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Mann-Kendall ve Sen'in yeni eğilim testlerinin Fırat-Dicle Havzasındaki bazı akarsuların aylık akış serileri ile karşılaştırılması

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Anahtar Kelimeler
Fırat-Dicle Havzasu,
Mann-Kendall,
Akım,
Şen's trend test,
Türkiye

Öz: Bir değişkenin düşük, orta ve yüksek değerleri hidrolojik, meteorolojik ve iklimsel olaylarda önemli bir konudur. Ayrıca, bu değerler, dünyanın çeşitli yerlerindeki bilimsel yönlere ve gerçek uygulamalara dayanan çeşitli tasarım parametrelerini belirlemek için kullanılır. Bu bağlamda, Fırat-Dicle Havzasında iki farklı istasyonda (2174-Murat Nehri (Akkonak) ve 2634-Garzan Çayı (Kozluk)) kaydedilen aylık akarsu verileri için yakın zamanda Şen tarafından önerilen yeni bir eğilim yöntemi kullanılmıştır. Aynı verilere Mann-Kendall eğilim testi de uygulandı. İstasyonların, Mann-Kendall ve Şen eğilim testine göre istatistiksel olarak %95 güven düzeyinde önemli düşüş eğilimi gösterdİ. Önerilen yöntem, akış akışı verisinin düşük, orta ve yüksek değerlerinin grafik olarak değerlendirilmesi açısından önemli bir avantaj sağladı.

Comparison of Mann-Kendall and Sen's innovative trend tests on measured monthly flows series of some streams in Euphrates-Tigris Basin

Keywords
Euphrates-Tigris Basin,
Mann-Kendall,
Streamflow,
Şen's trend test,
Turkey

Abstract: Low, medium and high values of a variable are a significant issue in hydrological, meteorological and climatological events; moreover, these values are used to decide various design parameters based on scientific aspects and real applications around the world. In this context, a new trend method recently proposed by Şen was used for monthly streamflow data recorded at two different stations (2174- Murat River (Akkonak) and 2634-Garzan Creek (Kozluk)) in Euphrates-Tigris Basin. The Mann-Kendall trend test was also applied to the same data. It was seen that the stations had statistically significant decreasing trend according to the Mann-Kendall and Şen trend test at 95% confidence level; moreover, the proposed method provided an important advantage in terms of graphically evaluation of low, medium and high values of streamflow data.

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1. Introduction

Trend analysis has also been used to decide various design parameters based on scientific aspects and for real applications around the world. For example, streamflow in a river is analyzed and used for planning, quality and designing studies of dams, channels, rivers and basins. In this context, there are many studies to determine trends of hydrological, meteorological and climatological variables, and these issues have been investigated by many scientists and organizations by using different methodologies [1-17] up to now. For instance, trend of streamflow (daily, monthly and annual recorded) was achieved by using parametric and non-parametric statistical tests in some relevant studies [18-27]. When these studies are examined, some implications can be summarized as follow. For example, Kalayci and Kahya [19] studied trend analysis of 11 different stations of the Sakarya River Basin by using Sen's T test, Mann-Kendall (MK) test, Spearman's Rho Test, Seasonal Kendall Test and Sen's estimator of slope techniques. Monthly mean streamflow data was used and they found all the stations have decreasing trend at the α=0.05 significant level. As another study of them, Kahya and Kalaycı [5] investigated trend analysis of the monthly mean streamflow data of the 83 stations. Homogeneity of trends in monthly streamflow was also tested by using a procedure developed by Van Belle and Hughes. One of the main points of their study is that streamflow as well as precipitation and temperature parameters should be evaluated together to understand trends (increasing, decreasing and trendless time series) of the streamflow. Cigizoglu et al. [20] investigated trend analysis of 24 hydrological basins. They used average, maximum and low of streamflow data of 100 stream gauging stations. Except for a few series, decreasing trends were obtained; moreover, they compared with their study with rainfall trends studies previously prepared in the literature. As a result, they found similar results with the literature. Eris and Agiralioglu [21] used the precipitation and streamflow data of the coastal part of the Eastern Black Sea Region. They used data of 38 precipitations (1960-2005) stations and 40 streamflow (1944-2006) stations. MK trend test and double mass curve method were used in the study. In our study, trend analysis of monthly streamflow of Euphrates-Tigris basin is firstly implemented by using a new method recently proposed by Şen and Mann-Kendall trend tests.

2. Material and Method

Turkey is located in the northern hemisphere and is between nearly 36° to 42° north latitudes and 26° to 45° east longitudes. Figure 1 shows the locations of the stations: 2174- Murat River (Akkonak) and 2634-Garzan Creek (Kozluk) in the Euphrates-Tigris Basin. This basin is the largest basin and has the highest mean annual streamflow in Turkey and has two big rivers: Fırat and Dicle. Both river basins were combined in 2011, and basin number was 21.

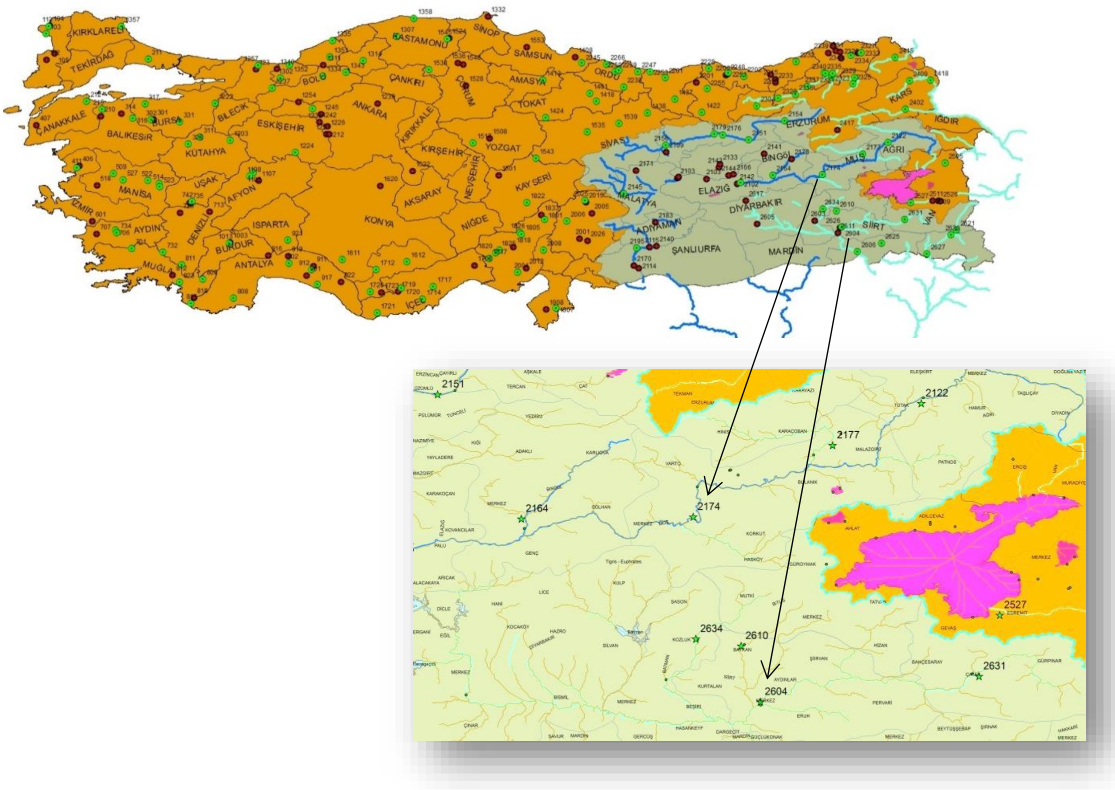

Figure 1. Locations of 2174-Murat River (Akkonak) and 2634-Garzan Creek (Kozluk) stations in Euphrates-Tigris Basin

Basic statistics of the monthly streamflow data recorded at both stations are given in Table 1. It can be seen that data has high positive skewness (right way); moreover, histograms of both stations are seen in Figure 2.

Table 1. Basic statistics of the streamflow variable in two stations of Euphrates-Tigris Basin

Order	Data date ranges	Station number	Number of data	Minimum value, m^3/s	Maximum value, m^3/s	Mean value(μ), m^3/s	Standard deviation (σ), m^3/s	Skewness coefficient (SC)
1	1987-2011	2174	260	5.78	1741.60	183.41	270.34	+2.78
2	2002-2011	2634	100	2.14	322.68	37.15	58.62	+2.66

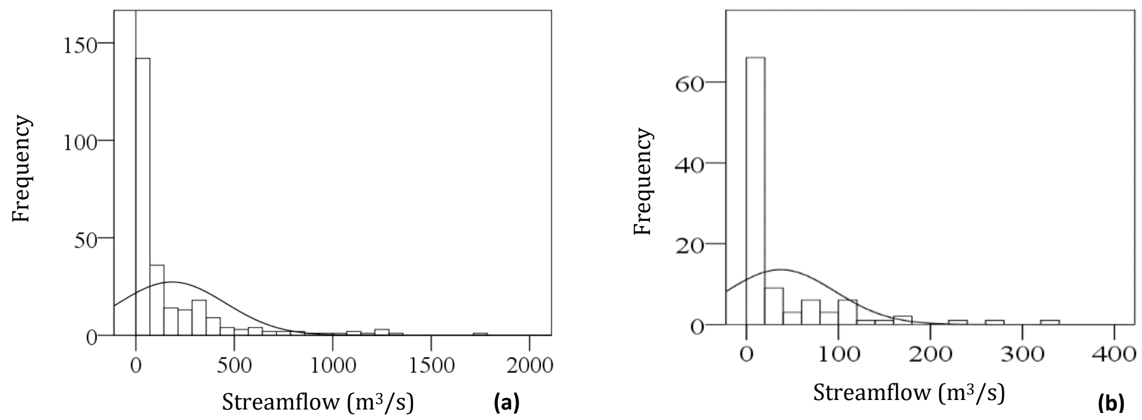

Figure 2. Histograms for (a) 2174-Murat River (Akkonak) and (b) 2634-Garzan Creek (Kozluk) stations

2.1. Mann-Kendall (MK) trend test

The MK test is one of the non-parametric tests to detect trend in a time series. Commonly used MK trend test is not described here because it can be found in related literature studies (4, 28, 29, 30, 31].

2.2. Şen trend test

A recorded time series is divided into two equal halves from the first date to the last date, and both sub-series are separately sorted in ascending manner. The first sub-series (X_i) is located on X-axis, and the other sub-series (X_j) is located on Y-axis (Figure 3) and plotted based on the Cartesian coordinate system. If data are collected on the 1:1 (45°) straight line, it can be said that there is no trend (a trendless time series). If data is in the below triangular area of the 1:1 straight line, it can be said that there is a decreasing trend in time series. If data is in the upper triangular area of the 1:1 straight line, it can be said that there is an increasing trend in time series [22]. Moreover, H_0 hypothesis refers to "There is no statistically significant trend in the time series". Opposite hypothesis, H_1, refers to "There is a statistically significant trend in the time series".

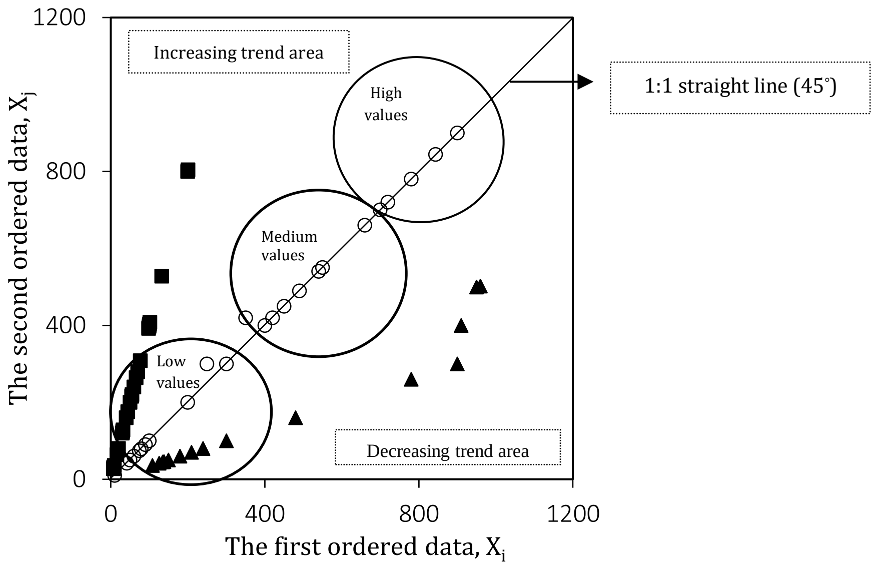

Figure 3. Graphic of decreasing, increasing and trendless areas (Şen, 2012, 2015)

Şen [32] proposed a new statistical process to the method. Steps of this method are given by the following formulas 1-6.

$$E(s) = \frac{2}{n}\left[E(\overline{y_2}) - E(\overline{y_1})\right] \quad (1)$$

$$\sigma_s^{\,2} = \frac{4}{n^2}\left[E(\overline{y_2}^{\,2}) - 2E(\overline{y_2 y_1}) - E(\overline{y_1}^{\,2})\right] \quad (2)$$

$$\rho_{\overline{y_2 y_1}} = \frac{E(\overline{y_2 y_1}) - E(\overline{y_2}) - E(\overline{y_1})}{\sigma_{\overline{y_2}} \sigma_{\overline{y_1}}} \tag{3}$$

$$\sigma_s^2 = \frac{8}{n^2} \frac{\sigma^2}{n} \left(1 - \rho_{\overline{y_2 y_1}}\right) \tag{4}$$

$$\sigma_s = \frac{2\sqrt{2}}{n\sqrt{n}} \sigma \sqrt{\left(1 - \rho_{\overline{y_2 y_1}}\right)} \tag{5}$$

$$CL_{(1-\alpha)} = 0 \mp s_{critical} \sigma_s \tag{6}$$

In here, (y1): mean of the first data, (y2): mean of the second data, ρ: correlation between first and second data, s: slope value, n: number of data, σ: standard deviation of all data, σ_s: slope standard deviation, and $s_{critical}$ denotes Z critical values in one-way hypothesis at 95% confidence level. Critical upper and lower limits calculated by Equation 6 are established to make for hypothesis test. If slope value, s, of each station is in outside the lower and upper confidence limits, and thus, the alternative hypotheses, H_1, are approved, and it can be said that there is a trend (Yes) in time series. The type of trend is stated depending on the slope (s) sign. Slope value (s) can be positive or negative. This means that there is an increasing (+) or a decreasing (-) trend in time series (Şen, 2015). This method was applied annual flow, annual total flow, annual total precipitation by Şen (2012), and the long-term recorded air temperature (Şen, 2014). Kisi and Ay [33] determined the trend of some water quality variables. Ay and Kisi (2014) applied to the streamflow data. Şen (2015) applied to air temperature, streamflow and rainfall data.

3. Results

Assumptions such as pre-whitening process (von Storch, 1995) [34] were not applied to the data in this study. Recorded data was taken into consideration not to lose originality of the time series in the trend methods [12, 22, 35, 31]. Table 2 shows the results of the MK trend test for both stations. Z value in each station was calculated and compared with normal distribution critical Z values at the 95% two-tailed confidence level. According to the MK trend test, because Z values (|-2.51| and |-2.49|) of both stations are bigger than critical value (|-1.96|), the stations have a decreasing trend; therefore, H_1 hypothesis is accepted for both stations.

Table 2. Results of the Mann-Kendall trend test

Station number	Data ranges	Test statistic (S)	Calculated ± Z value	Z critical value (α=0.05)	Trend	H_0, null hypothesis
2174	1987-2011	-3518	-2.51*	±1.96	Yes (-)	Reject
2634	2002-2011	-834	-2.49*	±1.96	Yes (-)	Reject

** indicates that trend is statistically significant at the 95% two-tailed confidence levels.*

Results of the Şen trend test are also given in Figures 4, 5 and Table 3. Low, medium and high values of the streamflow can be clearly seen in these graphics. Type of trend is seen in Table 3 (see row 15). For instance, a decreasing trend in high and medium values is seen for Murat River in Figure 4; moreover, the station has the decreasing time series as seen in Table 3; therefore, H_1 hypothesis is accepted. Slope value (-0.481) of this station in Table 3 is out of critical limits (-0.04091<s<+0.04091) for 95% confidence level.

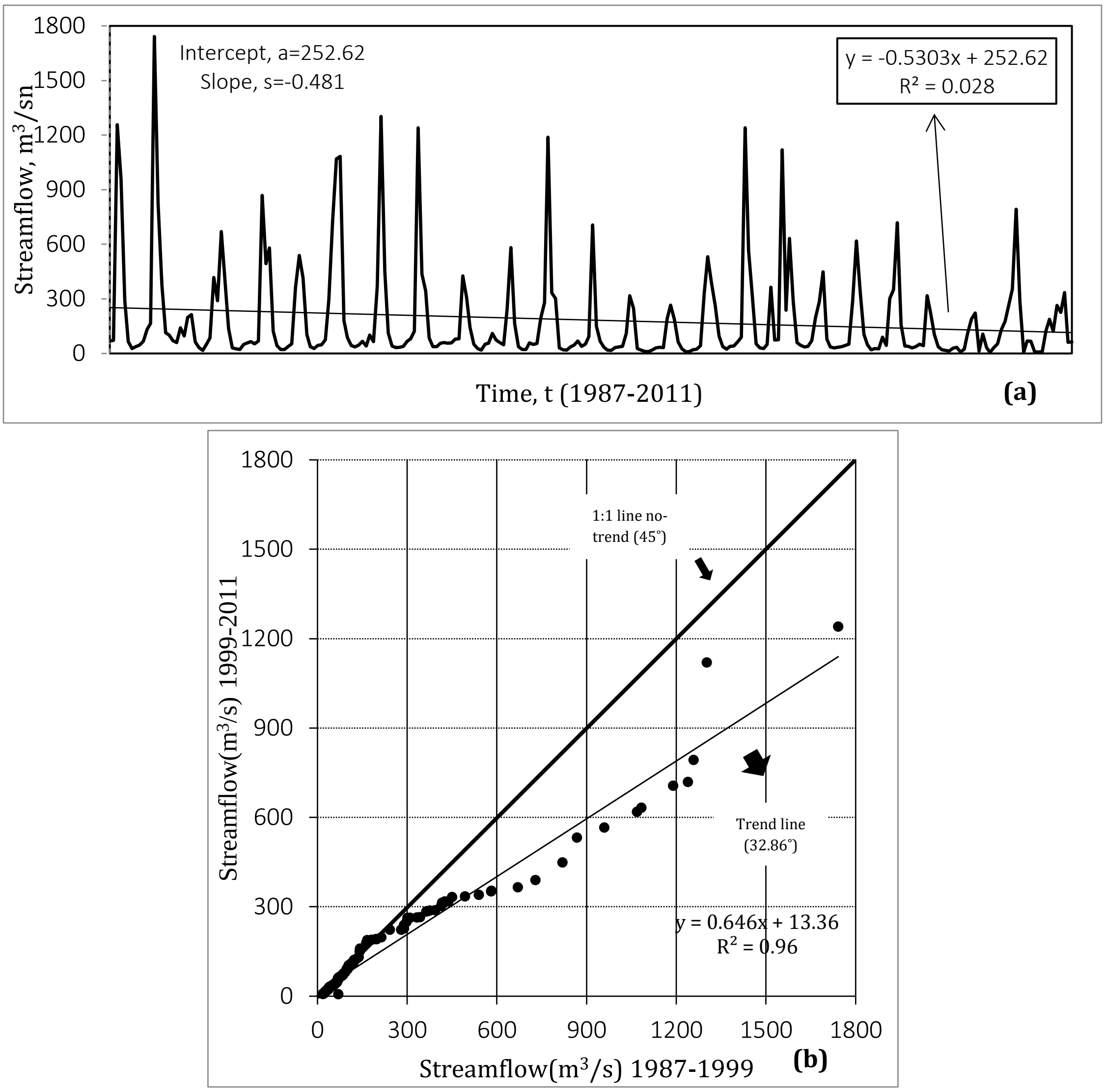

Figure 4. Results of Şen (2015) trend test and (a) time series and (b) scatter diagram of 2174-Murat River

A decreasing trend in low, high and medium values for Garzan Creek is seen in Figure 5; moreover, this station has the decreasing time series as seen in Table 3; therefore, H_1 hypothesis is accepted. In Table 3, slope value (-0.471) of this station is out of critical limits ($-0.0486<s<+0.0486$) for 95% confidence level.

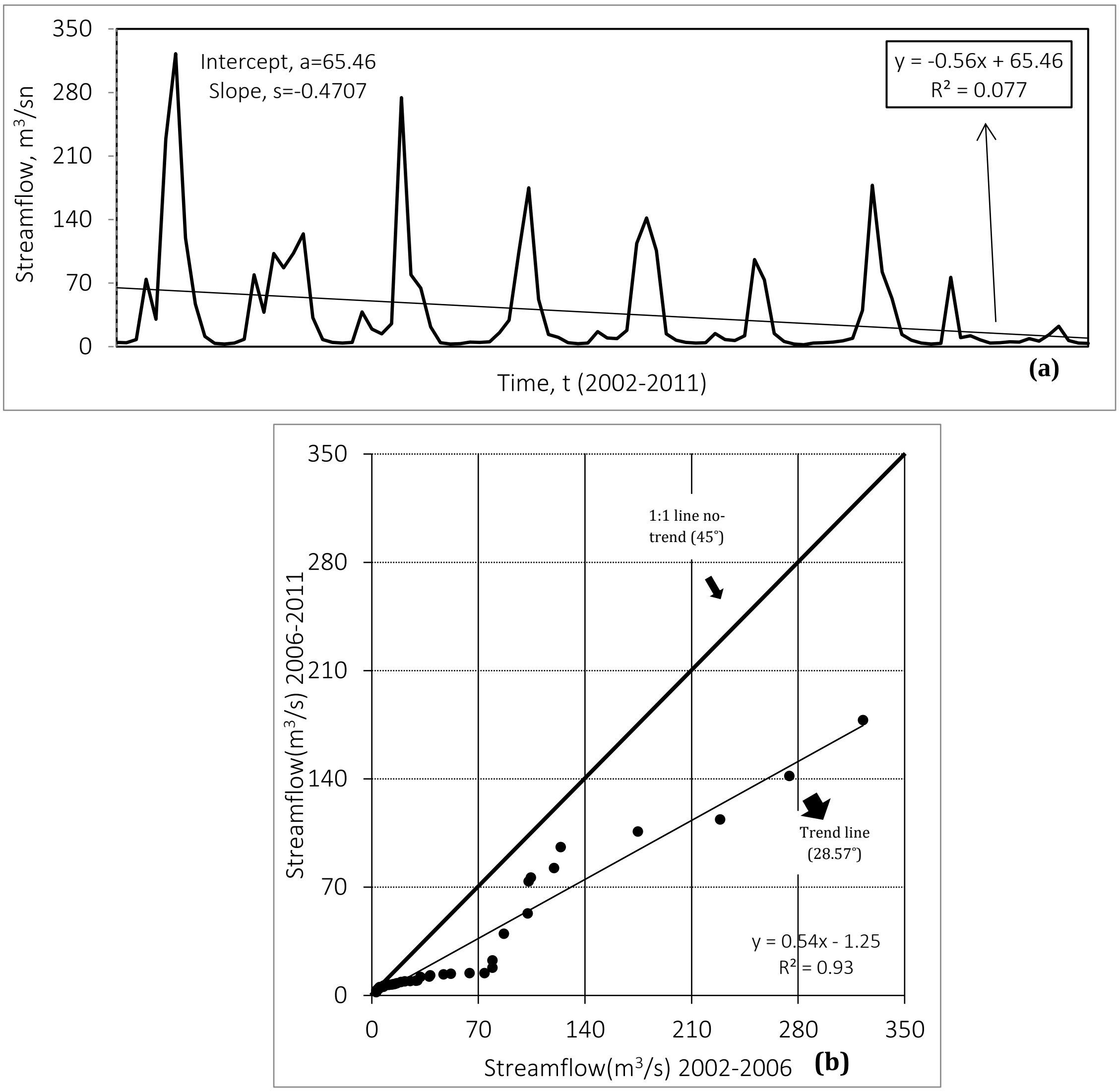

Figure 5. Results of Şen (2015) trend test and (a) time series and (b) scatter diagram of 2634-Garzan Creek

Table 3. Results of Şen (2015) trend test

1	Stations	2174- Murat River(Akkonak)	2634-Garzan Creek (Kozluk)
2	Type of data	Streamflow (m^3/s)	Streamflow (m^3/s)
3	Number of data, n	260	100
4	Slope, s (+ or -)	-0.481	-0.471
5	Intercept, a	252.62	64.46
6	Standard deviation, σ_n	270.34	58.62
7	Mean value, $\overline{X}_n$	183.41	37.15
8	Correlation coefficient (r), $\overline{\rho_{y_1}}, \overline{\rho_{y_2}}$	+0.9814	+0.9682
9	Slope standard deviation, σ_s	0.0248	0.0296
10	Significance level, α=0.05(One-way)	0.05	0.05
11	Lower CL (confidence limit) (95%)	-0.04091	-0.0486
12	Upper CL (confidence limit) (95%)	+0.04091	+0.0486
13	Hypothesis (H_0 or H_1)	H_1	H_1
14	Decision (Yes or No)	Yes	Yes
15	Type of trend (increasing, decreasing or no trend)	Decreasing	Decreasing

The variations of the streamflow of the stations are summarized in Table 4 in terms of low, medium and high values. In this table, Şen and MK test results are particularly evaluated. It is clearly seen from this table that the results of two methods have a statistically significant decreasing trend.

Table 4. Comparison results of the Mann-Kendall (MK) and Şen's trend tests for both stations

Station number and name	MK test result	Şen's trend test		
		Low values	Medium values	High values
2174- Murat River	Yes (-)	No	Yes (-)	Yes (-)
2634- Garzan Creek	Yes (-)	Yes (-)	Yes (-)	Yes (-)

4. Discussion and Conclusion

MK and Şen trend tests provide us some important aspects and complexity of the trend phenomenon. In this context, each station was analyzed individually, and both stations were compared with each other, and it was tried to tell some thoughts for trend of the streamflow and differences between two trend tests. As a result, general and specific findings derived from the study can be as follows. We can imply that trends of the streamflow recorded at two stations of Euphrates-Tigris Basin have a decreasing way. According to the results of state-of-art studies, streamflow in Euphrates-Tigris Basin of Turkey has been generally decreasing trend [9, 19, 36, 37, 38, 39]. Both trend tests gave same trend and the result of the tests was that there was a statistically decreasing trend. Şen [32] method gave some difference aspects of the trend analysis. It can be also said that Şen's test is more precision than the MK method, and shows all ranges (low, medium and high) of data, and data can be graphically furnished on the Cartesian coordinate system.

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