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Susurluk Havzası Akımlarının Trend Analiz Yöntemleri Kullanılarak Değerlendirilmesi

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Öz

Yıllık ortalama akım verilerinin trend analizi, daha iyi su kaynakları yönetimi, planlanması ve işletilmesi için çok önemlidir. Bu çalışmada, Susurluk Havzası üzerinde bulunan M. Kemal Paşa, Orhaneli ve Simav akım gözlem istasyonlarından alınan yıllık ortalama akım verileri Mann-Kendall, Spearman Rho ve Şen'in Yenilikçi trend yöntemleri ile test edilmiş ve istasyonlara ait eğilimler belirlenmeye çalışılmıştır ve bu yöntemlerin performansları değerlendirilmiştir. Ayrıca yıllık ortalama akım verileri regresyon analizine tabi tutulmuş ve denklem takımları elde edilmiştir. Her istasyon için azalış-artış miktarları yıllık ve 100 yıllık değişimleri m3/s cinsinden tespit edilmiştir. Sonuçlar irdelendiğinde sadece Şen'in Yenilikçi trend yöntemi analizlerinde 3 istasyon için de genel anlamda azalan bir trend tespit edilmiştir. Mann-Kendall ve Spearman Rho yöntemleri analizlerinde ise 3 istasyonda da herhangi bir trend tespit edilememiştir. Ayrıca 3 istasyona ait verilerin 100 yıllık değişim yüzdesi değerleri belirlenmiştir. Bu değerlere göre istasyonların akım değerlerinde gelecekte ciddi bir düşüş olacağı sonucuna varılmıştır.

Anahtar kelimeler: Akım, Trend, Mann-Kendall, Spearman's rho, Şen yenilikçi Trend testi

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Evaluation of Susurluk Basin Flows Using Trend Analysis Methods

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Abstract

Trend analysis of annual average flow data is very important for better water resources management, planning and operation. In this study, annual average flow data from M. Kemal Paşa, Orhaneli and Simav flow observation stations located in Susurluk Basin were tested with Mann-Kendall, Spearman Rho and Şen's Innovative trend methods and the trends of the stations were tried to be determined and the performances of these methods were evaluated. In addition, annual average flow data were submitted to regression analysis, yielding equation sets. For each station, the annual and 100-year changes in m^3/s were determined. Analyzing the results, only Şen's Innovative Trend Method analysis found a general decreasing trend for all 3 stations. In the analyses of Mann-Kendall and Spearman's Rho methods, no trend was detected in all 3 stations. In addition, 100-year percentage change values of the data of 3 stations were determined. According to these values, it is concluded that there will be a significant decrease in the flow values of the stations in the future.

Keywords: Flow, Trend, Mann-Kendall, Spearman's rho, ITA

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1. Introduction

Climate dynamics have a substantial impact on hydrological regimes in river basins around the world. Supply in the watersheds have substantial consequences on ecosystems, agriculture, forestry, fisheries, industry, and risk management [1]. With global warming and extreme weather events becoming more frequent, water resources are facing serious challenges. Global climate change is reducing water resources in many regions, and water scarcity is becoming more serious over time, especially in regions that are both arid and ecologically sensitive. It is of great importance to constantly monitor the water flow and take the necessary precautions to prevent these situations from occurring and to prevent water resources from decreasing [2].

Observational and historical hydroclimatological data are commonly utilized to plan and develop water resource projects [3]. As a result, identifying trends in streamflow in a watershed can help us understand the influence of climatic variability and change in the region. Trend analysis can also suggest future research requirements and directions, as well as assist decision makers in future planning [4].

Many approaches and studies have been devised and conducted in the literature to determine trends in hydrometeorological data (flow, precipitation, temperature, relative humidity, and so on). Examples of trend analysis methods often used in the literature include the Mann-Kendall (MK) test [5-6], Spearman Rho (SR) test [7], Şen Innovative Trend Analysis (ITA) [8-9], and Innovative Polygon Trend Analysis (IPTA) [10].

Gümüş and Yenigün made trend analyses of the annual average flows of 4 stations they selected from the Lower Euphrates Basin. They used the non-parametric MK test, one of the trend analysis methods. In addition, they used the non-parametric MK Order Correlation test to determine the starting year of the trend at the stations where trend detection was made. In conclusion; they detected a decreasing trend in half of the preferred stations. They determined the starting years of the decreasing trend as 1973-1985 [11]. In their study, Gumus and his colleagues determined the trends of monthly average and annual flow values of 16 stream measurement stations in the Tigris Basin. They used the Mann-Kendall test, Şen's Slope Method and Innovative Trend Analysis (ITA) method to determine trends. As a result, they stated that the trend directions of MK and ITA methods are generally similar [12]. Wang and his colleagues examined the flow processes of seven major rivers in terms of trend and stability at 7 stations in Western Europe. In the results of their analysis with the MK test, they found that there was no trend in the annual average flow values [13]. Ali and Abubaker used the MK test, Şen's Slope Estimator, and the Innovative Trend Method to analyze Yangtze River flow trends throughout seasonal and annual time periods. As a result, they detected a significant increasing trend only in the source region of the Yangtze River and a statistically non-significant decreasing trend in all study areas [14]. Summary information about the studies mentioned above and the current study are presented in Table 1.

Table 1. Summary of past studies

Study	Examined Stations	Method	Data Used	Data Examination Interval
Gümüş and Yenigün (2006)	Lower Euphrates Basin (Turkey)	Non-parametric MK test, Non-parametric MK Order Correlation test	Flow	Annual
Gumus et al. (2022)	Tigris Basin (Turkey)	MK, Sen’s Slope Estimator, Innovative trend analysis	Flow	Annual-Monthly
Wang et al. (2005)	Western Europe	MK, Seasonal Kendall test	Flow	Annual
Ali and Abubaker (2019)	Yangtze River (Western China)	MK, Sen’s Slope Estimator, Innovative trend analysis	Flow	Seasonal-Annual
This Study	Susurluk Basin (Turkey)	MK, SR, Innovative trend analysis	Flow	Annual

In this study, Mann-Kendall (MK), Spearman Rho (SR) and Sen's Innovative Trend Analysis (ITA) methods, which are nonparametric statistical trend analysis methods, were used to investigate the future trends of annual average flow data obtained from the General Directorate of State Hydraulic Works (DSİ) of Susurluk

Basin. One program (software) was created in Matlab program in order to obtain the results of trend analysis of annual average flow data more quickly using MK test and SR test methods. The 3 methods used in trend analysis were compared with each other in terms of performance. In addition, annual average flow data were applied to the regression method separately for all 3 stations and equation sets were obtained. According to the slope value of these equation sets, the annual and 100-year decrease or increase amounts were determined in m^3/s.

2. Material and Method

2.1. Study area and data used

Susurluk Basin was chosen as the study area. It is located in the west of Turkey and between the coordinates 39°- 40°N and 27°- 30°E. It covers approximately 3.11% of Turkey's surface area and has an area of approximately 24349.09 km^2 [15]. M. Kemal Paşa numbered 302, Orhaneli numbered 311 and Simav current observation stations numbered 316, located within the basin borders, were selected to be used in the study (Figure 1). Annual average flow data for these 3 stations were obtained from the General Directorate of State Hydraulic Works. Statistical analysis values of these data were given in Table 2.

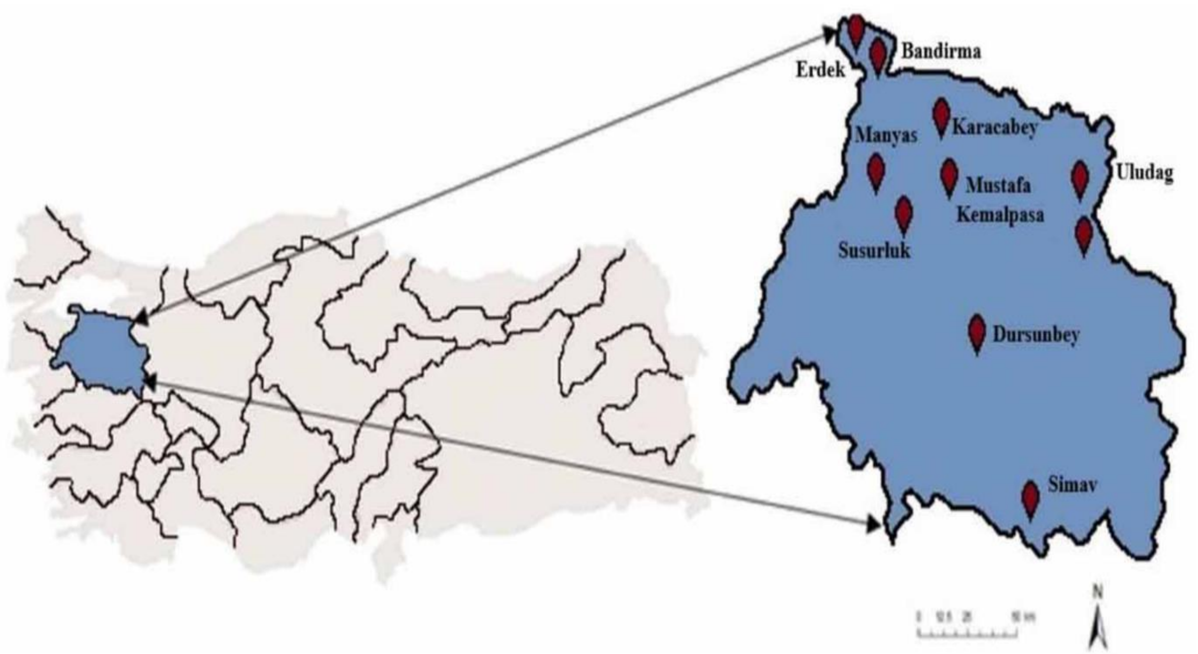

Figure 1. Susurluk Basin Location Map [16]

Table 2. Statistical analysis results of annual average flow data of stations

Station	Year	Coordinates	Number of Data	Minimum	Maximum	Average	Standard Deviation
Simav	1980-2011	39° 59' 10" N 28° 10' 34" E	32	9.23	76.57	37.36	17.59
Orhaneli	1980-2015	39° 37' 31" N 29° 27' 52" E	36	2.04	13.69	5.34	2.96
M Kemal Paşa	1980-2015	39° 57' 41" N 28° 30' 58" E	36	10.16	84.78	43.25	18.51

2.2. Methods used in the study

2.2.1. Mann-Kendall trend test

The MK test [5-6] is a rank-based nonparametric test that is insensitive to outliers. This test does not require that the data adhere to normal distribution assumptions [17-18]. Here's how the MK test statistic is calculated:

$$S = \sum_{i=1}^{n=1} \sum_{j=i+1}^{n} sign(x_j - x_i)\, , sign(x_j - x_i) = \begin{cases} +1 & (x_j - x_i) > 0 \\ 0 & (x_j - x_i) = 0 \\ -1 & (x_j - x_i) < 0 \end{cases} \quad (1)$$

A positive S value indicates an uptrend, whilst a negative S value indicates a downtrend. The variance value is calculated to get the Z value. The variance (S) is calculated as follows:

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

Equation 3 calculates the normal Z test statistic for a connected group (m) with a sample size of n>10.

$$Z = \frac{S \pm 1}{Var(S)^{1/2}} \quad (3)$$

In this equation, if S>0, S-1 is used, if S<0, S+1 is used, and if S=0, Z = 0. The positive value of Z indicates an increasing trend. Otherwise, it shows a downward trend [19].

2.2.2. Spearman's Rho trend test

The SR test [7-20] is another method of finding linear and nonlinear trends. It is a popular way to determine if there are patterns [21]. It is a quick and simple test for detecting whether a linear trend exists. As a result, it has become one of the most widely used trend analysis approaches for spotting current trends [22]. The null hypothesis (H_0) for this test asserts that all data in the time series are independent and uniformly distributed. The alternative hypothesis (H_1) holds that trends are either increasing or declining [23]. Equations 4 and 5 describe the test statistic R_{sp} and the standardized test statistic Z_{sp}, respectively.

$$R_{sp} = 1 - \frac{6 \sum_{i=1}^{n} (D_i - i)^2}{n(n^2 - 1)} \quad (4)$$

$$Z_{SR} = R_{sp} \sqrt{\frac{(n-2)}{(1 - R_{sp}{}^2)}} \quad (5)$$

Here, D_i is the observation order, and i is the chronological sequence number. N denotes the total length of the time series. Positive Z values indicate a growing trend across the hydrological time series, whilst negative Z values indicate diminishing trends. In normal distributions, if the Z value is above the significance level for $Z_{\alpha/2}$ ($\alpha = 0.05$), the null hypothesis (H_0) is rejected and the trend is accepted [24].

2.2.3. Şen trend test

The ITA approach was initially proposed by Şen [8]. The ITA's primary advantage over the MK test and other procedures is that it makes no assumptions (serial correlation, non-normality, sample size). First, the time series is divided into two equal parts and sorted in ascending order. The first and second sections of the time series are then plotted using the X and Y axes, respectively. Figure 2 illustrates the innovative method in Cartesian coordinates. When data is collected along the 1:1 ideal straight line (45° line), it is discovered that the time series has an increasing trend. If the data falls within the bottom triangular area of the ideal straight line, the time series shows a downward trend. As a result, the ITA method can identify low, medium, and high value trends in any hydro-meteorological or hydroclimatic time series [25-26-27].

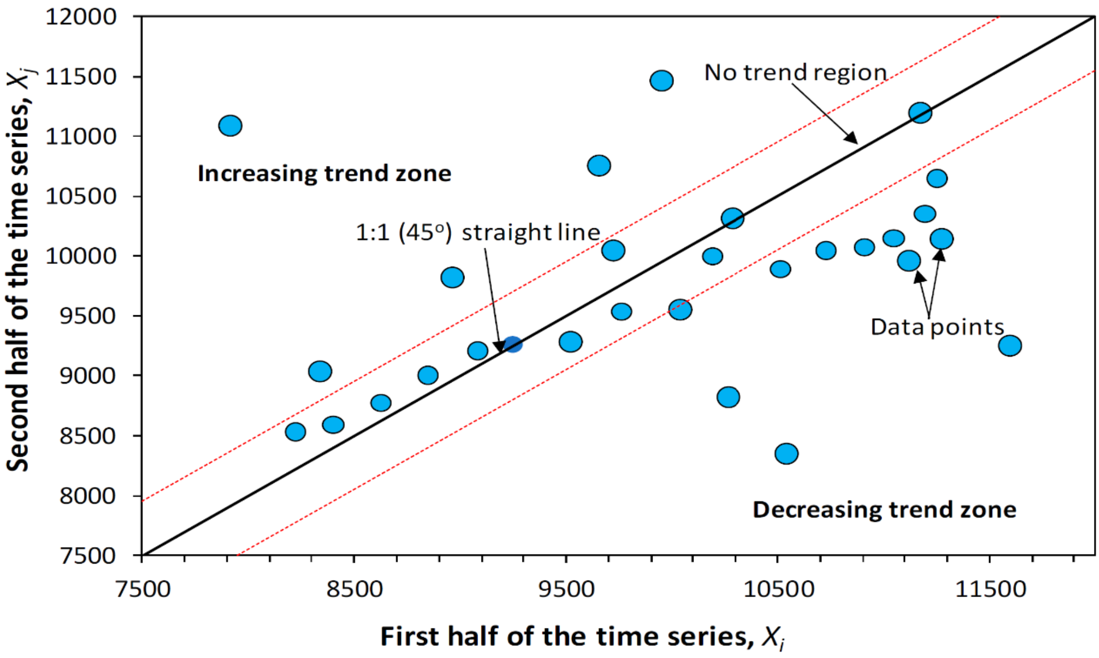

Figure 2. ITA method scatter result graph [28]

2.2.4. Regression analysis method

This method is based on the solution of the graph created by writing two different variables (dependent variable and independent variable) on separate axes. A line that best expresses the created graph should be selected. Then, the slope of the line needs to be determined [29]. This approach can be utilized for both linear and non-linear situations. There must be one dependent variable and at least one independent variable in this procedure (Equation 6) [30].

$$Y = \beta_0 + \beta_1 * X \tag{6}$$

Here β_0 represents a constant value. β_1 represents the slope of the line. If this equation is used for trend analysis, β_1 represents the increase or decrease values [31-32].

3. Findings and Discussions

In the study, the annual average flow values of M. Kemal Paşa, number 302, Orhaneli, number 311, and Simav stations, number 311, of the Susurluk Basin located in the west of Turkey, were analyzed by ITA, SR test and MK between the years 1980-2015, 1980-2015 and 1980-2011, respectively. Test methods were applied and trends were determined. A software was created using MATLAB program for SR and MK methods analyses. Additionally, flow data was applied to the regression method. Furthermore, the slope and first-order equations of the trend changes were found, as well as the changes in the flow data throughout the required years. The study's findings were summarized using tables and graphs.

Table 3 shows the annual average flow data trend analysis results for stations 302, 311, and 316. As a result, the statistical analyses of the MK test and the SR test are identical. Based on the results of the two methods, the absolute value of Z for all three stations is less than the $Z\alpha/2$ = 1.96 value of the standard normal distribution, which corresponds to the selected α = 0.05 level, indicating that "H0 = no trend" and concluding that there is no trend in the time series examined.

In the ITA method, it can be said that there was a trend of decreasing by 5% for low value flow data, increasing by 5% for average value flow data and increasing by 10% for high value flow data at station number 302. At station number 311, it was observed that there was no trend for low values, an increasing trend of 5% for medium values, and a decreasing trend of 10% for high values. At station number 316, a decreasing trend of 5% was observed at low and medium values, and a decreasing trend of over 10% was observed at high values. The graphs drawn for the ITA method are shown in Figure 3. In addition, annual average flow values for 3 stations were applied to regression analysis and first-order equation sets were determined to determine the slopes of trend changes. Then, the changes in annual average flow values for the given water year intervals at all 3 stations were calculated in terms of (m^3/s) (Figure 4).

Table 3. Results of annual average flow data of stations

	Mann-Kendall		Spearman Rho			
Station	**Z**	**Trend Z (0.95)**	**Z**	**Trend Z (0.95)**	**Annual Change (m^3/s)**	**100 Years Change (%)**
Simav	-0.8595	↔	-0.8889	↔	-0.3888	-40.39
Orhaneli	-0.5857	↔	-0.6097	↔	-0.0348	-24.45
M. Kemal Paşa	-1.4847	↔	-1.7197	↔	-0.7099	-60.48

Indicators: (↔) no trend

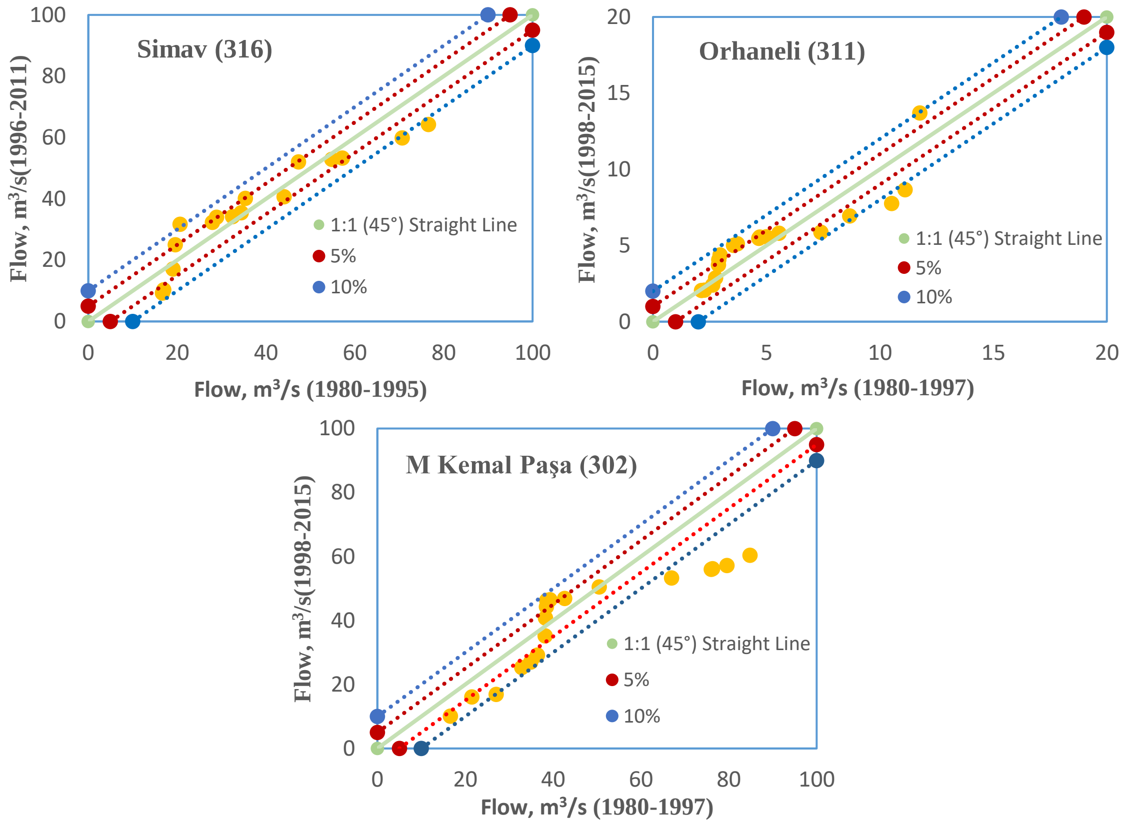

Figure 3. Trend graphs of annual average flow data of stations

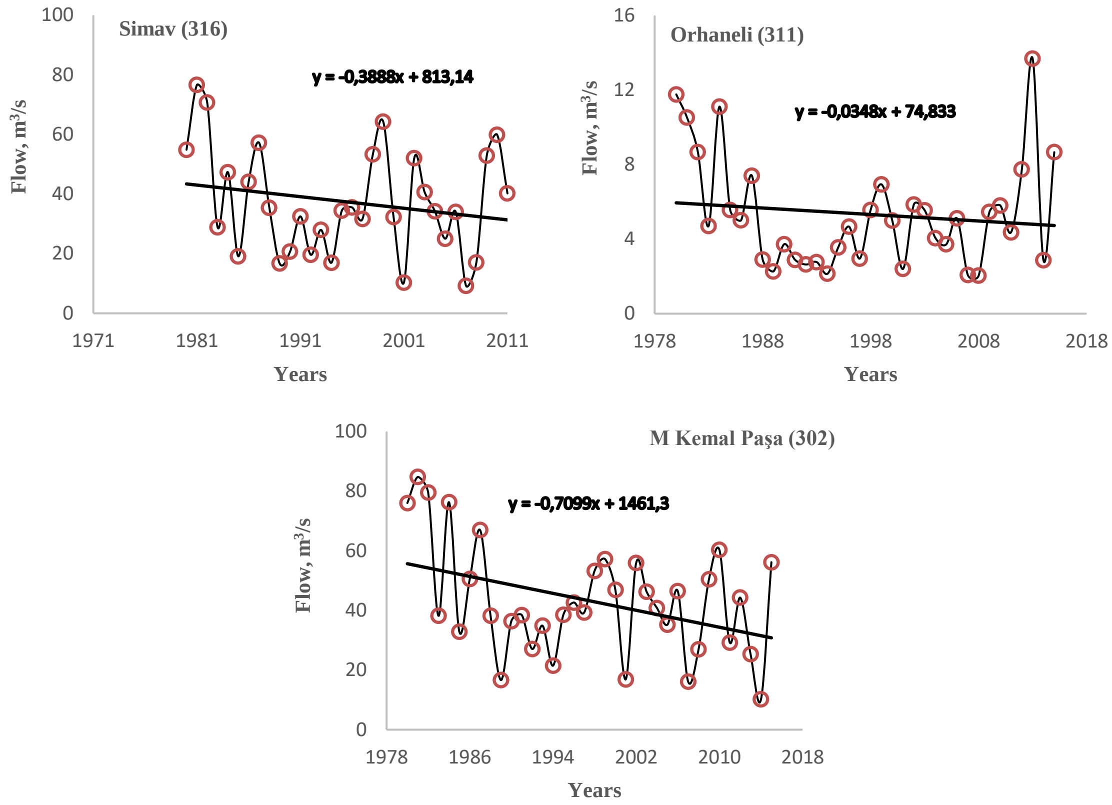

Figure 4. Annual average flow trend change of three stations

4. Results

In this study, the Susurluk Basin located in the west of Turkey was studied. Annual average flow data of M. Kemal Pasha numbered 302, Orhaneli numbered 311 and Simav stations numbered 316 in this basin were examined and trends were determined using MK, SR and ITA methods. Furthermore, annual average flow data were subjected to regression testing, and annual variations were calculated. Furthermore, the outcomes of the MK, SR, and ITA approaches, which differ from one another, were compared.

- As a result of the analysis, a general decreasing trend was detected in all 3 stations for annual average flow data using the ITA method.
- The MK and SR test statistical methods revealed no trend for all 3 stations. Furthermore, it was found that the MK and SR test statistical approaches produced equivalent results for all 3 stations.
- The trend slope direction and annual change values of the stations in the trend change graphs given in Figure 4 also confirm the results of the ITA method.
- According to the 100-year change percentage values of the 3 stations, it was concluded that the current values of the region where stations 302, 311 and 316 are located will also decrease significantly, but this reliability rate is statistically outside the 95% confidence interval.
- The results indicate that there may be a water shortage in this basin in the future. Therefore, necessary precautions should be taken to use water resources consciously.

5. Author Contribution Statement

Ramazan ACAR contributed to the formation of the idea and literature review in the study, evaluation of the results obtained, obtaining the data used and examining the results, checking the article for spelling and content.

6. Ethics Committee Approval and Conflict of Interest Declaration

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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