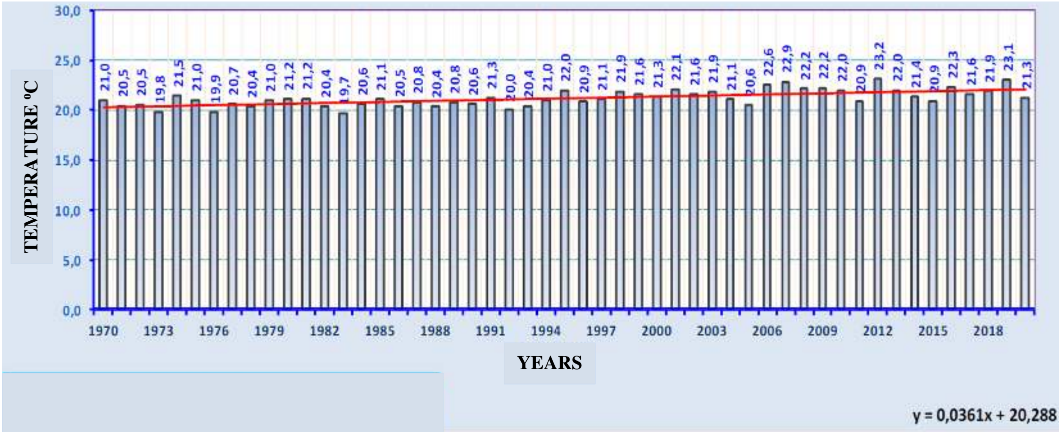


Figure 2.9 Average temperatures through the years between 1970-2020 for June [19]

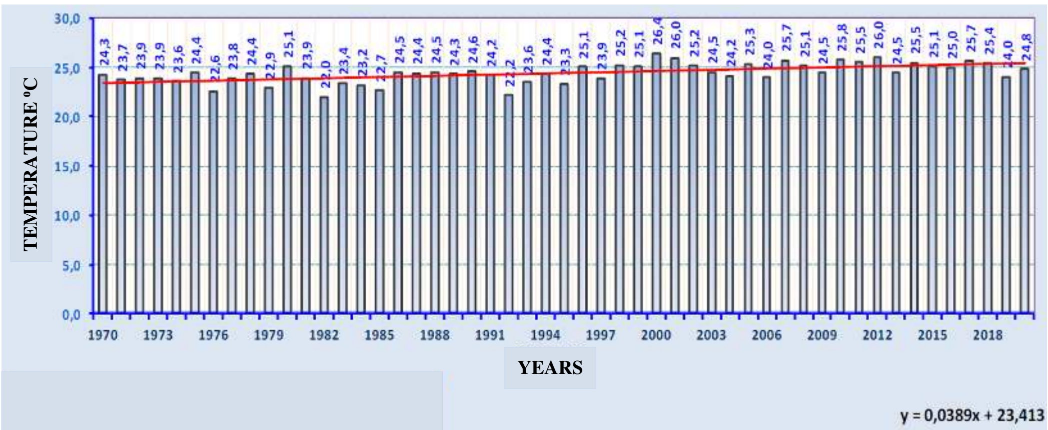


Figure 2.10 Average temperatures through the years between 1970-2020 for July [19]

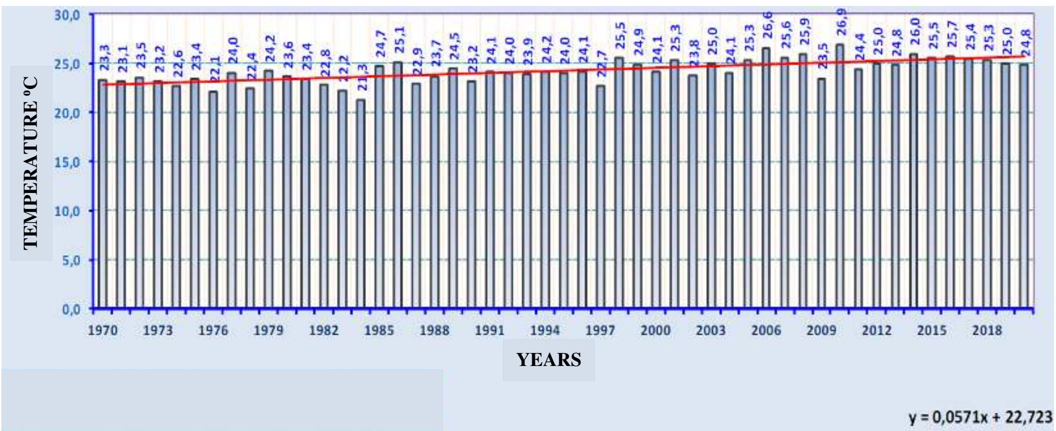


Figure 2.11 Average temperatures through the years between 1970-2020 for August [19]

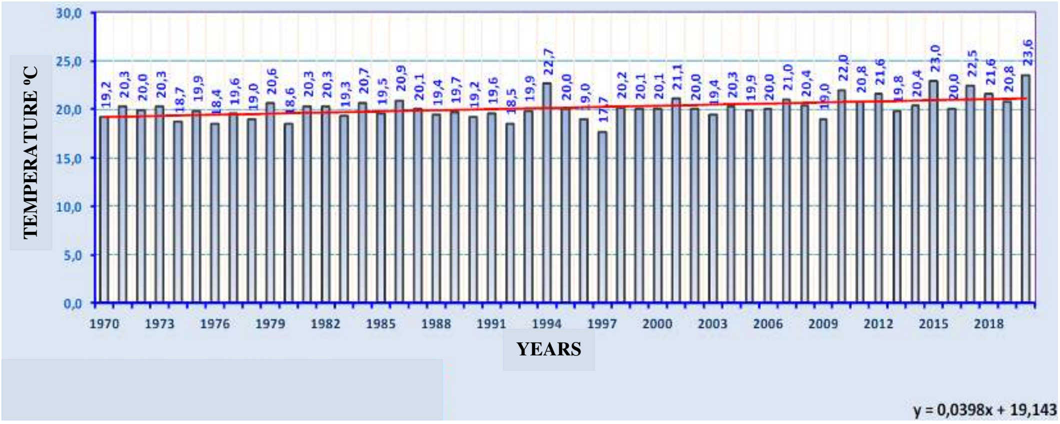


Figure 2.12 Average temperatures through the years between 1970-2020 for September [19]

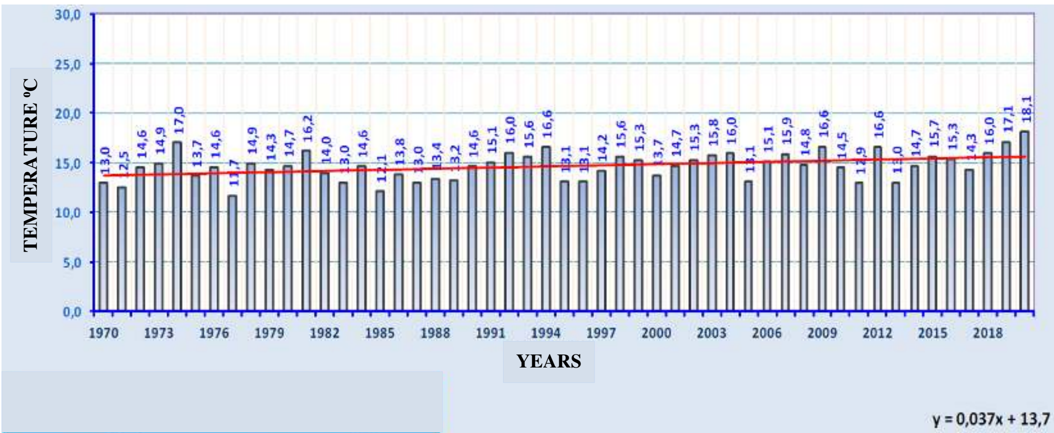


Figure 2.13 Average temperatures through the years between 1970-2020 for October [19]

Figure 2.4 shows the average temperatures through the years between 1970 and 2020 for January. It is seen that while the hottest year is 2003, the coldest year is 1972.

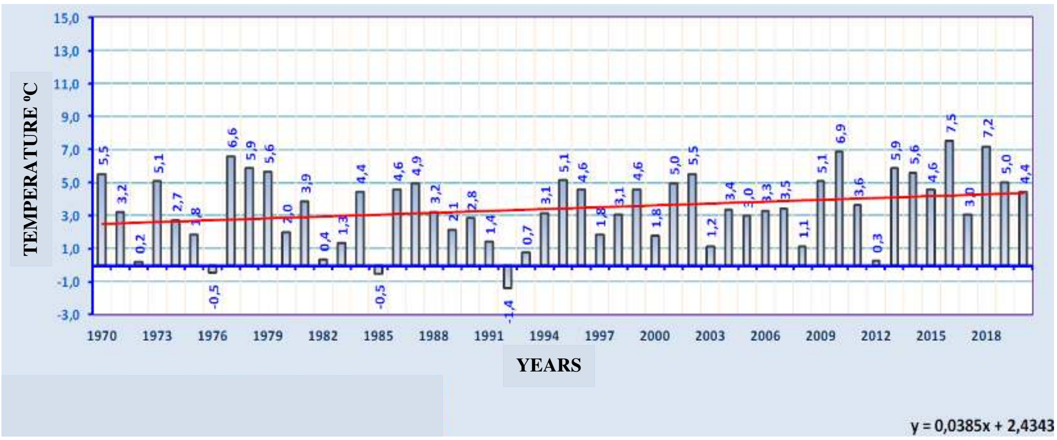


Figure **2.5** demonstrates the average temperatures through the years between 1970 and 2020 for February. It is seen that while the hottest year is 2015, the coldest year is 1992. Figure 2.6 illustrates the average temperatures through the years between 1970 and 2020 for March. It is seen that while the hottest year is 2001, the coldest year is 1987. Figure 2.7 demonstrates the average temperatures through the years between 1970 and 2020 for April. It is seen that while the hottest year is 1989, the coldest year is 1997. Figure 2.8 shows the average temperatures through the years between 1970 and 2020 for May. It is seen that while the hottest year is 2007, the coldest year is 1981 and 1986. Figure 2.9 illustrates the average temperatures through the years between 1970 and 2020 for June.

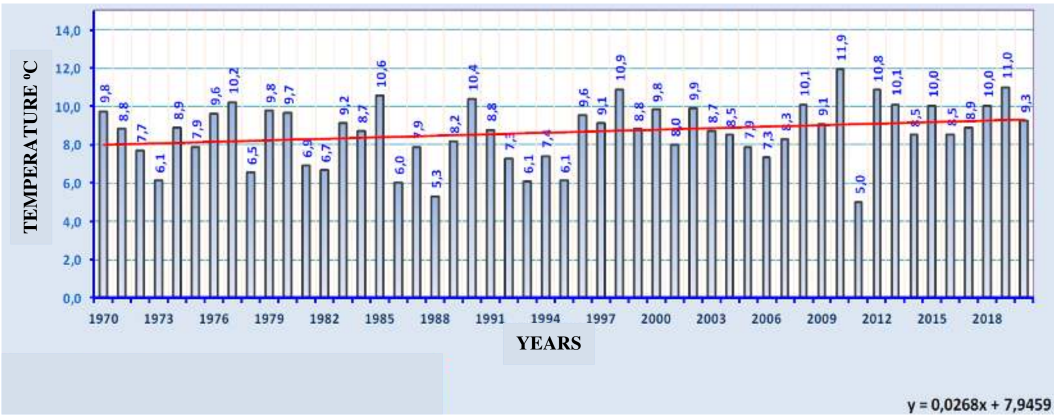


Figure 2.14 Average temperatures through the years between 1970-2020 for November [19]

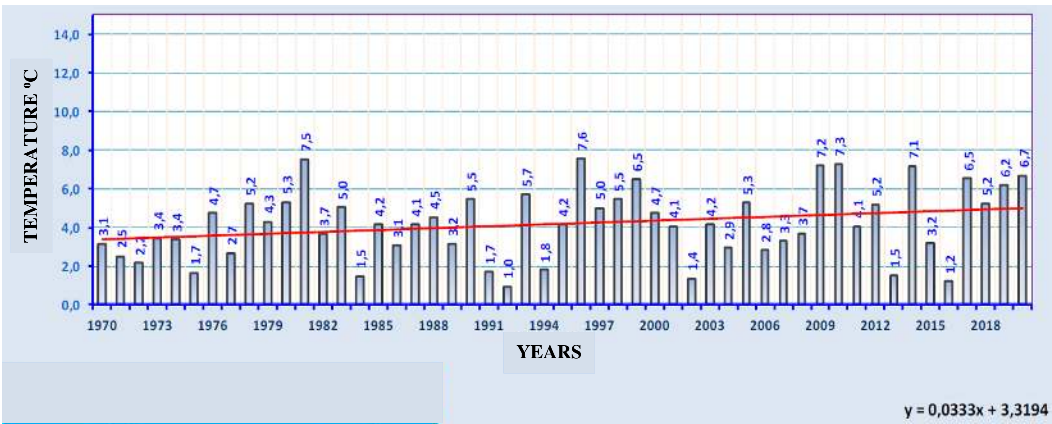


Figure 2.15 Average temperatures through the years between 1970-2020 for December [19]

It is seen that while the hottest year is 2012, the coldest year is 1983. Figure 2.10 illustrates the average temperatures through the years between 1970 and 2020 for

July. It is seen that while the hottest year is 2012, the coldest year is 1982. Figure 2.11 demonstrates the average temperatures through the years between 1970 and 2020 for August. It is seen that while the hottest year is 2010, the coldest year is 1984. Figure 2.12 shows the average temperatures through the years between 1970 and 2020 for September. It is seen that while the hottest year is 2015, the coldest year is 1997.

Figure 2.13 shows the average temperatures through the years between 1970 and 2020 for October. It is seen that while the hottest year is 1974, the coldest year is 1977. Figure 2.14 demonstrates the average temperatures through the years between 1970 and 2020 for November. It is seen that while the hottest year is 2010, the coldest year is 2011. Figure 2.15 illustrates the average temperatures through the years between 1970 and 2020 for December. It is seen that while the hottest year is 1996, the coldest year is 1992.

2.3 Precipitation

In this section, the change in precipitation in Turkey is investigated. The precipitation data is obtained from Turkish Directorate of Meteorology (TDM). Average annual precipitation is determined by considering 224 different measurement stations in different places of Turkey according to TDM. Precipitation values are taken for each year between 1970 and 2020.

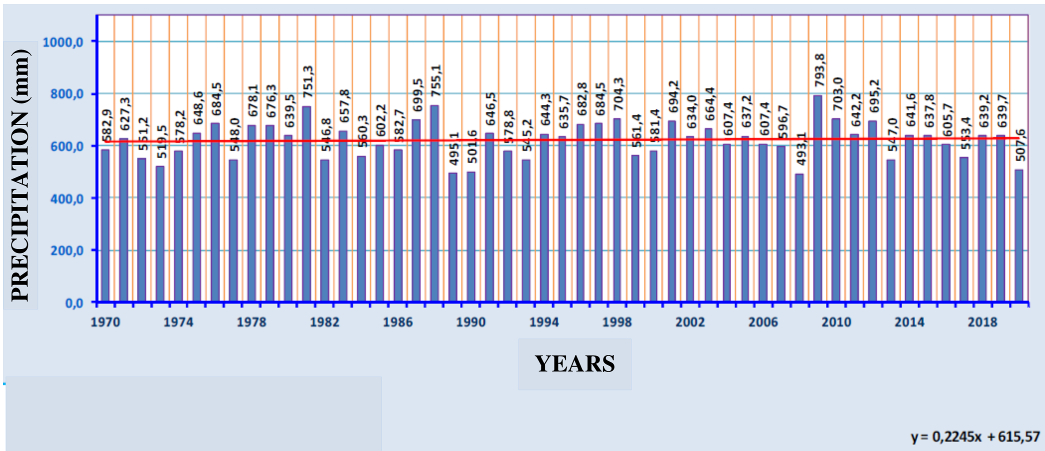


Figure 2.16 Average annual precipitation in Turkey between 1970 and 2020 [19]

Figure 2.16 shows the average annual precipitation in Turkey between 1970 and 2020. No trend can be seen in the average precipitation values through the years. To make it more analytical, it can be said that average annual temperature almost stays the same as seen in the red line in Figure 2.16. Average annual precipitation reaches its maximum value in 2009 as it becomes 793.8 mm. On the other hand, average annual precipitation takes its minimum value in 2008 as 493.1 mm. Considering all the data between 1970 and 2020, resulting average temperature is 621.4 mm. Moreover, while precipitations are rather low in 2017 and 2020, the highest precipitation value of the last 9 years and the third and fourth highest precipitation values of the last 30 years are observed in 2018 and 2019.

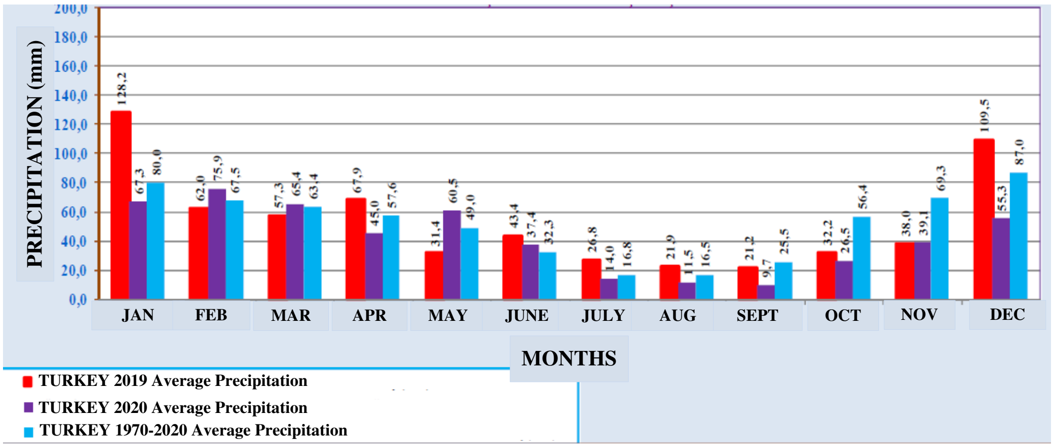


Figure 2.17 Average precipitations for each month in 1970-2020 with respect to average precipitations in 2019 and 2020 [19]

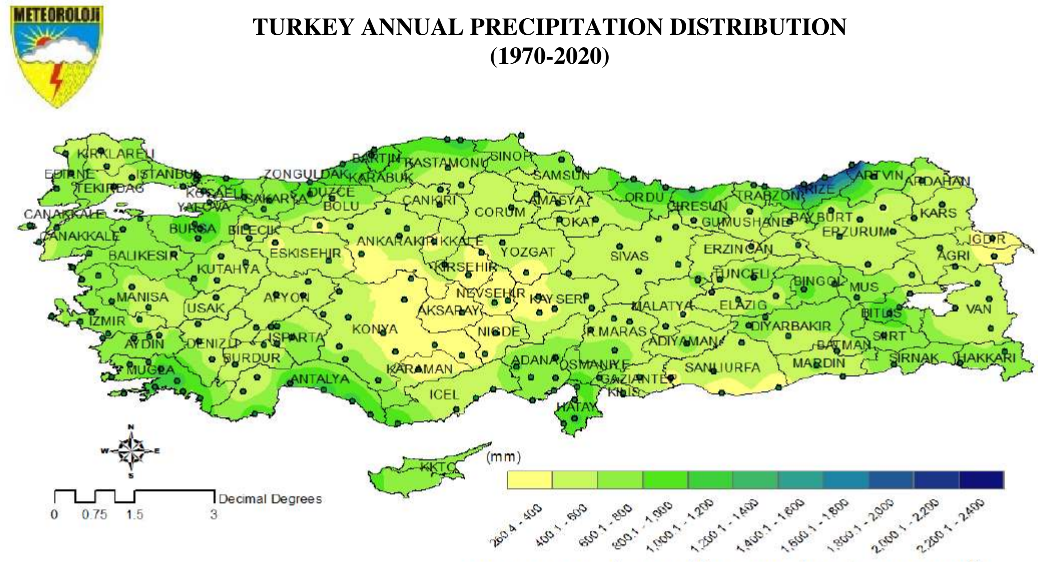


Figure 2.18 Total annual precipitations in Turkey between 1970-2020 [19]

Figure 2.17 demonstrates the comparison between the average temperatures for each month in 1970-2020 with respect to average temperatures in 2019 and 2020. In general, similar to what is seen in average annual precipitations, no general trend can be observed in the precipitation values. The only visible thing that can be said is that in summer months, an increase in precipitation is observed in 2019 compared to average values. Figure 2.18 gives a graphical representation of the total annual precipitations in Turkey between 1970-2020. It can be seen that while the highest precipitation is observed in North Black Sea region of Turkey, the lowest precipitation is seen in Central Anatolia region of Turkey.

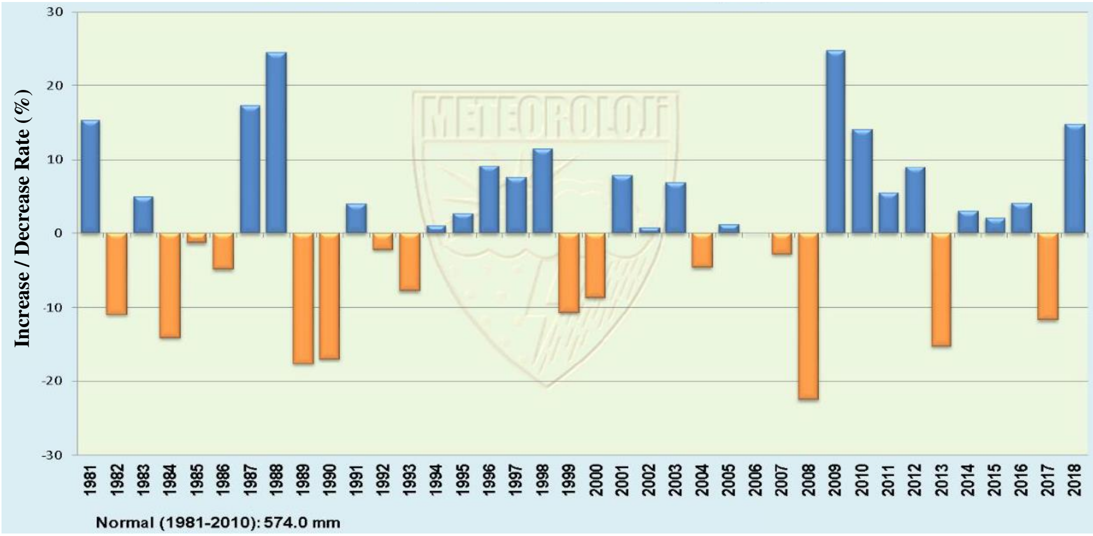


Figure 2.19 Average annual precipitations with respect to nominal precipitations between 1981 and 2018 [19]

In Figure 2.19, average annual precipitations with respect to nominal precipitations between 1981 and 2018 are given. It can be inferred that the years that have higher precipitations than the nominal precipitation value is more than the years that have lower precipitations than the nominal precipitation. Moreover, 2006 reflects the nominal precipitation value between 1981 and 2018.

Figure 2.20 illustrates the difference between the precipitation in 2018 and nominal precipitation value. As it is seen, there is a 100 % increase in precipitation around Adana and Mersin, there is a 25 % - 50 % decrease in precipitation around Sivas, Artvin and Kastamonu. In Table 2.1 and Figure 2.21, precipitations in 2018 increase with respect to previous year and the nominal value for all regions. Despite the general trend of increase, the smallest difference occurs in Karadeniz which has the greatest nominal precipitation value. On the contrary, greatest increase occurs in Güneydoğu Anadolu region which has the lowest nominal precipitation value. Therefore, it can be stated that precipitation increase in dry regions are greater than rainy regions.

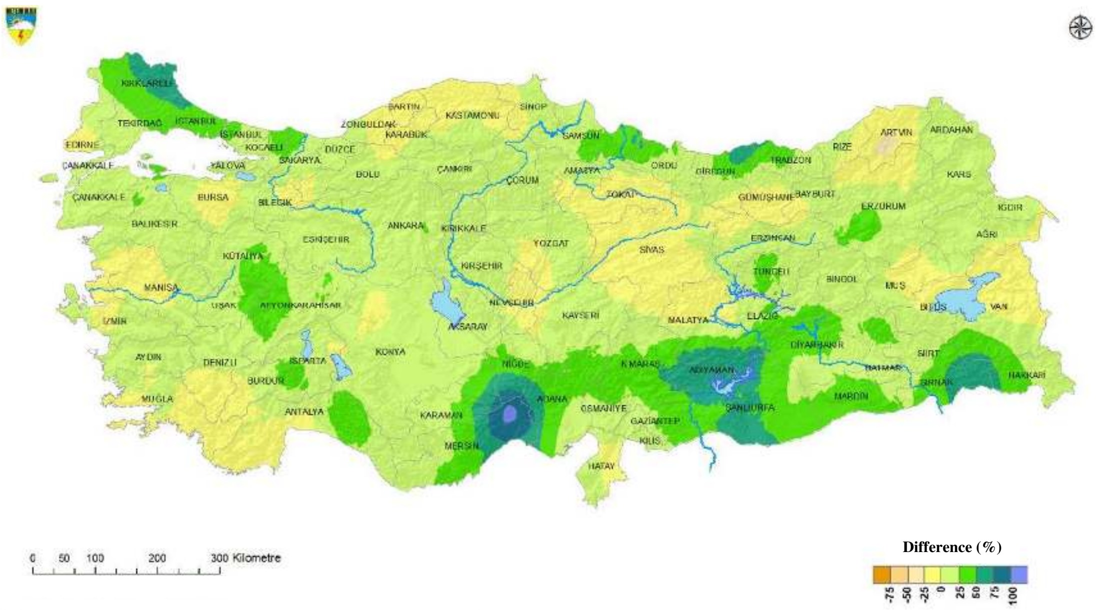


Figure 2.20 Precipitation in 2018 with respect to nominal precipitation value [19]

Table 2.1 Precipitation in different regions of Turkey and comparison of 2018 precipitations to previous years [19]

Regions	**Precipitation in 2018 (mm)**	**Nominal Precipitation (mm)**	**Precipitation in 2017 (mm)**	**2018 w.r.t. normal (%)**	**2018 w.r.t. 2017 (%)**
Marmara	780.5	662.3	686.5	+17.8	+13.7
Ege	651.8	592.2	592.9	+10.1	+9.9
Akdeniz	785.1	666.5	590.9	+17.8	+32.9
İç Anadolu	449.4	406.5	359.8	+10.6	+24.9
Karadeniz	733.5	696.5	637.7	+5.3	+15.0
Doğu Anadolu	638.9	558.3	428.8	+14.4	+49.0
Güneydoğu Anadolu	736.6	532.2	363.8	+38.4	+>100

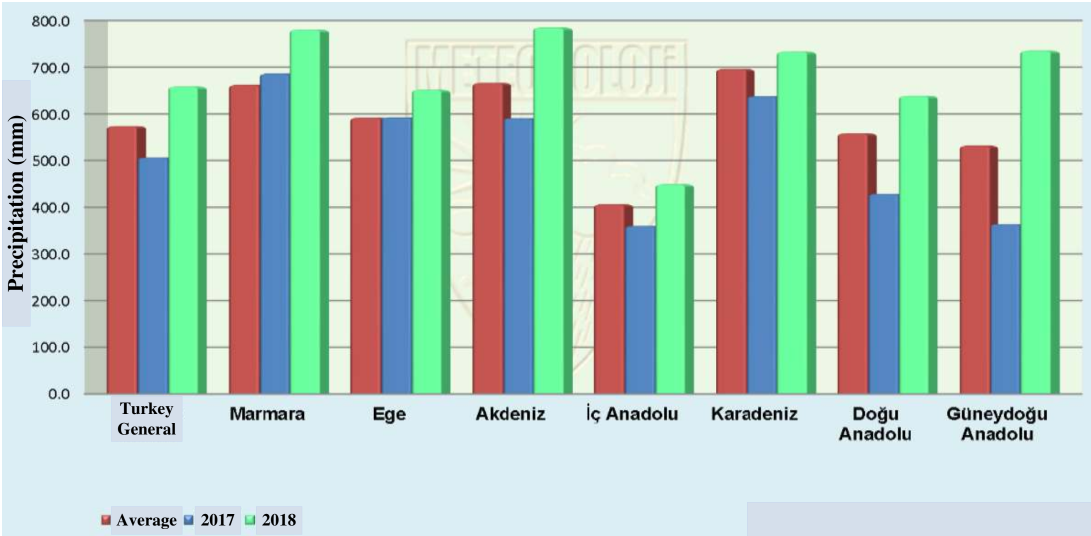


Figure 2.21 Graphical representation of precipitation in different regions of Turkey and comparison of 2018 and 2017 precipitations to average values [19]

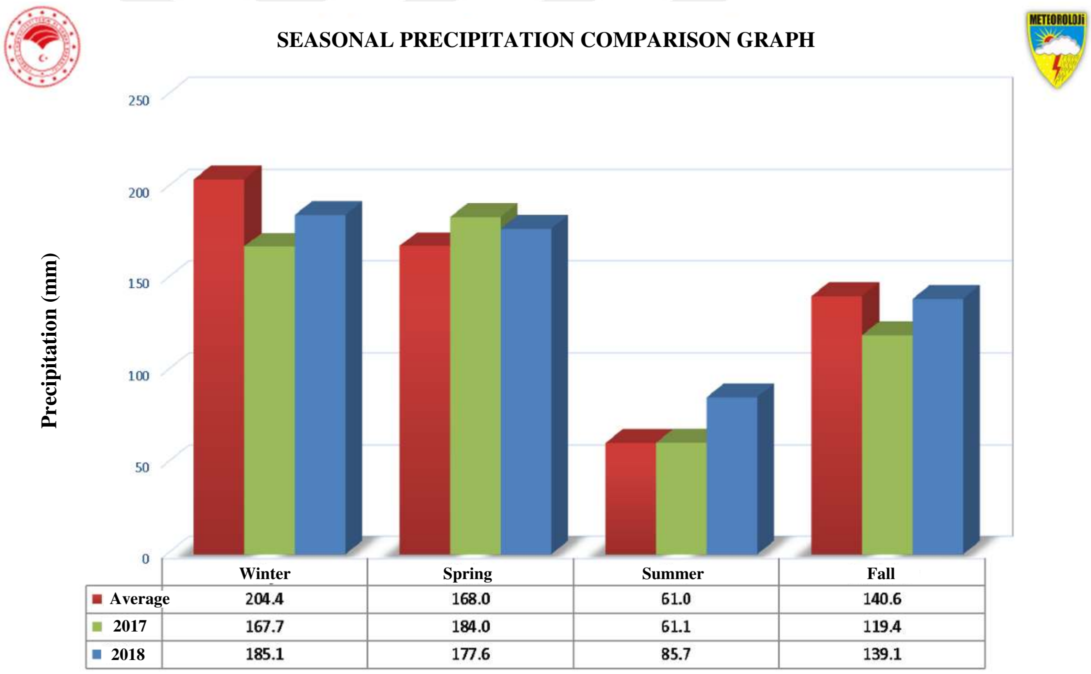
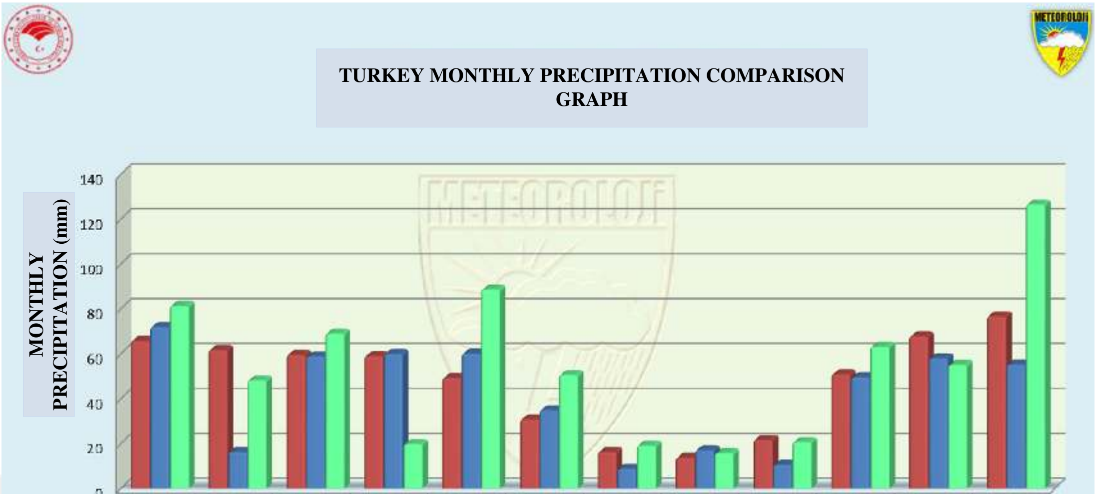


Figure 2.22 Comparison of 2017 and 2018 precipitations to average values for all seasons [19]

Figure 2.22 shows the comparison of 2017 and 2018 precipitations to nominal values for all seasons. According to Figure 2.22, it can be inferred that 2018 precipitation values increase in spring and summer seasons and decrease in winter season with respect to nominal precipitations. In addition, fall precipitations remain almost the same level.



	January	February	March	April	May	June	July	August	September	October	November	December
Average	65.8	61.8	59.6	59.1	49.3	30.8	16.4	13.8	21.8	51.0	67.8	76.8
2017	72.0	16.4	59.0	60.0	60.1	35.0	9.0	17.2	10.6	49.6	58.2	55.4
2018	81.4	48.3	69.1	19.9	88.6	50.7	19.2	15.8	20.7	63.2	55.2	126.6

Figure 2.23 Comparison of 2017 and 2018 precipitations to nominal values for all months [19]

Comparison of 2017 and 2018 precipitations to nominal values for all months is demonstrated in Figure 2.23. A decrease in precipitation occurs in 2018 with respect to nominal values in April; however, an increase happens in other months. It should be noted that precipitations in February, July and December increase almost 100 % compared to previous year.

Figure 2.24 demonstrates the precipitations in 2018 and nominal values for 25 different basins. Figure 2.25 gives a graphical representation of the change in precipitations in 2018 with respect to nominal values for all basins. According to Figure 2.25, it can easily be seen that an increase occurs in most of the basins. Moreover, according to Figure 2.24; while the greatest increase happens in Seyhan basin as 34 %, the greatest decrease occurs in Çoruh basin as 6 %.

Figure 2.26 shows the comparison of the number of rainy days in 2017 and 2018 with respect to nominal values. As it can be seen, number of rainy days is smaller than the nominal values in April of 2018, and greater in other months.

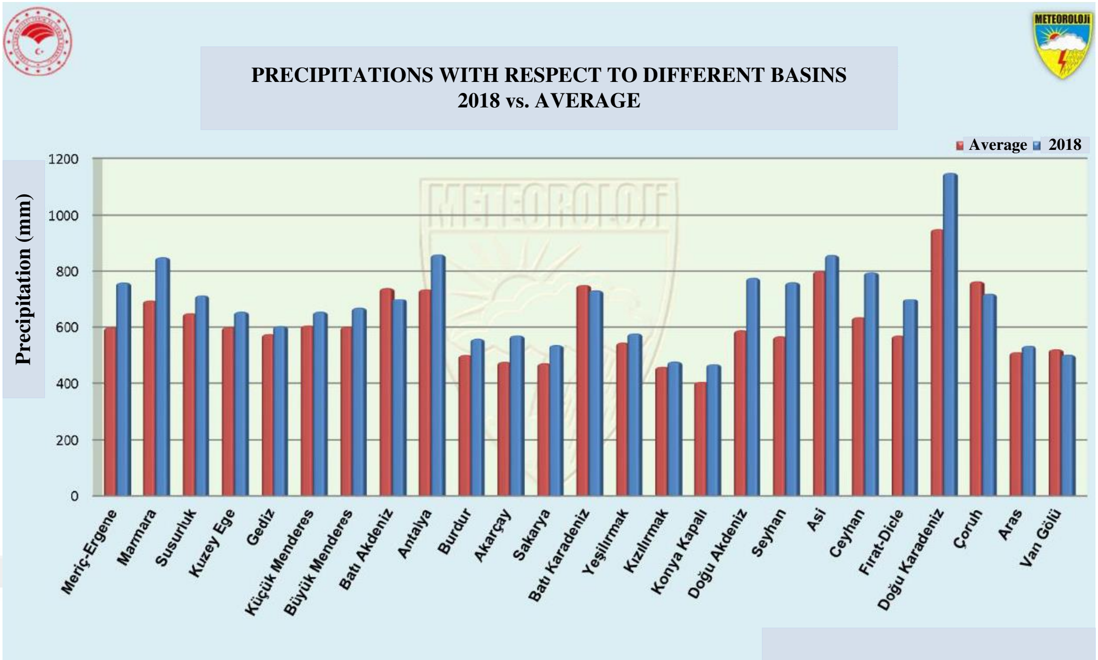


Figure 2.24 Comparison of 2018 precipitations to nominal values for 25 basins [19]

Figure 2.25 A graphical representation of the change in precipitations in 2018 with respect to nominal values for all basins [19]

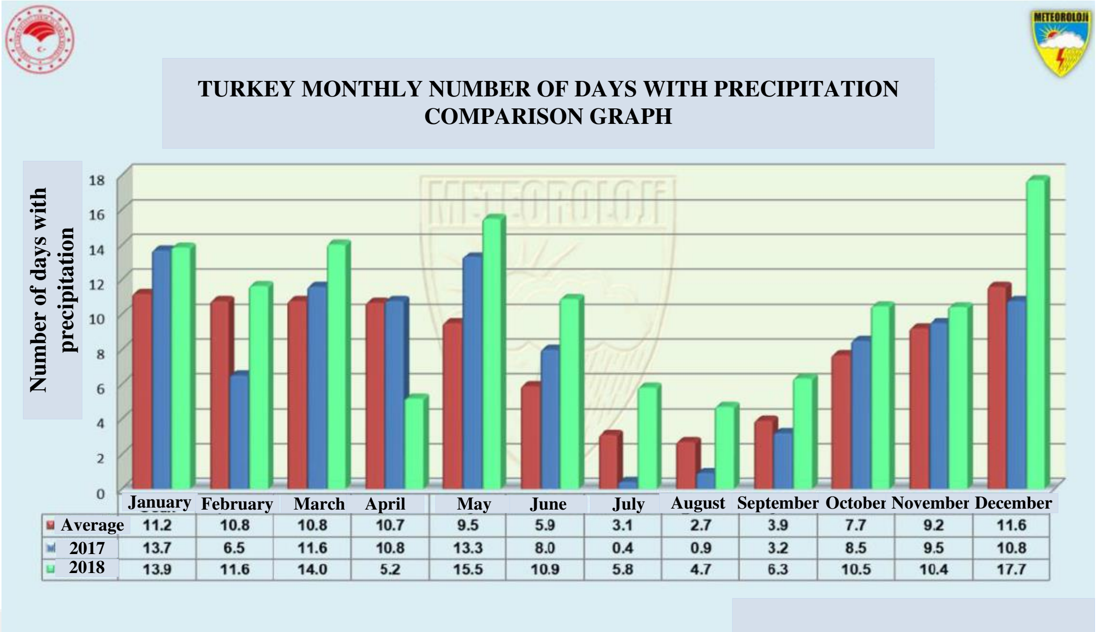


Figure 2.26 Comparison of the number of rainy days in 2017 and 2018 with respect to nominal values [19]

2.4 Moisture

In this section, the change in moisture in Turkey was investigated. The moisture data is obtained from Turkish Directorate of Meteorology (TDM). Average annual moisture is determined by considering 236 different measurement stations in different places of Turkey according to TDM. Moisture values are taken for each year between 1970 and 2020.

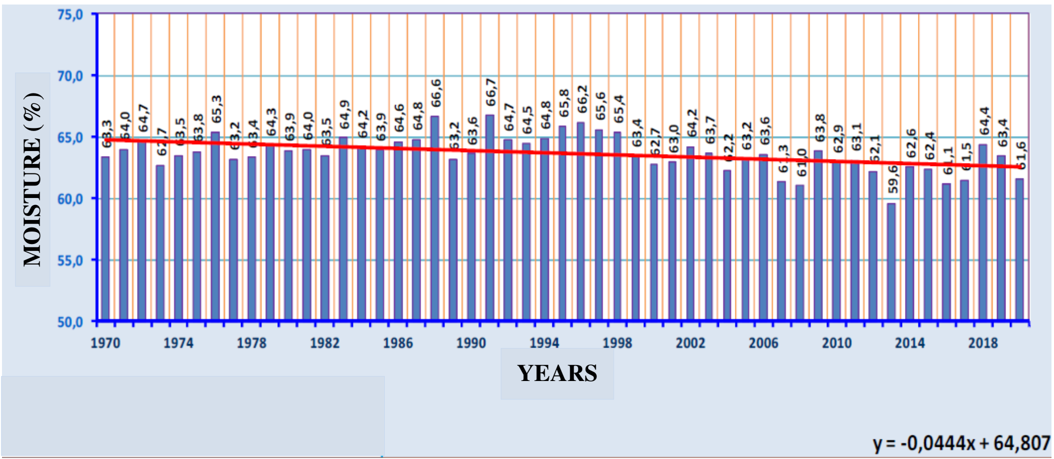


Figure 2.27 Average annual moisture in Turkey between 1970 and 2020 [19]

Figure 2.27 shows average annual moisture in Turkey between 1970 and 2020. While the highest average annual moisture is observed in 1991 as 66.7 %, the lowest value is obtained in 2013 as 59.6 %. Figure 2.28 demonstrates the average moisture for each month in 1970-2020 with respect to average moistures in 2019 and 2020. It can be seen that in general, moisture in 2019 is greater than the moisture in 2002. Another thing to point out is that there happens an increase in moisture in winter for the last two years compared to average moisture.

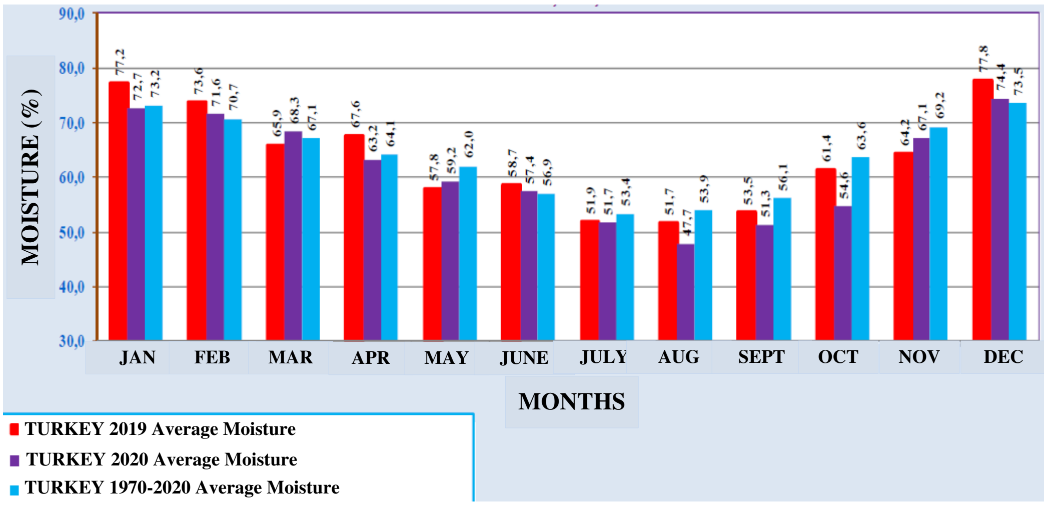


Figure 2.28 Average moisture for each month in 1970-2020 with respect to average moistures in 2019 and 2020 [19]

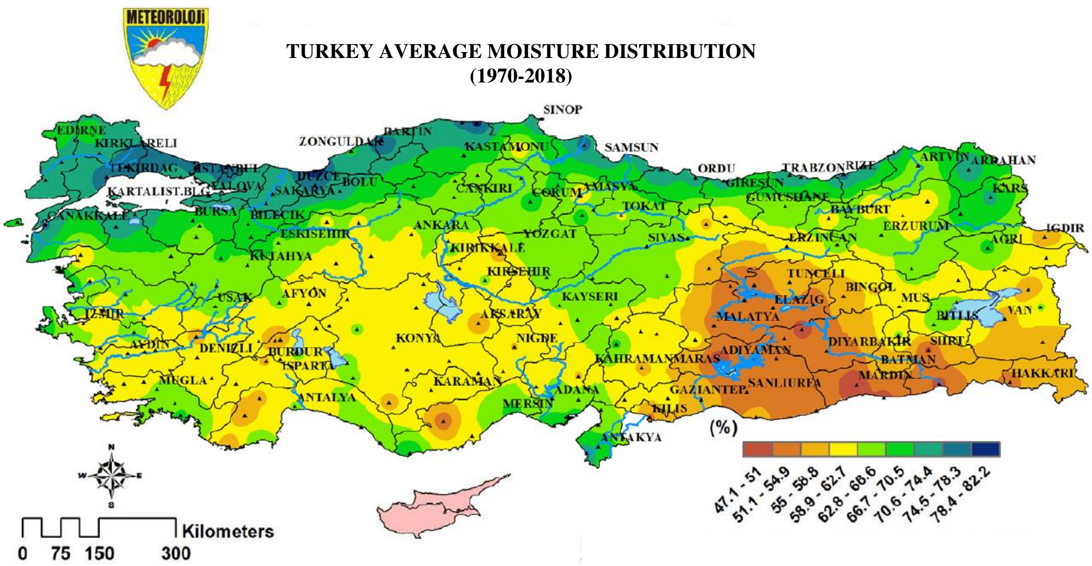


Figure 2.29 Graphical representation of the average moisture distribution in Turkey between 1970 and 2020 [19]

Figure 2.29 gives a graphical illustration of the average moisture distribution in Turkey between 1970 and 2020. It can be inferred that Karadeniz and Marmara regions of Turkey have the greatest average moisture and Güneydoğu Anadolu region has the least average moisture.

2.5 Evaporation

In this section, the change in evaporation in Turkey was investigated. The evaporation data is obtained from Turkish Directorate of Meteorology (TDM). Average annual moisture is determined by considering 84 different measurement stations in different places of Turkey according to TDM. Evaporation values are taken for each year between 1985 and 2020.

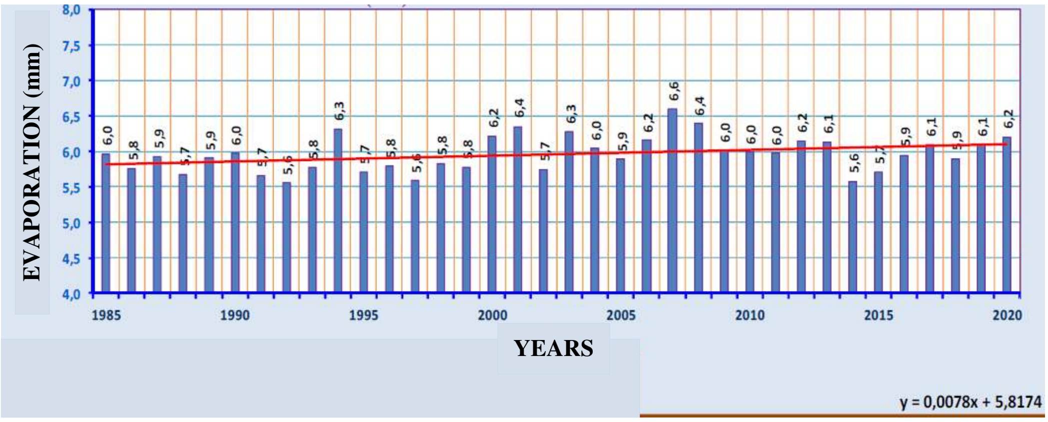


Figure 2.30 Average annual evaporation in Turkey between 1985 and 2020 [19]

Figure 2.30 shows average annual evaporation in Turkey between 1985 and 2020. While the highest average annual evaporation is observed in 2007 as 6.6 mm, the lowest value is obtained in 1992 as 5.6 mm. Average annual evaporation becomes 6.0 mm.

Figure 2.31 demonstrates the average evaporation for each month in 1985-2020 with respect to average evaporation in 2019 and 2020. It can be seen that in general, evaporation in 2020 is greater than the average evaporation and 2019 values.

Figure 2.32 gives a graphical representation of the amount of average daily open surface evaporation for each month (5-10) in 1985-2020. It can be inferred that Karadeniz and Marmara regions of Turkey have the greatest average evaporation and Güneydoğu Anadolu region has the least average evaporation.

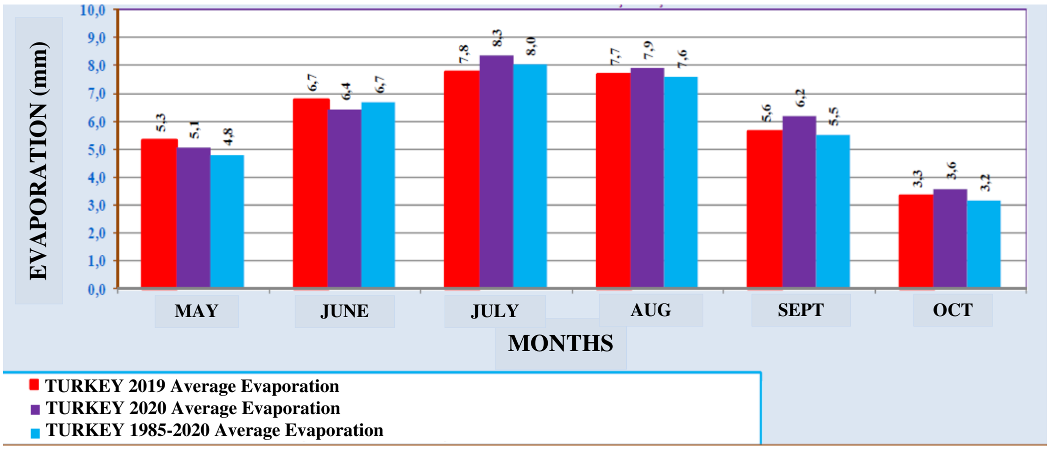


Figure 2.31 Average evaporation for each month (5-10) in 1985-2020 with respect to average evaporation in 2019 and 2020 [19]

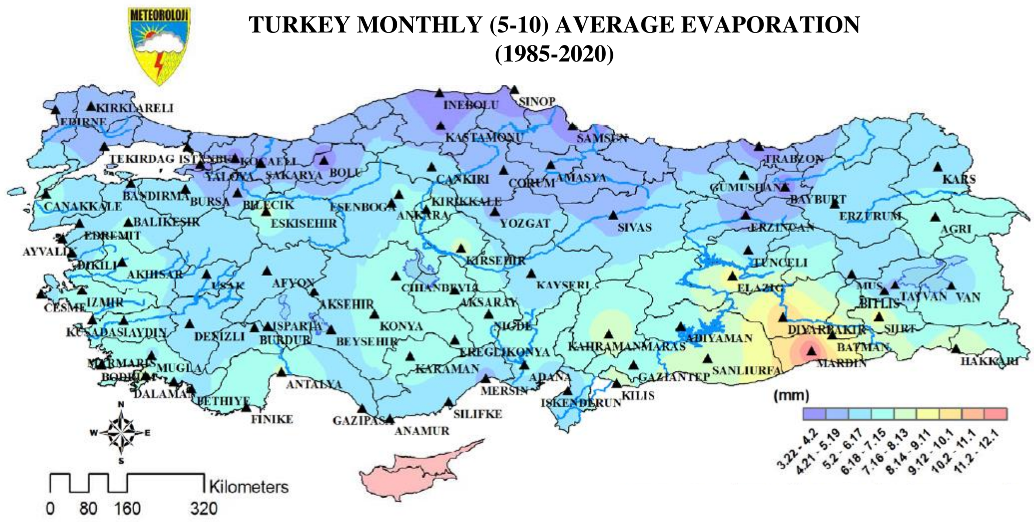


Figure 2.32 A graphical representation of the amount of average daily open surface evaporation for each month (5-10) in 1985-2020 [19]

2.6 Seawater Temperature

In this section, the change in seawater temperature in four seas of Turkey was investigated. The seawater temperature data is obtained from Turkish Directorate of Meteorology (TDM). Seawater temperature values are taken for each year between 1970 and 2018. Figure 2.33 demonstrates the average annual seawater temperature in Mediterranean Sea between 1970 and 2018. While the highest temperature is obtained in 2018 as 22.4 °C, the lowest temperature is observed in 1992 as 20.6 °C. Figure 2.34 shows average seawater temperature for each month in 1970-2018 with respect to average seawater temperature in 2017 and 2018 for Mediterranean Sea. In general, seawater temperatures in 2017 are greater than 2018 and average values.

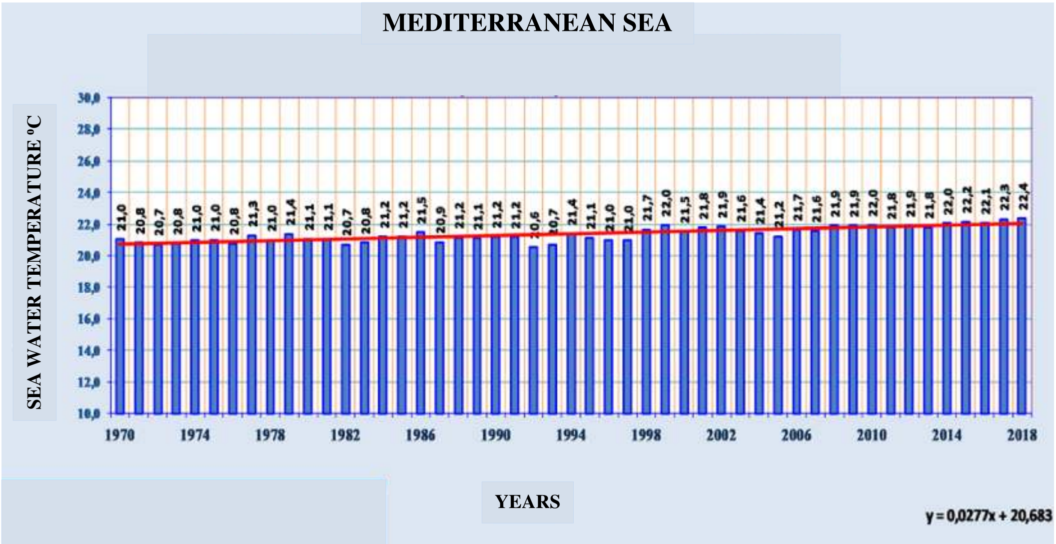


Figure 2.33 Average annual seawater temperature in Mediterranean Sea between 1970 and 2018 [19]

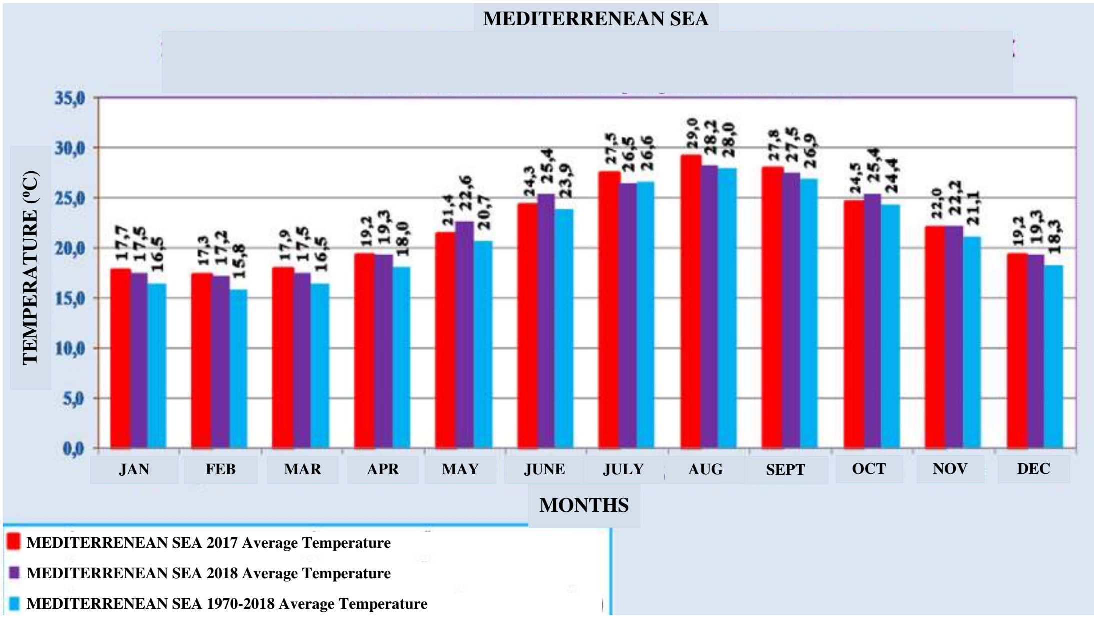


Figure 2.34 Average seawater temperature for each month in 1970-2018 with respect to average seawater temperature in 2017 and 2018 for Mediterranean Sea [19]

Figure 2.35 demonstrates the average annual seawater temperature in Black Sea between 1970 and 2018. While the highest temperature is obtained in 2018 as 16.5 °C, the lowest temperature is observed in 1987 as 13.8 °C. Figure 2.36 shows average seawater temperature for each month in 1970-2018 with respect to average seawater temperature in 2017 and 2018 for Mediterranean Sea. In general, seawater temperatures in 2018 are greater than 2017 and average values.

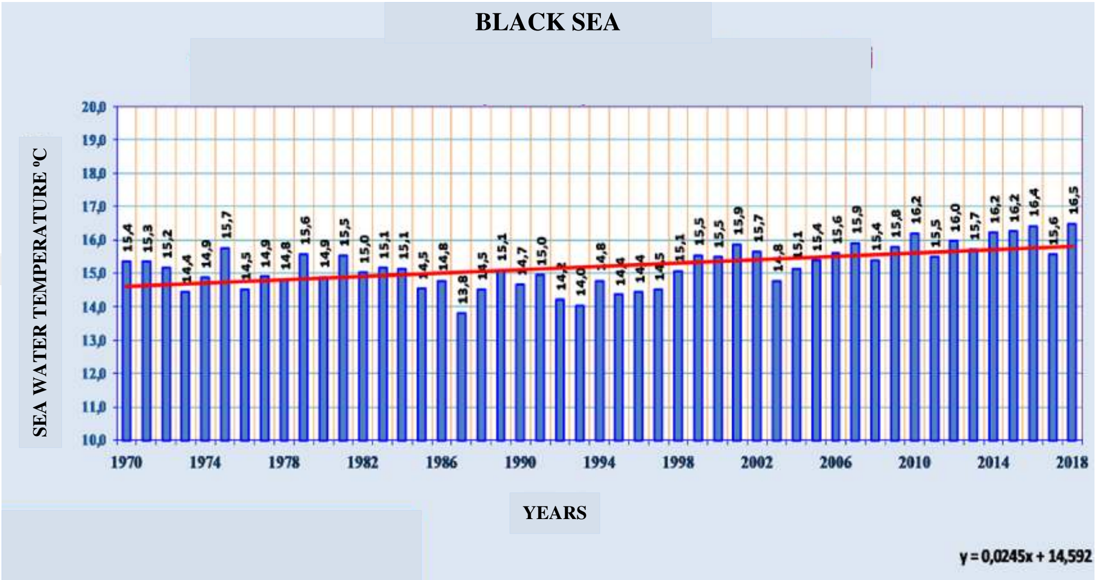


Figure 2.35 Average annual seawater temperature in Black Sea between 1970 and 2018 [19]

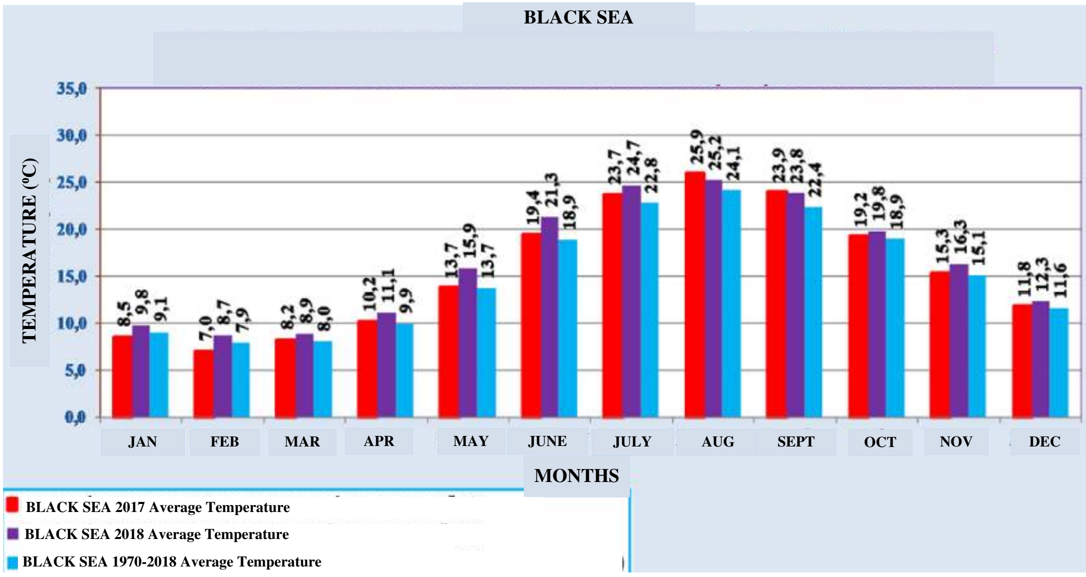


Figure 2.36 Average seawater temperature for each month in 1970-2018 with respect to average seawater temperature in 2017 and 2018 for Black Sea [19]

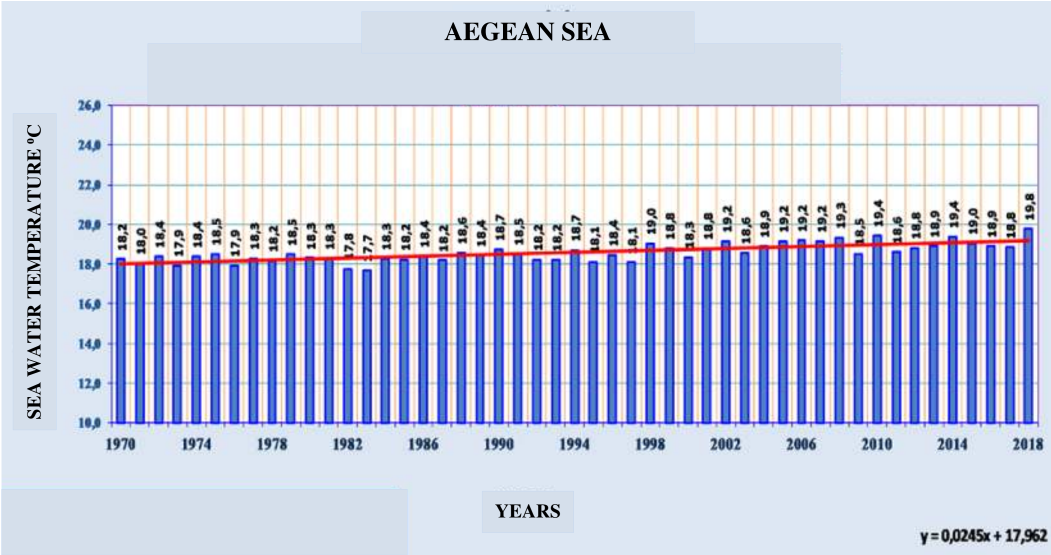


Figure 2.37 Average annual seawater temperature in Aegean Sea between 1970 and 2018 [19]

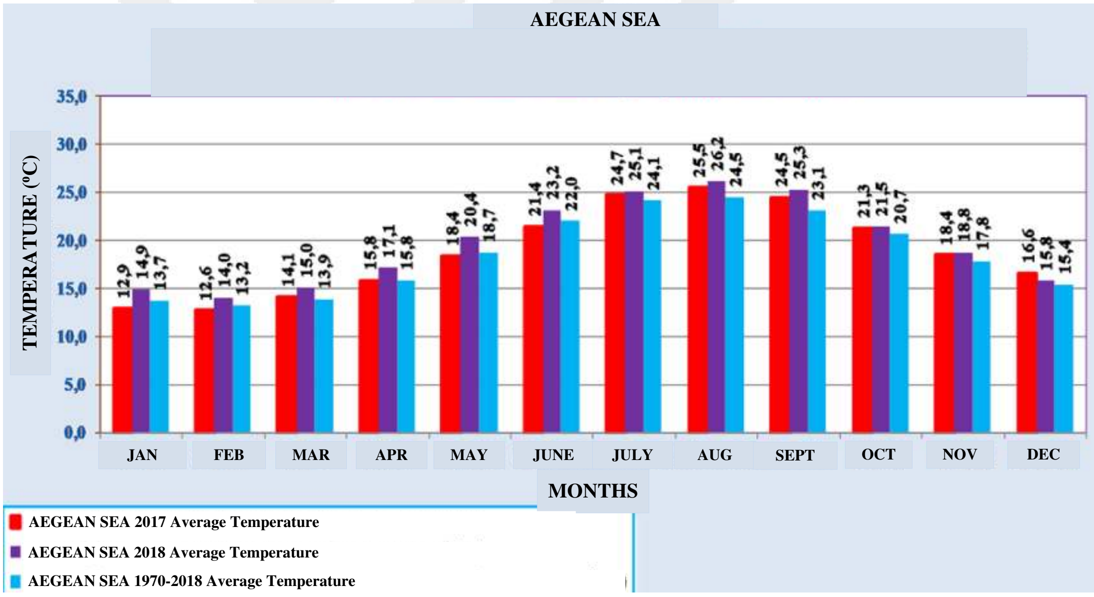


Figure 2.38 Average seawater temperature for each month in 1970-2018 with respect to average seawater temperature in 2017 and 2018 for Aegean Sea [19]

Figure 2.37 illustrates the average annual seawater temperature in Aegean Sea between 1970 and 2018. While the highest temperature is obtained in 2018 as 19.8 °C, the lowest temperature is observed in 1983 as 17.7 °C. Figure 2.38 shows average seawater temperature for each month in 1970-2018 with respect to average seawater temperature in 2017 and 2018 for Aegean Sea. In general, seawater temperatures in 2018 are greater than 2017 and average values.

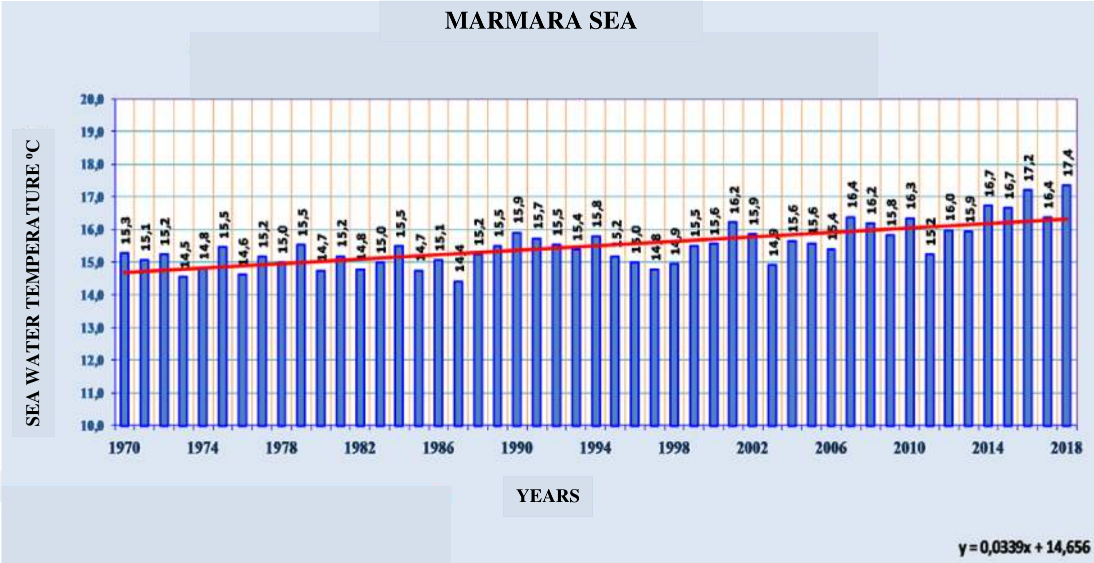


Figure 2.39 Average annual seawater temperature in Marmara Sea between 1970 and 2018 [19]

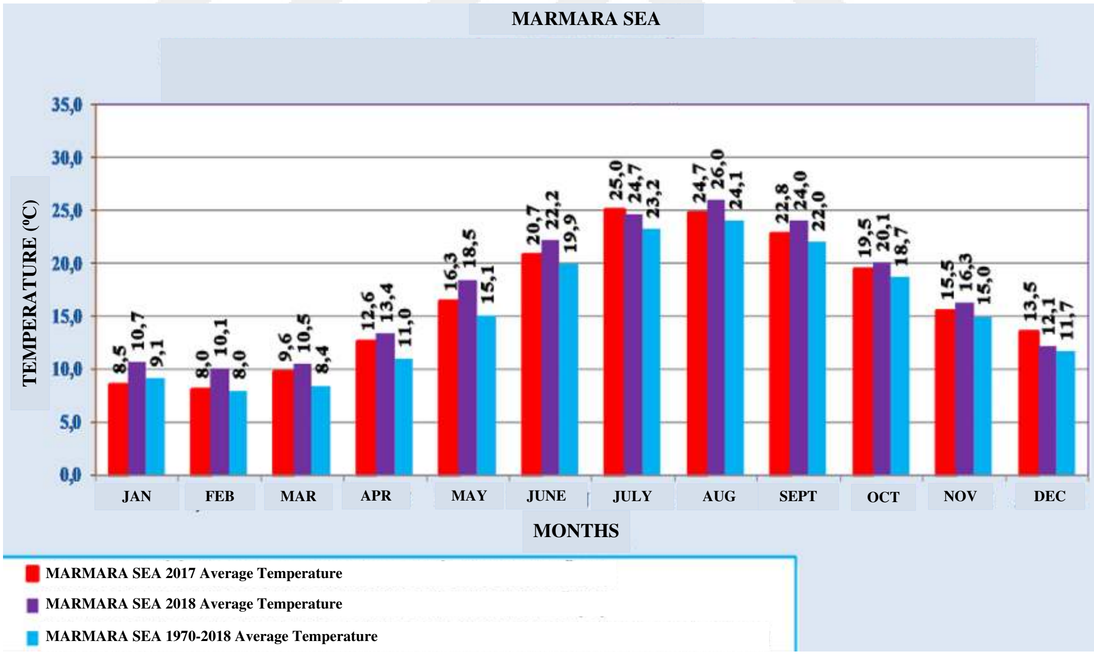


Figure 2.40 Average seawater temperature for each month in 1970-2018 with respect to average seawater temperature in 2017 and 2018 for Marmara Sea [19]

Figure 2.39 demonstrates the average annual seawater temperature in Marmara Sea between 1970 and 2018. While the highest temperature is obtained in 2018 as 17.4

°C, the lowest temperature is observed in 1987 as 14.4 °C. Figure 2.38 shows average seawater temperature for each month in 1970-2018 with respect to average seawater temperature in 2017 and 2018 for Marmara Sea. In general, seawater temperatures in 2018 are greater than 2017 and average values.

2.7 Soil Temperature at 50 cm Depth

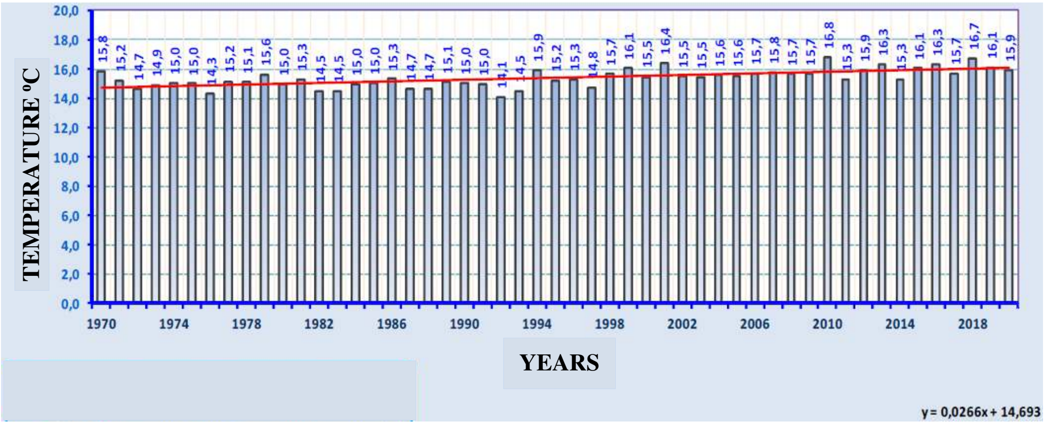


Figure 2.41 Average annual soil temperature at 50 cm depth between 1970 and 2020 [19]

In this section, the change in evaporation in Turkey was investigated. The soil temperature data is obtained from Turkish Directorate of Meteorology (TDM). Average annual soil temperature is determined by considering 177 different measurement stations in different places of Turkey according to TDM. Soil temperature values are taken for each year between 1970 and 2020.

Figure 2.41 demonstrates the average annual soil temperature at 50 cm depth between 1970 and 2020. While the highest temperature is obtained in 2010 as 16.8 °C, the lowest temperature is observed in 1992 as 14.1 °C. Figure 2.42 shows average soil temperature at 50 cm depth for each month in 1970-2020 with respect to average soil temperature at 50 cm depth in 2019 and 2020. In general, soil temperatures in 2019 are greater than 2020 and average values. Figure 2.43 gives a graphical representation of average annual soil temperature at 50 cm depth between 1970 and 2020. It can be inferred that while the highest soil temperature is observed in Günaydoğu, Akdeniz and Ege regions, the lowest soil temperature is seen in İç Anadolu and Doğu Anadolu regions.

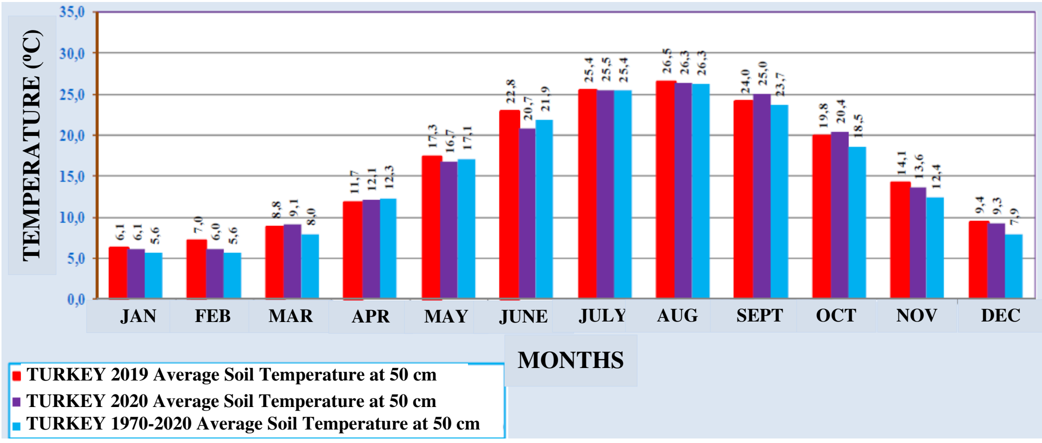


Figure 2.42 Average soil temperature at 50 cm depth for each month in 1970-2020 with respect to average soil temperature at 50 cm depth in 2019 and 2020 [19]

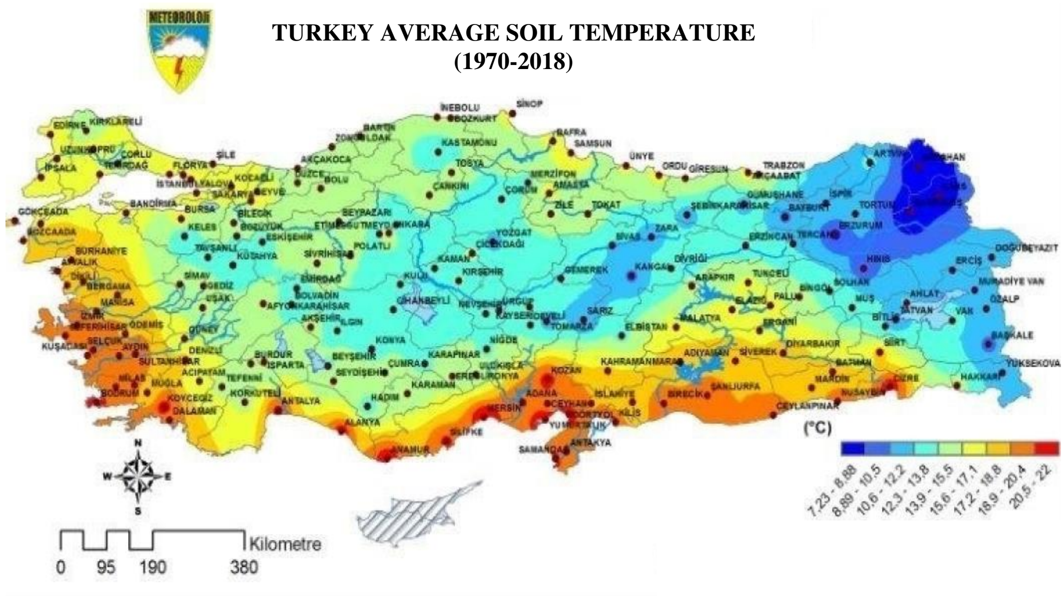


Figure 2.43 A graphical representation of average annual soil temperature at 50 cm depth between 1970 and 2020 [19]

2.8 The Number of Days Covered with Snow

In this section, the change in the number of days covered with snow in Turkey was investigated. The number of days covered with snow data is obtained from Turkish Directorate of Meteorology (TDM). Average annual soil temperature is determined by considering 94 different measurement stations in different places of Turkey according to TDM. Soil temperature values are taken for each year between 1970 and 2018.

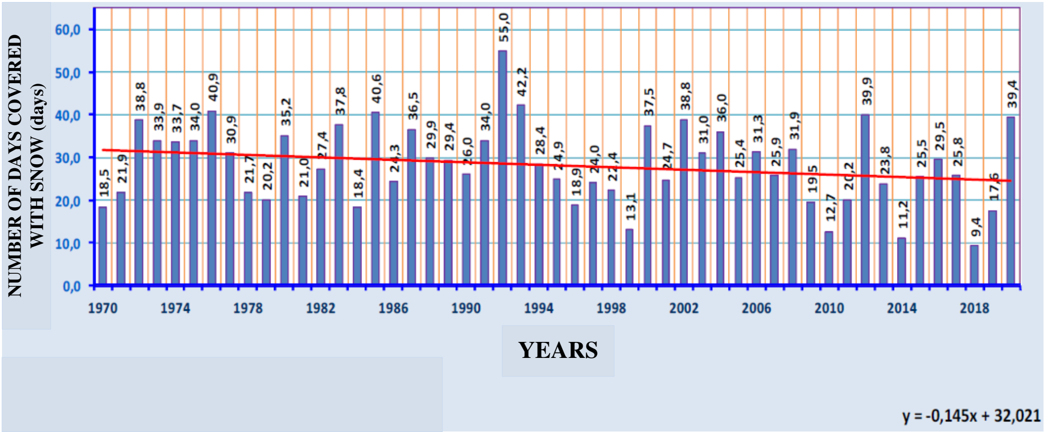


Figure 2.44 Average annual number of days covered with snow between 1970 and 2020 [19]

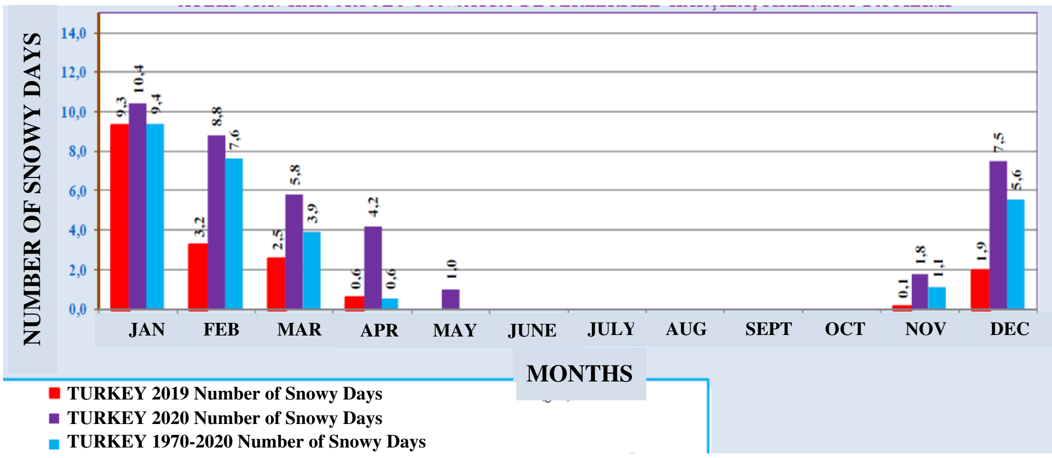


Figure 2.45 Average number of days covered with snow for each month in 1970-2020 with respect to average number of days covered with snow in 2019 and 2020 [19]

Figure 2.44 demonstrates average annual number of days covered with snow between 1970 and 2020. While the greatest number of days covered with snow is obtained in 1992 as 55 days, the least temperature is observed in 2018 as 9.4 days. Figure 2.45 shows average number of days covered with snow for each month in 1970-2020 with respect to average number of days covered with snow in 2019 and 2020. It can be inferred that the number of days covered with snow decreases drastically in 2019. However, there is a great increase in 2020 compared to previous year and average value.

CHAPTER III

ANALYSIS OF CLIMATE DATA IN TURKEY

3.1 Introduction

In this chapter, climate data in Turkey was deeply investigated. For this reason, trend analysis of the measurements given in Chapter II was presented to see how the climate data behaves. Then, Van Lake basin was taken as a case study to insert another degree of freedom to the study in terms of investigating the effects of climate parameters on hydrological parameters and variations in temperature, precipitation, flow and lake level parameters were investigated.

3.2 Trend Analysis Methods

Since hydrological parameters are randomly and continuously changing parameters, special analysis methods are required to obtain the trend of the data that is measured. Classical parametric methods do not help since they include assumptions like normality, linearity and independence [28], [29]. That is why using non-parametric techniques are more suitable for analyzing hydrological data than parametric techniques [30], [31]. In this work, three types of trend analysis techniques which are Pearson correlation coefficient, Spearman's Rho and Mann-Kendall and tests were used.

3.2.1 Pearson Correlation Coefficient Test

Pearson correlation coefficient is the most widely used measure of correlation among researchers and refers to the linear relationship between the two variables or real-valued vectors [32]. In Pearson correlation coefficient test, it is aimed to draw a line which is the best fit among two sets of variables. Then Pearson correlation coefficient states how far the two sets of data samples from the best fit line. The formula to describe the Pearson correlation coefficient is as follows [33],[34]:

$$r_P = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}} \tag{3.1}$$

where $\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$ and $\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$ refer to mean of x and y respectively. Moreover, n is the number of samples and r_p is the Pearson correlation coefficient.

Pearson correlation coefficient r_p takes values between -1 and +1. A positive r_p refers to positive correlation and a negative r_p indicates negative correlation between the two sets of variables [35]. The more r_p gets close to -1 or +1, the more the correlation between the two sets of variables becomes stronger. Strength of the correlation can be described using the Table 3.1 [36].

Table 3.1 Strength of correlation with respect to correlation coefficient

$\lvert r_p \rvert$ or $\lvert r_s \rvert$	**Relationship**
0 – 0.2	Very Weak
0.2 – 0.4	Weak
0.4 – 0.6	Moderate
0.6 – 0.8	Strong
0.8 – 1	Very Strong

3.2.2 Spearman's Rho

Spearman's correlation coefficient is a statistical measure of the strength of a monotonic relationship between paired data. In a sample, it is denoted by $r_s$and is by design constrained as follows [19]:

$$-1 \leq r_s \leq 1 \tag{3.2}$$

The closer r_s is to +1 or -1, stronger the monotonic relationship. Correlation is an effect size and so the strength of the correlation can be described with respect to the correlation coefficient r_s as seen in Table 3.1.

$$r_s = 1 - 6\frac{\sum_{i=1}^{n}(R_{xi} - i)^2}{(n^3 - n)} \tag{3.3}$$

$$Z = r_s\sqrt{n-1} \tag{3.4}$$

Correlation coefficient r_s can be calculated using equation (3.2). In equation (3.3), R_{xi} can be determined by ordering the data from small to large or vice versa. Here, n is the number of samples that are used in the data. According to correlation coefficient r_s, a null hypothesis (H_0) is determined.

Confidence in a relationship is formally determined not just by the correlation coefficient but also by the number of pairs in your data. If there are very few pairs then the coefficient needs to be very close to 1 or –1 for it to be deemed "statistically significant", but if there are many pairs then a coefficient closer to 0 can still be considered "highly significant". The standard method that statisticians use to measure the significance of their empirical analyses is the p-value. If number of samples is greater than 30, normal distribution tables are used to determine the p-value. If p-value is greater than some predetermined significance level, it is concluded that not enough evidence exists to reject the null hypothesis.

3.2.3 Mann-Kendall Test

The Mann-Kendall Test is used to analyze data collected over time for consistently increasing or decreasing trends. It is a non-parametric test, which means it works for all distributions [37]. The null hypothesis H_0 for this test is that there is no trend in the series [26]. The three alternative hypotheses are that there is a negative, non-null, or positive trend. In this test, the series (x_1, x_2, x_3, …., x_n) is divided into two parts. For i < j, the number of (x_i, x_j) couples that have the property of $x_i < x_j$ is called P, and the number of (x_i, x_j) couples that have the property of $x_i > x_j$ is M. Under these circumstances, test statistics S can be calculated as [24]

$$S = P - M \tag{3.5}$$

Using equation (3.5), Kendall correlation coefficient τ can be calculated as

$$\tau = \frac{S}{n(n-1)/2} \tag{3.6}$$

Moreover, for n is greater or equal to 10,

$$\sigma_s = \sqrt{n(n-1)(2n+5)/18} \tag{3.7}$$

$$\left.\begin{aligned} Z &= \frac{S-1}{\sigma_s}, & S > 0 \\ Z &= 0, & S = 0 \\ Z &= \frac{S+1}{\sigma_s}, & S < 0 \end{aligned}\right\} \tag{3.8}$$

Here, Z is the standard normal distribution of the series. It can be used to determine the p-value of the correlation using standard distribution table. Again, if p-value is greater than some predetermined significance level, it is concluded that not enough evidence exists to reject the null hypothesis [18], [25], [38].

It should be noted that if there are same observations in the series, σ_s can be calculated as follows:

$$\sigma_s = \sqrt{\left[n(n-1)(2n+5) - \sum_i t_i(t_i-1)(2t_i+5)\right]/18} \tag{3.9}$$

Here, t_i represents the number of samples that are the same.

3.3 Trend Analysis of Climate Data in Turkey

In this section, trend analysis of climate data in Turkey will be held for Pearson Correlation coefficient, Spearman’s Rho and Mann-Kendall tests.

3.3.1 Temperature

Pearson Correlation coefficient, Spearman’s Rho and Mann-Kendall test results for temperature data of Turkey were given in Table 3.2. According to Pearson correlation coefficient test, it is observed that there is a strong increasing trend in temperature in years. On the other hand, according to Spearman’s Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be rejected since p-value is much lower than the predetermined significance level ($\alpha = 0.05$) for both tests. Moreover, considering r_s and τ, it can be said that there is a strong increasing trend and moderately increasing trend in temperature according to Spearman’s Rho and Mann-Kendall tests respectively.

Table 3.2 Turkey temperature data test results

Test Name	r_s , r_p or τ	p-value
Pearson	0.681	-
Spearman's Rho	0.707	6.81e-9
Mann-Kendall	0.531	6.52e-8

3.3.2 Precipitation

Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for precipitation data of Turkey were given in Table 3.3. According to Pearson correlation coefficient test, it is observed that there is no trend in precipitation in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be accepted since p-value is much higher than the predetermined significance level ($\alpha = 0.05$) for both tests. Hence, conclusion is achieved that there is no trend in precipitation data of Turkey considering all three tests.

Table 3.3 Turkey precipitation data test results

Test Name	r_s or τ	p-value
Pearson	0.047	-
Spearman's Rho	0.049	0.733
Mann-Kendall	0.031	0.758

3.3.3 Moisture

Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for moisture data of Turkey were given in Table 3.4. According to Pearson correlation coefficient test, it is observed that there is a moderate decreasing trend in moisture in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be rejected since p-value is much lower than the predetermined significance level ($\alpha = 0.05$) for both tests. Moreover, considering r_s and τ, it can be said that there is a moderately decreasing trend and weak decreasing trend in moisture according to Spearman's Rho and Mann-Kendall tests respectively.

Table 3.4 Turkey moisture data test results

Test Name	r_s or τ	p-value
Pearson	-0.46	-
Spearman's Rho	-0.47	5.45e-4
Mann-Kendall	-0.30	0.0023

3.3.4 Evaporation

Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for evaporation data of Turkey were given in Table 3.5. According to Pearson correlation coefficient test, it is observed that there is a weak increasing trend in evaporation in years. Furthermore, according to Spearman's Rho test, null hypothesis which is no trend is available can be rejected since p-value is lower than the predetermined significance level ($\alpha = 0.05$). Adding the value of r_s on the conclusion, it can be said that there is a weak increasing trend in evaporation according to Spearman's Rho test. On the other hand, according to Mann-Kendall test, null hypothesis which is no trend is available can be accepted since p-value is much higher than the predetermined significance level ($\alpha = 0.05$). Hence, conclusion is achieved that there is no trend in evaporation according to Mann-Kendall test.

Table 3.5 Turkey evaporation data test results

Test Name	r_s or τ	p-value
Pearson	0.30	-
Spearman's Rho	0.33	0.049
Mann-Kendall	0.22	0.074

3.3.5 Seawater Temperature of Mediterranean Sea

Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for seawater temperature data of Mediterranean Sea were given in Table 3.6. According to Pearson correlation coefficient test, it is observed that there is a very strong increasing trend in seawater temperature data of Mediterranean Sea in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be rejected since p-value is much lower than the predetermined significance level ($\alpha = 0.05$) for both tests. Moreover, considering r_s and τ, it can be said that there is a very strong increasing trend and strong increasing trend in seawater temperature data of Mediterranean Sea according to Spearman's Rho and Mann-Kendall tests respectively.

Table 3.6 Mediterranean Sea water temperature data test results

Test Name	r_s or τ	p-value
Pearson	0.83	-
Spearman's Rho	0.81	1.32e-12
Mann-Kendall	0.64	2.14e-10

3.3.6 Soil Temperature at 50 cm Depth

Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for soil temperature data of Turkey were given in Table 3.7. According to Pearson correlation coefficient test, it is observed that there is a strong increasing trend in soil temperature data at 50 cm depth in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be rejected since p-value is much lower than the predetermined significance level ($\alpha = 0.05$) for both tests. Moreover, considering r_s and τ, it can be said that there is a strong increasing trend and moderately increasing trend in soil temperature data at 50 cm depth according to Spearman's Rho and Mann-Kendall tests respectively.

Table 3.7 Soil temperature data test results

Test Name	r_s or τ	p-value
Pearson	0.66	-
Spearman's Rho	0.69	2.58e-8
Mann-Kendall	0.50	3.81e-7

3.3.7 Number of Snowy Days

Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for number of snowy days data of Turkey were given in Table 3.8. According to Pearson correlation coefficient test, it is observed that there is a weak decreasing trend in number of snowy days in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be accepted since p-value is much higher than the predetermined significance level (α = 0.05) for both tests. Hence, conclusion is achieved that there is no trend in number of snowy days data of Turkey considering both tests.

Table 3.8 Number of snowy days data test results

Test Name	r_s or τ	p-value
Pearson	-0.24	-
Spearman's Rho	-0.21	0.14
Mann-Kendall	-0.15	0.13

3.4 Case Study: Trend Analysis of Climate Data in Van Lake Basin

In this section, Van Lake basin was taken as a case study to insert another degree of freedom to the study in terms of investigating the effects of climate parameters on hydrological parameters. For this reason, average temperature, precipitation, flow and lake level parameters of Van Lake basin is obtained between 1980 and 2016 from [39].

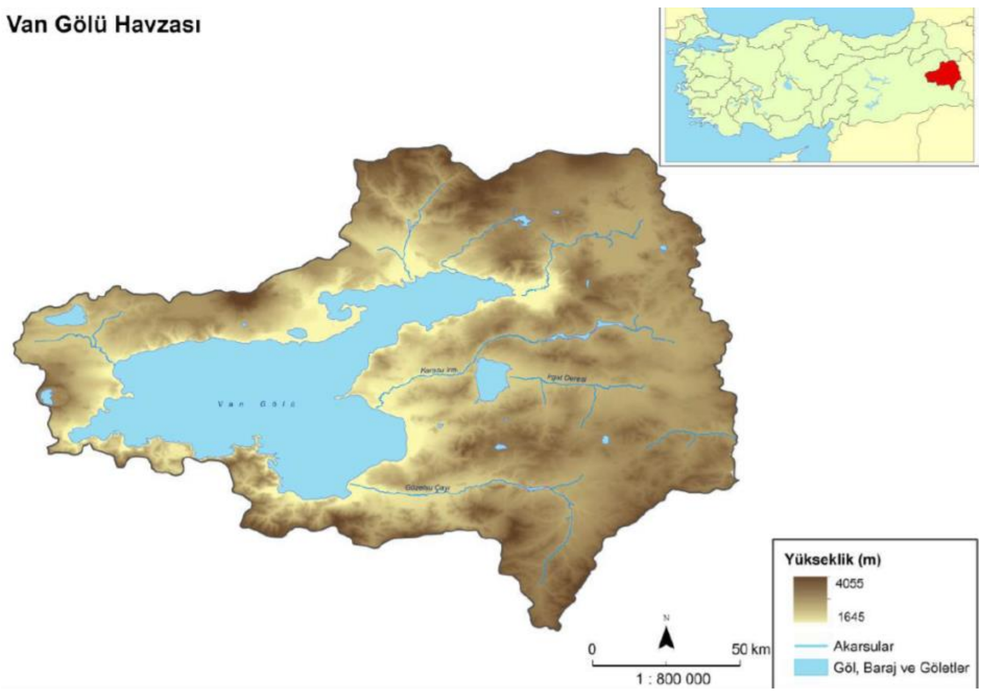


Figure 3.1 Van Lake basin and its position in Turkey map [39]

Similar to what has been done to climate data of Turkey, trend analysis of each parameter was held by using Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall tests. Furthermore, correlation analysis of those parameters between each other was held to see if climate parameters directly or indirectly affect hydrological parameters in Van Lake basin. Figure 3.1 shows Van Lake basin and its position in Turkey map.

3.4.1 Temperature of Van Lake

Here, temperature data of Van Lake were analyzed. Figure 3.2 demonstrates average annual temperature data of Van Lake basin between 1980 and 2016.

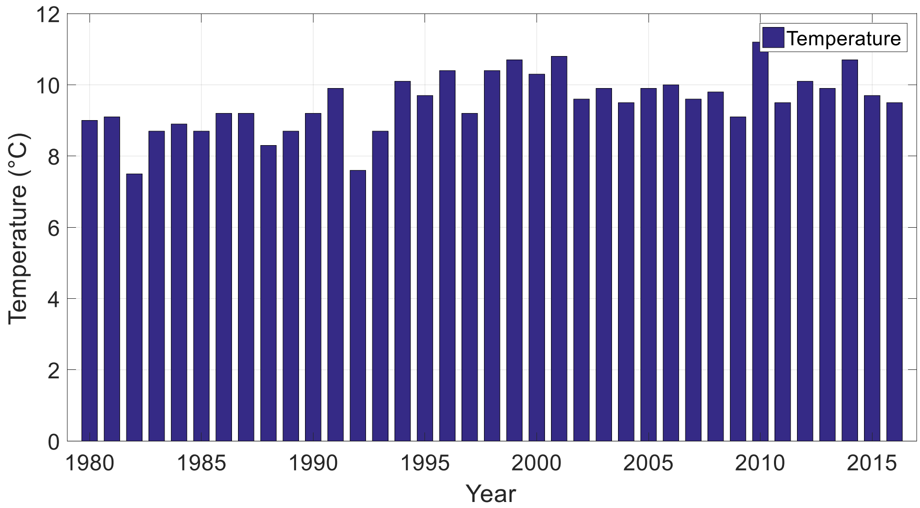


Figure 3.2 Average annual temperature data of Van Lake basin between 1980 and 2016

Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for temperature data of Van Lake basin are given in Table 3.9. According to Pearson correlation coefficient test, it is observed that there is a moderately increasing trend in temperature in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be rejected since p-value is much lower than the predetermined significance level (α = 0.05) for both tests. Moreover, considering r_s and τ, it can be said that there is a moderately increasing trend and weak increasing trend in temperature of Van Lake basin according to Spearman's Rho and Mann-Kendall tests respectively.

Table 3.9 Temperature data test results for Van Lake basin

Test Name	r_s or τ	p-value
Pearson	0.59	-
Spearman’s Rho	0.6	9.01e-5
Mann-Kendall	0.4	7.13e-4

3.4.2 Precipitation of Van Lake

Here, precipitation data of Van Lake were analyzed. Figure 3.3 demonstrates average annual precipitation data of Van Lake basin between 1980 and 2016.

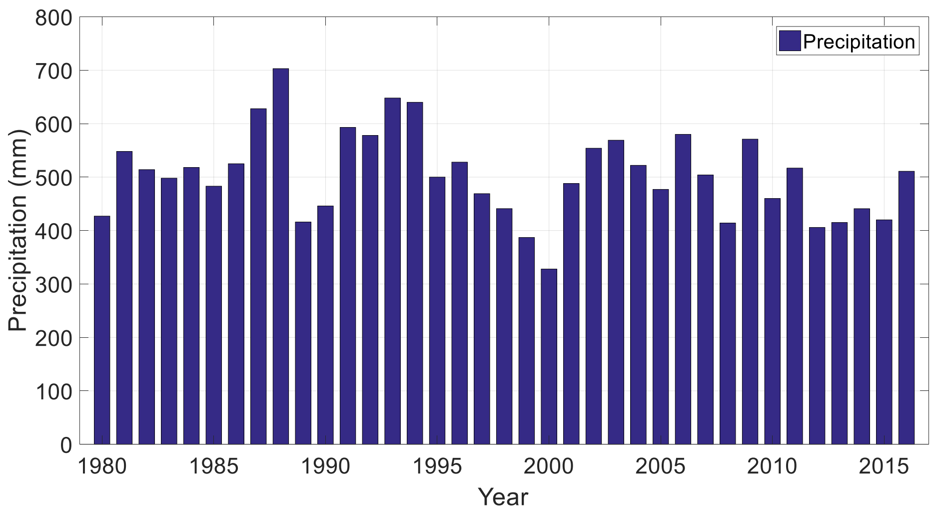


Figure 3.3 Average annual precipitation data of Van Lake basin between 1980 and 2016

Pearson Correlation coefficient, Spearman’s Rho and Mann-Kendall test results for precipitation data of Van Lake basin are given in Table 3.10. According to Pearson correlation coefficient test, it is observed that there is a weak decreasing trend in precipitation in years. It can be said that r_s and τ generate a null hypothesis such that there is a weak decreasing trend in precipitation. On the other hand, according to Spearman’s Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be accepted since p-value is much higher than the predetermined significance level ($\alpha = 0.05$) for both tests. Hence, conclusion is achieved that there is no trend in precipitation of Van Lake basin considering both tests.

Table 3.10 Precipitation data test results for Van Lake basin

Test Name	**r_s or τ**	**p-value**
Pearson	-0.29	-
Spearman's Rho	-0.29	0.08
Mann-Kendall	-0.19	0.10

3.4.3 Flow of Van Lake

Here, flow data of Van Lake were analyzed. Figure 3.4 demonstrates average annual flow data of Van Lake basin between 1980 and 2016.

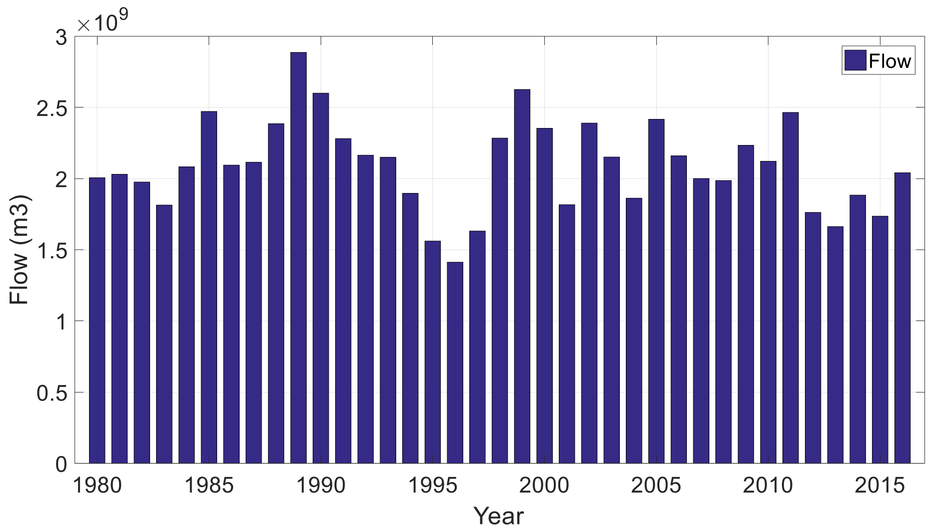


Figure 3.4 Average annual flow data of Van Lake basin between 1980 and 2016

Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for flow data of Van Lake basin are given in Table 3.11. According to Pearson correlation coefficient test, it is observed that there is a very weak decreasing trend in flow in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be rejected since p-value is much lower than the predetermined significance level (α = 0.05) for both tests. Moreover, considering r_s and τ, it can be said that there is a very weak increasing trend in flow of Van Lake basin considering both tests. Hence, conclusion is achieved that there is a very weak decreasing trend in flow of Van Lake basin considering all three tests.

Table 3.11 Flow data test results for Van Lake basin

Test Name	r_s or τ	p-value
Pearson	-0.18	-
Spearman's Rho	-0.15	0.036
Mann-Kendall	-0.09	0.046

3.4.4 Lake Level of Van Lake

Here, level data of Van Lake were analyzed. Figure 3.5 demonstrates average annual level data of Van Lake basin between 1980 and 2016.

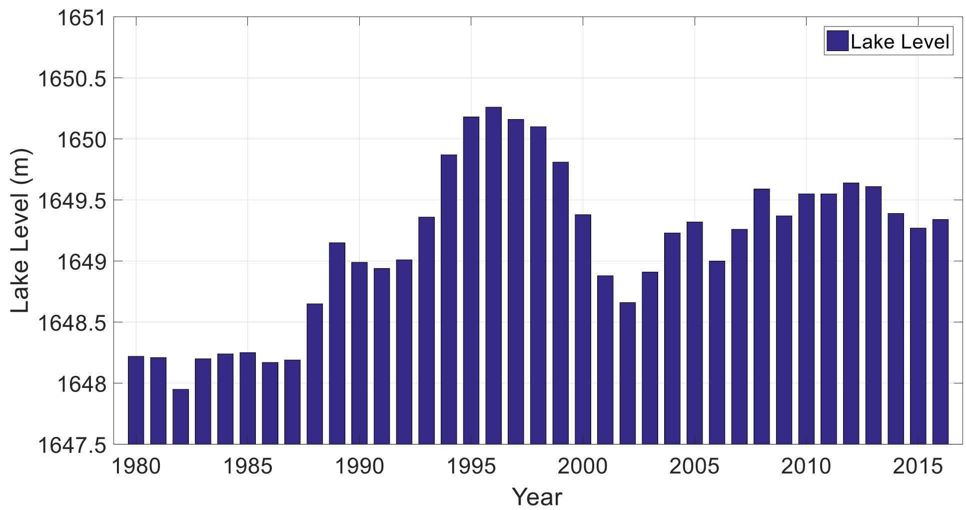


Figure 3.5 Average annual level data of Van Lake basin between 1980 and 2016

Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for level data of Van Lake basin are given in Table 3.12. According to Pearson correlation coefficient test, it is observed that there is a moderately increasing trend in lake level in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be rejected since p-value is much lower than the predetermined significance level (α = 0.05) for both tests. Moreover, considering r_s and τ, it can be said that there is a moderately increasing trend and weak increasing trend in lake level of Van Lake basin according to Spearman's Rho and Mann-Kendall tests respectively.

Table 3.12 Level data test results for Van Lake basin

Test Name	r_s or τ	p-value
Pearson	0.60	-
Spearman's Rho	0.60	1.07e-4
Mann-Kendall	0.42	2.50e-4

3.4.5 Correlation of Precipitation and Flow of Van Lake

Here, correlation between precipitation and flow data of Van Lake were analyzed. Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for precipitation and flow data of Van Lake basin are given in Table 3.13. According to Pearson correlation coefficient test, it is observed that there is simply no trend between precipitation and flow in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be accepted since p-value is much higher than the predetermined significance level (α = 0.05) for both tests. Hence, conclusion is achieved that there is no trend between precipitation and flow of Van Lake basin considering both tests. The reasons for this no correlation can be given as follows:

- Not all flow measurements are obtained for long years.
- The challenges to obtain precise measurements in evaporation due to the differences in factors such as summer-winter, night-day and slope.

Table 3.13 Precipitation vs. flow test results for Van Lake basin

Test Name	r_s or τ	p-value
Pearson	-0.006	-
Spearman's Rho	0.09	0.61
Mann-Kendall	0.08	0.51

3.4.6 Correlation of Precipitation and Level of Van Lake

Here, correlation between precipitation and level data of Van Lake will be analyzed. Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for precipitation and level data of Van Lake basin are given in Table 3.14. According to

Pearson correlation coefficient test, it is observed that there is a weak decreasing trend between precipitation and level data of Van Lake in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be rejected since p-value is lower than the predetermined significance level ($\alpha = 0.05$) for both tests. Moreover, considering r_s and τ, it can be said that there is a weak decreasing trend and very weak decreasing trend between precipitation and level data of Van Lake basin according to Spearman's Rho and Mann-Kendall tests respectively. The reasons for this weak decreasing correlation can be given as follows:

- Underground waters reach to the lake with a time delay.
- The problems in measuring surface waters due to heavy rains and snow melts.

Table 3.14 Precipitation vs. level test results for Van Lake basin

Test Name	r_s or τ	p-value
Pearson	-0.26	-
Spearman's Rho	-0.35	0.03
Mann-Kendall	-0.23	0.04

3.4.7 Correlation of Temperature and Level of Van Lake

Here, correlation between temperature and level data of Van Lake were analyzed. Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for temperature and level data of Van Lake basin are given in Table 3.15. According to Pearson correlation coefficient test, it is observed that there is a moderately increasing trend in between temperature and level data in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be rejected since p-value is much lower than the predetermined significance level ($\alpha = 0.05$) for both tests. Moreover, considering r_s and τ, it can be said that there is a moderately increasing trend and weak increasing trend between temperature and level data of Van Lake basin according to Spearman's Rho and Mann-Kendall tests respectively.

Table 3.15 Temperature vs. level test results for Van Lake basin

Test Name	r_s or τ	p-value
Pearson	0.56	-
Spearman's Rho	0.58	1.45e-4
Mann-Kendall	0.41	4.60e-4

3.4.8 Correlation of Temperature and Flow of Van Lake

Here, correlation between temperature and flow data of Van Lake were analyzed. Pearson Correlation coefficient, Spearman's Rho and Mann-Kendall test results for temperature and flow data of Van Lake basin are given in Table 3.15. According to Pearson correlation coefficient test, it is observed that there is a very weak decreasing trend between temperature and flow data of Van Lake basin in years. On the other hand, according to Spearman's Rho and Mann-Kendall tests, null hypothesis which is no trend is available can be accepted since p-value is much higher than the predetermined significance level ($\alpha = 0.05$) for both tests. Hence, conclusion is achieved that there is no trend between precipitation and flow of Van Lake basin considering both tests.

Table 3.16 Temperature vs. flow test results for Van Lake basin

Test Name	r_s or τ	p-value
Pearson	-0.17	-
Spearman's Rho	-0.17	0.32
Mann-Kendall	-0.12	0.31

CHAPTER IV

CONCLUSIONS

The reasons of climate change can be mainly divided into two main groups which are greenhouse gases and human factors. Increase in the greenhouse gas (GHG) concentrations in the atmosphere is the main cause of the climate change in the world. Humans are changing the climate of the world by burning of fossil fuels, urbanization, deforestation, agriculture, and industrial processes. Since the Industrial Revolution, atmospheric concentrations of GHGs have increased significantly by human-caused factors as stated above. Effects of climate change on water resources have attracted a widespread interest among researchers during the last decade. To investigate the changes in both climate and hydrological parameters, trend analysis methods should be used. Detecting trends in hydrological and climate parameters have attracted a considerable interest among researchers during last decades. Trend detection plays a key role in revealing the climate change during a period of time and forecasting the direction of climate change for future planning. Recent improvements on trend detection methods make it easier to investigate both climate change and water resources and to detect changes and any trends on those parameters.

Trend analysis methods are mainly divided into two main groups which are parametric (distribution dependent) tests and non-parametric (distribution-free) tests. As the name suggests, parametric tests depend on the data set. On the other hand, non-parametric tests do not have the dependence on the data set and provide accurate results even in the absence of some part of the data set. Furthermore, the power and significance of the test result are not intervened by the actual distribution of the data set. Hence, it can be said that non-parametric tests are more suitable to investigate trends in hydrological and climate parameters since those parameters are generally skewed and contamination by outliers is possible. The most commonly used non-parametric tests are Pearson correlation coefficient test, Spearman’s Rho test and Mann-Kendall test.

Multiple researchers have used non-parametric trend analysis methods to investigate the change in climate and hydrological parameters on different regions of the world. Furthermore, trend analysis of climate and hydrological parameters in Turkey has also been held by various researchers.

In this work, Pearson correlation coefficient test, Spearman’s Rho test and Mann-Kendall test were employed to analyze trends in climate parameters of Turkey and both climate and hydrological parameters of Van Lake basin. Firstly, how climate changed over the past 50 years was analyzed in terms of average annual temperature, precipitation, evaporation, moisture, sea water temperatures, soil temperature and number of snowy days in Turkey. Then, these climate parameters were analyzed by the abovementioned non-parametric trend analysis techniques and their trends were evaluated. Moreover, Van Lake basin was taken as a case study to insert another degree of freedom to the study in terms of investigating the effects of climate parameters on hydrological parameters and variations in temperature, precipitation, flow and lake level parameters were investigated. Again, trends of those climate and hydrological variables were evaluated. In addition to this, correlation of those parameters was obtained to see if climate parameters directly or indirectly affect hydrological parameters in Van Lake basin.

In this work, Pearson correlation coefficient test, Spearman’s Rho test and Mann-Kendall test were employed to analyze trends in climate parameters of Turkey and both climate and hydrological parameters of Van Lake basin. Firstly, how climate changed over the past 50 years was analyzed in terms of average annual temperature, precipitation, evaporation, moisture, sea water temperatures, soil temperature and number of snowy days in Turkey. Then, these climate parameters were analyzed by the abovementioned non-parametric trend analysis techniques and their trends were evaluated. It is implied from the results that while Pearson Correlation coefficient and Spearman’s Rho tests provide similar trend results for different climate variables, Mann-Kendall test tends to output results that are more of a no trend side of the spectrum. Another observation is that although most of the time Spearman’s Rho and Mann-Kendall tests agree upon accepting or rejecting null hypothesis, there is a single case where they disagree on accepting the null hypothesis which is evaporation data of Turkey. It is also inferred from the results that while temperature is increasing in a substantial amount, precipitation and flow decreases rapidly. Hence, it can be said that the climate change around the world are also reflected on the climate parameters of Turkey.

Moreover, Van Lake basin was taken as a case study to insert another degree of freedom to the study in terms of investigating the effects of climate parameters on hydrological parameters and variations in temperature, precipitation, flow and lake level parameters were investigated. Again, trends of those climate and hydrological variables were evaluated. In addition to this, correlation of those parameters was obtained to see if climate parameters directly or indirectly affect hydrological parameters in Van Lake basin. Similar to the results of climate variables of Turkey, Pearson Correlation coefficient and Spearman's Rho tests provide similar correlation results for different climate variables, Mann-Kendall test gives somewhat different results compared to the other two. Regarding the climate parameters, similar results have been obtained in Van Lake basin compared to climate parameters of Turkey. Temperature has greatly increased for the past decades in Van Lake basin. However, it should be noted that the increase in Turkey in general is greater than the increase in Van Lake basin. Furthermore, precipitation has also decreased in Van Lake basin which shows us the climate change has affected Van Lake basin as well. Regarding the correlation between climate and hydrological parameters of Van Lake basin, it can be said that the decrease in precipitation has affected the lake level, however some other unmeasurable factors result in an increase in lake level. Moreover, flow of Van Lake basin has been unaffected by neither temperature nor precipitation. Further studies may be required to investigate the relationships between climate and hydrological parameters of Van Lake basin.

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