DOI: 10.15233/gfz.2018.35.3

Original scientific paper

UDC 556.5

Trend analysis of monthly streamflows using Şen's innovative trend method

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Received 20 June 2017, in final form 17 December 2017

Trend analysis of monthly mean streamflows is essential for better water resources management and planning. In this study, Mann Kendall (MK), Şen's method and Şen's innovative trend method (ITM) were employed in order to examine the possible trends of monthly streamflows obtained from nine stations from three basins (Yakabasi and Derecikviran in Western Black Sea Basin; Durucasu, Sutluce, Kale and Gomeleonu in Yesilirmak Basin; Simsirli, Tozkoy and Topluca in Eastern Black Sea Basin) located in Black Sea Region of Turkey. Based on the MK, streamflow data of Tozkoy Station which is located in western part of the Eastern Black Sea Region showed a significantly increasing trend while a significantly decreasing trend was found for the Yakabasi, Derecikviran, Durucasu and Sutluce stations which are situated in western part of the Black Sea Region. According to the Şen's trend method, a significantly decreasing trend was seen in Durucasu, Sutluce, Yakabasi and Derecikviran stations while Tozkoy station showed significantly increasing trend. According to the ITM, low-medium values of Tozkoy Station indicated slightly increasing trend while low and medium streamflow values of Yakabasi, Derecikviran, Durucasu and Sutluce stations showed a decreasing trend. High streamflow values of Derecikviran and Sutluce stations showed a decreasing trend while corresponding values of Yakabasi, Simsirli and Tozköy stations indicated an increasing trend. It was showed that trends of low, medium, and high data can be easily identified by ITM which has some advantages (having no assumption such as serial relationship, nonnormality, test number) over the Şen's method and Mann-Kendall test.

Keywords: monthly mean streamflows, trend analysis, Mann-Kendall, Şen's method, innovative trend method

1. Introduction

Observation of the streamflows data is one of the most important issues in water resources planning, management and designing related projects. There are many factors such as climate change and anthropogenic activities which are effective on time-dependent streamflow data. Identifying possible trends in historical streamflow data is one of the main steps in water resources. Decision on water management and policies is mainly affected by a detection of a significant trend in streamflow (Yenigun et al. 2008).

There are numerous studies related to trend analysis of hydro-meteorological time series (Kahya and Kalayci, 2004; Cigizoglu et al., 2005; Topaloglu, 2006; Yenigün et al., 2008; Kim and Jain, 2010; Tabari and Marofi, 2010; Tabari and Talaee, 2011; Eris and Agiralioglu, 2012; Shadmani et al., 2012; Unal et al., 2012; Tabari et al., 2012; Palizdan et al., 2014; Sayemuzzaman and Jha, 2014). Kahya and Kalayci (2004) used non-parametric Spearman's Rho, Şen's T, MK, and the Seasonal Kendall trend tests for examining the possible trends in monthly flows of Turkey. They showed that basins situated in western Turkey generally exhibited decreasing trend, significant at the 0.05 or lower level, while the basins situated in eastern part of Turkey showed no trend. Cigizoglu et al. (2005) examined the possible trends in high, mean, and low streamflows of some rivers in Turkey. They used nonparametric MK test and parametric t test. They indicated that flows showed a decreasing trend except at a few stations. Topaloglu (2006) utilized the MK for identifying possible trend in annual minimum, mean and maximum streamflows and monthly mean streamflows in 26 basins of Turkey. He reported that of the 26 basins, only basins with the number of 14-16 and 22-25 showed significant upward trend for small number of stations situated mostly in the Black Sea, Central and Eastern Anatolia regions. Yenigün et al. (2008) investigated the trends in streamflow of the Euphrates basin, Turkey, by using non-parametric trend tests (MK and Spearman's rho). They found that there were significant decreasing trends in six stations and an upward trend for only one station. Kim and Jain (2010) employed a quantile regression methodology for a regional analysis of the changes in streamflow seasonality. Eris and Agiralioglu (2012) investigated the trend analysis of hydro-meteorological time series from Eastern Black Sea Region of Turkey using MK test. They used annual precipitation data of 38 stations and flow data of 40 stations. For annual flow data, they found no trend in 35 stations while the remaining stations showed significant trends. Unal et al. (2012) examined the temporal and spatial variability of precipitations in Turkey and the results showed that there were decreasing trends in annual precipitations dominating throughout Anatolia, including west, and southwest sections.

Recently, innovative trend method (ITM) first proposed by Şen (2012) has been succesfully applied in hydrological time series (Şen, 2014; Kişi and Ay, 2014; Haktanir and Citakoglu, 2014; Ay and Kişi, 2015). Şen (2012) proposed ITM and applied to annual total precipitation and streamflow time series of some stations in Turkey. Şen (2014) applied ITM to set of temperature records from the Marmara region in Turkey and he reported that this new method did not have any restriction, and it was applicable whether the time series was serially correlated, nonnormally distributed, or had short record length. Kişi and Ay (2014) applied

Mann-Kendall and ITM for water quality parameters of the Kizilirmak River, Turkey. Haktanir and Citakoglu (2014) used innovative trend method, MK and linear regression trend, von Neumann independence, Wald-Wolfowitz stationarity, and Mann-Whitney homogeneity tests for trends of maximum rainfall series of standard durations recorded in Turkey. The test results indicated that almost 90% of all annual maximum rainfall series were trend free, stationary, independent, and homogeneous at 5% probability. Ay and Kişi (2015) investigated the trends of monthly total precipitations of Black Sea and Central Anatolia regions, Turkey by using MK and ITM. They have succesfully evaluated the trends of low, medium and high precipitations using ITM. According to the our best knowledge, there is no published study related to use of ITM in trend analysis of streamflows. In the current study, ITM was also used to examine the possible trends in low, medium and high monthly streamflow values. The main goal of the study is to investigate the trends of long term streamflow data of Black Sea Region, Turkey using MK, Şen's method and ITM. The next section briefly describes the case study and trend methods used in the analysis. The 3rd section gives the trend analsysis results and discussion. The conclusions derived from the analaysis is provided in the last section.

1. Materials and methods

2.1. Case study

In the study, monthly mean streamflow data from nine stations, Yakabasi, Derecikviran, Durucasu, Sutluce, Kale, Gomeleonu, Simsirli, Tozkoy and Topluca, Black Sea Region of Turkey (Fig. 1) were used. Data cover the period of 1964-2007 without any gap or missing values. Double mass curve method (DMCM) was applied for seeing the homogeneity of each data set (Searcy and Hardison, 1960). According to the graphical DMCM, all streamflow data were found to be homogeneous. As an example, the curve of the Yakabasi (1302) station is shown in Fig. 2. The straight line indicates homogeneity of the data. The Black Sea coast has the highest rainfall amount in Turkey. Its eastern part receives 2,200 millimeters annual rainfall and is the only region in the country that collects rainfall throughout the year. The climate of this region is wet and humid (generally winter 4°C and summer 22°C). Annual mean total rainfall is 842 mm and 19.4% of this is contributed by summer precipitations. Annual mean relative humidity is very high, 71% (Sensoy et al., 2008). Basic statistics of the used streamflow data are provided in Tab. 1 for each station. The stations' numbers and basins are also included in the table. In the table, WBS, YES and EBS indicate the Western Black Sea, Yesilirmak and Eastern Black Sea, respectively. Average precipitations in WBS, YES and EBS basins are 811, 496 and 198 mm/year and their river basin areas are 29598, 36114 and 24 077 km^2, respectively (Kahya and Kalayci, 2004). It is apparent from the table that Durucasu station has the highest skewness followed by Kale station while the Yakabasi has the lowest value. The stations in Yesilirmak Basin generally higher skewed distribution than those of the WBS and EBS. Kale Station has the highest mean and streamflow range while the lowest mean and range belong to Tozkoy Station.

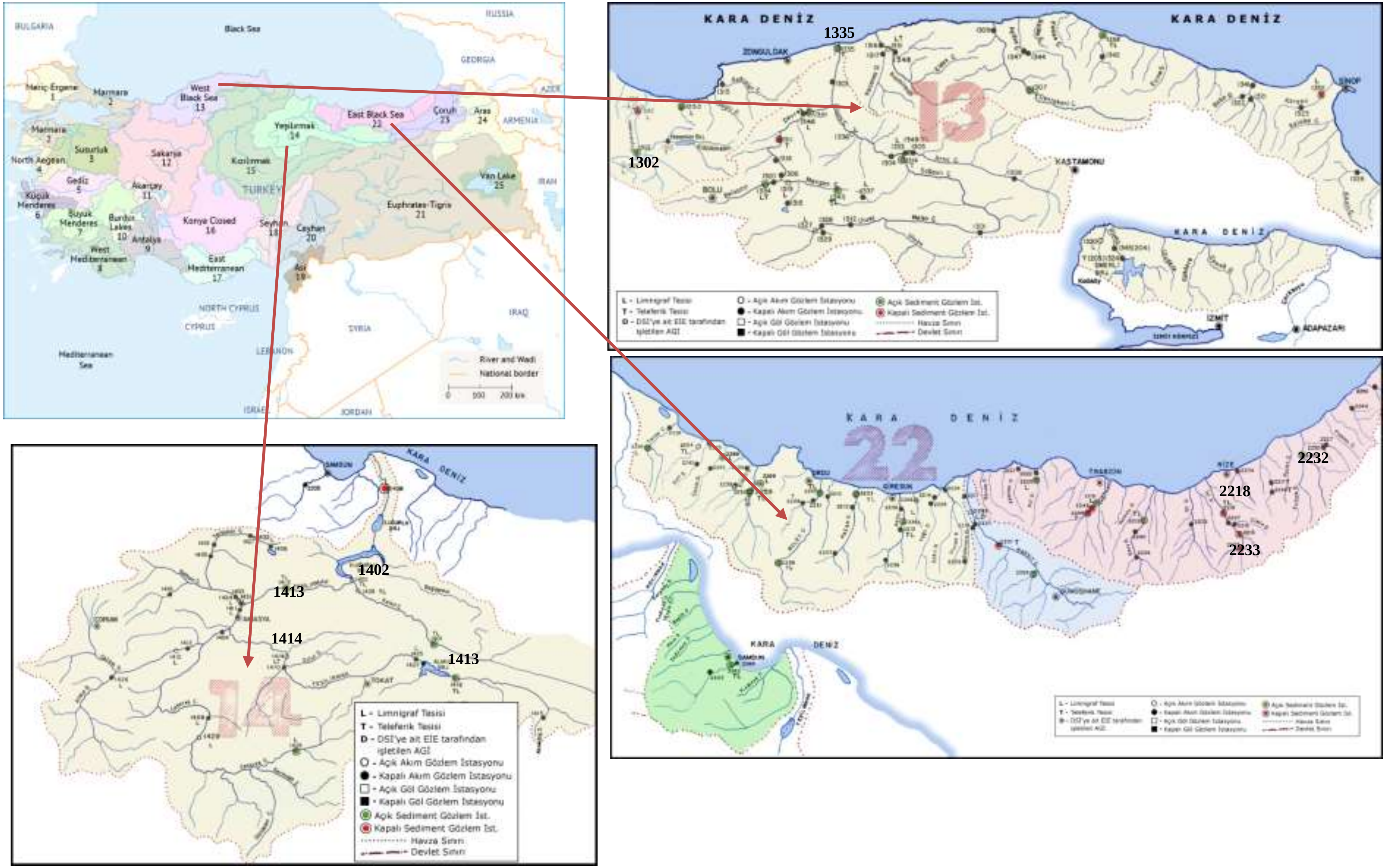

Figure 1. Geographical location of the basins and studied stations (Yakabasi, 1302; Derecikviran,1335; Durucasu, 1413; Sutluce, 1414; Kale,1402; Gomeleonu, 1418; Simsirli,2218; Tozkoy, 2233; Topluca, 2232) in Black Sea Region of Turkey.

Table 1. Basic statistics of the observed monthly streamflow in Black Sea Region (1964–2007).

Statistics	Station no	Basin	Mean	Range	Sd	Cv	Skewness
Yakabasi	1302	WBS	37.73	162.8	29.46	0.78	0.98
Derecikviran	1335	WBS	98.76	562.8	89.13	0.90	1.62
Durucasu	1413	YES	61.37	346.6	53.21	0.87	1.87
Sutluce	1414	YES	23.29	87.30	15.68	0.67	1.41
Kale	1402	YES	150.8	750.7	121.7	0.81	1.84
Gomeleonu	1418	YES	18.30	109.7	20.50	1.12	1.76
Simsirli	2218	EBS	27.85	97.80	20.63	0.74	1.42
Tozkoy	2233	EBS	6.63	35.90	7.09	1.07	1.55
Topluca	2232	EBS	28.79	118.2	20.15	0.70	1.37

WBS: Western Black Sea, YES: Yesilirmak, EBS: Eastern Black Sea

Range: Difference between maximum and minimum values, Sd: Standard deviation, Cv: Variation coefficient

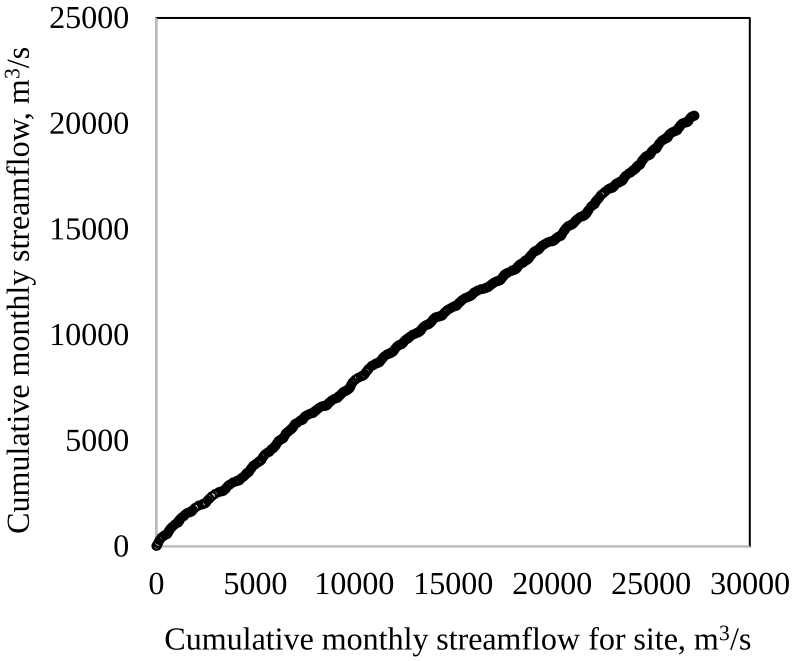

Figure 2. Double mass curve of Yakabasi (1302) station.

2.2. Trend tests

In this study, three different types of trend methods were applied for test. First, nonparametric Mann-Kendall trend test was used in order to examine the presence of a monotonic increasing or decreasing trends. Second, Şen's method was applied to estimate the true slope of a linear trend (Gilbert, 1987). Finally, innovative trend method was considered to check the possible trends in low, medium and high streamflow data. The Mann-Kendall test is designed for monotonic cases and thus it is not suitable for cases with seasonal or other cycle data. In the Şen's method, which uses a linear model to estimate the trend's slope and the residuals' variance, data should be constant in time. It should be noted that the Şen's method is not highly affected by outliers or single data errors. The mentioned methods offer many advantages that have made them useful in analyzing hydrological time series data.

2.3.1. Mann-Kendall test

The Mann-Kendall test is applied in cases when the time series data values x_i are assumed to suit the following model

$$x_i = f(t_i) + \varepsilon_i \tag{1}$$

where $f(t)$ = a continuous monotonic time dependent function, ε_i = residuals which are assumed to be from the same distribution having zero mean. Therefore, it is expected that the distribution's variance should be constant in time.

The aim is to test the null hypothesis of no trend, the null hypothesis (H_0), i.e. the data x_i is randomly ordered in time, versus the alternative hypothesis (H_1) where an upward or downward monotonic trends exist. Hence, two statistics might be computed depending on the data length, the S statistics provided by Gilbert (1987) and the Z statistics. S test is utilized for the time series having data points less than 10, whereas normal approximation is utilized for the time series having 10 or more data points (n) (Kişi, 2015).

The Mann-Kendall test statistic S can be computed using the following formula:

$$S = \sum_{j=1}^{n-1} \sum_{k=k+1}^{n} \operatorname{sgn}\left(x_k - x_j\right) \tag{2}$$

In the above formula x_j and x_k are the data values at times j and k, $j > k$, respectively, and

$$\operatorname{sgn}\left(x_k - x_j\right) = \begin{cases} 1 & \text{if } x_k - x_j > 0 \\ 0 & \text{if } x_k - x_j = 0 \\ -1 & \text{if } x_k - x_j < 0 \end{cases} \tag{3}$$

If data points are less than 10, the absolute value of S is compared with the theoretical distribution of MK (Gilbert, 1987). If the absolute value of S equals or exceeds a specific value $S_{\alpha'/2}$ (which has the probability less than α'/2), then at certain probability level H_0 is rejected.

It is worth noting that a positive S value represents an increasing trend whereas a negative value shows a decreasing trend. The significance level of 0.001 shows that there is a 0.1% probability that the values x_i are from a random distribution and with that probability we make a mistake when H_0 is rejected (Niazi et al., 2014).

If data points are more than 9 (which is the case of this research) the normal approximation test should be used. However, precaution should be taken when the number of data values is close to 10 as well as several tied values in the time series, the validity of normal approximation may be reduced, it may reduce the validity of the normal approximation.

For data points which are distributed identically and independently with a zero mean, the variance of S can be computed by the following equation

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p (t_p - 1)(2t_p + 5)\right] \tag{4}$$

where q denotes the number of tied groups and t_p represents the number of data values in the q^{th} set. The statistic of the Mann–Kendall test, Z, can be computed considering the values of S and $VAR(S)$ as below:

$$Z = \begin{cases} \frac{S+1}{\sqrt{VAR(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \frac{S+1}{VAR(S)} & \text{if } S < 0 \end{cases} \tag{5}$$

The presence of a trend's significance is evaluated by computing the Z value. A positive/negative value of Z indicates an increasing/decreasing trend.

In a two-sided trend test, with α' indicating the significance level, the null hypothesis is rejected if the $|Z| > Z_{1-\alpha'/2}$, where $Z_{1-\alpha'/2}$ is get from the standard normal cumulative distribution tables.

2.3.2 Şen's method

The nonparametric Şen's method (Şen, 1968) is useful tool for estimating the true slope of an existing linear trend. Therefore, $f(t)$ in equation (1) is equivalent to

$$f(t) = Qt + B \tag{6}$$

where Q stands for the slope and B is a constant. First, the slopes of all data pairs are calculated as below:

$$Q_i = (x_j - x_k) / (j - k), \quad j > k. \tag{7}$$

In the above relation, N slopes can be calculated which estimate Q_i ($N = n(n-1)/2$, n = data points. The median of these N values of Q_i is the Şen's estimator of slope. This method is valid for n as small as 10 unless there are many ties.

In this study, two frequent confidence levels $\alpha' = 0.01$ and $\alpha' = 0.05$ were applied, bringing about two diverse confidence intervals. First $C_{\alpha'}$ is computed as:

$$C_{\alpha} = Z_{1-\alpha'/2}\sqrt{VAR(S)} \tag{8}$$

In the above relation, $Z_{1-\alpha'/2}$ can be obtained from the standard normal distribution.

Next, for calculating the lower and upper intervals of Q ($Q_{\min}$ and $Q_{\max}$), $M_1 = (N - C_{\alpha'}) / 2$ and $M_2 = (N + C_{\alpha'}) / 2$ are calculated which are the M_1th largest and the $(M_2 + 1)$th largest of the N ordered slope estimates Q_i.

The median of $x_i - Qt_i$ gives an estimate of B (Sirois, 1998). Similarly, estimation of the constant B of the 99% and 95% confidence intervals' lines can be computed through the same methodology.

2.3.3. Innovative trend method

Innovative trend method (ITM), which is new trend analysis, was first introduced by Şen (2012). He claimed that commonly utilized Mann-Kendall and Spearman's rho tests have some restrictive assumptions, for example, independent structure of the time series, normal distribution, and data length (Kişi, 2015). In this method, time series is split into two equivalent sets. Both sets are individually sorted in ascending order. The first portion of the time series is placed on the horizontal x-axis, while the second 50% of the time series is placed on the vertical y-axis. The procedure of ITM is shown in Fig. 3 on the Cartesian coordinate system. Data points plotted on the 45° ideal line indicate no trend in the time series. There is an/a increasing/decreasing trend if data are placed on the upper/lower triangular area of the ideal line (Şen, 2012; Şen, 2014).

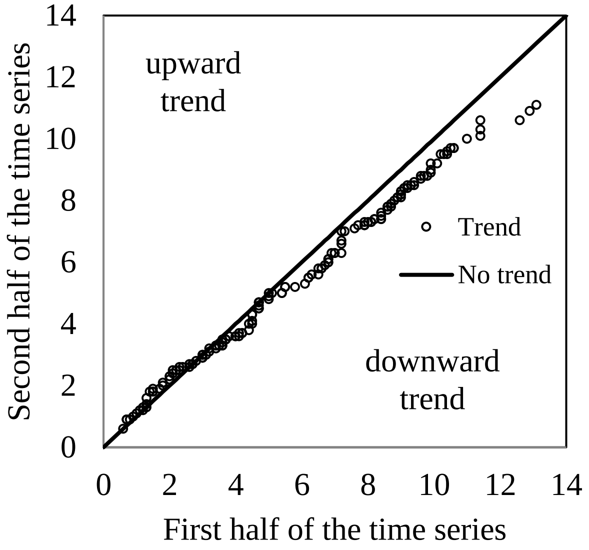

Figure 3. The innovative trend method proposed by Şen (2012)

3. Results and discussion

3.1. Mann-Kendall

MK trend test results for each station are provided in Tab. 2 according to the confidence levels of 10%, 5% and 1%. In this study, pre-whitening was not employed because it causes loss of time series' originality (Sang et al., 2014; Şen, 2012). From Tab. 2, it is apparent that the Yakabasi, Derecikviran, Durucasu, Sutluce, Gomeleonu and Simsirli stations show downward trend, while the Kale and Topluca stations have upward trend but not significant. Durucasu and Sutluce have significantly decreasing trends with respect to 1% confidence level while the Yakabasi and Derecikviran show decreasing trends with respect to 5% confidence level. Out of nine stations, only Tozkoy Station has significantly increasing trend according to

Table 2. Mann-Kendall test results of the monthly streamflows (1964−2007).

Station	Calculated $\pm Z$	Critical			H_0 hypothesis			Trend		
		$\pm Z_{0.90}$	$\pm Z_{0.95}$	$\pm Z_{0.99}$	α'=10%	α'=5%	α'=1%	α'=10%	α'=5%	α'=1%
Yakabasi	−2.065**	±1.645	±1.96	±2.576	Reject	Reject	Accept	Yes (−)	Yes (−)	No
Derecikviran	−2.230**	±1.645	±1.96	±2.576	Reject	Reject	Accept	Yes (−)	Yes (−)	No
Durucasu	−6.000***	±1.645	±1.96	±2.576	Reject	Reject	Reject	Yes (−)	Yes (−)	Yes (−)
Sutluce	−8.747***	±1.645	±1.96	±2.576	Reject	Reject	Reject	Yes (−)	Yes (−)	Yes (−)
Kale	1.066	±1.645	±1.96	±2.576	Accept	Accept	Accept	No	No	No
Gomeleonu	−0.638	±1.645	±1.96	±2.576	Accept	Accept	Accept	No	No	No
Simsirli	−0.141	±1.645	±1.96	±2.576	Accept	Accept	Accept	No	No	No
Tozkoy	1.738*	±1.645	±1.96	±2.576	Reject	Accept	Accept	Yes (+)	No	No
Topluca	1.291	±1.645	±1.96	±2.576	Accept	Accept	Accept	No	No	No

***trend at α' = 0.01 level. **trend at α' = 0.05 level. *trend at α' = 0.1 level.

the 10% confidence level. Topluca also shows increasing trend close to significance limit. No significant trend was found for the Kale, Gomeleonu, Simsirli and Topluca stations. It should be noted that the Tozkoy and Topluca stations are located in the Eastern Black Sea Region. Unal et al. (2012) analyzed the trends of Turkey's precipitations and they reported that an upward trend exists in annual precipitations of Eastern Black Sea Region. Topaloglu (2004) identified the trends of monthly streamflows in Turkey using MK test. He found downward trend in Yakabasi, Derecikviran, Simsirli, Durucasu and Sutluce stations. Saris et al. (2010) investigated the trends in streamflow data of northeast Turkey using MK. They found no significant trend for the Simsirli and Topluca stations while Tozkoy indicated increasing trend according to their study. The MK provided inverse trends in the monthly streamflow time series at the nearby stations of Durucasu (or Sutluce with significant negative trend) and Kale (with increasing trend). Turkes and Sumer (2004) reported that opposite trends at two neighbouring stations may be owing to some natural dynamics and special situations. Urbanization (variations in land uses, for example, non-agricultural usages of lands, vegetation cover etc.) might have also caused for opposite streamflow trends at these two nearby stations.

3.2. Şen's trend analysis

Şen's monthly trend test results are given in Tab. 3, in which the 3rd column presents the significance level at which the time series shows trends, and Z value evaluates the presence of such a statistically significant trends, i.e. a positive Z value shows an increasing trend while a negative value displays a decreasing trend. To estimate the true slope of an existing trend (as change per month) the Şen's nonparametric method is applied, where Q is the slope and B is a constant (Equation 6). Table 3 also gives their maximum and minimum values ($Q_{\max}$ and $B_{\min}$) for each confidence level. It is clear from the table that the Durucasu and Sutluce show significantly decreasing trends according to the confidence level less than 1% while the Yakabasi and Derecikviran have decreasing trends with respect to 3% and 2% confidence levels, respectively, in a monthly basis. Similar to the MK test, only Tozkoy Station indicates significantly increasing trend according to the 8% confidence level. Topluca also shows increasing trend but not significant (greater than 30%). Also, for the Kale, Gomeleonu and Simsirli stations, no significant trend was found (i.e., 28%, 52% and 88%, respectively).

Table 3. Sen's test results of the monthly streamflows (1964−2007).

Station	Test *Z*	Significance	Q	$Q_{min}99$	$Q_{max}99$	$Q_{min}95$	$Q_{max}95$	B	$B_{min}99$	$B_{max}99$	$B_{min}95$	$B_{max}95$
Yakabasi	−2.07	0.03	−0.012	−0.029	0.003	−0.024	−0.0005	30.8	35.3	26.8	34.1	27.7
Derecikviran	−2.23	0.02	−0.030	−0.072	0.005	−0.061	−0.004	74.9	86.3	65.6	83.3	67.8
Durucasu	−6.00	< 0.01	−0.053	−0.076	−0.030	−0.070	−0.036	57.5	63.6	51.3	62.1	52.8
Sutluce	−8.83	< 0.01	−0.029	−0.038	−0.021	−0.036	−0.023	26.5	28.9	24.2	28.3	24.7
Kale	1.07	0.28	0.021	−0.031	0.070	−0.017	0.058	101.9	116	88.9	112	92.0
Gomeleonu	−0.64	0.52	−0.001	−0.005	0.003	−0.004	0.002	8.64	9.71	7.51	9.45	7.81
Simsirli	−0.14	0.88	−0.0003	−0.007	0.006	−0.005	0.005	18.4	20.1	16.6	19.7	17.1
Tozkoy	1.74	0.08	0.001	−0.0003	0.002	0.000	0.002	2.68	2.99	2.33	2.90	2.41
Topluca	0.96	0.33	0.003	−0.005	0.012	−0.003	0.010	19.8	22.0	17.5	21.5	18.0

3.3. Innovative trend analysis

In this section of the study, innovative trend method was applied to the monthly streamflows. The scattered streamflow data were divided into "low", "medium" and "high" groups following the studies of Şen (2012) and Oztopal and Şen (2017). The results of the ITM are shown in Fig. 4 for the Yakabasi and Derecikviran stations. According to the figure, low and medium streamflow values (< 100 m^3/s) of Yakabasi station show monotonic decreasing trend while the high values have slightly increasing trend. In Derecikviran station, low, medium and high streamflows show decreasing trend. Figure 5 illustrates the monthly streamflow trends of Durucasu and Sutluce stations. It is clear from the figure that there exists a decreasing trend for the low and medium values (< 190 m^3/s) of the Durucasu while the high values show no trend in some cases (between 190 m^3/s and < 300 m^3/s). In Sutluce station, the low, medium and high streamflow values show highly decreasing trend similar to the MK and Şen's trend tests. The ITM results for the monthly streamflow data of Kale and Gomeleonu stations are provided in Fig. 6. In Kale station, the low (< 150 m^3/s) and low-medium (between 150 m^3/s and 480 m^3/s) streamflow values respectively show slightly increasing and decreasing trends while the high (> 480 m^3/s) values generally indicate no trend. From the figure, it is clear that no trend exists for the low, medium and high streamflow values of Gomeleonu station. However, there is an increasing trend in some cases including high streamflows (between 75 m^3/s and < 95 m^3/s). Figure 7 gives the ITM results of the Simsirli and Topluca stations. In Simsirli station, no significant trend is seen for the low and medium streamflows while the high streamflow values (>70 m^3/s) indicate slightly increasing trend. The low, medium and high streamflows of the Topluca station show slightly increasing trend. Trend results of Tozkoy station are illustrated in Fig. 8. As seen from the figure, the low-medium (< 13 m^3/s) values indicate slightly increasing trend. The medium (between 13 m^3/s and 20 m^3/s) streamflow values show no trend whereas the peak values show upward trend.

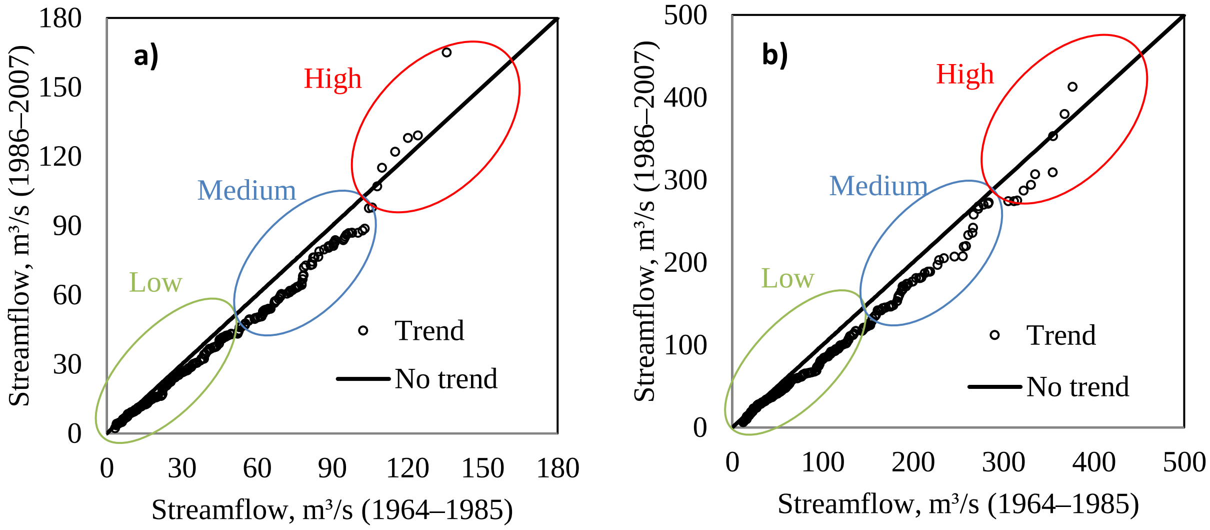

Figure 4. The results of innovative trend method for (*a*) Yakabasi and (*b*) Derecikviran stations.

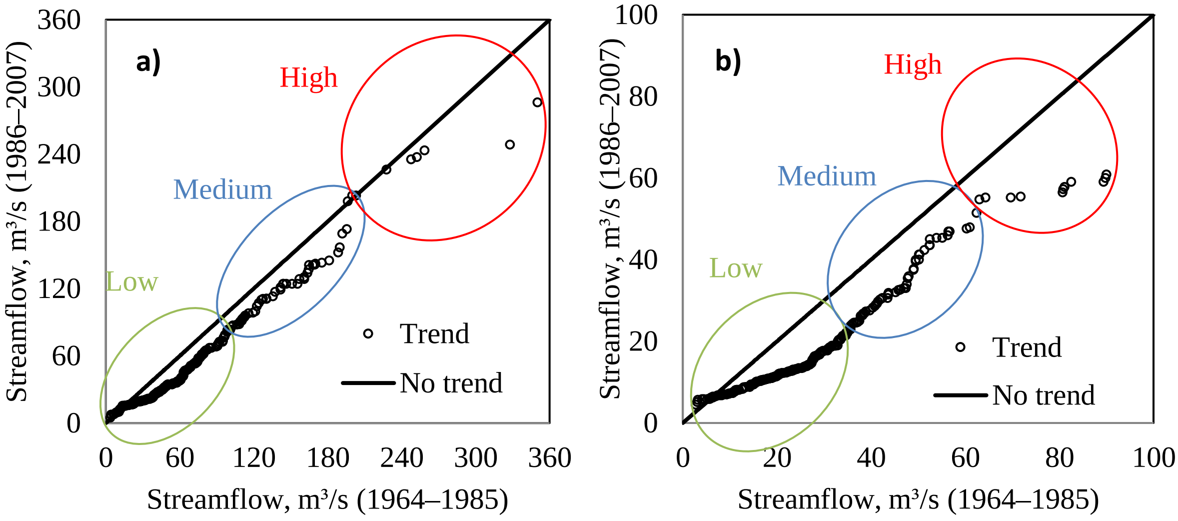

Figure 5. The results of innovative trend method for (*a*) Durucasu and (*b*) Sutluce stations.

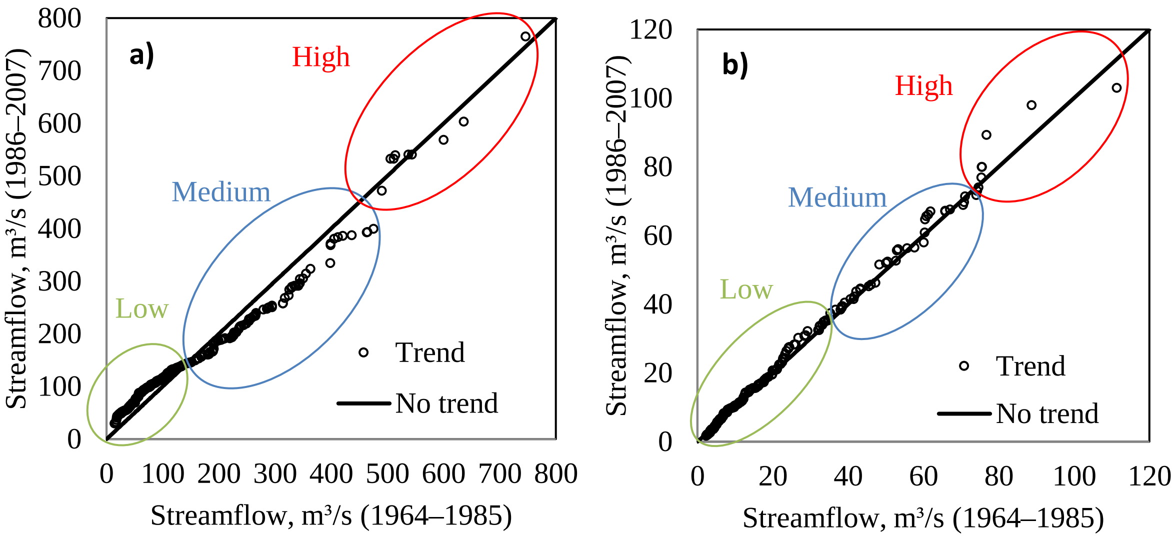

Figure 6. The results of innovative trend method for (*a*) Kale and (*b*) Gomelonu stations.

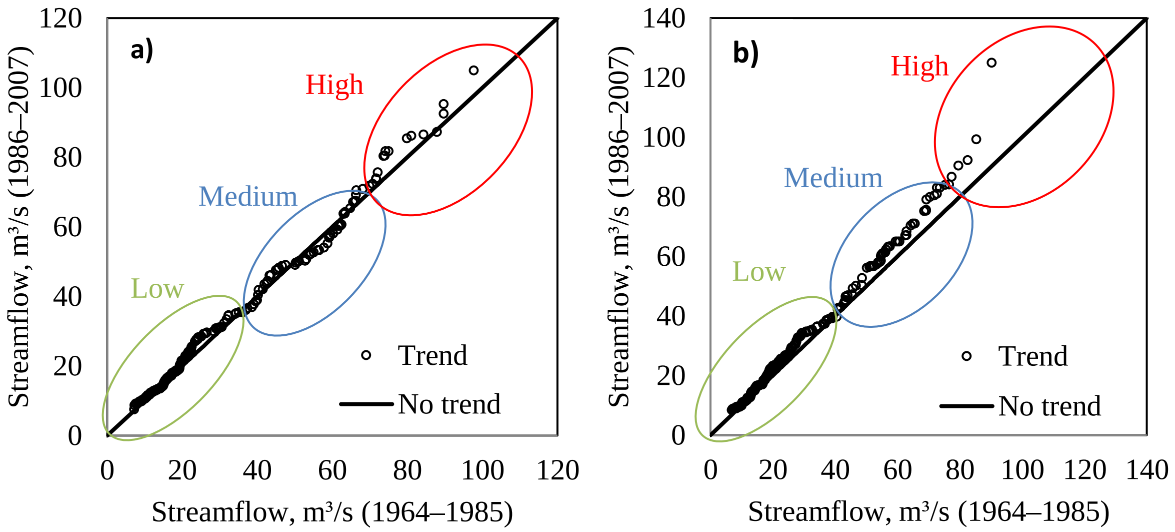

Figure 7. The results of innovative trend method for (*a*) Simsirli and (*b*) Topluca stations.

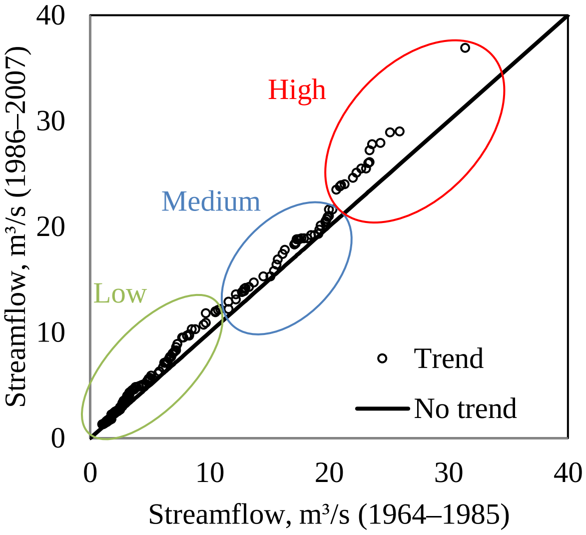

Figure 8. The results of innovative trend method for Tozkoy station.

4. Conclusion

In the present study, trends of monthly streamflows were analyzed by innovative trend method, MK and Şen's method. According to the MK, Yakabasi, Derecikviran, Durucasu and Sutluce which are located in western part of the Black Sea Region indicated a significantly decreasing trend with respect to 5% and 1% confidence levels while the Tozkoy Station which is situated in eastern part of the Black Sea Region showed a significantly increasing trend according to the 10% confidence level. In the Kale, Gomeleonu, Simsirli and Topluca stations, no trend was found. Şen's trend method indicated that there is a significantly decreasing trend in Durucasu and Sutluce stations with respect to 1% confidence level while the Yakabasi and Derecikviran had decreasing trends according to the 10% and 5% confidence levels, respectively. Tozkoy Station indicated significantly increasing trend according to the 5% confidence level. The streamflows of the Kale, Gomeleonu, Simsirli and Topluca stations did not show a significant trend. According to the innovative trend method, different trends were found for the low, medium and high streamflows in some cases. The low and medium streamflow values of the Yakabasi, Derecikviran, Durucasu and Sutluce stations showed a decreasing trend while the low-medium values of the Tozköy Station indicated slightly increasing trend. The high streamflow values of the Yakabasi, Simsirli and Tozköy stations showed an increasing trend while the corresponding values of the Derecikviran and Sutluce stations indicated a decreasing trend.

The study showed that innovative trend method has a few points of interest in relative to Mann-Kendall and Şen's trend methods. One is that it does not include any assumptions (e.g., serial relationship, nonnormality, test number, etc.) compared to MK and Şen's trend method. The other point is that the trends of low, medium, and high data can be easily identified by innovative trend method. This new method can provide a useful information and a priori view to the authorities and designers and can be used in climate change scenarios.

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