



# Evaluation of long-term monthly mean streamflow trend in the Mediterranean basins using different methods

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## Abstract

Knowledge of the historical changes in streamflow is essential for operating and planning water structures. Hence, the monthly mean streamflow trends of 20 streamflow gauge stations in Turkey's Mediterranean basins, which are sensitive to climate change, are examined using the Mann–Kendall test, and trend slopes are calculated using Sen's slope method. Furthermore, the innovative trend significance test (ITST) and recently proposed innovative polygon trend analysis (IPTA) method are used to analyse the historical changes in streamflow values at the stations. The trend analysis results of a total of 240-time series between 1977 and 2015 are evaluated and compared with three different trend methods. As a result of the study, the MK method determined significant trends in only 24% (3 increasing, 55 decreasing), ITST in 83% (41 increasing, 158 decreasing), and IPTA in 82% (38 increasing, 158 decreasing) of the 240-time series. The IPTA and ITST methods are more sensitive to determining significant monthly streamflow trends than the MK method. In addition, there is a more significant decrease in the streamflow values of the stations located east of the basin, and the trend slope value reaches  $-26\%$ /decade. Therefore, the results of the streamflow trend in the Mediterranean basins will benefit decision-makers in planning the efficient use of water resources in the region.

## 1 Introduction

In recent years, an unprecedented rise in global temperature has been associated with increased greenhouse gas emissions due to human activities. It is reported that the global average surface temperature may increase by approximately  $4.4\text{ }^{\circ}\text{C}$  by 2100 due to the gas concentration on the earth in the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC, 2021). This process leads to abnormalities in climate parameters, such as precipitation and evapotranspiration in a particular region (Yue et al., 2003). The streamflow is sensitive to changes in precipitation and evapotranspiration and is directly affected

by these changes. In addition, the streamflow contains all the effects of climate change in their river basins (Genta et al., 1998). Therefore, it is an important issue to investigate changes that may be caused by climate change on the streamflow. For example, according to the IPCC report, Turkey, located in the Eastern Mediterranean region, is sensitive to climate change. Thus, researching the impact of climate change on river flows in this region is essential for designing and operating water structures built or planned on rivers for different purposes, particularly for energy production and irrigation water supply.

Trend analysis methods are frequently preferred in evaluating the impact of climate change on hydro-meteorological time series. With these methods, the direction and magnitude of the change in the time series can be determined for a specific time period. The Mann–Kendall (MK) test (Kendall, 1948; Mann, 1945) is a widely used classical method to determine trends in hydro-meteorological time series (Gadedjisso-Tossou et al., 2021; Gocic and Trajkovic, 2013; Rahman et al., 2016; Singh et al., 2021a, 2020). The MK test is a non-parametric method that can be applied independently of the distribution of the time series. However, this method also has some limitations, such as the time series being a certain length or the serial

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correlation effect in the time series when applying the method (Yue et al., 2002). In addition to the classical MK test, different methods have been proposed to determine trends in recent years. The innovative trend analysis (ITA) is one of these methods proposed by Şen (2012). With this method, the changes in low, medium, and high values in the time series can be examined, and historical records are evaluated from a different perspective than the MK test. Şen (2017) then proposed the innovative trend significance test (ITST) to quantitatively determine the presence of a trend at a certain significance level of ITA results. Many researchers have used ITA and ITST to determine the trends of various parameters in different studies (Caloiro et al., 2020; Seenu and Jayakumar, 2021; Singh et al., 2021b; Şişman and Kizilöz, 2021; Wang et al., 2020; Wu et al., 2022). Moreover, with the innovative polygon trend analysis (IPTA), another supportive method proposed by Şen et al. (2019), it is possible to determine the changes in consecutive time periods in the time series. Although this is a relatively newly proposed method, it has been preferred in different studies as a supporting method in addition to the MK test in determining the trend of hydro-meteorological time series. For example, Ceribasi and Ceyhunlu (2021) calculated the total monthly precipitation values in Turkey's Susurluk weather, Achite et al. (2021) precipitation values in Algeria's Wadi Sly basin, Şan et al. (2021) precipitation data in Vietnam, and Ahmed et al. (2021) evaluated the trend of monthly streamflow values in Pakistan's Hindukush-Karakoram-Himalaya region using the IPTA method. When the trend analysis studies conducted using ITA/ITST and IPTA methods are examined in the literature, it is reported that trend presence is determined in more time series with both methods than with the MK test (Akçay et al., 2022; Arab Amiri and Gocić, 2021; Gul and Ren, 2022; Hirca et al., 2022; Singh et al., 2021b).

In the Mediterranean region, located in the south of Turkey, besides being the most important touristic region of the country, critical agricultural activities are also carried out. The rivers in the region are essential in generating the energy required for tourism activities and being a source of irrigation water for agricultural production. Therefore, it is necessary to determine the change in streamflow values in the region for these activities to be efficient and sustainable. Although no study determines the trend of streamflow values in the Mediterranean basin in the literature, there is still a limited number of studies covering some stations in this basin. These studies generally focus on determining the trend of annual mean streamflow values. For example, Kahya and Kalaycı (2004) examined annual mean streamflow values change between 1964 and 1994 at 86 stations throughout Turkey. In addition, Topaloğlu (2006) determined the annual mean streamflow values trend from 1968 to 1997 for 84 stations representing the whole of Turkey using the MK test.

As a result of these two studies, the annual mean streamflow values in the Mediterranean basin tend to decrease.

As mentioned, some studies evaluate the trend of streamflow values in the Mediterranean region with the MK method, although it includes a limited number of stations and outdated data. However, by adding more actual data than the studies in the literature, it will be possible to evaluate the trend structure of the streamflow values in the basin in more detail. Additionally, there is no study about the Mediterranean region streamflow values trend with ITA and IPTA methods. In addition, the IPTA method is a newly proposed trend analysis method, and the evaluation of the method has been made with a limited number of studies, for example, Achite et al. (2021), Ahmed et al. (2021), Ceribasi and Ceyhunlu (2021), and Hirca et al. (2022). However, investigating the usability of the method as an alternative trend analysis method will benefit practitioners. Contrary to previous studies, which mostly investigate annual streamflow trends, it may be more beneficial for practitioners to examine the trend of monthly streamflow values, especially in more specific studies such as irrigation water use or energy production planning.

The main goal of this study is to evaluate the trend of monthly mean streamflow values recorded between 1977 and 2015 from 20 streamflow gauge stations in the Mediterranean region and compare different trend analysis methods' results on the region. For this purpose, firstly, the MK test, frequently used in the literature, is used to determine the trend of streamflow values, and Sen's slope method is used to determine the trend's slope. In addition to the MK test, ITST and the recently proposed IPTA method are used to assess the trends of the streamflow values, and the results of the three different trend methods are compared.

## 2 Material and methods

### 2.1 Study area

The study area, which can also be called the Mediterranean basin, consists of the Western Mediterranean, Antalya, and Eastern Mediterranean basins located on the southern coasts of Turkey and the boundaries of which are given in Fig. 1. These three basins, which have a Mediterranean climate, cover 15.5% of Turkey's potential water participation rate, with an average annual flow of 6.97 km<sup>3</sup>, 11.25 km<sup>3</sup>, and 8.24 km<sup>3</sup>, respectively (DSI, 2016). In the region where summer tourism is at the forefront, there are important tourism facilities, and these facilities are generally located on the coast. Another important economic activity in the region is agriculture, and 20.22% of the economy in the region is dependent on agriculture. Therefore, it is necessary to analyse the change in the streamflow values in the region to

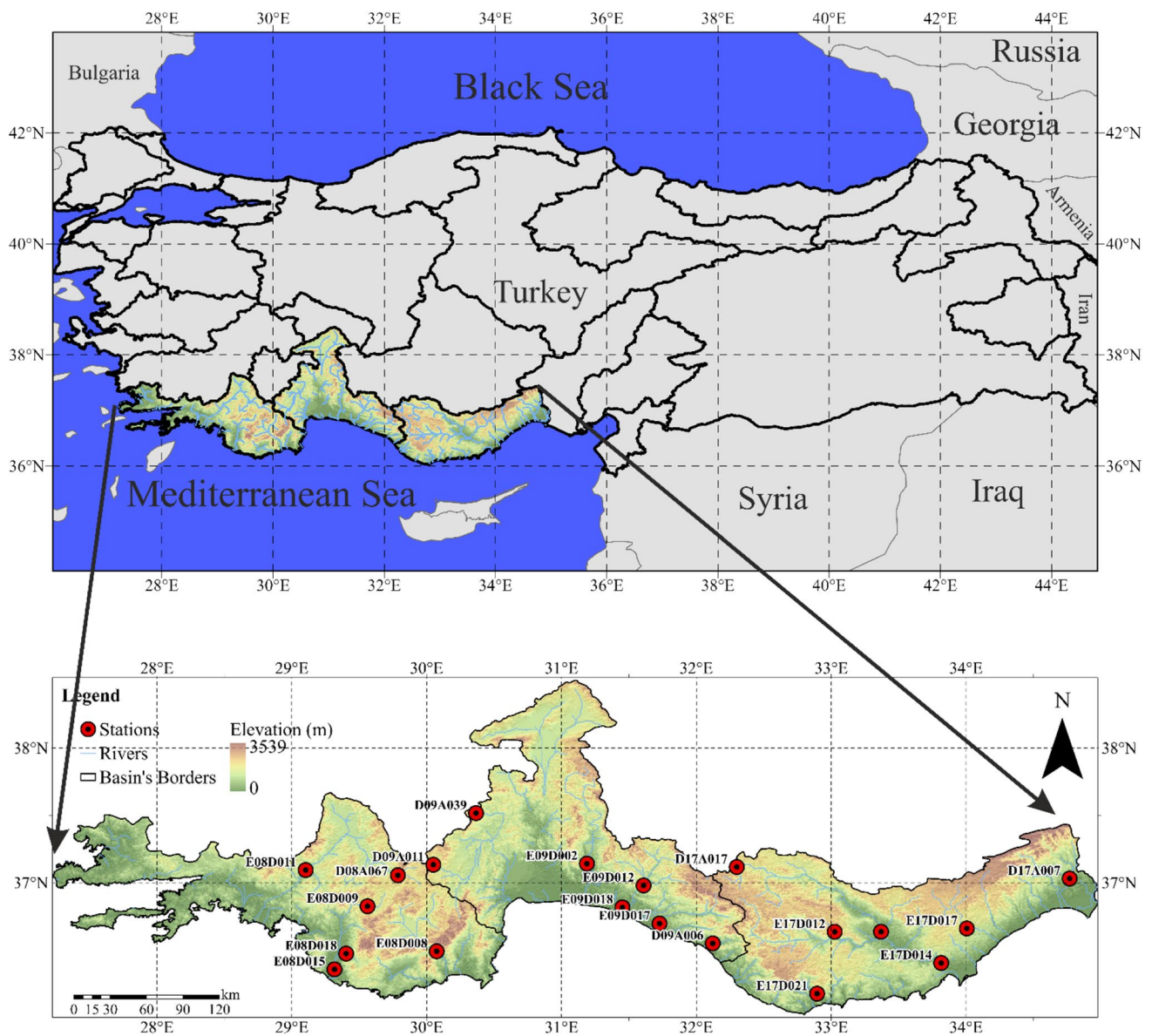


Fig. 1 Study area

ensure the continuity of the activities carried out depending on the river flows and protect the efficiency of the investments made.

### 2.2 Data

There are 141 streamflow gauge stations operated by the General Directorate of State Hydraulic Works in the study area. However, in the selection of stations used in the study, attention is paid to ensure that the time series is of sufficient length, there is no missing data, it has not been moved for any reason, and it is not located in the downstream part of any dam. The number of stations meeting these criteria is determined as 20. The station numbers, altitude (m),

drainage area (km<sup>2</sup>), mean discharge (m<sup>3</sup>/s), latitude (°), longitude (°), and measuring range information of the stations are given in Table 1. The data ranges of the streamflow gauge stations used in the analysis vary between 1960 and 2015, but the common year scale measured between 1977 and 2015 at all stations is used to determine the trends.

### 2.3 Methods

#### 2.3.1 Mann–Kendall test

The MK test (Kendall, 1948; Mann, 1945) is the most widely used classical and non-parametric test to determine the trend of hydro-meteorological data. The detail of the test is given

**Table 1** Information about the streamflow stations

Station number	Station name	Altitude (m)	Drainage area (km <sup>2</sup> )	Mean discharge (m <sup>3</sup> /s)	Latitude (°)	Longitude (°)	Measuring range
D08A067	Söğüt Gölü-Çıkış	1390	445.0	0.839	29.79	37.06	1972–2015
D09A006	Dim Çayı-Batı Sahil Sulama Kanalı	38	195.0	0.946	32.12	36.55	1971–2015
D09A011	Korkuteli Çayı-Salamur Boğazı	1190	130.7	1.755	30.05	37.13	1969–2015
D09A039	Onaç Barajı-Giriş	835	217.7	0.534	30.37	37.52	1974–2015
D17A007	Pamuk Deresi-Keşbükü	132	599.0	11.916	34.77	37.03	1977–2015
D17A017	Göksu-Gördürüp Köprüsü	1241	364.0	5.076	32.30	37.12	1977–2015
E08D008	Başgöz Çayı-Çatallar	342	770.0	3.292	30.07	36.49	1962–2015
E08D009	Eşen Çayı-Kavaklıdere	1115	546.8	3.773	29.56	36.83	1956–2015
E08D011	Dalaman Çayı-Suçatı	595	3890.6	14.071	29.10	37.09	1960–2015
E08D015	Eşen Çayı-Kınık	8	2448.0	37.566	29.32	36.36	1971–2015
E08D018	Karaçay-Kayadibi	110	234.1	14.266	29.40	36.47	1977–2015
E09D002	Köprüçay-Beşkonak	116	1942.4	85.642	31.19	37.14	1939–2015
E09D012	Manavgat Çayı-Sinanhoca	245	625.6	70.074	31.61	36.98	1963–2015
E09D017	Alara Çayı-Alarahan	28	875.5	30.090	31.73	36.70	1968–2015
E09D018	Manavgat Çayı-Şelale	4	1324.4	130.211	31.45	36.82	1971–2015
E17D012	Göksu Nehri-Bucakışla	397	2689.2	27.007	33.03	36.64	1961–2014
E17D014	Göksu Nehri-Karahacılı	24	10,065.2	106.294	33.82	36.40	1960–2015
E17D017	Lamas Çayı-Kızılgeçit	975	1005.2	5.160	34.01	36.66	1965–2015
E17D020	Göksu Nehri-Hamam	127	4304.0	42.998	33.37	36.64	1965–2015
E17D021	Anamur Çayı-Alaköprü	37	313.2	24.133	32.9089	36.18	1967–2015

by Gumus (2019). The absolute value of the calculated  $Z$  value with the MK test is compared with the corresponding standard  $z$  value at the selected confidence interval. If the absolute value of  $Z$  is greater than the standard  $z$  value, the null hypothesis ( $H_0$ ) is rejected, and it is concluded that there is a significant trend; otherwise,  $H_0$  is accepted, and it is concluded that there is no significant trend. The  $H_0$  hypothesis is checked for the 95% confidence interval in this study.

It is necessary to check the serial correlation in the time series before applying the MK test to a dataset (Yue et al., 2002). Here-with, it is checked whether the lag-1 correlation coefficient ( $r_1$ ) is within the range,  $(-1 \pm 1.645\sqrt{n} - 2)/(n - 1)$  proposed by Salas et al. (1980). If the  $r_1$  value is within the range, it is accepted that there is no serial correlation, and if it is outside of the range, it is considered that there is a serial correlation effect. In cases where there is no serial correlation effect, the original time series is used. In the case of serial correlation, the “pre-whitened” series is obtained by applying the “pre-whitening” (von Storch and Navarra, 1995) procedure to the time series, and the MK test is applied to these new series.

### 2.3.2 Sen’s slope method

It is a non-parametric test used to determine a trend’s magnitude (slope), developed by Sen (1968). This method, with its

structure not affected by big data errors or outliers, is applied to calculate the change in unit time if there is a linear trend in the time series of the data (Yu et al., 1993). The trend’s slope ( $Q_{med}$ ) is the median of all slopes ( $Q_i$ ) between data pairs in the same series. The detail of the method is given by Gumus (2019).

### 2.3.3 Innovative trend significance test

The ITST, proposed by Şen (2017), is a method that quantitatively evaluates the ITA method, which graphically displays the presence of a trend in a time series. In the ITST method, the time series is divided into two equal parts, and the arithmetic averages ( $y_1$  and  $y_2$ ) are calculated separately.

In this method, to determine the trend of the time series, the first-order moment ( $E(s)$ ), cross-correlation coefficient ( $\rho$ ), variance ( $\sigma_s^2$ ), and standard deviation ( $\sigma_s$ ) are calculated. The detail of these variables can be found in the study of Şen (2017). The confidence interval ( $CI_{(1-\alpha)} = 0 \pm s_{cri}\sigma_s$ ) of the trend slope is used if there is a trend.  $s_{cri}$  expresses the  $z$  value in the standard normal distribution at a given confidence interval. If the trend slope is in this range, it is considered “no trend” if it is less than the lower value, “descending trend,” and if it is greater than the upper range value, it is considered an “increasing trend.” The trend existence is checked for the 95% confidence interval in this study.

### 2.3.4 Innovative polygon trend analysis

In the IPTA method, proposed by Şen et al. (2019), information can be obtained about the magnitude and slope of trend transitions between consecutive elements (for example, months) besides determining the trend of a time series. In this method, which can also be applied to different time scales, parameters such as mean, minimum, maximum, standard deviation, and skewness of time series can also be used as inputs.

In this method, as in ITST, the time series is divided into two equal groups for all segments (“month” used as time series in this study). Then, a polygon is formed by calculating the average of the two-half series of each month (or any other parameters) and plotting them in the Cartesian coordinate system. Finally, the trend lengths and slopes are calculated as in Eqs. 1 and 2, respectively, if needed.

$$|AB| = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \tag{1}$$

$$s = (y_2 - x_2)/(y_1 - x_1) \tag{2}$$

In the equations,  $x_1$  and  $x_2$  are the values of two consecutive points in the first half on the horizontal (for example, January and February), and  $y_1$  and  $y_2$  are the values of the two consecutive points in the second half on the vertical. The detail of the method is given by (Şen et al., 2019).

## 3 Results and discussion

### 3.1 The MK test

Before applying the MK test, the serial correlation effect in the dataset should be examined and removed, if any. Therefore, the lag-1 correlation coefficients ( $r_1$ ) of the monthly mean streamflow values in the Mediterranean basin are

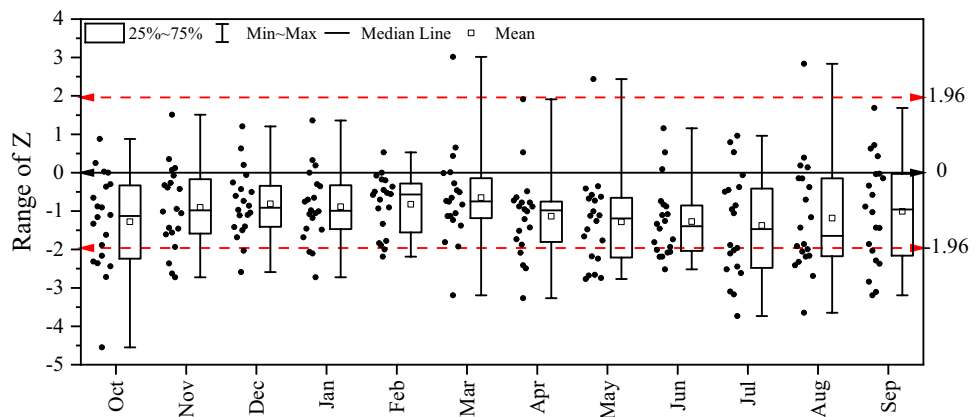
calculated. A serial correlation effect is observed at stations D09A006 and E08D008 in all months, at stations D08A067, D09A011, E08D011, and E08E015 in 11 months, and at station E17D017 in 10 months. In the time series in which serial correlation is determined, the effect of serial correlation is removed with the “pre-whitening” method in the streamflow values, and the MK test is applied to the pre-whitened series.

The box plot of the MK test’s Z values according to the months is given in Fig. 2, and the heat map is given in Fig. 3. According to Fig. 2, the mean and median values of the Z value are negative in all months. This means that the region’s streamflow values generally show a decreasing trend. In addition, the number of stations showed a significant increase in March, May, and August is only one. The months in which the trend is determined in the least number of stations are February, March, and December.

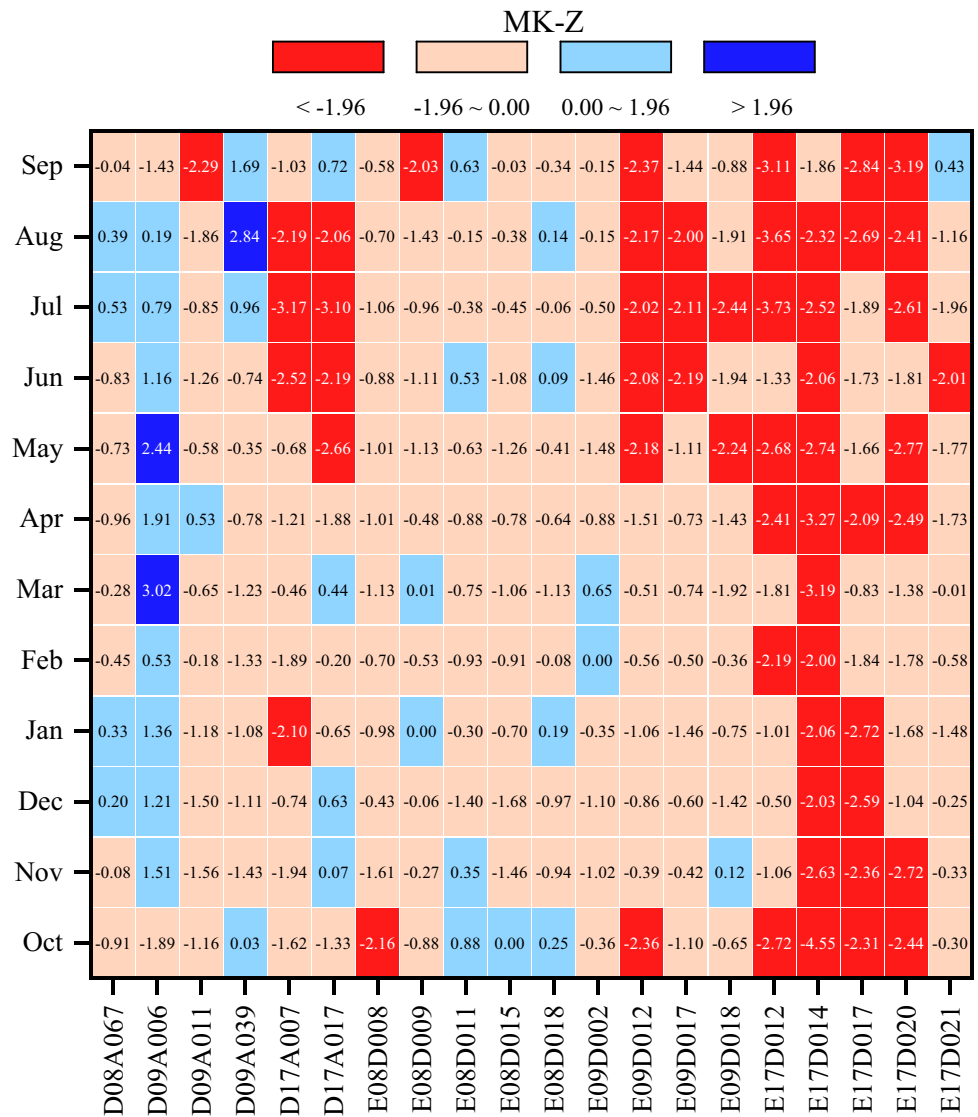
From Fig. 3, which shows the evaluation by stations, it is clearly seen that the most significant decrease occurred at station E17D014 in 11 months. While no significant trend is detected at this station’s 95% confidence interval only in September, a significant decreasing trend is observed in all the remaining months. Apart from station E17D014, the stations with the highest decreasing trend are E17D012, E17D017, and E17D020A statistically significant decreasing trend is observed in these stations in 7 months. At stations E09D012, D017A007, and D17A017, the number of months with a significant decreasing trend is 6, 4, and 4, respectively. The common of the stations having the most significant decreasing trend is that all of these stations are located in the east. This situation reveals that the region’s east is riskier regarding water stress. Simsek (2021) stated that the eastern part of the region is risky in terms of drought in the study evaluating the hydrological drought of the Mediterranean region. The trend analysis results of the current study support the results of Simsek (2021).

Stations D09A006 and D09A039 are the only ones showing a significant increasing trend in the region. While station

Fig. 2 The distribution of the MK-Z values



**Fig. 3** The heatmap of the MK-Z values

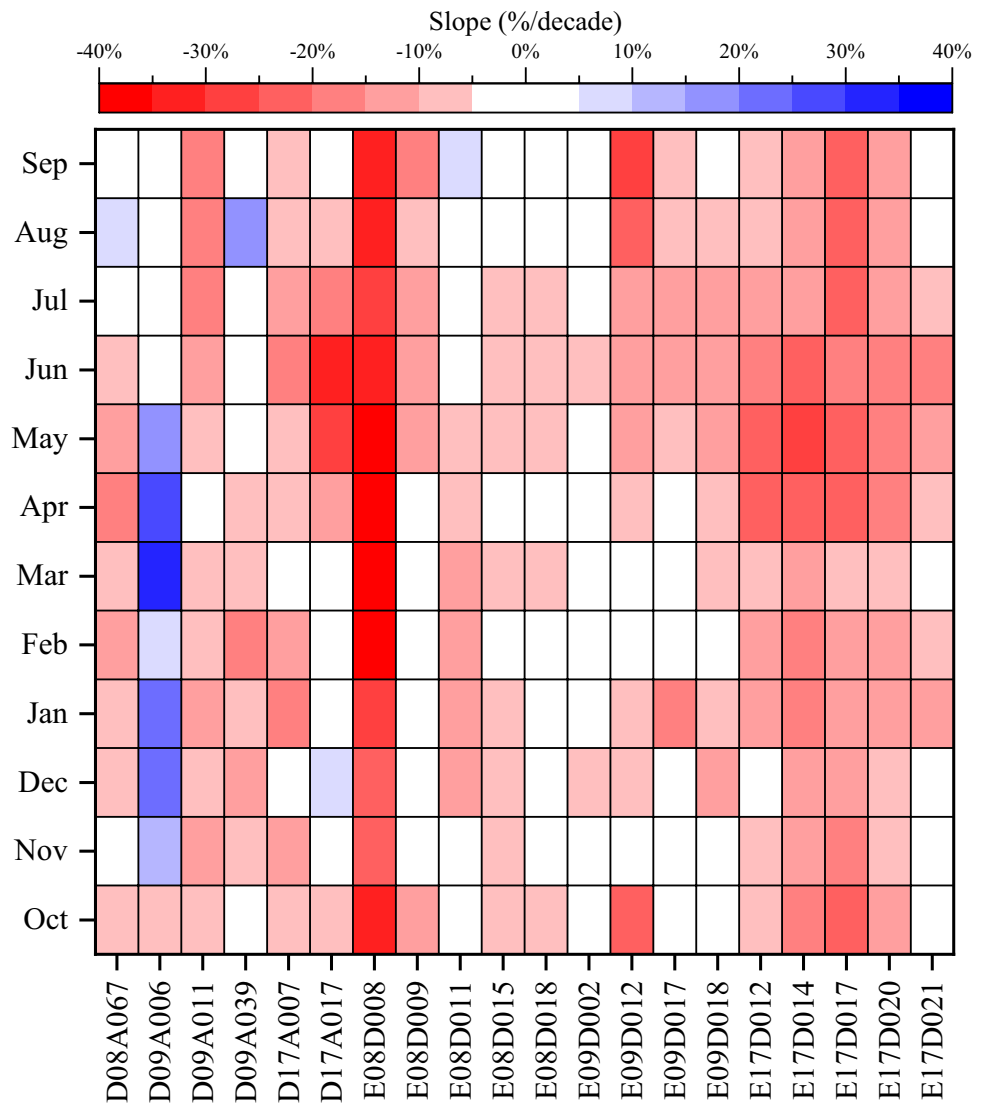


D09A006 increases in 10 of 12 months, these increases are statistically significant only in March and May. Though D09A039 has increased in 4 months, a significant increase occurred only in August. A decreasing trend is observed in 84% of the region (23% of which decreased significantly) within 240 months (20 stations 12 months). While the percentage of stations with an increasing trend is 16%, this increase is significant only at 1%.

Figure 4 shows the  $Q_{med}$  values obtained with Sen's slope, which calculates the magnitude of changes occurring in the region. The streamflow values of the station where the river is measured vary significantly depending on the place of the river (main or side tributary). Therefore, percentage changes are used to compare the magnitudes of change between stations. The percentage change value is obtained by dividing each month's Sen's slope value ( $m^3/s/year$ ) by the long-term average of the station's relevant month. To better understand the change, instead

of the annual change, these values are multiplied by ten, and the change over the decade is examined. Since the changes in the range/decade value within the range of  $\pm 5\%$  are quite low, these value changes are shown in white in the graph. Accordingly, since the decreasing trend has been determined by the MK test in a significant majority of the stations, it is seen that Sen's slope values are also mostly in the decreasing direction, and the results are consistent with the Z values. Although the most remarkable change is observed at station E08D008 with approximately 40%, a significant trend is determined only in October at this station. However, at station E17D014, where the significant trend is determined the most, the change varies between 11 and 26%. At this station, the amount of decreasing exceeded 26% in May. A similar situation is observed at stations E17D017 and E17D020, which show a significant decreasing trend. The averages of Sen's slope values in the whole region show that the decrease

**Fig. 4** The change of trend slopes according to Sen's slope method (%/decade)



in May and June is higher than in other months. During these months, the streamflow in the region decreased by about 13%/decade. As the slightest decrease percentage is 5%/decade in March, this value is 9%/decade on average throughout the region. The decrease in the streamflow values of the rivers in the eastern region, where the stations with the most significant trends are located, is relatively high compared to the basin in general. Here, the average decrease in May and June reaches 20%/decade. In addition, the decrease rate, which is 9%/decade across the basin, is 12%/decade in the east. As the stations whose Sen's slope value increased above 5%/decade are evaluated, it is seen that station D09A006 shows a significant increase in December, January, March, and April, while the increase is limited in the remaining stations. Considering that a significant increasing trend is determined only in March and May at the relevant station, the increase, especially in March, is remarkable. In addition, the number of stations

with an increase of more than 5%/decade in the region is only nine.

### 3.2 The ITST

The MK is the most used test to determine the presence of a trend in a time series. In addition, different trend analysis methods have been frequently preferred to support the results of the MK test in recent years. The ITA is one of the primaries of these methods. On the other hand, ITST determines the presence of a trend according to the significance level of the ITA method with numerical calculations. The results obtained from the analysis of ITST are given in Fig. 5. In the graph, the trend slope symbol in the red area means a significantly decreasing trend in the 95% confidence interval. If the squared sign is in the blue area, it is concluded that a significantly increasing trend occurs in the 95% confidence interval. It is seen that there is a significant

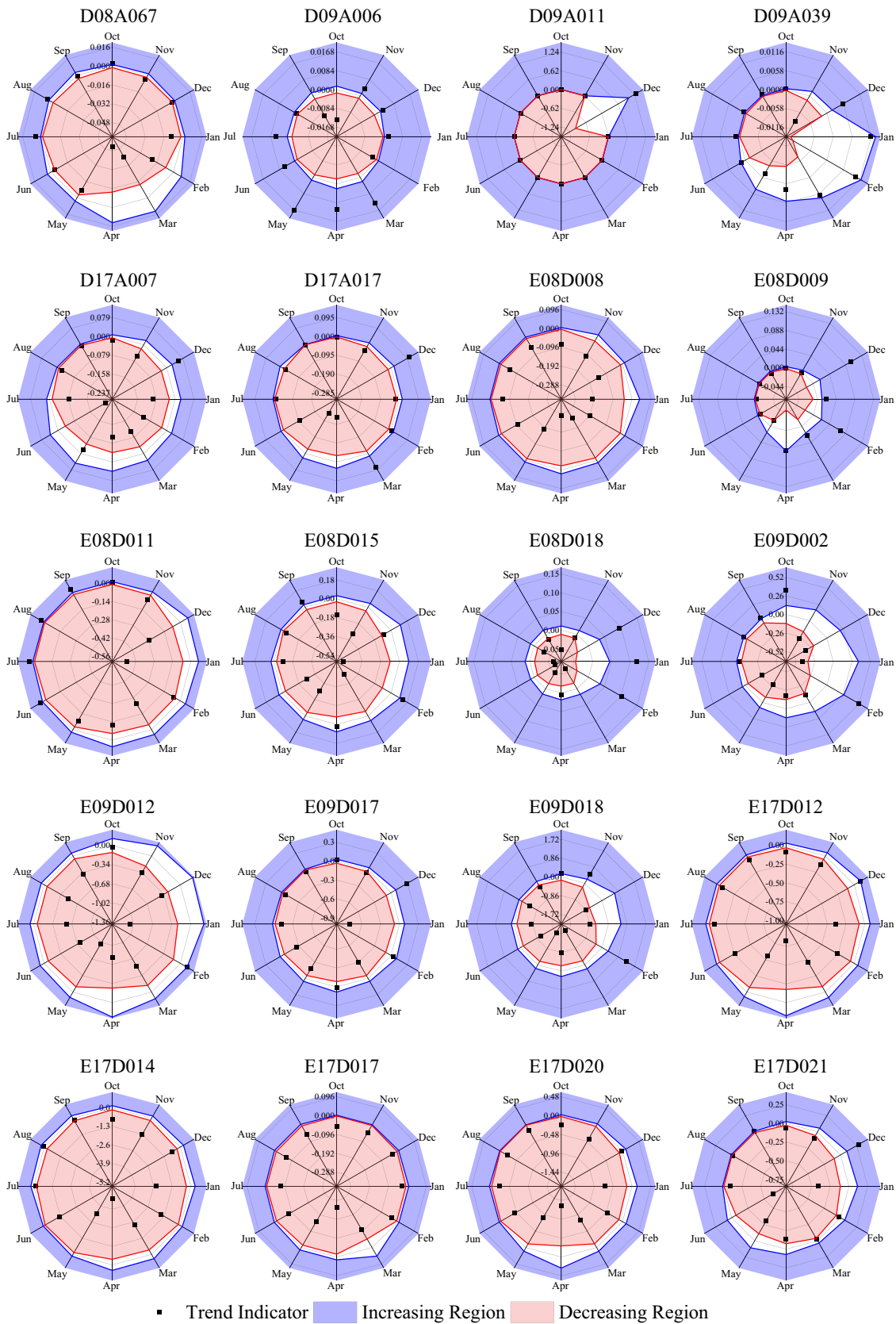


Fig. 5 The radar graphs of the ITST for all stations



decreasing trend in the vast majority of stations, as seen in Fig. 5. In the east of the region, in all months, according to the ITST, similar to the MK test, decreasing trends are observed at station E17D017 in all months and 11 months at stations E17D012 and E17D020. The station with the least decreasing trend is station D09A039. While a decreasing trend is determined in this station only in 1 month, no significant trend is determined in 7 months. An increasing trend is determined in 8 months at station D09A006. According to these results, a significant trend is also determined by ITST in the all-time series, in which a significant trend is

determined in the MK test. However, at stations D08D067, E08D011, E08D015, E08D018, and E09D002, where no significant trend is detected in the MK test, a significant trend is observed in many months with ITST. In the ITST method, a significant increasing trend is determined in 17% of the total 240-time series and a significant decreasing trend in 66%. It has been observed that the significant decreasing trend detection sensitivity of the ITST method, which detects a significant decreasing trend almost three times more than the MK test, is considerably higher. In addition, the percentage of time series with an insignificant increasing trend in

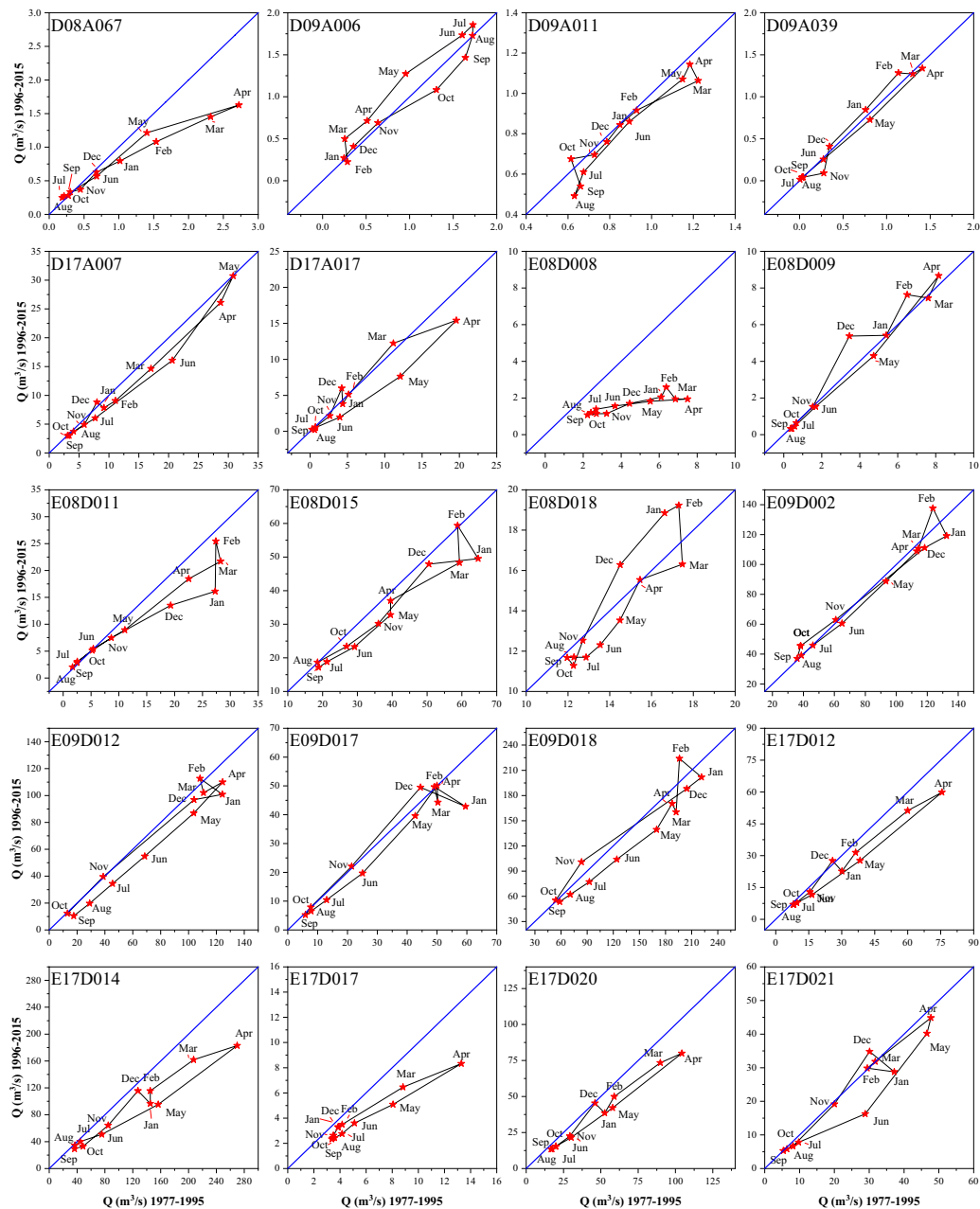


Fig. 6 The IPTA graphs for all stations

the MK test is 16%, and the percentage of time series with a significant increasing trend is 1%. However, with ITST, it is determined that 17% of the time series showed the presence of a significant increasing trend.

### 3.3 The IPTA

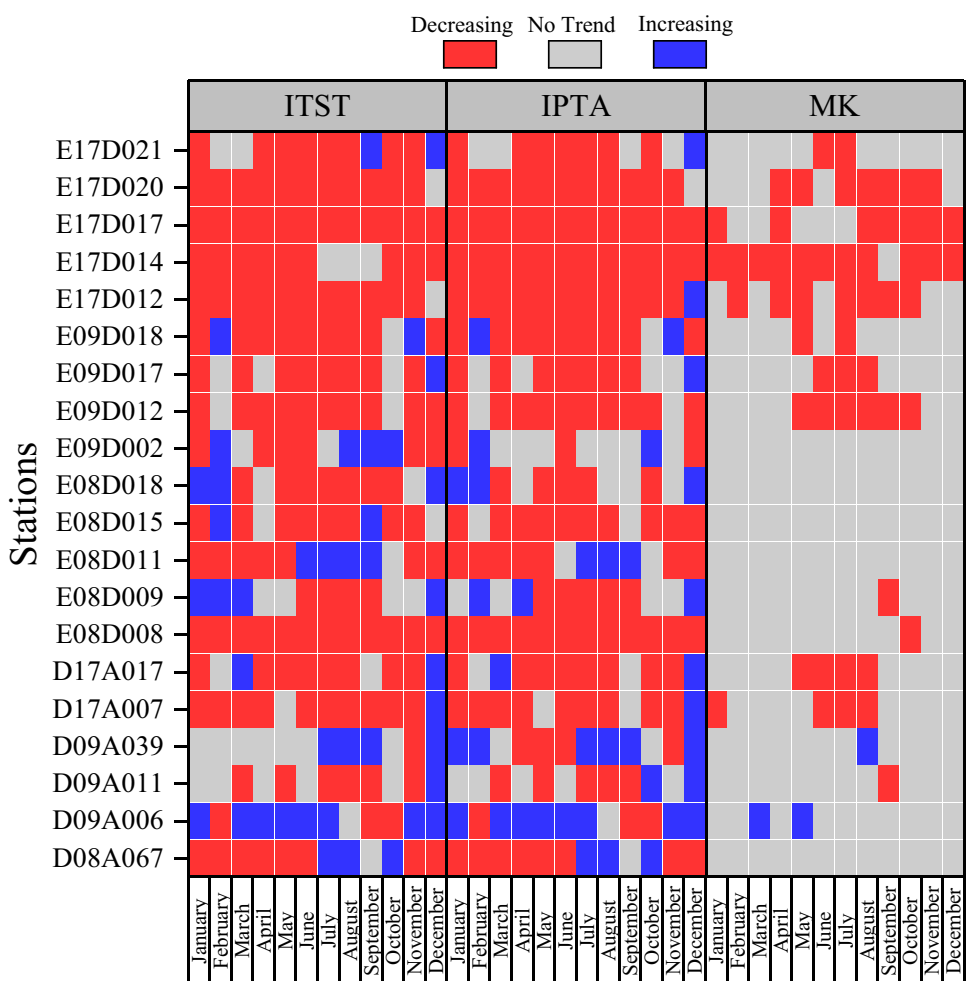
The trend analysis results of the monthly mean streamflow in the Mediterranean region using the IPTA method are given in Fig. 6. The complex structure of the polygons created in the IPTA method indicates that the structure of the evaluated time series is complex and dynamic (Şen et al., 2019). Values above the 1:1 line indicate an increasing trend, while values below indicate a decreasing trend. Accordingly, it is seen that the polygons formed at all stations except for E08D018, which are evaluated in the region, have a very complex structure. Therefore, it can be interpreted that the streamflow structure in the region is highly variable. In addition, stations E08D008, E17D014, and E17D017 have a monotonic decrease structure, and a decrease is observed in all months at these stations. A decreasing trend occurred in 11 months at stations E17D012 and E17D020. The highest increasing trend occurred at station

D09A006 in 8 months and at station D09A039 in 6 months. As the month-based trend conditions in the region are evaluated, a decreasing trend is observed at 17 stations in May and June and at 15 stations in January and July, while an increasing trend is observed at ten stations in December. The percentage of time series with a decreasing trend in the IPTA method is 66%, similar to the ITST. Although there is no complete agreement here, it has been seen that the results obtained with the IPTA method are mostly similar to the ITST.

### 3.4 Comparison of the trend methods and a general assessment

Figure 7 demonstrates a comparative graph of the months and stations in the region for which the trend is determined by MK, ITST, and IPTA methods. In the 240-time series, a significant trend rate is detected at only 24% (3 increasing, 55 decreasing) with the MK test, 83% (41 increasing, 158 decreasing) with the ITST, and 82% (38 increasing, 158 decreasing) with the IPTA. It is pointed out that the ITST determines more significant trends than the MK test regarding the studies conducted on MK and ITST in trend

Fig. 7 Comparing the trend test results for all stations

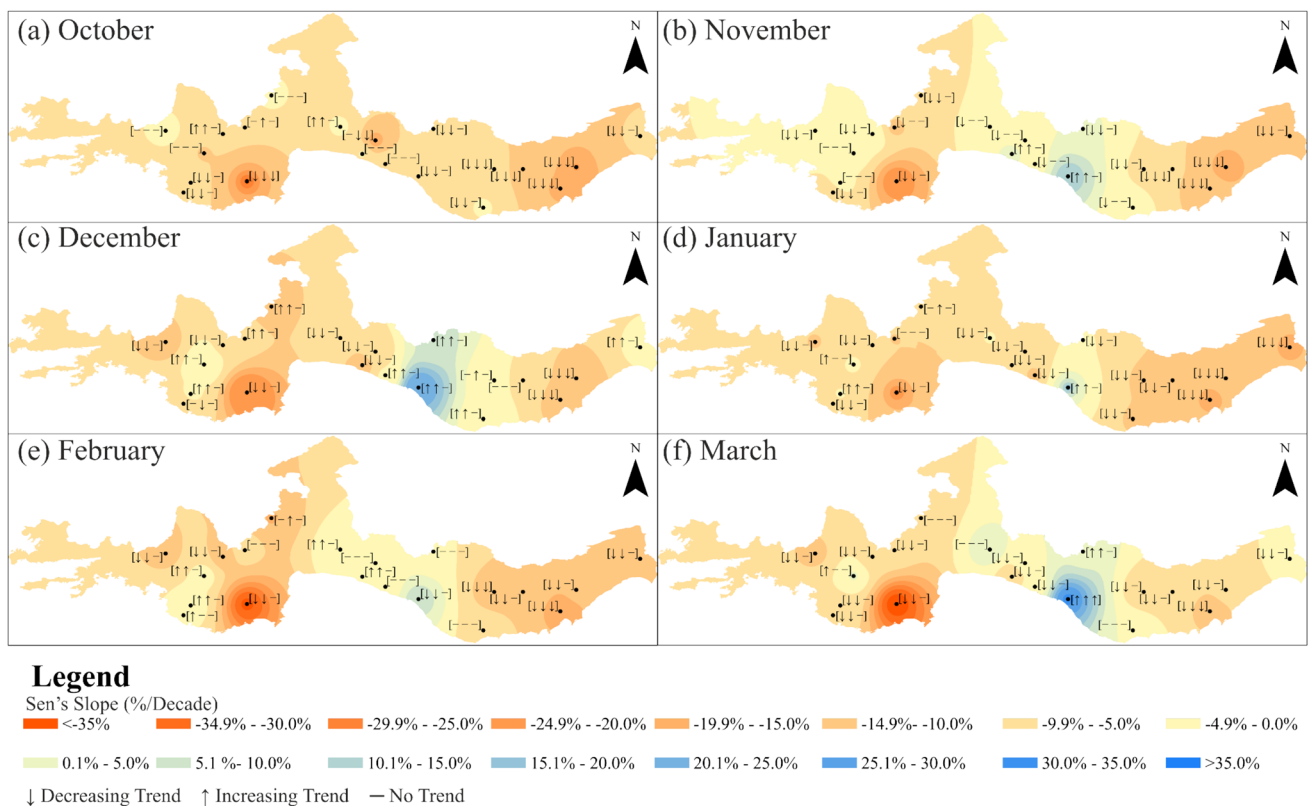


determination (Akçay et al., 2022; Gumus et al., 2022; Şan et al., 2021). Moreover, the IPTA method is novel in detecting the trend of hydro-meteorological data. It is reported that this method determined more significant trends than the MK test, similar to the ITST (Akçay et al., 2022; Arab Amiri and Gocić, 2021; Gul and Ren, 2022; Hirca et al., 2022; Singh et al., 2021b). For example, Hirca et al. (2022) compared the MK and IPTA methods in determining the trend of precipitation data, and a significant trend was determined in 12.5% of the studied months with the MK test, while a trend was determined in 81% of the months with IPTA. Şan et al. (2021) evaluated the trend of precipitation data in Vietnam with the IPTA, ITST, and MK tests. A significant trend was determined in 90% of the months examined by the ITST and IPTA methods. However, the trend was determined only in 23% of the months examined by the MK test. The present study states that the ITST and IPTA methods give similar results in trend determination. The MK test, on the other hand, determines the trend in a smaller number of time series compared to the other two methods. Thus, it can be said that the ITST and IPTA methods are more sensitive than the MK test in determining the trend of streamflow data.

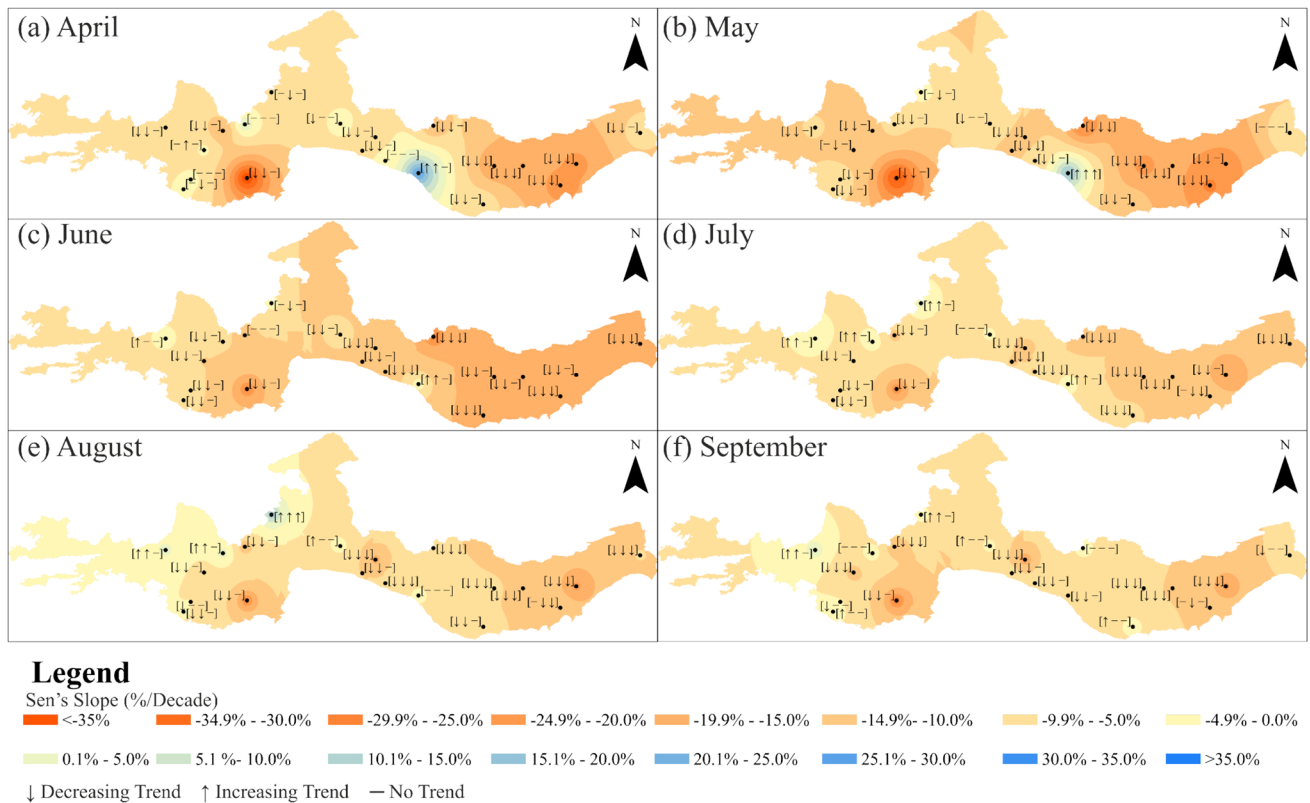
The spatial distribution of the Sen’s slope values (%/decade) in the Mediterranean region is given for October–March

and April–September in Figs. 8 and 9, respectively. These maps show trend directions obtained by three methods monthly at each station. In the maps, each symbol in square brackets represents the trend direction obtained by a method: [IPTA, ITST, MK]. Monthly spatial distributions of trend results show that increasing trend slopes are observed only in a limited part of the central part of the basin. The highest increase occurred in this region in December, March, and April. However, in the rest of the basin, the streamflow values decrease in almost every region, highest in the southwest part of the basin. In addition, according to IPTA and ITS methods, a mostly decreasing trend is determined in a significant part of the basin. However, in the MK method, it is understood that the stations with a decreasing trend mostly occur in the eastern part of the basin.

There is no study evaluating the monthly mean streamflow values trend in the Mediterranean basin in the literature. However, there are a limited number of studies covering some stations in the region and evaluating the trend of annual mean streamflow values of those stations. For example, the trend of annual mean streamflow values of 83 stations between 1964 and 1994 in Turkey was evaluated by Kahya and Kalaycı (2004). As a result of that study that used the MK test, a significant decreasing trend was determined in most



**Fig. 8** Spatial distribution of trend analysis results for **a** October, **b** November, **c** December, **d** January, **e** February, **f** March



**Fig. 9** Spatial distribution of trend analysis results for **a** April, **b** May, **c** June, **d** July, **e** August, **f** September

of the Mediterranean basin. Topaloğlu (2006) examined the trend of annual mean streamflow values between 1968 and 1997 belonging to 84 streamflow gauge stations in different regions of Turkey. While the west and east stations of the Mediterranean region showed a significant decreasing trend, a non-significant decreasing trend was determined in the middle region. Hadi and Tombul (2018) examined the trend of annual and seasonal precipitation values between 1981 and 2010 in Turkey, and they reported a significant decrease trend in precipitation in the Mediterranean region. Gumus (2019) analysed the trend of seasonal and annual precipitation values between 1970 and 2010 of the Seyhan-Ceyhan basins, located in the east of the Mediterranean region, using the MK test. As a result of that study, it was reported that the region showed a decreasing trend in the spring (March, April, and May), although it was not significant. The present study results, conducted with actual data (until 2015), show that the situation in the past continues, and the streamflow values in the Mediterranean region have a severe decreasing trend. Although a significant trend is determined in a small number of stations with the MK test, as Sen's slope, ITST, and IPTA results are added, it can be said that the water resources in the region are at serious risk. However, in future studies, it is recommended to determine the main causes of this decrease (its relationship

with climatic parameters) specific to this basin so that it will enable the establishment of preventive mechanisms against water scarcity. Thus, it will be possible to evaluate climate change's effect on streamflow values in the future under different scenarios.

## 4 Conclusion

In this study, the trend analysis of monthly mean streamflow values of the Mediterranean basin, one of Turkey's most important basins, is conducted. In addition to the classical MK method, which is the only method used in previous studies for an annual streamflow trend, the trends of monthly streamflow values are investigated with the ITST and the newly proposed IPTA methods, and the results are compared. In addition, trend slopes and existence according to three methods are evaluated spatially. The study results show that the trend of the monthly mean streamflow values of the Mediterranean basin is mainly determined as decreasing. In the previous studies made in the Mediterranean region, it is observed that the trend structure of streamflow values, which has been determined in the decreasing direction, has not changed positively. That is, the decreasing trend existence

continued. Moreover, it is found that the IPTA and ITST methods are more sensitive than the MK test in determining the trend in the dataset. Therefore, using some supportive analysis methods in addition to the MK test while conducting studies may be appropriate.

In conclusion, this study shows a significant decrease in river flow, particularly east of the basin. For this reason, it is regarded that the practitioners and decision-makers should consider these changes in the Mediterranean basin during the planning phase. Furthermore, it is recommended to carry out a future projection of streamflow in the Mediterranean region. Thus, the possible effects of future climate change on the regional water resources and the risk structure will be evaluated.

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**Author contribution** VG: conceptualization, coding, performing analysis, and writing the manuscript; OS: preparing the graphics, interpreting results, and writing the manuscript; and YA: interpreting results and writing the discussion.

**Data availability** The datasets used and/or analysed during the current study are available from the corresponding author on a reasonable request.

## Declarations

**Competing interests** The authors declare no competing interests.

**Ethics approval** Not applicable.

**Consent to participate** Not applicable.

**Consent for publication** All the co-authors are familiar and agree with the content of this paper.

**Conflict of interest** The authors declare no competing interests.

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