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The Effect of Global Climate Change on Monthly and Annual Precipitation Amounts in Bingöl Province (Turkey)

Sebahattin KAYA [1*]

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Abstract

Climate change is an important problem that has emerged as a result of global warming. Because climate change causes changes in precipitation characteristics, it has an impact on precipitation and therefore on water resources. For this reason, it is important to investigate the effect of climate change on precipitation. In this research, trend analyzes of monthly and annual amounts of precipitation observed in the 60-year period between 1961 and 2020 at Bingöl Meteorology Station were made. Mann-Kendall test, Spearman Rho test and Sen`s slope test were used for trend analysis. It has been determined that there is a statistically insignificant decrease trend in the precipitation amounts of February, April, November, and December; while there is a statistically insignificant increase trend in the precipitation amounts of January, March, May, June, August, September, and October. It has been determined that there is a statistically insignificant decreasing trend in the annual precipitation amount. According to the Mann-Kendal and Spearman Rho tests, there is a statistically insignificant decrease trend in the precipitation amount in July, and there is no trend according to Sen`s slope test.

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Küresel İklim Değişikliğinin Bingöl İli Aylık ve Yıllık Yağış Miktarlarına Etkisi

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Öz

İklim değişikliği küresel ısınmanın sonucu olarak ortaya çıkmış olan önemli bir sorundur. İklim değişikliği yağış özelliklerinin değişmesine neden olduğu için yağışlar ve dolayısıyla su kaynakları üzerinde etkili olmaktadır. Bu nedenle iklim değişikliğinin yağışlar üzerindeki etkisinin araştırılması önemli olmaktadır. Bu araştırmada, Bingöl Meteoroloji İstasyonunda 1961-2020 yılları arasındaki 60 yıllık dönemde gözlenmiş olan yağışların aylık ve yıllık miktarlarının eğilim analizleri yapılmıştır. Eğilim analizlerinin yapılmasında Mann-Kendal testi, Spearman Rho testi ve Sen`in eğim testi kullanılmıştır. Şubat, Nisan, Kasım ve Aralık ayları yağış miktarlarında istatistiksel olarak önemsiz bir azalma eğiliminin olduğu, Ocak, Mart, Mayıs, Haziran, Ağustos, Eylül ve Ekim ayları yağış miktarlarında ise istatistiksel olarak önemsiz bir artış eğiliminin olduğu belirlenmiştir. Yıllık yağış miktarında da istatistiksel olarak önemsiz bir azalma eğilimi olduğu belirlenmiştir. Temmuz ayı yağış miktarında ise Mann-Kendal ve Spearman Rho testlerine göre istatistiksel yönden önemli olmayan bir azalış eğilimi, Sen`in eğim testine göre ise bir eğilim olmadığı belirlenmiştir.

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[1] *Corressponding author, https://orcid.org/0000-0003-3007-4177, Bingöl Üniversitesi Ziraat Fakültesi, Biyosistem Mühendisliği Bölümü, Bingöl, Türkiye, skaya@bingol.edu.tr.

Introduction

Today, the demand for water; it is increasing rapidly due to the efforts to increase agricultural production as a result rapid population growth and industrialization. However, the available water resources are quite limited in some regions and it is necessary to make the best use of these resources (Saplıoglu and Coban, 2013).

Turkey is not a country having rich water resources in terms of water per capita. Due to the increase in water use as a result of changing climatic conditions and increasing population, planned use of water resources, protection and development of water resources have become mandatory in order to avoid water shortages (Tokgoz and Partal, 2020).

Global warming, which has direct and indirect effects on water resources, increases the importance of water and water resources. As a result of global warming, serious problems are experienced in water resources and it is expected to cause a decrease in agricultural and forest products, energy shortage, and population movement from coastal areas to inland parts. In order to protect the ecological balance and ensure the sustainable development of human communities, water resources must be used in a way that can meet current and future needs (Karaman and Gokalp, 2010).

One of the important effects of climate change due to global warming occurs in precipitation. As a climate element, precipitation is one of the most variable parameters in terms of time and space. In addition, since precipitation is one of the most influential parameters on the hydrological cycle, it is one of the most vital climatic events that affect human life positively and negatively (Köyceğiz and Buyukyildiz, 2019).

Because climate change affects the structure, spatial and temporal distribution, intensity, duration and amount of precipitation, it has an impact on precipitation and therefore on water resources. Changes in precipitation due to climate change may cause very important problems in terms of hydrology and water resources (Kanber et al., 2010). Therefore, identifying precipitation trends is important in planning water resource management projects and flood mitigation infrastructure. The trend in precipitation has been extensively studied by many researchers (Lazaro et al., 2001; Partal and Kahya, 2006; Besel and Kayikci, 2016; Nourani et al., 2018; Buyukkaracigan, 2019; Köycegiz and Buyukyildiz, 2019; Coskun, 2020; Tokgoz and Partal, 2020) using different methods at global and regional scales. This research was carried out to determine the change in precipitation values due to climate change and the amount of future precipitation depending on this change, especially in Bingöl Plain, which has a dry summer season.

Material and Method

In this research, monthly averages of daily precipitation data observed at Bingöl Meteorological Station of the General Directorate of Meteorology of the Republic of Turkey, which was located in the Central district of Bingöl province, during the 60-year period between 1961 and 2020 were used. Bingöl province is located between 38°29' and 39°32' northern latitudes and 39°55' and 41°15' east longitudes in the Upper Euphrates section of the Eastern Anatolia Region (Anonymous, 2023). Bingöl Meteorology Station has the coordinates 38°53' north - 40°30' east and is 1139 m above sea level (Anonymous, 2021). Bingöl is bordered by Erzincan and Erzurum in the north, Diyarbakır in the south Muş in the east and Tunceli and Elazığ in the west.

The precipitation regime of Bingöl province reflects the continental precipitation regime. However, when the climatic conditions in the region are considered as a whole, it is seen that it has a unique feature between the Mediterranean and the continental regime (Soylu, 2013). Some meteorological data observed in Bingöl Meteorology Station between 1961 and 2018 are given in Table 1 (Anonymous, 2021).

Table 1. Some perennial climate values of Bingöl province (1961-2018)

Months	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Annual
Mean Temp. (°C)	2.4	-1.2	4.1	10.7	16.1	21.9	26.6	26.4	21.2	14.2	6.7	0.5	12.1
Mean Max. Temp. (°C)	2.2	3.7	9.4	16.6	22.8	29.3	34.5	34.7	29.7	21.4	12.5	5.0	18.5
Mean Min. Temp. (°C)	-6.0	-5.0	-0.2	5.7	10.1	14.7	19.0	18.6	13.6	8.2	2.2	-2.9	6.5
Mean Sunshine Duration (hours day^{-1})	3.3	4.3	4.9	5.6	7.1	9.2	9.5	9.0	8.2	6.0	4.4	3.1	6.2
Mean Rainy Day	12.8	12.4	13.8	14.9	14.0	5.5	1.7	1.3	2.6	8.5	9.3	12.8	109.6
Mean Rainfall (mm)	138.4	131.9	127.5	116.5	75.9	21.3	5.6	3.1	11.5	66.7	107.3	137.6	943.3

Non-parametric Mann-Kendal and Spearman's Rho test and Sen's slope test were used to determine whether the monthly and annual mean precipitation values have changed over time (from year to year) and if there is, whether the change is increasing or decreasing. Two methods, parametric and non-parametric methods, are used in trend research. In parametric methods, the actual value of the data is used, while in non-parametric methods, the sequence number obtained by sorting the data is used, so the data do not have to comply with the normal distribution. Also, parametric test assumptions are not sought in non-parametric tests (Arslan, 2017). In these tests, there are assumptions such as the independence of the data and their random selection. However, they are easier and fewer assumptions than the assumptions in parametric tests (Besel and Kayikci, 2016). XLSTAT software program was used to analyze according to Mann-Kendall and Sen's slope tests (Anonymous, 2022), and JMP16 software program was used to analyze according to Spearman's Rho test (SAS, 2022).

Mann-Kendall test

The non-parametric Mann-Kendall test is a frequently used test to determine the statistical significance of increasing or decreasing trends in hydrometeorological time series (Yue and Wang, 2022). It is a specific implementation of Kendall's test known as Tau. In this method, the order of the data is more important than the size. Particularly useful as it can also be used in case of missing data and the data does not have to fit a distribution (Cosun and Karabulut, 2009a; Cosun and Karabulut, 2009b).

In the Mann-Kendall test; according to the H_0 hypothesis, the time-ordered (x_1, x_2, … , x_n) observation values are time-independent and similarly distributed random variables. The alternative hypothesis H_1

of a two-sided test is that the distributions of x_i and x_j are not identical for all ($i, \leq n$) with ($i \neq j$). The Mann-Kendall test (S), which has a mean of zero (0) and the variance calculated by the equation (3), is calculated using the equations (1) and (2) below and is asymptotically normal (Tabari et al., 2011).

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i) \tag{1}$$

Here n is the data length in years, *sign* is the sign function. The trend test is applied to the data set x_i sorted by $i = 1, \ldots, n-1$ and the data set x_j sorted by $j = i+1, \ldots, n$. When S is $n \geq 8$, it shows approximately normal distribution with mean and variance. If $n \geq 30$, the z-test approaches the t-test. The sign function, *sign*, specified in the above formula is compared with the other sorted data set x_j by taking x_i as a reference point as shown in the equation below.

$$sign(x_j - x_i) = \begin{Bmatrix} 1\ ;\ x_j > x_i \\ 0\ ;\ x_j = x_i \\ -1\ ;\ x_j < x_i \end{Bmatrix} \tag{2}$$

The variance of S is calculated with the following equation.

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{k} t_i(t_i-1)(2t_i+5)}{18} \tag{3}$$

Where k is the number of connected observations in the data set and t_i is the number of data in the i*th* connected observation. The summation term in Equation (3) is used only when there are linked observations in the data. The standardized Mann-Kendall statistic Z can be calculated as given in Equation (4). Positive values of Z indicate increasing trends, while negative values of Z show decreasing trends (Tabari et al., 2011; Sapolyo and Topaloglu, 2020).

$$Z = \begin{cases} \frac{S-1}{\sqrt{\boldsymbol{Var}(S)}}\ ;\ S > 0 \\ 0\ ;\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}\ ;\ S < 0 \end{cases} \tag{4}$$

Here, the absolute Z values of the Mann-Kendall statistics are compared with the ($Z_{\alpha/2}$) value taken from the standard normal distribution table at the 100%(1 - α) confidence level. If the absolute Z value is less than $Z_{\alpha/2}$ ($|Z| < Z_{\alpha/2}$), the H_0 hypothesis is accepted. Otherwise, H_0 is rejected and it is concluded that there is a trend. If the value of Z is positive, it is decided that the trend is in the increasing direction, and if it is negative, it is in the decreasing direction (Tabari et al., 2011; Besel ve Kayikci, 2016; Buyukkaracigan, 2019). In this study, the significance level (α) was taken as 0.05 and therefore the confidence level was 95%.

Spearman's Rho test

Spearman's Rho test, which is one of the non-parametric trend tests and based on rank statistics, determines whether there is a correlation between two observation series. This test is a quick and easy way to identify the trend (Besel and Kayıkcı, 2016).

In Spearman's Rho test, the observation series is x ($x_1, x_2, \ldots, x_n$), according to the H_0 hypothesis, xi (i=1, 2, … , n) values are equally probable distributions. According to the H_1 hypothesis, these values increase or decrease over time. Spearman's Rho test statistic is calculated with the following equation.

$$r_s = 1 - 6\frac{\left[\sum_{i=1}^{n}\left(R(X_{\mathrm{i}})-i\right)^2\right]}{(n^3-n)} \quad (5)$$

Here, the rank statistic (Xi) is determined by sorting the data from largest to smallest or smallest to largest. i refers to the order of observation of the data, and n refers to the total number of observations. The test statistic (Z) of rs is calculated with the following equation.

$$Z = r_s\sqrt{n-1} \quad (6)$$

The absolute Z value obtained here is compared with the ($Z_{\alpha/2}$) value obtained from the standard normal distribution table at a 95% confidence level. If the absolute Z value is less than $Z_{\alpha/2}$ ($|Z| < Z_{\alpha/2}$), the H_0 hypothesis is accepted and it is concluded that there is no particular trend (Besel ve Kayikci, 2016; Buyukkaracigan, 2019).

Sen's Slope Estimation Method

If there is a linear trend in a time series, the true slope (change in unit time) can be estimated using a simple nonparametric procedure developed by Sen (Sen, 1968). The slope estimates of N pairs of data are first calculated by the following equation (Tabari et al., 2011):

$$Qi = \frac{x_j - x_k}{j-k} \qquad (i=1,\ldots\ldots,N) \quad (7)$$

where x_j and x_k are data values at times j and k ($j > k$), respectively. The median of N number of Q values is Sen's slope estimator. If N is odd, Sen's estimator is calculated as:

$$Q_{med} = Q_{[(N+1)/2]} \quad (8)$$

If N is even, Sen's estimator is calculated as:

$$Q_{med} = \frac{1}{2}\left(Q_{[N/2]} + Q_{[(N+2)/2]}\right) \quad (9)$$

Finally, Partal and Kâhya (2006] stated that the Q_{med} value was tested with a two-sided test at the confidence interval of 100%(1 - α) and the true slope could be obtained with the non-parametric test (Tabari et al., 2011). In this study, the significance level (α) was taken as 0.05 and therefore the confidence level was 95%.

$$C_\alpha = Z_{(\alpha/2)}\sqrt{Var(S)} \quad (10)$$

where $Var(S)$ is defined in Equation (3) and $Z_{(a/2)}$ is obtained from the standard normal distribution. Then M_1 and M_2 are calculated as follows.

$$M_1 = (N - C_\alpha)/2 \quad (11)$$

$$M_2 = (N + C_\alpha)/2 \quad (12)$$

The lower and upper limits of the confidence interval (Q_{min} and Q_{max}) are the M_1th and $(M_1+1)\ th$ largest of the N ordered slope estimates (Q_i). If M_1 is not an integer, the lower limit is interpolated. Accordingly, if M_2 is not an integer, the upper bound is interpolated (Tabari et al., 2011).

Results and Discussion

The annual total precipitation values for the 60-year period are given in Figure 1. The 60-year precipitation values for the months are not given in the text. The lowest, highest and average precipitation values for each month of the year and the whole year in the 60-year period and the years in which these values are seen are given in Table 2.

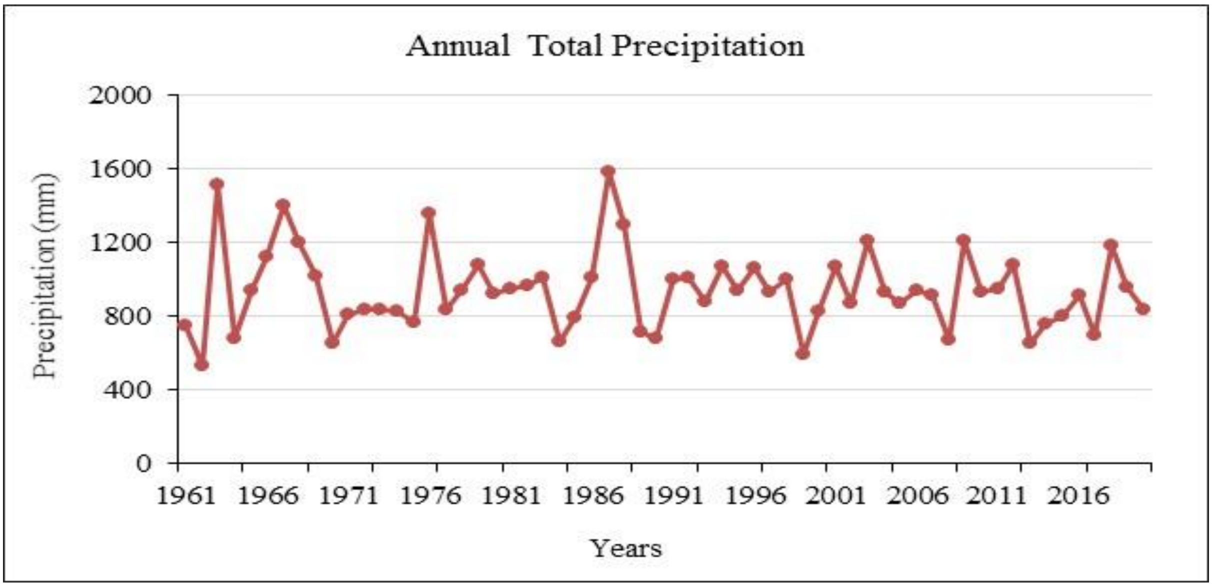

Figure 1. Annual total precipitation values

Table 2. Monthly and annual minimum, maximum and mean rainfall amounts and the years they were observed in the 60-year period between 1961-2020

Months	Minimum value (mm)	The year with the minimum value	Maximum value (mm)	The year with the maximum value	Mean value (mm)
January	1.3	1971	484.5	1963	138.7
February	25.6	1974	298.1	1992	130.0
March	36.1	1990	284.4	1988	129.7
April	12.8	1989	333.5	1982	117.8

May	9.1	1989	238.9	1993	77.4
June	0.2	1970	91.6	1972	20.5
July	0.1	1999-2005	39.1	2006	5.4
August	0.1	2002	43.4	2000	3.1
September	0.1	1978-1990	64.4	2009	11.4
October	3.2	1964	220.9	2015	64.9
November	2.7	1978	236.6	1983	105.0
December	3.4	1995	377.8	1987	136.8
Annual	532.4	1962	1579.1	1987	940.7

It is understood from Table 2 that the lowest monthly precipitation values for all months of the year were seen in 2005 and previous years and that there was no accumulation in certain years or years. There was no precipitation in June of 1966 and 2006, and in July of 1961, 1965, 1968, 1969, 1971, 1974, 1978, 1983, 1989, 1993, 1995, 1996, 2000, 2008, 2013, 2015 and 2017. Similarly, there was no precipitation in August of 1961, 1962, 1963, 1964, 1965, 1967, 1969, 1973, 1975, 1978, 1979, 1980, 1984, 1986, 1990, 1994, 1997, 2004, 2013, 2016 and 2018. There was no precipitation in September in 1962, 1964, 1973, 1984, 1993, 2007, 2017 and 2019, and in October in 2020. Table 2 illustrates that the highest precipitation values of all months of the year within the 60-year period have been distributed within the 60-year period without showing a distinctive feature. In addition, the lowest value of annual precipitation, sum of monthly precipitation, was seen in 1962 (532.4 mm) and the highest value in 1987 (1579.1 mm). Furthermore, the mean annual precipitation in the 60-year period was 940.7 mm.

The trend analysis results of monthly and annual precipitation values determined by Sen`s slope test, Mann-Kendal test and Spearman Rho test are given in Table 3. Table 3 shows that the absolute Z values obtained by the Mann-Kendal test and Spearman-Rho test for all months of the year are smaller than the value of 1.96 taken according to $Z_{0.025}$ from the standard normal distribution (Z) table. The fact that the calculated absolute Z value is less than the table $Z_{\alpha/2}$ value indicates that the H_0 hypothesis is accepted and the H_1 hypothesis is rejected, and therefore there is no statistically significant trend. Additionally, Table 3 shows that the (p) values obtained by Mann-Kendall and Spearman-Rho tests for all months are greater than (α=0.05) and therefore there is no statistically significant trend. According to the results of Mann-Kendall test and Spearman-Rho test, negative (-) Z values were obtained in February, April, July, November, December and on an annual scale. This shows that there is a statistically insignificant ($p>0.05$) decrease trend in precipitation amount in the mentioned months and annual scale, and an increase trend that is not statistically significant ($p>0.05$) in other months.

Table 3. Trend analysis results determined by Sen's slope test, Mann-Kendall test and Spearman Rho test of monthly and annual precipitation values (1961-2020, α=0.05)

Months	Sen's slope estimation	Mann-Kendal test			Spearman-Rho test		
		τ	Z	p	ρ	Z	p
January	0.675	0.095	1.084	0.284	0.140	1.067	0.287

February	-0.214	-0.047	-0.529	0.598	-0.082	-0.625	0.532
March	0.097	0.021	0.242	0.818	-0.055	0.417	0.678
April	-0.579	-0.122	-1.371	0.171	-0.153	-1.170	0.242
May	0.191	0.054	0.619	0.545	0.078	0.589	0.555
June	0.006	0.008	0.102	0.929	0.022	0.168	0.869
July	0.000	-0.015	-0.161	0.872	-0.026	-0.193	0.845
August	0.005	0.158	1.835	0.069	0.242	1.859	0.063
September	0.204	0.110	1.245	0.218	0.138	1.052	0.293
October	0.046	0.009	0.108	0.924	0.024	0.185	0.856
November	-0.729	-0.160	-1.799	0.072	-0.230	-1.759	0.078
December	-0.622	-0.087	-0.976	0.329	-0.122	-0.926	0.354
Annual	-0.363	-0.024	-0.261	0.794	-0.034	-0.256	0.797

The 60-year precipitation amounts of the months showing an increasing and decreasing trend in monthly precipitation are given in Figure 2 and Figure 3, respectively. According to Sen`s slope test, negative (-) slopes were obtained in February, April, November, December and on an annual scale, which indicates that there is a decreasing trend in precipitation in these months and on an annual scale. The slope value of Sen for July was determined as 0.000, which indicates that there is no increase or decrease trend in the precipitation amount of the month in question. The results obtained in studies conducted by many researchers on this subject are given below. In the research conducted by Tosunoglu (2017) to determine the annual, seasonal and monthly maximum precipitation trends from the daily maximum precipitation data of 5 stations in the Çoruh basin in Turkey, it was determined that there were statistically significant trend increases. Demir et al. (2008) stated that there was a slight upward trend in precipitation values in the Black Sea and Eastern Anatolia Regions, a decrease in spring and winter precipitation in the Black Sea region, and an increase in autumn precipitation. Yilmaz et al. (2010) stated that the temperature and precipitation amounts of Hopa and Artvin stations in Turkey were examined over a 35-year period, and there was a slight increase in the series of temperature and precipitation values. Demir et al. (2017) stated that there was a statistically non-significant decreasing trend in the annual rainfall in Bingöl province in the period between 1975 and 2016.

By using non-parametric methods such as Sen T test and Mann-Kendall test, data obtained from 96 precipitation measurement stations across Turkey by Partal and Kahya (2006), the trend changes in annual average and monthly precipitation amounts were examined. As a result of the study, it was stated that the precipitations showed a decreasing trend especially in 14 different stations in January. Similarly, Turkes et al. (2007) observed a high decrease in annual total precipitation and precipitation density, especially in the Mediterranean Region, in a study conducted on data from 111 precipitation measurement stations across Turkey.

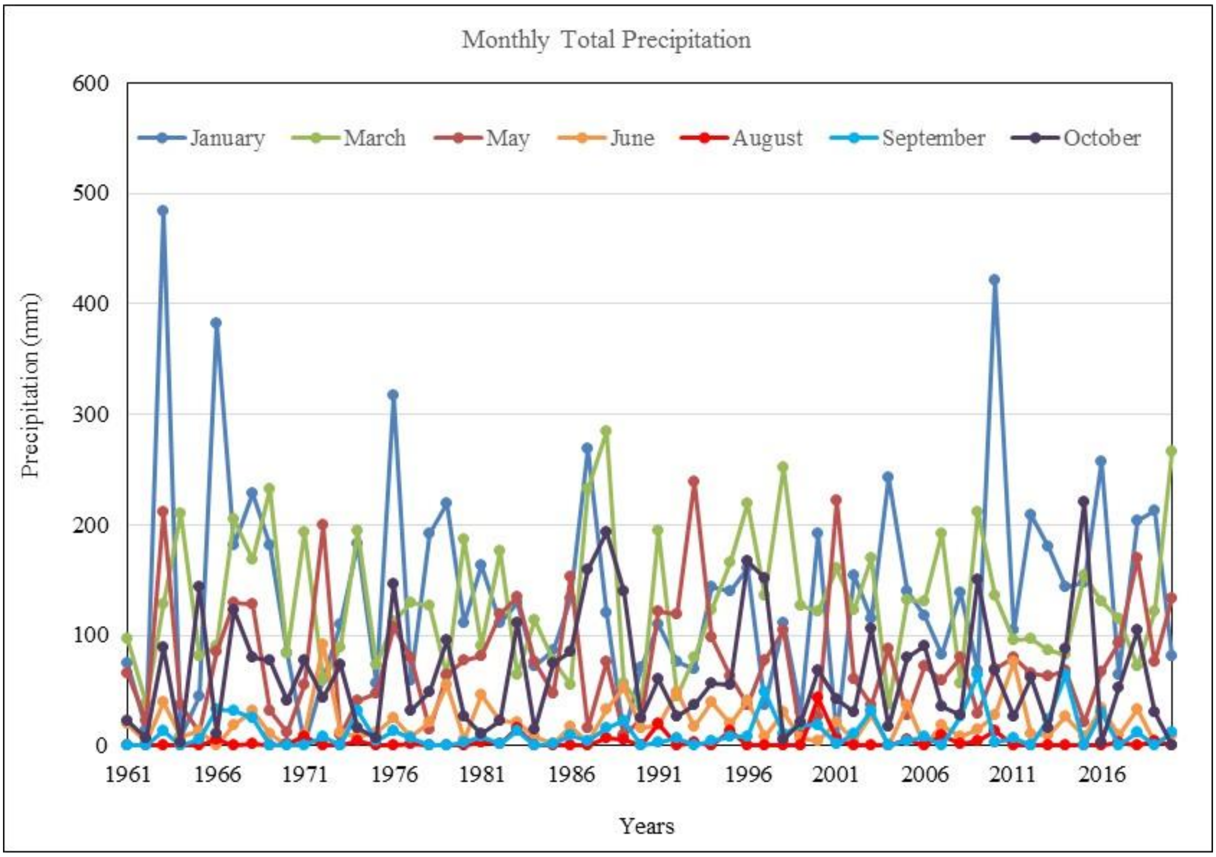

Figure 2. 60-year precipitation amounts of the months showing an increasing trend in precipitation

In the study conducted by Cosun and Karabulut (2009b) on the precipitation data taken from the meteorological stations in Kahramanmaraş province in the Mediterranean region; It has been determined that there is a statistically insignificant decrease trend in the precipitation amounts of winter, spring and summer seasons, and an increase trend that is not statistically significant in the autumn season.

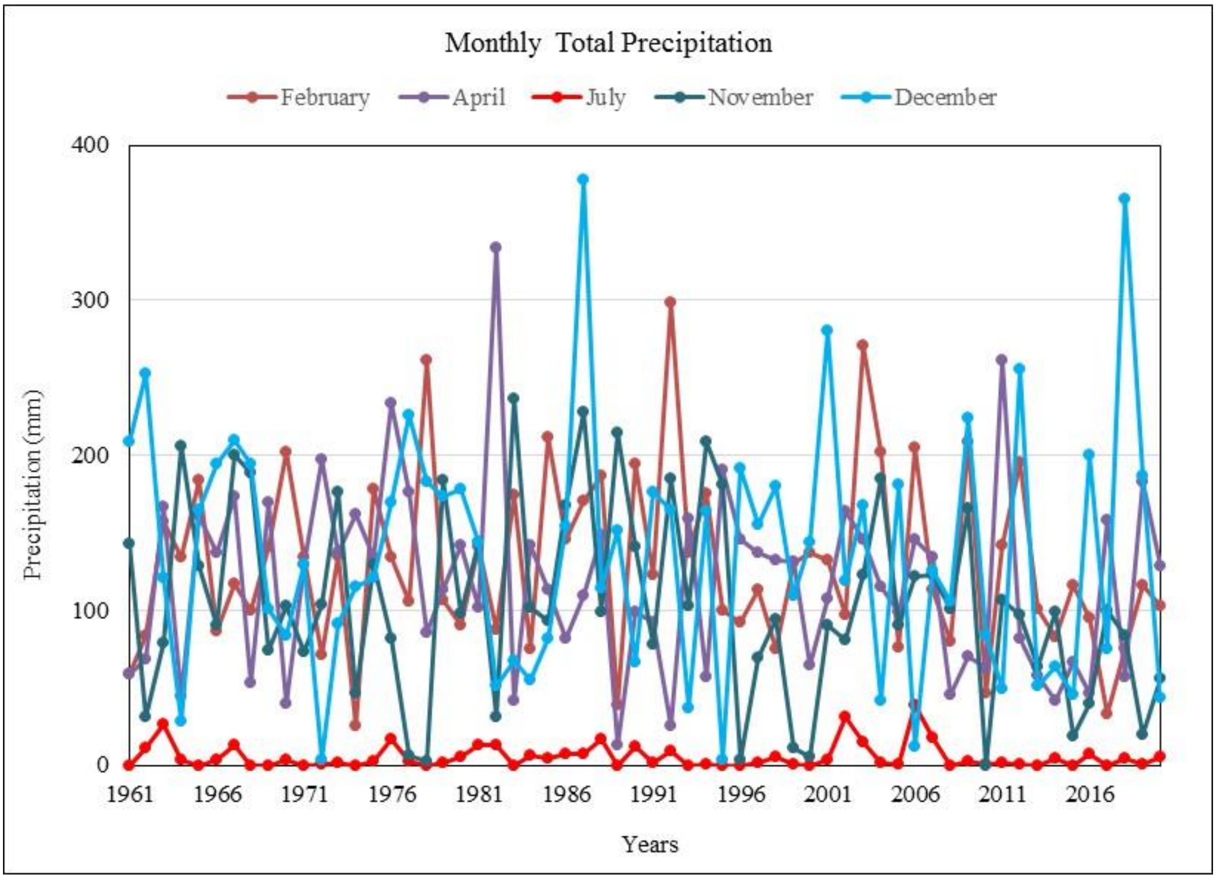

Figure 3. 60-year precipitation amounts of the months showing a decreasing trend in precipitation

Turkes (1996) stated that there were statistically significant trends as a result of examining the spatial and temporal characteristics of precipitation, and a general decrease in annual precipitation occurred. Turkes et al. (2009) stated that the decrease in precipitation occurred in the Mediterranean Region and areas with a Mediterranean transitional climate, and this situation was associated with mid-latitude cyclones in Northern Anatolia and high pressure areas originating from Eastern Europe and Siberia. The main reason for the occurrence of negative trends in precipitation, especially in winter, is seen as the stated situation (Coskun, 2020).

Conclusions

In particular, the accumulation of greenhouse gases released into the atmosphere by various human activities such as burning fossil fuels, urbanization, deforestation and industrial processes is constantly increasing. Due to this increase, the increase in temperature in the lower parts of the earth and atmosphere due to the intensification of the natural greenhouse effect is called global warming (Karaman and Gokalp, 2010). The global climate change mentioned today, on the other hand, defines the increase in the average surface temperature of the earth and the changes in the climate as a result of the rapid increase in the greenhouse gas accumulations released into the atmosphere (Kanber et al., 2010; Zwane, 2019).

Precipitation irregularity, which is a result of climate variability, reduces crop production. This situation can pose a risk in terms of food security and cause hunger in the world. From a broader perspective, climate change can disrupt the economic structure of countries by negatively affecting sustainable natural resources and agricultural productivity.

In this study, the effect of climate change, which is effective on a global scale, on monthly and annual precipitation amounts in the 60-year period between 1961 and 2020 in the Bingöl Plain conditions was examined. According to the results obtained, it was determined that there was no statistically significant trend in monthly and annual precipitation amounts in the said 60-year period. It was determined that there was a statistically insignificant decrease trend in February, April, November, December and throughout the year, and a statistically insignificant increase trend in January, March, May, June, August, September and October. According to the results of Mann-Kendal and Spearman-Rho tests, there was a statistically insignificant decrease trend in the amount of precipitation in July, and there was no trend according to Sen`s slope test. The decreasing trend in rainfall in February, April, July, November, December and the whole year will negatively affect agricultural production. Agricultural activities need to be planned taking this situation into consideration.

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