

Trend Analysis of Monthly Average Flows of Kızılırmak Basin

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Received date: 22.07.2019

Accepted date: 14.11.2019

How to cite: Citakoglu, H. & Minarecioglu, N. (2019). Trend analysis of monthly average flows of Kızılırmak Basin. *Anatolian Env. and Anim. Sciences*, 4(3), 435-440.

Atıf yapmak için: Citakoglu, H. & Minarecioglu, N. (2019). Kızılırmak Havzası ortalama akımlarının trend analizi. *Anadolu Çev. ve Hay. Dergisi*, 4(3), 435-440.

Abstract: The impact of climate change on meteorological data and water resources is one of the subjects of interest in both hydrology and meteorology. The change in meteorological occurrences due to the atmospheric circulation of climate is an important factor in the design of water structures and water management issues. In this study, trend analysis was performed by using monthly average current values taken from three different current observation stations in Kızılırmak basin and the presence of meaningful trend was investigated. Mann Kendall (MK) and Modified Mann Kendall (Hamed) and Spearman's Rho (SRHO) methods are the non-parametric methods used in trend analysis of basin flows. The linear regression method, which is a parametric method, is also included in the study of trend. Pettit method was used to determine the beginning of the trend. The mean monthly flow data between the years of 1970 and 2010 were taken from 15-03, 15-68 and 15-208 stations analyzed and as a result an increasing trend in 15-68 stations and a decreasing trend was determined in 15-208 and 15-03 stations. According to the Pettit test, the beginning of the increase trend in flow at station 15-68 is September 1986. And the beginning of the decrease in the 15-208 station was in April 1989 and the beginning of the decrease in the 15-03 stations took place in 1999-September.

Keywords: Kızılırmak basin, Mann Kendall, modified Mann Kendall (Hamed), Spearman's Rho, Trend analysis.

Kızılırmak Havzası Ortalama Akımlarının Trend Analizi

Öz: İklim değişikliğinin meteorolojik verilere ve su kaynaklarına etkisi son yıllarda hem hidroloji hem de meteoroloji alanında ilgi çeken konulardan birisidir. İklimin atmosferik sirkülasyona etkisiyle meteorolojik oluşumlarda meydana gelen değişim su yapılarının tasarımı ve su yönetimi konuları üzerinde önemli bir etkidir. Yapılan çalışmada Kızılırmak havzasında bulunan üç farklı akım gözlem istasyonundan alınan aylık ortalama akım değerleri kullanılarak trend analizi yapılmış, anlamlı trend varlığı araştırılmıştır. Havza akımlarının trend analizinde kullanılan Mann Kendall (MK) ve Modifiye Mann Kendall (Hamed), Spearman'nın Rho (SR) yöntemleri parametrik olmayan yöntemlerdir. Parametrik bir yöntem olan Lineer regresyon yöntemi de trend araştırılmasına dahil edilmiştir. Trendin başlangıcını belirlemek amacıyla da Pettit yöntemi kullanılmıştır. Çalışmada DSİ'ye ait 15-208, 15-68 ve EİE 'ye ait 15-03 istasyonlarından alınan, 1970-2010 yılları arasındaki ortalama akım değerleri kullanılmış ve sonuçta 15-68 nolu istasyonda artan yönde trend gözlenirken, 15-208 ve 15-03 nolu istasyonlarda azalan yönde bir trend varlığı tespit edilmiştir. Pettit testine göre 15-68 nolu istasyonda akımlardaki artışın başlangıcı 1986- Eylül ayı, 15-208 nolu istasyonda azalmanın başlangıcı 1989 Nisan ayı ve 15-03 nolu istasyonda yine azalmanın başlangıcı 1999-Eylül aylarında gerçekleşmiştir.

Anahtar sözcükler: Kızılırmak havzası, Mann Kendall, modifiye Mann Kendall (Hamed), Spearman Rho testi, Trend analizi.

INTRODUCTION

Climate is one of the most important subjects of meteorological and hydrological field in recent years. The researches have underlined that climate change has been felt to be felt all over the world since the 1980s. Especially the changes in precipitation and other meteorological parameters affect the water resources to a great extent. For this reason, the levels of changes in precipitation and stream currents should be monitored and examined. Since Turkey has semi-arid climate is adversely affected by drought brings. In order to determine the effect of the climatic changes that occur in our country on the flows and meteorological parameters, trends of flows should be known. In particular, assessing the extent of impact of water resources is very important for the management and operation of water resources. While the determination of low and average current values is necessary for planning of dams and reservoir calculations, it is necessary to know flood size currents in terms of design and operation of flood structures (Cigizoglu at al., 2005). Estimating the changes in flows makes future planning and taking measures more effective. It is very important for planning and design to determine the periods in which the current currents will increase or decrease in the coming years and to take the necessary measures. Trend analysis is the most commonly used method for determining the effects of climate impacts on meteorological phenomena and changes in water resources.

Gumus and Yenigun, (2006) performed trend analysis of average flows for 4 stations located in the Lower Fırat basin. The Mann-Kendall method was used for the determination of the trend in the research, and the Mann-Kendall Order Correlation test was used to detect beginning the trend. As a result of the analyzes, they stated that there was a decreasing trend in the half of the stations and the movement in the decreasing direction started in 1973-1985 period.

Ceribasi at al. (2013), carried out trend analysis by using Mann-Kendall test and Spearman's Rho test for flow data in the area covering the Western Black Sea Basin, East Black Sea Basin and Sakarya Basin. The non-parametric Mann-Kendall Order Correlation test was chosen to determine the beginning of the trend. According to the results of the analysis in the Western Black Sea and Sakarya Basin of some stations trend is decreasing, in the East Black Sea Basin has not seen trend.

In the Iberian peninsula, annual and seasonal trends were analyzed on currents in 187 sub-basins and identified significant reductions in flows in winter and spring throughout the year in most of the peninsula, especially in southern regions. They also underlined that the dams built in the region did not change the direction of trends (Lorenzo-Lacruz at al. 2012).

Trend analysis was performed by using monthly flow data in 11 stations in Sakarya basin. In the trend

analysis, the nonparametric Spearman's Rho, Sen's T and Seasonal Mann-Kendall tests were used and a significant trend was observed in the trend analysis in 64%. It is stated that trends are decreasing, and decreases started in March-April 1980 period (Özel at al., 2014).

Tekkanat and Saris, (2015), for trend analysis, 42-year monthly flow of the Porsuk river basin was applied to Mann-Kendall, Spearman's Rho and Sen's T test. The mean, maximum and minimum currents decreased significantly. They determined that the beginning time of the trend was 1980 with the Mann-Kendall Order Correlation test.

In the trend study on flow and precipitation in Iran's Karkheh River Basin (KRB), two different versions of the Mann-Kendall test were conducted. In the data sets covering the period 1974-2011, a downward trend of about 70% was determined. According to Theil-Sen's estimator, the results are negative. In addition, there was significant correlation between precipitation and average flows on an annual basis (Zamani at al., 2017).

In the study Turkey's Seyhan basins of the flow and precipitation, has investigated the homogeneity of the time series. They also conducted a trend research with the Mann-Kendall test. The magnitude of the trend was examined by Theil-Sen test and the years when the change started with Pettit test. According to the results, the data set was determined homogeneously at 0.05 significance level. Trend tests vary at each station on an annual scale. No long-term trend was detected on a monthly scale. According to the Pettit test, the most frequent change was in 1981 (Hadi at al., 2019).

In the Yangtze River basin, changes in the annual maximum precipitation flows were investigated. The correlations between extreme precipitation and flow were examined. In the trend research conducted with Mann-Kendall test, no trend was observed in annual precipitation and flows, but increases in extreme summer rainfall were observed (Du at al., 2019).

The data of 25 flow stations and 43 flood stations on homogeneity, trend, stasis and periodicity in Kerala, India were examined. In the study, it was found that the daily series were not homogeneous except for the flood data and were stationary. Changes in daily flows have been found in most of the river basin. Moderate changes were observed in the flood series (Drissia at al., 2019).

A trend study was carried out on sediment and flow values at 11 stations in the Jinsha River Basin. While no significant increase in flow was observed in the time series, in 1985 there was a sudden change in flows both in the upper and middle parts of the river and in 1980 and 2013 there was a sudden change in the direction of flow.

(Adib & Tavancheh, 2019), In the study carried out in Iran Dez basin, the tendencies of precipitation and currents were examined by Mann-Kendall test. In the period of 1981-

2012, it was stated that rainfall was not a significant trend but the currents had negative tendency (Lu at al., 2019).

In this study, non-parametric Mann-Kendall (MK) and Modified Mann-Kendall (Hamed), Spearman's Rho (SR) methods and Linear regression and Innovative Sen Trend analysis were applied to the flows obtained from three different flow observation stations in Kızılırmak basin. While Sen Slope test was used to determine the level of trend, the point where change began with the Pettit test was investigated.

MATERIAL and METHODS

The Kızılırmak Basin is the second largest basin is located east of Central Anatolia Region of Turkey. Its length is 1.151 km and Drainage area is 78.180 km². The Kızılırmak River starts from the vicinity of the Sivas İmranlı, and passes through the Bafra Plain to the Black Sea by passing through Kayseri, Nevşehir, Aksaray, Kırşehir, Ankara, Kırıkkale, Çankırı, Çorum, Sinop and Samsun provinces. The physical map of the Kızılırmak Basin and the basin is given in Figure 1.

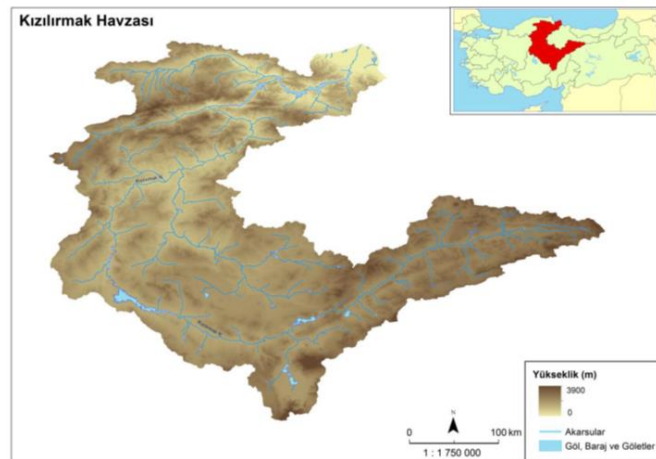


Figure 1. Physical Map of Kızılırmak Basin.

Mann-Kendall (MK) Test: MK Test is a non-parametric test which is applied most in researching the trends of climatic data and considers the sequences rather than the numerical values of the data (Burn & Elnur, 2002). H_0 hypothesis predicts that the series consists of random variables, whereas hypothesis H_1 suggests a similar distribution. To investigate the accuracy of hypotheses, the MK test statistic S value should be calculated. If the average of the calculated S test statistic is zero, the series has a normal distribution. In cases where S test statistics are -1 and 1, Z value is calculated depending on the variance of the series. At defined α significance level the $Z_{\alpha/2}$ value obtained from the standard normal distribution tables is compared to the Z value calculated. If the Z value is small and equal, the acceptance of the H_0 hypothesis should be rejected if it is large. When S value of MK test statistic is negative, it

indicates that there is a decreasing trend. When positive, it indicates that there is increasing trend. (Kendall, 1975)

Modified Mann-Kendall Test (Hamed): In the MK test, the null hypothesis neglects the presence of autocorrelation in the data, if the data are arranged independently and randomly. However, in case of autocorrelation presence, the data may be misleading. Therefore, Modified MK is recommended to be used to determine the trends of data with autocorrelation (Hamed & Rao, 1998). Modified MK, If there is a significant autocorrelation between the data to make the Mann-Kendall test more stronger, it is recommended that the variance of the S value, which is the test statistic, be calculated differently.

Spearman's Rho Test (SRHO): This test, which is applied to investigate the correlation relationship between the two observed data, is the fast and simple method of determining the existence of linear trends. The sequence statistic of the test, $R(x_i)$, is generated by sorting data from small to large or large to small. X is the vector of the series listed; According to the H_0 hypothesis, x_i values from $i = 1$...to n , $x_i = (x_1, x_2, \dots, x_n)$ x_i have the same probability distributions. According to the hypothesis H_1 , the values of x_i ranging from $i = 1$...to n are increased or decreased over time (Zeybekoğlu & Karahan, 2017). If the calculated Z value is greater than the value of $Z_{\alpha/2}$ obtained from the standard normal distribution tables in the α significance level, then the hypothesis H_0 is not accepted and the presence of the trend is determined by the r_s value expressed as the statistics of Spearman's Rho. If $r_s < 0$, it is concluded that the trend is in decreasing direction and if $r_s > 0$, the trend is increasing (Yuce at al., 2018).

Linear Regression Method: Linear Regression is the regression analysis used to determine the x-dependent change of the variable y (Atik, Deniz, & Yıldız, 2007). The regression equation is $y = ax + b$; The coefficient a denotes the direction and value of the trend. The existence of a linear relationship between x and y is expressed according to their distribution in the x-y plane of the observation pairs. In order to be able to talk about a relationship between x and y, the distribution must be spread around a line. If there is such a distribution there is a linear relationship between the observation pairs. For an increasing trend, the coefficient a should be positive. For a trend in the decreasing direction, the coefficient a must be negative. The fact that the coefficient a is close to zero indicates that there is no change (Güner Bacanlı & Tugrul, 2016).

Innovative Sen Trend Test: This method is a graphical method that observes the distribution of data to x and y axes by sorting the data according to numerical values and separating the first and second half equal. If the distribution of data is spreading in the upper region of the 45-degree axis line, an increasing trend is observed. However, if the distribution of data is spreading in the lower part of the axis, a decreasing trend is observed.

Pettit Test: In the Pettit test, which is used to determine the beginning of the change in a data series and can determine the beginning of the change on a monthly and yearly basis, the null hypothesis argues that the sequence consists of independent and random elements. The other hypothesis is that there is a sudden change of direction at one point in the sequence (Pettit, 1979). When the elements in the array are plotted as a graph, the absolute maximum value of the array points to the direction of the direction change.

RESULTS and DISCUSSION

Water is one of the most important sources for human. However, the hydrological cycle associated with the Earth's climate cycle also changes in the amount of water resources due to changes in the climate. But, since the change of this big period will not happen at a time, monitoring of the process and taking necessary precaution are important in terms of storing water resources and water resources management. For this reason, trend analysis is carried out to determine the increase or decrease of current values over many years. In this study, three different current monitoring stations of Kızılırmak Basin were used to determine the trends of mean flow data.

First, the trend was investigated by linear regression method. The results and comments are explained with tables. In the trend analysis made by linear regression, as shown in Table 1, the values of the A and B coefficients of the current data of the stations 68, 208 and 15-03 in Kızılırmak Basin and the t value of the coefficient B were expressed. At the station 68, Because of the t value of the coefficient B for the 5% significance value is greater than $t_{cri} = 1.96$, it is mentioned that the trend is present and the trend is in an increasing direction since the coefficient B is greater than zero. The t value of the coefficient B in the station 208 is less than $t_{cri} = -1.96$, indicating a trend in the data. However, the fact that the coefficient B is less than zero indicates that the trend is decreasing. Similarly, in the 1503 station, the t value of the coefficient B was less than $t_{cri} = -1.96$, so it was determined that the trend was decreasing in this station because the trend was smaller than zero.

Table 1. Results of the linear regression trend test applied to current data of stations 68, 208 and 15-03 in Kızılırmak Basin according to 5% critical probability level.

Station ID	A	B	t_t	t_{cri}	Trend
68	1.33	0.005	2.62	1.967	Upward
208	0.405	-0.001	-2.057	1.97	Downward
15-03	279.314	-0.344	-2.718	1.965	Downward

The non-parametric Mann-Kendall method is often used in trend analysis and is based on Z statistics. The calculated Z values are compared to the known Z value according to the 5% significance value.

Table 2. Results of MK trend test applied to current data of stations 68, 208 and 15-03 of Kızılırmak Basin according to 5% critical probability level.

Station ID	MK Statistic	$Z_{calculated}$	Tail probability	Trend
68	11523	5.453	0	Upward
208	-1229	-0.988	0.1616	---
15-03	-18845	-5.367	0	Upward

In station 68, when the calculated Z value and the 5% significance level value (1.96) are compared, it indicates that there is a trend in the data because the calculated Z value is greater than 1.96. As can be seen in Table 2, as the MK statistical value is greater than zero indicates that the trend is in an increasing direction. But, since the calculated Z value of the station 15-03 is smaller than -1.96 and the MK Statistics value is smaller than zero, the trend is downwards. In station 208, The Z values calculated are less than 1.96, indicating that there is no trend presence in these series. On Table 3 shows the results of Spearman's Rho trend analysis applied to current data of three different stations in Kızılırmak basin.

As can be seen in Table 3, In station 68 since the calculated Z values are greater than 1.96, there is a trend and the positive test statistics indicate that the direction of the trend is increasing. In the station 15-03, the calculated Z value is less than -1.96 and Spearman's Rho Test indicates a trend in decreasing direction because the statistical value is negative. When the data of station 208 is taken into consideration, it indicates that there is no trend because Z value is smaller than 1.96.

Table 3. Results of Spearman's Rho trend test applied to current data of stations 68, 208 and 15-03 of Kızılırmak Basin according to 5% critical probability level.

Station ID	Statistic of Test	Z	Trend
68	0.2934	5.418	Upward
208	-0.0555	-0.858	---
15-03	-0.235	-5.143	Downward

Innovative Sen trend test, which is one of the most recent trend methods, is different from other trend tests. Trends are expressed graphically and not based on assumptions are important features. This method is based on t statistics and the results are shown in Table 4. Figure 3 shows the graphs formed according to the Innovative Sen trend method. The first half of the time series generated by the data is placed on the x-axis and the second half on the y-axis. The condition of the points obtained on the 45° slope line is examined. When we look at the distribution of data in station 68, the trend is observed in increasing direction because of the distribution in the upper part of the slope line. At the same time, when we look at the results numerically, as can be seen in Table 4, it can be said that the slope has a trend since it is not between the limit values.

Table 4. Results of Innovative Sen trend test applied to current data of stations 68, 208 and 15-03 of Kızılırmak Basin according to 5% critical probability level.

Station ID	Slope	Standard Deviation	Standard Deviation of slope	Lower Limit	Upper Limit	Trend
68	0.003	3.45	0	0	0	Upward
208	0	0.306	0	0	0	—
15-03	-0.302	387.824	0.084	-0.137	0.137	—

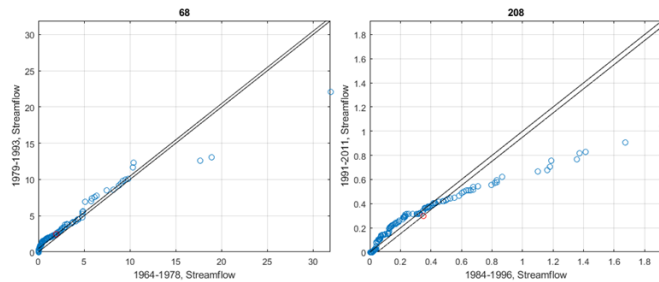


Figure 2. The Innovative Sen trend test graphs applied to the current data of stations 68, 208 and 15-03 in Kızılırmak Basin.

Table 5. Results of trend test applied to current data of stations 68, 208 and 15-03 of Kızılırmak Basin according to 5% critical probability level.

Station ID	Modified MK-(Hamed)	Linear	MK	Spearman's Rho	Innovative Sen	Pettit
68	Upward	Upward	Upward	Upward	Upward	1986-September
208	—	Downward	—	Downward	—	1989-April
15-03	Downward	Downward	Downward	Downward	—	1999-September

Table 5 shows the comparison of the results of 5 different trend tests on the streams of Kızılırmak basin. As can be seen in Table 5, 5 different trend test results of the current data are matched at station 68. It was observed that only the Innovative Sen test did not show a trend in station 15-03, but the other 4 methods had a decreasing trend. Differences were observed in 208 stations. The Pettit test was used to determine the start-up of trends in three different stations based on the trend results. Table 5 gives Pettit test results. As can be seen in Table 5, station 68 has an increasing trend in all 5 different trend tests. As a result of the Pettit test charts, it was observed that the flow data started to increase since 1986-September. The decreasing trend was observed at station 15-03 and station 208, and the beginning of the decreasing trend was determined for the station 15-03 as 1999-September and for station 208 as 1989-April.

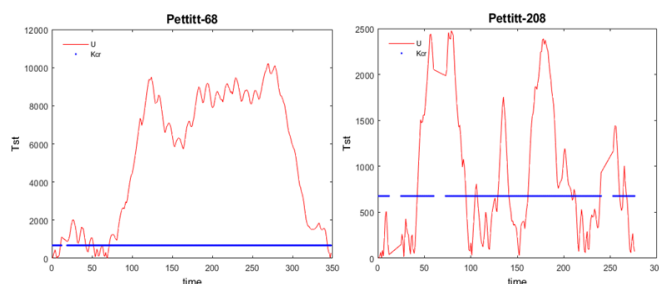


Figure 2. The Pettit test graphs applied to the current data of stations 68 and 208 in Kızılırmak Basin.

CONCLUSION

In this study, Linear Regression, MK, Modified MK, Spearman's Rho and Sen Trend methods were applied to the current data obtained from three different current observation stations in Kızılırmak Basin. According to the analysis;

- The current of station 68 has shown an increasing trend in all methods.
- The current data from station 15-03 shows a decreasing trend in all four methods except Innovative Sen analysis.
- While there is a decrease trend in the station 208 in the Linear Regression and Spearman's Rho methods, the other three methods showed no trend.
- The beginning of the increasing trend was observed at station 68 in 1986 and at station 208 in 1989 and it was determined as 1999 at the station 15-03 with decreasing trend.
- In the study using the mean flow data of three different current observation stations, the trend was 100% in the Linear Regression and Spearman's Rho tests, while the MK and Modified MK (Hamed) tests showed a trend of 67%. The Innovative Sen analysis showed a trend of 33%.

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