Pamukkale UnivMuh BilimDerg, 25(8), 956-961, 2019
(Uluslararası Kentsel Su ve Atıksu Yönetimi Sempozyumu (UKSAY)-2018 Özel Sayısı)

Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi

Pamukkale University Journal of Engineering Sciences

Temporal trend analysis of extreme precipitation: a case study of Konya Closed Basin

Ekstrem yağışların zamansal eğilim analizi: Konya Kapalı Havzası örneği

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Geliş Tarihi/Received: 12.04.2019, Kabul Tarihi/Accepted: 09.10.2019 doi: 10.5505/pajes.2019.86658
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Özel Sayı Makalesi/Special Issue Article

Abstract

The changes in the intensity and frequency of extreme climatic events bring about many important problems in terms of social, economic and environmental. Especially, it is very important to inquire the influences of climate change on extreme precipitation. Spatial and temporal trends of extreme precipitation have been investigated by many researchers at global, regional and local scales in recent years. This study is about the temporal variability of extreme precipitation of 4 meteorology station (Konya, Karaman, Aksaray, Nigde) on Konya Closed Basin in Turkey. Trend analysis of extreme precipitations was conducted by means of the Spearman's Rho (SR), Mann-Kendall (MK) and Innovative Şen Trend test. According to the results of trend methods, non-significant decreasing trends are observed in extreme precipitation data of Aksaray, Karaman and Nigde meteorology stations while non-significant increasing trend is shown only in Konya meteorology station.

Keywords: Precipitation, Trend analysis, Konya closed basin

Öz

Aşırı iklim olaylarının sıklığı ve yoğunluğundaki değişiklikler önemli sosyal, ekonomik ve çevresel sorunlara neden olmaktadır. Özellikle, iklim değişikliğinin ekstrem yağışlar üzerindeki etkilerini araştırmak çok önemlidir. Son yıllarda birçok araştırmacı tarafından küresel, bölgesel ve yerel ölçekte ekstrem yağışların mekansal ve zamansal değişimi araştırılmıştır. Bu çalışmada, Türkiye'de Konya Kapalı Havzası'nda bulunan 4 meteoroloji istasyonunun (Konya, Karaman, Aksaray, Niğde)ekstrem yağışlarının zamansal değişimi araştırılmıştır. Bu amaçla, Mann-Kendall (MK), Spearman's Rho ve Innovative Şen Trend testleri kullanılmıştır. Trend yöntemlerinin sonuçlarına göre Aksaray, Karaman ve Niğde meteoroloji istasyonlarında ekstrem yağış verileri istatistiksel olarak anlamlı olmayan azalma, Konya meteoroloji istasyonunda ise anlamlı olmayan artış eğilimleri elde edilmiştir.

Anahtar Kelimeler: Yağış, Trend analizi, Konya kapalı havzası

1 Introduction

One of the important impacts of global climate change occurs in precipitation. Precipitation is one of the most variable parameters in terms of time and space in climate elements. Precipitation, which is one of the most influential parameters on the hydrological cycle, is also one of the most vital climate events that positively and negatively affect human life. As a result of extreme precipitation, which causes drought in the event of scarcity and floods in the case of multiple, is causing serious social disruption, environmental, economic, social adverse effects and loss of human life worldwife each year as a result of these events. Extreme precipitation causes flooding. Determination of extreme precipitation trends is an important for planning/designing of water resources management projects and flood mitigation infrastructure. The trend in precipitation has been studied extensively using different methods at the global and regional scales by many researchers [1]-[7]. Alexander et al. [8] investigated the data of 5948 stations in the world and found a meaningful increasing trend in extreme precipitation during 1951-2003 periods. Decreasing precipitation trends have been obtained by Mavromatis and Stathis [9] in Greece and Western Africa. Mei et al. [10] studied an analysis of daily precipitation time series from 1960 to 2013 for 26 meteorological stations of Jing-Jin-Jii region in northern China.

Shrestha [11] reported an increasing trend in extreme precipitation in Nepal, while Chu et al. [12] found that extreme precipitation has an increasing trend since the 1950s in the typhoon season in Taiwan. Ozgur and Yilmaz [13] examined the trend of daily extreme precipitation using Mann Kendall (MK) trend test in 6 meteorological stations for the Eastern Black Sea Region. In this study, the threshold value for daily extreme precipitation was selected as 10 mm and it was determined that there must be an increase trend in amount of daily precipitation over time exceeding the threshold value. Acar and Senocak [14] examined the trends of annual extreme precipitation with different time periods (t= 1, 6, 12 and 24 hours) in seven stations with approximately 50 years' time periods in the Mediterranean hydro-climatic region (western Turkey). Non-parametric tests (such as MK and Sen's T tests) were used to detect trends, and as a result, positive trends were generally determined in annual extreme precipitation. While the station showing the most important positive trend was İzmir station in all periods, it was determined that the annual precipitation of Antalya and Bursa stations increased for a while. According to the study, North Atlantic Oscillation (NAO) has a significant effect on Mediterranean precipitation trends in general. Hadi and Tombul [15] analyzed the precipitation data of the Hopa meteorological station and compared the results with the flood in Hopa in August 2015. In this study, trends, stationarity and homogeneity of extreme precipitation events were examined. In addition, the optimal probability distributions representing the Intensity-Duration-Frequency (IDF) curves were determined and a formula representing the IDF was developed. Finally, flood observations were compared and calculated their return periods. Tosunoğlu [16] investigated the trends of daily maximum precipitation in three time periods: annual, seasonal and monthly, using the daily maximum rainfall data of 5 stations in the Çoruh basin. MK, modified MK (mMK), Theil-Sen (TH) and MK Rank Correlation (MKRK) tests were used to determine trends. According to MK and mMK test results, there was a statistically significant increase in daily maximum precipitation values in January, March, July, August and October and a significant decrease trend in May and December. There were also statistically significant increasing trends in annual and seasonal time scales.

This study is about the temporal variability of extreme precipitation. For this aim, annual extreme precipitation time series of four meteorological stations (Konya, Karaman, Aksaray, Nigde) located on the Konya Closed Basin in Turkey were used. The trends of the annual extreme precipitation values of four observation stations are investigated by traditional MK and Spearman's Rho (SR) tests and the innovative Şen trend method which is used frequently in recent years and gives the results graphically. In addition, linear trend lines are plotted to compare the results obtained from the MK and SR tests for each station.

2 Study area and data

The Konya Closed Basin which is located in the Central Anatolian Region of Turkey, between 36°51' - 39°29' North and 31°36' - 34°52' East is selected as study area (Figure 1). It is formed by the air movements of an old riverbed rising in the middle of Anatolia. The basin does not have the ability to drain its waters into the sea due to its natural topography. It is covered about 6.4% of Turkey's land, and the total area of the river basin is 49,786 km^2. The Basin is surrounded by Kızılırmak and Seyhan to the east, Antalya and Akarçay to the west, Kızılırmak and Sakarya to the north and Eastern Mediterranean basins to the south. The average annual precipitation in Konya Closed Basin is about 407 mm, and the annual average flow of the basin is 191.53 m^3/s. The annual maximum precipitation data used in this study belongs to four meteorological stations on Konya Closed Basin. These stations are operated by the Turkish State Meteorological Service. These stations are Nigde, Karaman, Aksaray and Konya. The studied area and location of the used stations are shown in Figure 1, and the features of selected meteorological stations are shown in Table 1.

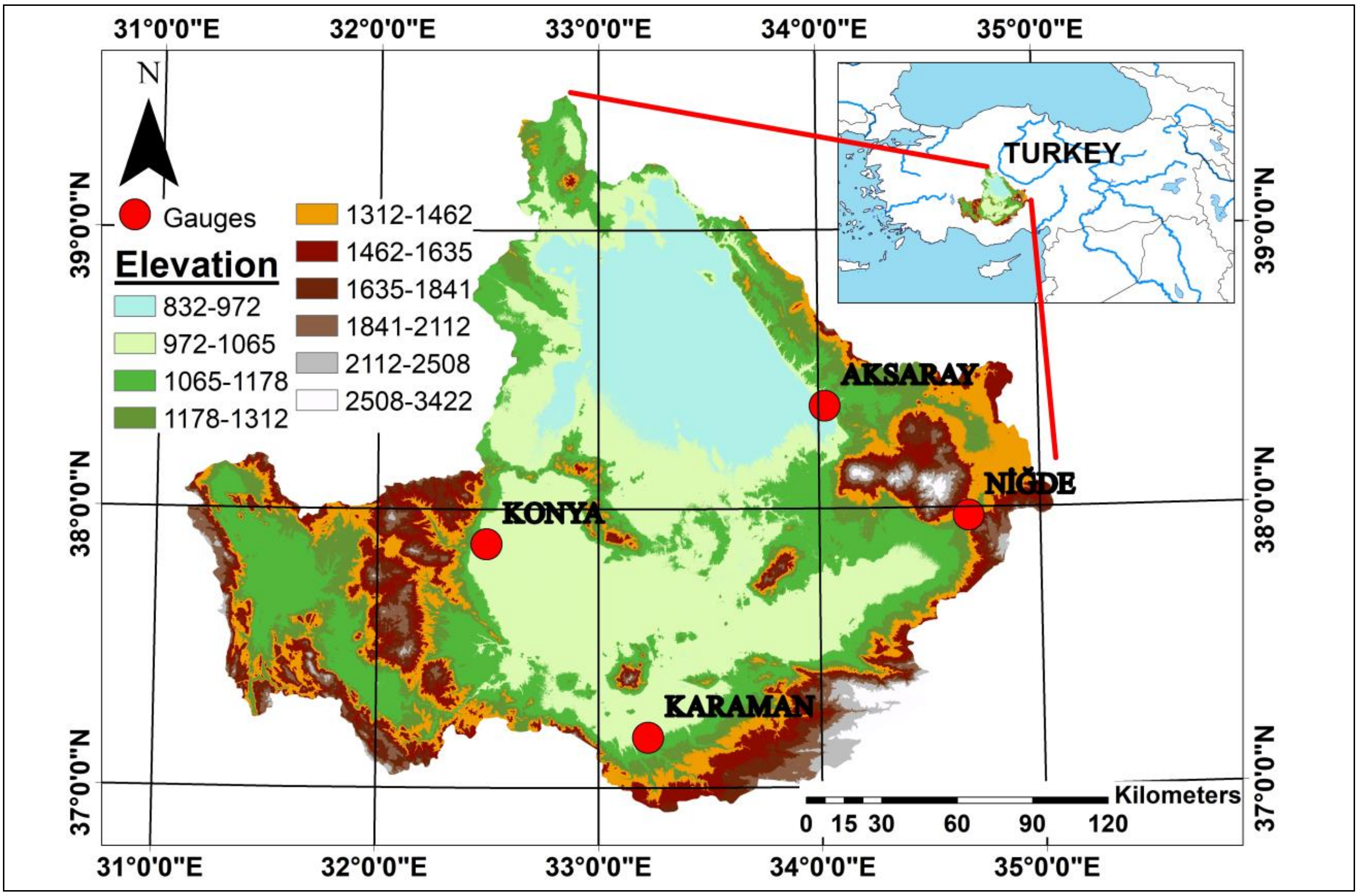

Figure 1: The location of studied stations in Konya Closed Basin.

Table 1: Information of meteorological stations.

Station Name	Station ID	Latitude	Longitude	Elevation (m)	Data Period
Nigde	17250	37° 58'	34° 41'	1211	1935-2017
Konya	17244	37° 52'	32° 29'	1031	1929-2006
Karaman	17246	37° 11'	33° 13'	1024	1929-2017
Aksaray	17192	38° 23'	34° 03'	961	1938-2017

The observation periods without gaps or missing values were selected at the stations used. The annual extreme precipitation data used in this study was calculated from the monthly total precipitation observations.

Descriptive statistics of the annual extreme precipitation for the studied stations are presented in Table 2. As seen, the lowest (8.24) and highest (12.66) standard deviation are present in Aksaray and Konya, respectively. On the other hand, Nigde and Aksaray have the minimum (0.92) and maximum (1.85) skewness values, respectively. The lowest (11.40 mm) and the highest (15.6 mm) minimum precipitation are observed in Nigde and Karaman stations, respectively. Nigde and Konya stations have to lowest (54.5 mm) and highest (73.7 mm) maximum precipitation values, respectively. According to the mean of the four stations' extreme precipitation values, the lowest (26.37 mm) and highest (31.36 mm) average values are obtained in Aksaray and Karaman stations, respectively.

Table 2: Statistical properties of the annual extreme precipitation for studied stations.

Station Name	Min (mm)	Max (mm)	Mean (mm)	Standard Deviation	Skewness
Nigde	11.40	54.50	26.39	9.04	0.92
Konya	12.50	73.70	30.27	12.66	1.44
Karaman	15.60	69.80	31.36	11.03	1.28
Aksaray	14.1	65.80	26.37	8.24	1.85

3 Methods

In this study, three different trend methods were used to detect trends of annual maximum precipitation in four stations on Konya Closed Basin. First, non-parametric MK trend test was used to examine the presence of a monotonic decreasing and increasing trends. Secondly, non-parametric Spearman's Rho (SR) trend test was applied to determine the trend of precipitation data. Finally, Şen innovative trend method was used to detect the possible trends.

3.1 Mann-Kendall and Spearman's Rho trend methods

There are many trend methods available that can be used to determine trends in climate events. In this study, MK and SR which are non-parametric methods were used to determine trends of maximum precipitation.

The MK test [17], [18], which is commonly used to determine a monotonic trend in the hydrological and meteorological time series, is a rank-based non-parametric test that does not require normal distribution of the data.

Another non-parametric trend test, which can be used to determine whether there is a monotonic trend in the hydrological and meteorological time series, is the SR test, which is considered to have independent and identically distributed of time series [19], [20]. In both trend tests, the null hypothesis (H_0) indicates that there is no trend in time series; the alternative hypothesis (H_1) shows that there is a trend in time series.

The positive (negative) values of the test statistics in MK and SR methods show an increasing (decreasing) trend. The computational procedure of these two trend test is not defined here because they can be found in related studies in the literature.

3.2 Şen innovative trend method

The Şen innovative trend method, which is successfully applied in hydrological and meteorological time series, is first proposed by Şen [21]. In this method, the existing data series are divided into two equal parts, and each sorted from small to large individually. Then, the first sub-series (X_i) and the second sub-series (X_j) are aligned on the X-axis and on the Y-axis, respectively in the Cartesian coordinate system (Figure 2).

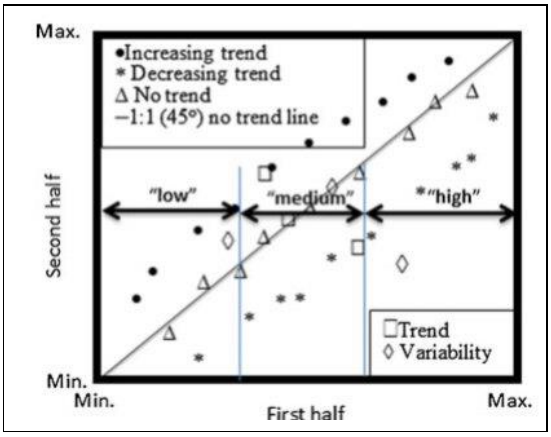

Figure 2: Innovative trend templates [22].

This method depends on the 1:1 line on a Cartesian coordinate system, and any deviation from this line shows trend existence. In the case of no trend in the given time series, data set are collected around the 1:1 (45^0) straight line. In time series, the values below the 1:1 straight line indicate a monotonic decreasing trend, while values above the 1:1 straight line represent a monotonic increasing trend [21].

4 Application and results

The trends of annual maximum precipitation obtained from four stations in the Konya Closed Basin are investigated in this study. The results obtained using non-parametric trend methods (MK, SR) for annual maximum precipitation series are given in Table 3.

The Z value calculated for each station was compared with the critical Z value at the 95% significance level.

Table 3 shows that the calculated Z values are smaller than the critical Z value (±1.96). According to the non-parametric trend tests applied, annual extreme precipitation data of four stations have no statistically significant trend. If the p value is greater than the significance level α = 0.05, H_0 is accepted. Accepting H_0 represents that there is no trend in time series, while rejecting H_0 represents that the trend is determined. The p values for the MK results are greater than 0.05 in Table 3.

According to this test, there are no significant trends in the stations used. Therefore, Ho hypothesis is accepted, while H_1 hypothesis is rejected for four stations. MK and SR test results show that Konya station (Z_{MK}=1.00, Z_{SR}=1.04) has a statistically insignificant increasing trend, and Nigde (Z_{MK}=-0.08, Z_{SR}=-0.23), Karaman (Z_{MK}=-0.75, Z_{SR}=-0.82) and Aksaray (Z_{MK}=-0.21, Z_{SR}=-0.24) stations have a statistically insignificant decreasing trend.

In addition, linear trend lines are plotted to compare the results obtained from the MK and SR tests for each station. The linear function slopes for four stations in Figure 3 are similar with the results of MK, SR in Table 3. Figure 3 depicts the linear trend line of the annual maximum precipitation for the studied stations.

Table 3: Results of the MK, SR and innovative trend tests for the studied stations.

Method		Nigde	Konya	Karaman	Aksaray
MK	Kendall's tau	-0.006	0.077	-0.054	-0.016
	S	-21.0	232	-213	-52
	Var(S)	64644.33	53706.67	79611.67	57921.33
	Z	-0.08	1.00	-0.75	-0.21
	p-value	0.934>	0.317>	0.450>	0.829>
SR	Z	-0.23	1.04	-0.82	-0.14
Variation		Decreasing	Increasing	Decreasing	Decreasing
Şen Innovative Trend	Low	Increasing	Increasing	-	-
	Medium	-	Increasing	Decreasing	-
	High	-	Decreasing	-	-
Trend		No	No	No	No
Z critical value (α=0.05)		±1.96			

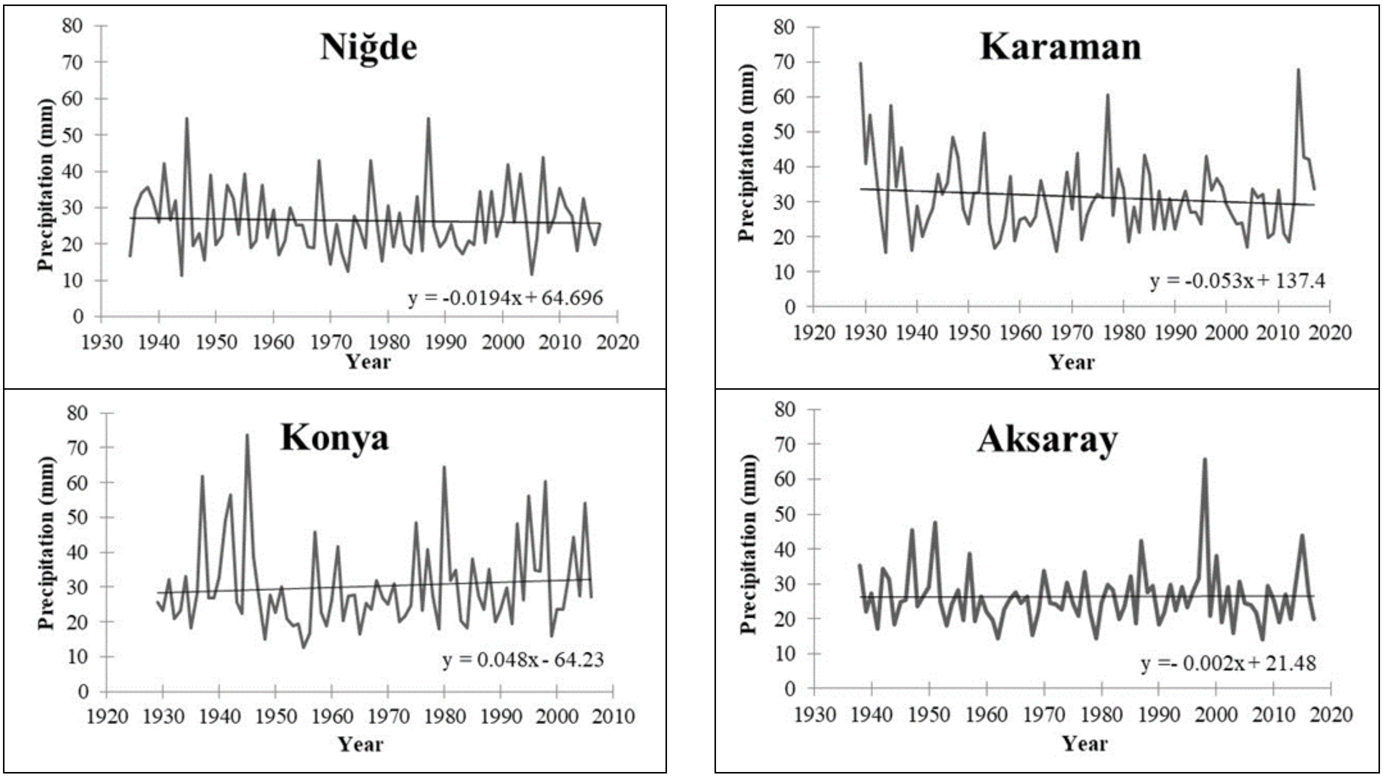

Figure 3: Linear trend lines and time series of annual extreme precipitation in the studied stations.

It is observed that the linear trend line of Konya meteorological station increases and the slope of linear function for Konya is positive (0.048). Linear trend lines are decreasing in the three other stations except for Konya station. The linear function slopes for Nigde, Karaman and Aksaray stations are negative. The slopes of Nigde, Karaman and Aksaray are -0.019, -0.053 and -0.002, respectively.

Results of the Şen innovative trend test for studied meteorological stations are also given in Figure 4 and Table 3. Table 3 shows the variation of annual extreme precipitation data at low, medium and high values according to Şen innovative trend method. According to the Innovative trend graphs in Figure 4, it is seen that the values of each sub-series are scattered around the 1: 1 (45^0) straight line in almost all stations, and thus there is no trend in annual extreme precipitation data at the stations examined.

This study shows that there is a great similarity between the statistical results from MK, SR, slopes of linear function and innovative trend analysis methods.

According to literature, many studies have been performed on the variation of precipitation and river flow data in Turkey. Some of these studies include all or some of the stations used in this study.

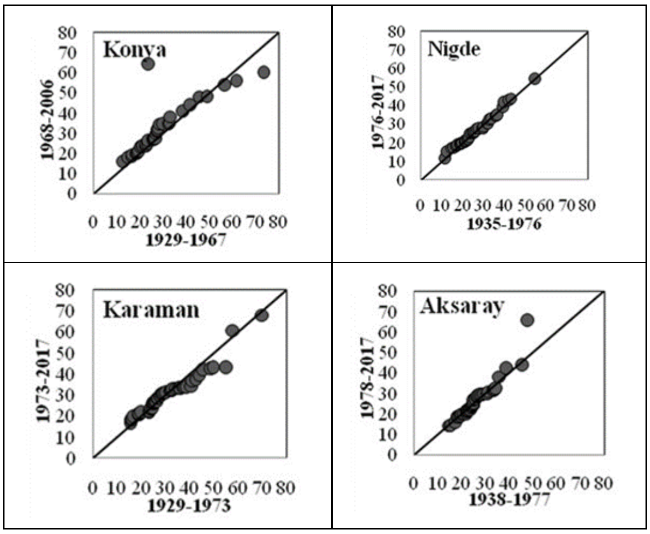

Figure 4: The graphics of Innovative trend test for studied stations.

Sensoy et al. [23] found a significant decrease in the 90% significance level in the annual precipitation of Karaman station for the period 1960-2010. Turkes et al. [24] studied the spatiotemporal variability of annual precipitation series of 97 stations (in the period 1930-2002) in Turkey. They determined an insignificant increasing trend in Konya and Aksaray stations, and an insignificant decrease trend in Niğde and Karaman stations. Partal [25] examined the trend analysis (for the period 1929 to 1993) of precipitation data of 96 observation stations located in Turkey. According to the MK method trend results obtained from the studied stations, they determined a decreasing trend for Niğde (z=-2.18), Konya (z=-0.18), Karaman stations (z=-0.12), and an increasing trend for Aksaray station (z = 0.02). Yılmaz [26] studied trend analysis of Annual Instantaneous Maximum flows time series from 1961 to 2015 for 153 gauge stations in Turkey. The trends in annual mean flow from 1970-2011 for 96 gauge station located in Turkey was investigated by Elmalı [27]. In these two studies, a generally decreasing trend was determined in the flow data at the stations located in Konya Closed Basin.

According to the results obtained from these studies, where trend analysis of precipitation and flow data are performed, there is generally a decreasing trend in both flow and precipitation data. The observation periods used in these studies and observation periods used in our study do not include exactly the same time interval. There is also a difference in the stations used. However, the results obtained in these studies are generally similar to those obtained in our study (for the same or near stations). In another study, Demir [28] examined the effect of Southern Oscillation on the total annual precipitation data of 14 stations in Central Anatolia. According to Demir's study, it is determined that Konya station (1928-2017) has a statistically insignificant increasing trend, and Nigde (Z1935-2017), Karaman (1959-2017) and Aksaray (1964-2017) stations have a statistically insignificant decreasing trend. This study which is examined the change in annual total precipitation, is the closest to our study in terms of observation period and stations used. The results obtained in annual total precipitation and the results obtained in annual extreme precipitation are identical.

5 Conclusions

In this study, it was investigated whether there is a trend in maximum precipitation using annual maximum precipitation of four stations (Nigde, Konya, Karaman and Aksaray) on Konya Closed Basin in Turkey. In this context, trends of the annual maximum precipitation were investigated by using the MK, SR and recently proposed innovative Şen trend analysis. According to the trend methods, annual maximum precipitation data of four stations have no statistically significant trend. However, according to the results of trend methods, non-significant decreasing trends are observed in extreme precipitation data of Aksaray, Karaman and Nigde meteorology stations while non-significant increasing trend is shown only in Konya meteorology station.

The results can be used as a reference to adaptive water resources management for further studies by local governments. Especially in Konya Closed basin where agricultural production is intense, decreases in precipitation due to climate change will affect agricultural production and social life and political situation in this basin.

Especially in recent years, studies on the research of climate change are increasing all over the world. The increase in these studies in our country will be effective in the use of existing water resources and the determination of future projects.

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