TREND ANALYSIS OF STREAMS IN THE WESTERN MEDITERRANEAN BASIN OF TURKEY

Kemal Saplıoğlu[1,]*, Murat Kilit[2], and Bekir K. Yavuz[3]

[1] Süleyman Demirel University, Engineering Faculty, Civil Engineering Department, 32260 Isparta, Turkey
[2] Afyon Kocatepe University, Engineering Faculty, Civil Engineering Department, 03200 Afyon, Turkey
[3] Turkish Petroleum Refineries Co., Project & Investments Department, 35800 Izmir, Turkey

ABSTRACT

Today, global climate change has made itself widely evident. In the planning of water resources, it is of great importance to determine certain parameters, such as precipitation and flow, for the preparation of future projects. In our study, we tried to analyze the streams in the Western Mediterranean Basin of Turkey monthly and annually. Applying Mann-Kendall trend test, it was tried to observe whether a trend changed or not, in the safety range of 95%. Moreover, scatter diagrams are created to determine the slopes of increase and decrease on the trend-line, and to foresee the flow-rates. Eventually, the trends for each station are determined plotting Şen diagrams, and these trends' compliance with Mann-Kendall test is evaluated. According to the results, some serious decreasing trends are observed in all stations both annually and monthly. Besides, the trend changes occurred especially in summer when the amount of rainfall was very low and almost all of the flows of rivers were provided by underground sources. Moreover, it was discovered that there is a strong correlation between Sen test and Mann-Kendall trend analysis. The angles between x-axis and trend-lines in Sen diagram test were analyzed, and angles less than 36 degree were statically found to stand for a strong trend change.

KEYWORDS: Western Mediterranean, Mann-Kendall, flow, trend analysis, Dalaman River, Esencay, Sen diagram test

1. INTRODUCTION

Nowadays, the water demand has remarkably increased due to the rapid increase in population, the efforts for developing agricultural foods depending on rising population, and the industrial growth. On the other hand, available water resources are quite limited in some areas, and they have to be used carefully and efficiently. Republic of Turkey on Climate Change National Certificate [1], a strategy, is assigned to increase the studies of climate changes and to discuss the results of these studies. Climate changes cause increasing of surface and ground water consumption and of vaporization [2]. In the studies for the solutions of climate changes, the most important freshwater bodies, such as rainfall, streams, lakes, and groundwater resources, should all be evaluated and planned appropriately. Actually, determination of these freshwater body trends in the future is the most significant factor considering the ongoing planning. The precautions can be taken clarifying the trend changes in advance. To illustrate, in summer time, the reduction of stream levels originates from the reduction of the groundwater resource level that is mainly reasoned by digging pits unconsciously. In such a case, altering the trend from decrease to increase could be possible with controlling digging pits. Furthermore, if increase in the trend is over the critical level that might result in some damages, precautions should also be taken prior. Therefore, in literature, many studies have examined the effects of rainfalls and temperature on flow-rates and reservoir capacities.

Partal and Kahya [3] analyzed trend changes in amount of rainfall annually and monthly. They completed the analysis using nonparametric methods of Sen's T test and Mann-Kendall using 96 rainfall measurement stations at various places of Turkey. As a result of this study, especially in 14 stations, the decrease of rainfall in January was remarkable. Turkes *et al.* [4], in their study on 111 rainfall measurement stations, tried to analyze long-term changes and tendencies in rainfall intensity series based on time and place properties. They observed a serious decrease in amount of rainfall and intensity of rainfall, especially in the Mediterranean region of Turkey. Karbulut and Cosun [5] studied on data from meteorology stations in Kahramanmaras which is a southeast province of the Mediterranean region of Turkey. They found stability in the region about the annual amount of rainfalls. Effect of climate change on rivers in the Mediterranean region of Turkey was investigated by Albek [6]. In this study, results show that significant changes can be expected in near future with possible impacts on the water quality and ecological status of rivers. Gonecgil and Icel [7] observed annual and seasonal trend changes using a one-directional variant analysis to the data of 11 meteorology stations at the coasts of the southeast Mediterranean

* Corresponding author

region of Turkey, in between 1975-2006. In their analysis, a decrease in the numbers of rainy days, especially in spring and winter, was observed. Bahadir [8] modeled the data of temperature degrees and amount of rainfall in southeast Anatolian region of Turkey with ARIMA. In this study, after the very cold year of 1992, an obvious increase in the average temperature degrees was stated. If only the greenhouse effects are examined, it is indicated that the temperature increase will be 1-3 °C per year until 2050, and when the sulphate particle changes are taken into account, the increase becomes 1-2 °C per year. Bahadir [9] tried to predict prospective temperature and rainfall increases using Box-Jenkins technique on 6 stations characterizing 3 different climate types on a line of north-south direction. In this study, in our next 15 years, an increase of 0.3 °C in Black Sea region and of 0.6 °C in Mediterranean region was determined. Additionally, about the rainfalls, an increase of 25-50 mm for Black Sea region and of 2-100 mm for Mediterranean region was determined. Republic of Turkey on Climate Change National Certificate [1] made a study on Kizilirmak, which is the longest river in Turkey, and its basin whether they are affected by climate changes or not. According to this study, an inverse proportion between temperature and flow is observed while a direct proportion between rainfall and flow is observed.

Gregory [10] studied annual rainfall trend changes in England. Suzuki [11] made a similar study in Japan. In 1973, Jagannathan and Parthasarathy [12], and in 1974, Parthasarathy and Dhar [13] analyzed the trend changes of rainfall in India. Also Goswami *et al.* [14] examined the monsoon rainfalls [15] representing 80% of rainfalls in India. In Canada, an increase of 1-2 °C per year was detected by Plummer *et al.* [16], and also an increase of rainfall amount was determined by Mekis and Hogg, [17] Stone *et al.* [18], Zhang *et al.* [19]. Groleau *et al.* [20] examined the trend changes of rainfalls in winter in Canada. They used Mann-Kendall test to the data of 60 air stations about the trend of the most hazardous rainfalls which were in January and February. As a result, in 25 of 60 air stations, an increase was observed, and 18 of these stations were stated in positive direction according to the significant level of 5%. Tabari *et al.* [21] made a study about climate changes in 13 stations covering the east, south and southeast part of Iran between the years 1966-2005. They reached their conclusion by taking the average of Mann-Kendall, Mann-Whitney, and Mann-Kendall Rank Correlation tests. According to the results, from the beginning of 1970's, increases of 0.412 °C in average values, 0.452 °C in maximum values, and 0.493 °C in minimum values were obtained. He *et al.* [22] used linear regression, Mann–Kendall test, and wavelet transform to reveal the variation characteristics of observed stream-flow and natural stream-flow in the Yellow River basin.

In this study, we analyzed the effects of climate change on the streams of the Western Mediterranean Basin of Turkey where most of the fresh water resources are located, in monthly and annually time scales.

2. MATERIALS AND METHODS

2.1 Study area and method

As study area, southwest part of Mediterranean Region of Turkey was chosen, where most of the fresh water resources of Turkey are located. In this basin, six discharge gauge stations are operated by Electrical Works Administration. Three of these six stations are eliminated because of missing data or having a regime extremely affected by external factors, such as regulation and dam effects. Among three stations, the first station No. 809 Kavaklidere is located on Seki valley of Fethiye-Elmalı way on Esencay River. It is located on 29033'44 E - 36049'36 N, has a rainfall area of 546.8 km², and an elevation of 1115 m. The measurement of this station is available since July 1956. The second study station is No. 811 Sucalti station (29006'05 E -37005'34 N), located 54 km south of Acipayam County in Denizli, and having a rainfall area of 3819.8 km² and the elevation of 589 m. The measurement of this station is available since July 1960. The final station is No. 812 Akkopru station (28056'00 E - 36055'01 N) located at the intersection of Dalaman river and Koycegiz-Fethiye way; its rainfall area is 4622.3 km² and the elevation is 128 m. The measurement of this station is also available since June 1963 [23].

The Mann Kendall test [24, 25] which is nonparametric, is independent from the data distribution. The Mann-Kendall statistic S is given as follows [26]:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(x_j - x_i) \tag{1}$$

The application of the trend test is done to a time series xi that is ranked from i = 1,2,………n-1 ,and xj, which is ranked from j = i+1,2,……….n. Each of the data points xi is taken as a reference point which is compared with the rest of the data points xj, so that follows [26]:

$$Sgn(x_j - x_i) = \begin{cases} +1, > (x_j - x_i) \\ 0, = (x_j - x_i) \\ -1, < (x_j - x_i) \end{cases} \tag{2}$$

It has been documented that when n ≥8, the statistic S is approximately normally distributed with the mean [26].

$$E(S) = 0 \tag{3}$$

The variance statistic is given as follows:

$$Var(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(i)(i-1)(2i+5)}{18} \tag{4}$$

where, t_i is considered as the number of ties up to sample i. The test statistics Z is computed as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} \\ 0, S = 0 \\ \frac{S-1}{\sqrt{Var(S)}}, S < 0 \end{cases} \tag{5}$$

It is concluded that if the absolute value of Z, calculated according to the above method, is less than the Z/2 value of a normal distribution at the α significance level, zero hypothesis is accepted and time serial does not include a trend. If it is greater than Z/2, time serial includes a trend, and if S is positive, this trend is an increasing one. If S is negative, on the other hand, trend is decreasing. As the data is not required to be compatible with a distribution, this test is particularly useful [27, 28].

A new trend analysis methodology by Şen [29] depends on the 1:1 line on a Cartesian coordinate system, where it corresponds to trend free case, and any deviation from this line indicates trend existence, and the closer are the plots to 1:1 line, the smaller is the trend slope.

Apart from the 1:1 line, upper and lower triangular areas correspond to trend existence, when two different time series are plotted against each other. In order to illustrate the effectiveness of the proposed methodology, Fig. 1 is prepared as the plot of sorted time series versus two trend-embedded synthetic time series. Each series is obtained by adding a linear monotonic increasing and decreasing trend into the original time series in the upper and lower graphs of Fig. 1. In the middle square, plots versus trend free time series are given after sorting in ascending

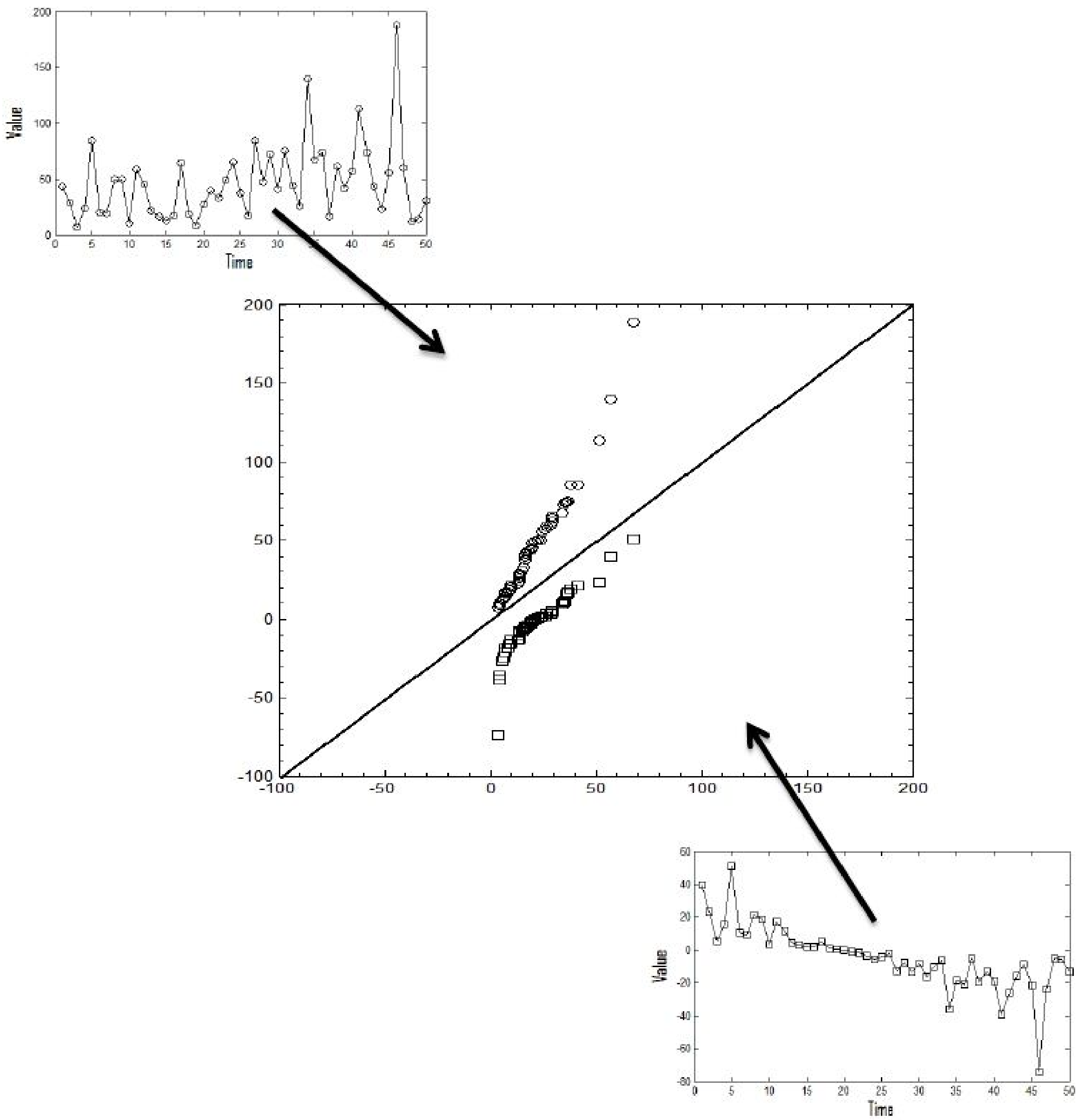

FIGURE 1 - Decreasing and increasing trends versus trend free time series [29].

order. The final product yields the fact that the upper (lower) triangular area includes increasing (decreasing) trends, respectively. Additionally, on the 1:1 plots, increasing trend time series points can be interpreted by considering low and high values subjectively in two groups. Hence, since low values are concentrated near the 1:1 line, the trend existence is weaker than the group of high values, which significantly deviate from the 1:1 line. On the other hand, in the lower triangular area, the time series have a low values' cluster, this time away from the line, whereas high values approach the 1:1 line implying comparatively weaker trend existence in the structure of the time series, considered all based on visualization. [29-31].

The most elementary type of regression model is the simple linear regression model, which can be expressed by the following equation [32-34]:

$$y_t = \beta_1 + \beta_2 . X_t + u_t \quad (6)$$

The subscript t is used to index the observations of a sample. The total number of observations, also called the sample size, will be denoted by n. Thus, for a sample of size n, the subscript t runs from 1 to n. Each observation comprises an observation on a dependent variable, written as y_t for observation t, and an observation on a single explanatory variable, or independent variable, written as X_t. The relation (Equation 6) links the observations on the dependent and the explanatory variables for each observation in terms of two unknown parameters, β_1, β_2, and an unobserved error term, u_t. Thus, of the five quantities that appear in (Equation 6), two, y_t and X_t, are observed, and three, β_1, β_2, and ut, are not. Three of them, y_t, X_t, and u_t, are specific to observation t, while the other two, the parameters, are common to all n observations. Here is a simple example of how a regression model like (Equation 6) could arise in economics. Suppose that the index t is a time index, as the notation suggests. Each value of t could represent a year, for instance. Then y_t could be household consumption as measured in year t, and X_t could be measured as disposable income of households in the same year. In that case, (Equation 6) would represent what in elementary macroeconomics is called a consumption function [31].

3. RESULTS AND DISCUSSIONS

Herein, flow-rate values of 3 stations located in western basin of Mediterranean region of Turkey are examined according to Mann-Kendal, Regression tests and Şen test. The trends are observed both annually and monthly. The results are summarized in Tables 1, 2, and 3. In these tables, some values are summarized as follows: annual or monthly average flow-rates, test statistic value S of Mann-Kendall test, Z value which is for testing the accuracy of hypothesis, and the β_1 values of Eq. 3 calculated by regression analysis of data used in scatter chart regardless of trend-line. The probability of trend is evaluated according to 95% confidence interval. The months and the years which Z value exceeds 1.96 are indicated as that the trend-line occurs in 95% confidence interval. Additionally, β_2 coefficients point out the amount of increase or decrease of annual average of flow-rates.

According to the Mann-Kendall test, 3 stations are all observed in decreasing trend. Moreover, when the annual changes are analyzed, there is a serious decreasing trend for the station No. 809 on Esencay River, except the heavy rain period between November and May. When we look at the stations No. 811 and No. 812, which are on Dalaman River, a decreasing trend for all months is observed for the station No. 811 located in the headwater, and a decreasing trend for all months, except November and December, is observed for the station No. 812.

Additionally to the regression analysis, the β_2 coefficients in equation 3 point out annual decrease, and are crucial parameters to foresee the flow-rates. According to these results, there can be periodic droughts, especially for the seasons with negligible amount of rainfall. The

TABLE 1 - Annual and monthly trend analysis of station no. 809.

Month	Mean Flow Rate (m^3/s)	S	Z	Trend Z (0,95)	Annual Change (m^3/s)	Şen Trend Test
October	0.75	-512	-3.81	↓	-0.0116	↓
November	1.56	54	0.40	↔	0.0049	↔
December	4.34	-154	-1.14	↔	-0.0169	↔
January	5.74	-184	-1.37	↔	-0.0689	↓
February	7.30	-106	-0.79	↔	-0.0259	↓
March	7.96	-200	-1.49	↔	-0.0659	↓
April	8.52	-155	-1.15	↔	-0.044	↓
May	4.78	-171	-1.27	↔	-0.0387	↓
June	1.80	-326	-2.43	↓	-0.0183	↓
July	0.67	-542	-4.04	↓	-0.0139	↓
August	0.39	-426	-3.17	↓	-0.0055	↓
September	0.48	-563	-4.20	↓	-0.0087	↓
Annual	3.69	-272	-2.02	↓	-0.023	↓

(↓) Denotes decreasing and (↔) denotes no trend

TABLE 2 - Annual and monthly trend analysis of station no. 811.

Month	Mean Flow Rate (m³/s)	S	Z	Trend Z (0,95)	Annual Change (m³/s)	Şen Trend Test
October	5.55	-437	-4.13	↓	-0.113	↓
November	8.44	-295	-2.79	↓	-0.103	↓
December	18.87	-325	-3.07	↓	-0.403	↓
January	25.18	-350	-3.31	↓	-0.732	↓
February	28.98	-412	-3.90	↓	-0.759	↓
March	28.56	-431	-4.08	↓	-0.707	↓
April	23.22	-334	-3.16	↓	-0.492	↓
May	12.30	-484	-4.58	↓	-0.403	↓
June	6.24	-462	-4.37	↓	-0.174	↓
July	3.34	-466	-4.41	↓	-0.087	↓
August	2.09	-390	-3.69	↓	-0.042	↓
September	3.10	-363	-3.43	↓	-0.068	↓
Annual	13.82	-441	-4.17	↓	-0.340	↓

TABLE 3 - Annual and monthly trend analysis of station no. 812.

Month	Mean Flow Rate (m³/s)	S	Z	Trend Z (0,95)	Annual Change (m³/s)	Şen Trend Test
October	18.32	-388	-3.92	↓	-0.211	↓
November	28.55	-83	-0.83	↔	-0.078	↔
December	63.88	-106	-1.44	↔	-0.960	↓
January	77.16	-200	-2.02	↓	-1.781	↓
February	76.42	-235	-2.37	↓	-0.895	↓
March	70.84	-289	-2.92	↓	-1.128	↓
April	58.14	-226	-2.28	↓	-0.710	↓
May	35.36	-328	-3.31	↓	-0.589	↓
June	22.35	-357	-3.61	↓	-0.283	↓
July	16.80	-393	-3.97	↓	-0.196	↓
August	14.41	-334	-3.37	↓	-0.128	↓
September	14.96	-341	-3.44	↓	-0.156	↓
Annual	41.44	-315	-3.18	↓	-0.594	↓

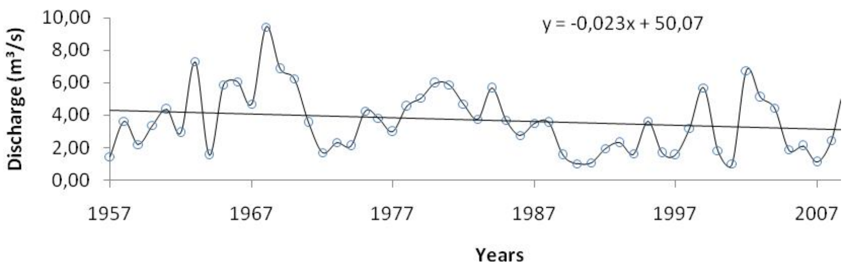

FIGURE 2 - The mean annual flow rates of the station No. 809

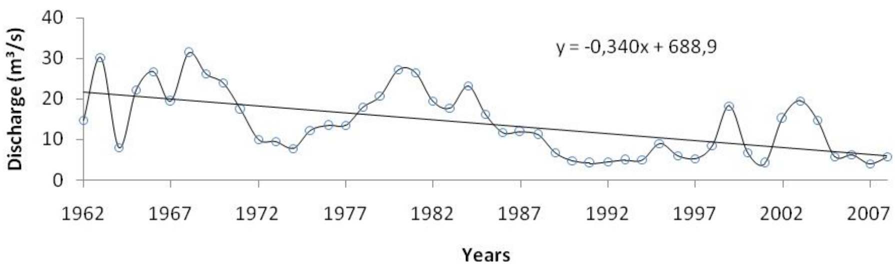

FIGURE 3 - The mean annual flow-rates of the station No. 811.

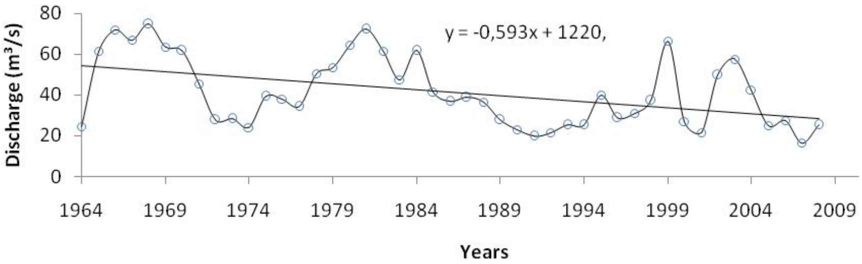

FIGURE 4 - The mean annual flow-rates of the station No. 812.

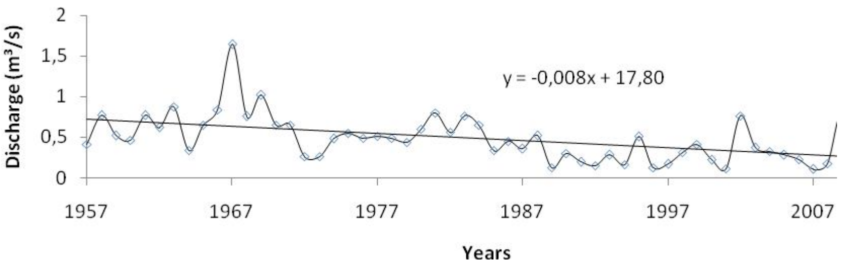

FIGURE 5. The mean flow-rates of September of the station No. 809.

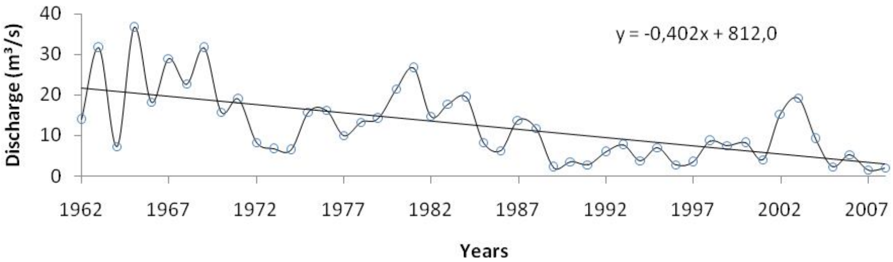

FIGURE 6. The mean flow-rates of May of the station No. 811.

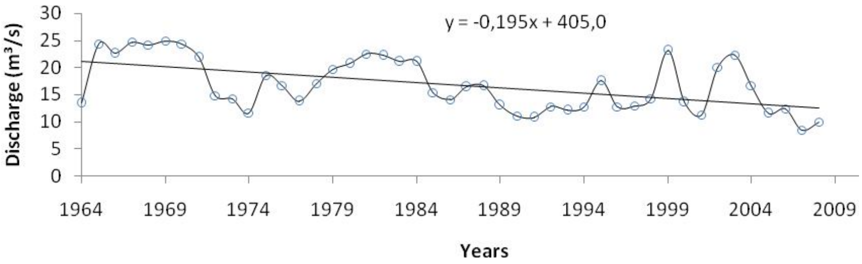

FIGURE 7. The mean flow-rates of July of the station No. 812.

results of regression analysis are tabulated at the rightmost columns of Tables 1, 2, and 3. The mean annual flow-rate changes of the stations No. 809, No. 811, and No. 812 are shown in the scatter charts of Figs. 2, 3, and 4. For the same stations, the flow-rate changes of the months with maximum values are shown in Figs. 5, 6, and 7.

Annual and monthly results obtained from Şen test are shown in Figs. 8, 9, and 10. The decreasing trends have been detected in almost all of these findings. However, the amount of the decrease varies according to the stations and months. From the results of station 811, a clear decrease in monthly and annual averages can be

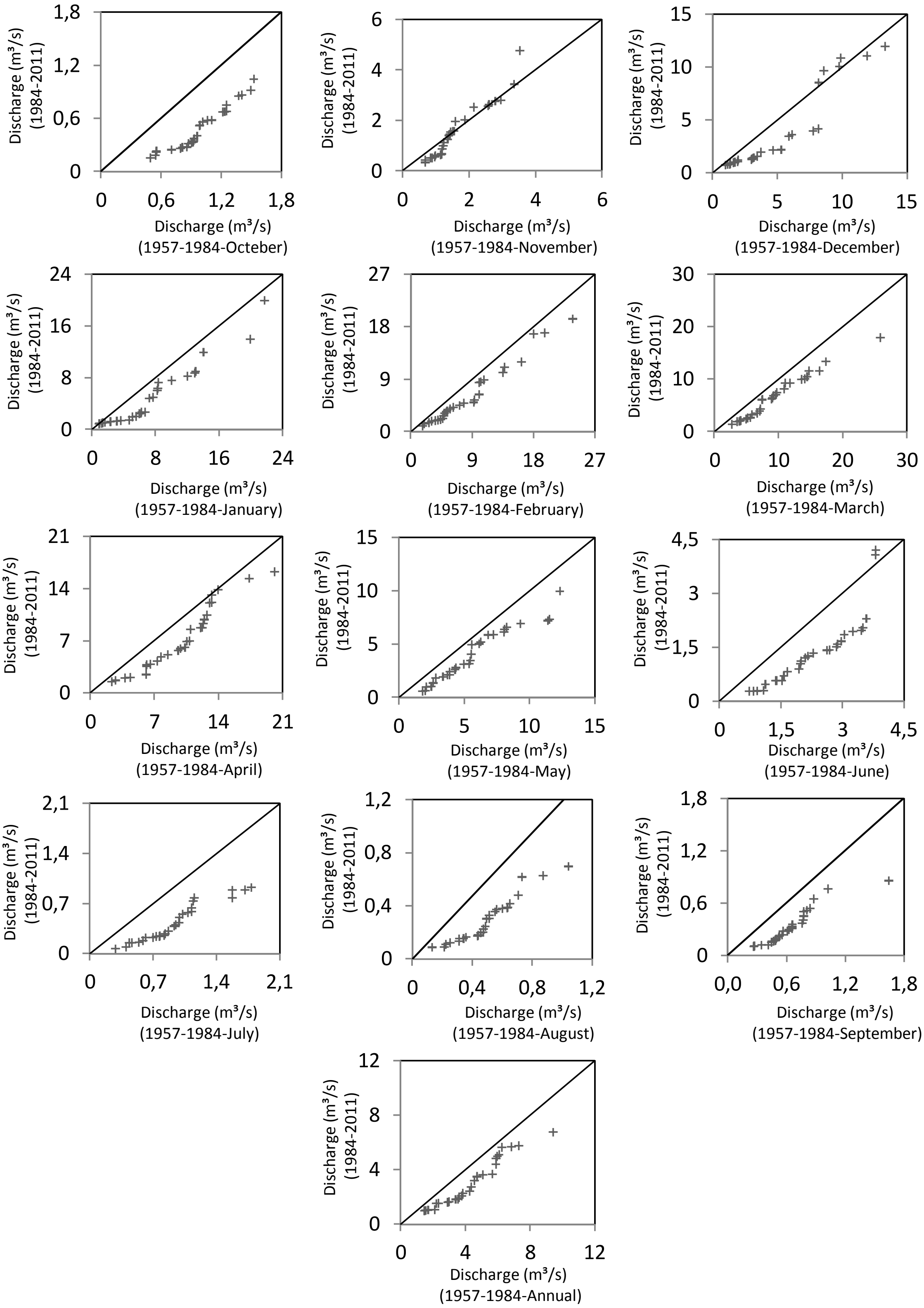

FIGURE 8 - The discharge changes of station 809 as a result of Şen test.

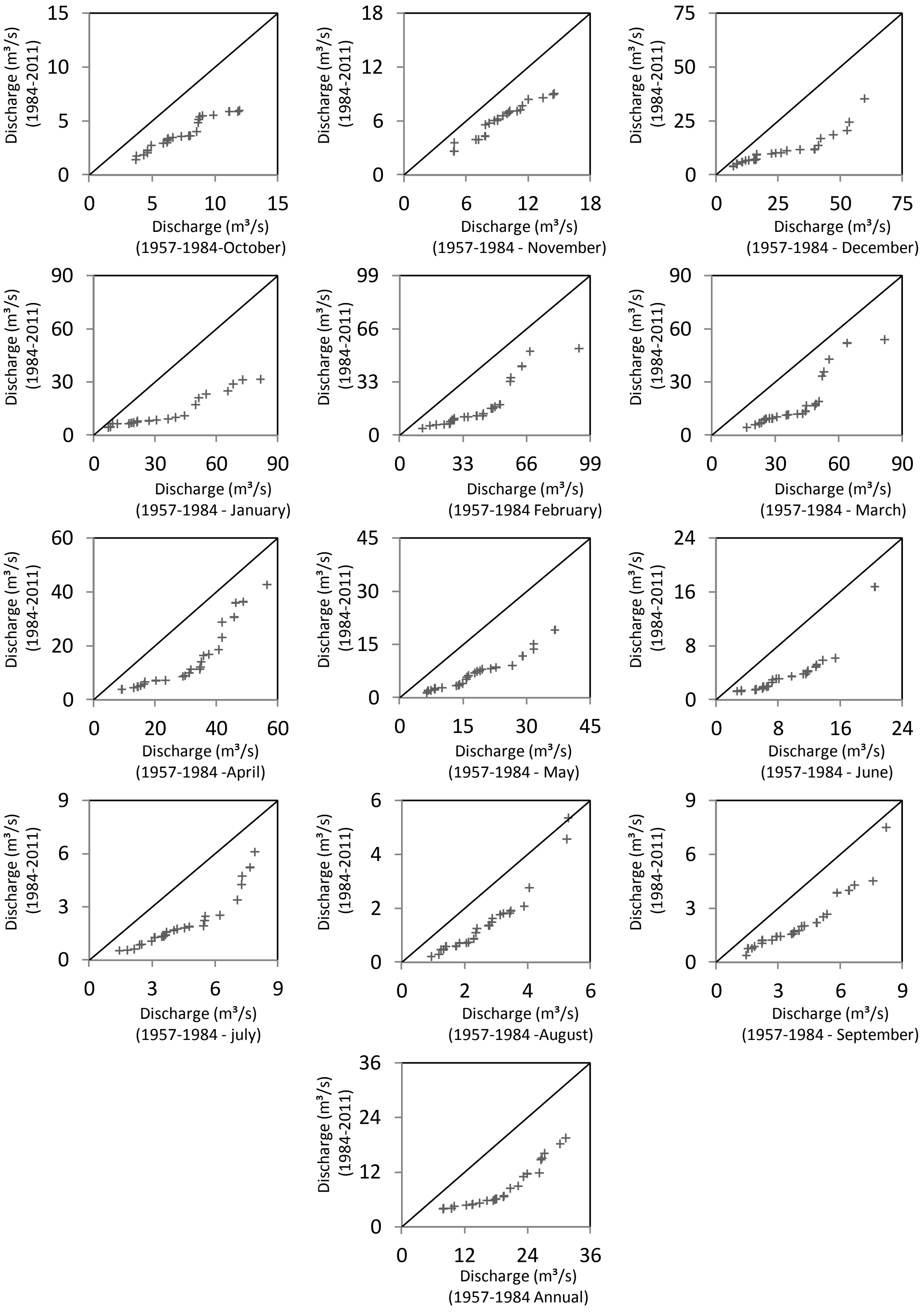

FIGURE 9 - The discharge changes of station 811 as a result of Şen test.

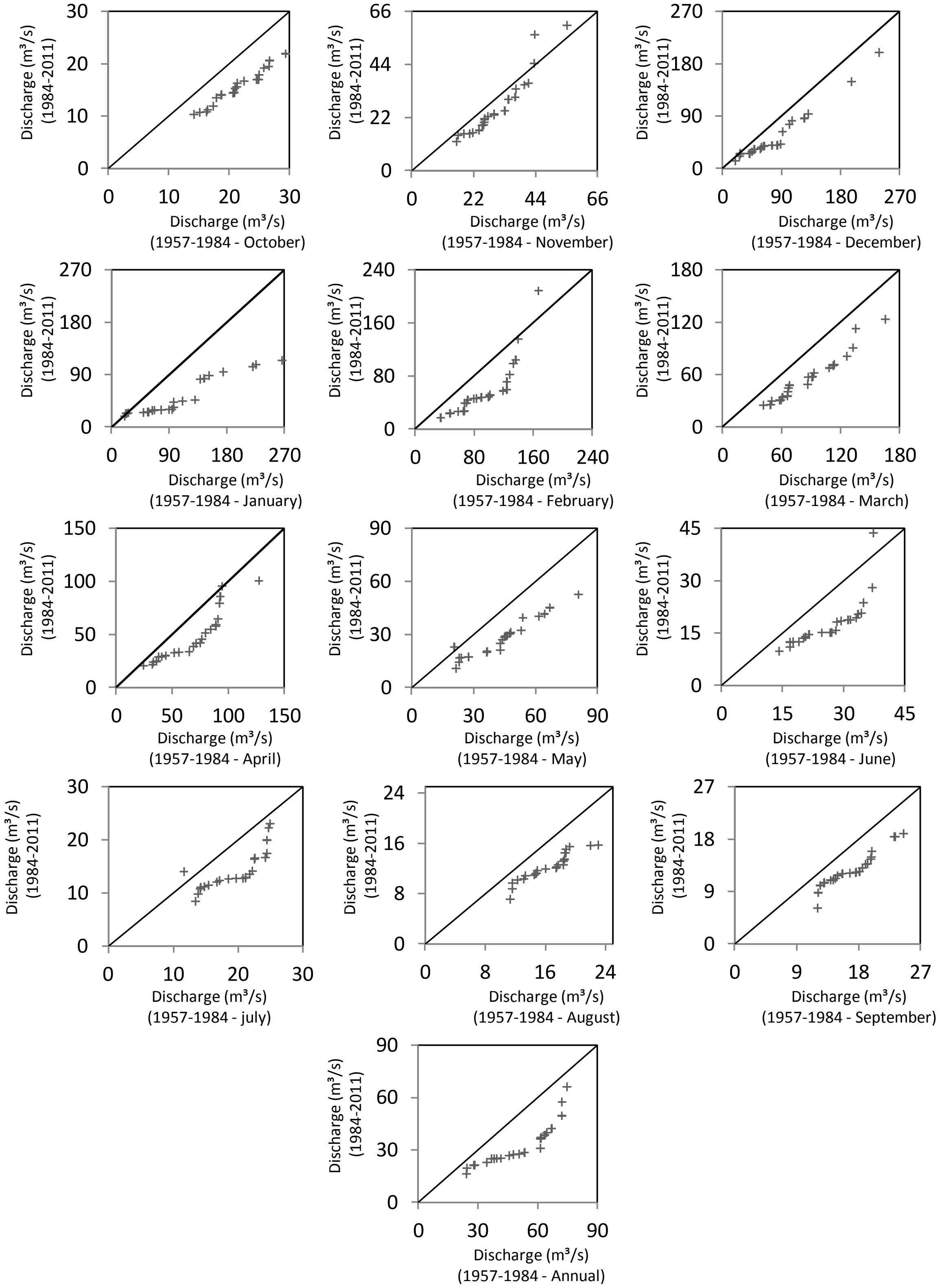

FIGURE 10 - The discharge changes of station 812 as a result of Şen test.

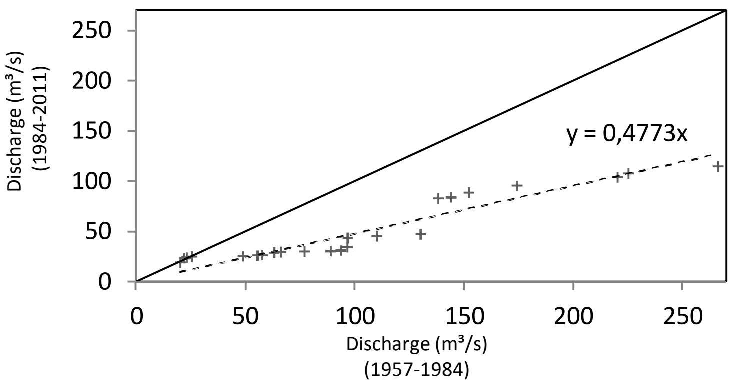

FIGURE 11. Determination of Şen test trend-line.

TABLE 4 - Comparison of Mann-Kendall Z test results and Şen test angles.

	Station 809		Station 811		Station 812	
Month	Z	Şen Trend Test Angle	Z	Şen Trend Test Angle	Z	Şen Trend Test Angle
October	-3.81	27.70	-4.13	27.89	-3.92	36.11
November	0.40	45.71	-2.79	32.70	-0.83	42.58
December	-1.14	39.96	-3.07	23.90	-1.44	36.52
January	-1.37	36.32	-3.31	22.28	-2.02	25.52
February	-0.79	38.08	-3.90	26.23	-2.37	34.93
March	-1.49	35.99	-4.08	27.03	-2.92	33.80
April	-1.15	38.13	-3.16	28.59	-2.28	36.04
May	-1.27	36.03	-4.58	22.18	-3.31	32.85
June	-2.43	33.17	-4.37	24.61	-3.61	34.23
July	-4.04	26.19	-4.41	27.40	-3.97	36.25
August	-3.17	31,71	-3.69	32.46	-3.37	36.71
September	-4.20	28.61	-3.43	30.87	-3.44	36.99
Annual	-2.02	36.24	-4.17	25.79	-3.18	33.22

seen (Fig. 9). When the results of station 809 (Fig. 8) are examined, the decrease in all months, except October and November, is in question. For the station 812, a decrease for all months and annual draws the attention, except November (Fig. 10). When the analysis in the study is evaluated, a decrease in discharge of rivers is seen all over the region. Due to the similar results of all three methods, an existing decrease is proven. In June, July, August and September when the flow of rivers are supplied by the groundwater, the decrease is more remarkable which shows us the groundwater amount is also decreasing in the region.

In the final part of the study, the trend-lines of the graphics used in Sen test are obtained (Fig. 11), and the angles between these trend-lines and x-axis are found. In general, the angles are all found to be less than 45 degrees in the figures.

According to Sen test, being less than 45 degrees means that there is a decreasing trend [29]. For Mann-Kendall test, Z statistic values shall have 95% confidence bounds ($|z|>1.96$), to be a meaningful argument. In Table 4, Mann-Kendall Z test results and Sen test angles are compared.

In Table 4, the Z test values obtained by Mann-Kendall test and trend-lines in Sen test are compared. According to this comparison, where the values are in 95% confidence bounds for Mann-Kendall test and the angles of Sen test range between 0° and 36°, they are found to be very similar for each test. However, the bigger angles between 36° and 45° are determined to be useless in 95% confidence bounds.

4. CONCLUSION

In the study, 3 stations (Esencay and Dalaman river), located on Western Mediterranean Basin of Turkey, are analyzed. The trends of flow-rates are tried to be figured out using Mann-Kendall test. According to the results, some serious decreasing trends are observed in all stations both annually and monthly. Besides, the trend changes occur especially in summer when the amount of rainfall is very low, and almost all of the flows of rivers are provided by underground sources. This situation shows us a remarkable decrease of the underground water levels. With respect to slope of the trend-lines of the figures, a risk of vanishing of the flow-rates is observed, especially in stations No. 809 and No.811 in drought seasons, which are predicted to occur in 30 or 50 years. This prediction is 80 years for the station No. 812.

The second crucial result in this study is tried to be found by the comparison between trend-line of Sen test and Mann-Kendall test. According to the results, when the angels are between 0^0 and 36^0, there is a meaningful decrease in values. Nonetheless, when the angels are between 36^0 and 45^0, there is still a decrease in the values but it is statistically not meaningful. Furthermore, it is determined that the results in Sen test and Mann-Kendall test have a correlation.

According to these data, the protection and development of the available water sources have become vital for the region. Especially for the drought seasons, it would be a critical precaution to increase or, at least, to keep the level of the underground sources, which feeds the rivers, equal. Therefore, the water flow by the available wells should be provided in a controlled way. Also, increasing the level of underground sources can be provided constructing new reservoirs. This type of structures simplifies the control of suction.

The global climate rapidly changes day by day; for this reason, the regions which may suffer from the climate change of every country, should be detected as soon as possible. The precautions mentioned before can help these regions to minimize the damages of the climate changes.

The authors have declared no conflict of interest.

REFERENCES

[1] Republic of Turkey on Climate Change National Certificate 2010-2020, (2013) http://www.tarimreformu.gov.tr/iklim/dosya/strateji.pdf.(in Turkish)

[2] Bahadır, M. (2011) Statistical analysis of the current changes in the Kizilirmak River. International Periodical For The Literature and History of Turkish or Turkic Volume 6/3 summer 2011, p, 1339-1356 Turkey.(in Turkish)

[3] Partal, T. and Kahya, E. (2006) Trend analysis in Turkish precipitation data. Hydrological Proceses. 20, 2011-2026.

[4] Turkes, M. Koc, T. and Sarıs, F. (2007) The sum of rainfall and intensity of hot summers sequences analysis of spatial and temporal changes and trends. Cografi Bilimler Dergisi 51, 57-73. (in Turkish)

[5] Karbulut, M. and Cosun, F. (2009) Trend Analysis of rainfall in Kahramanmaras. Coğrafi Bilimler Dergisi 71, 65-83 (in Turkish).

[6] Albek, M. (2008) The effects of climate change on rivers in the Mediterreanean Region of Turkey. Fresenius Environmental Bulletin 17 (9b), 1492-1500.

[7] Gonecgil, B. and Icel, G. (2010) Changes in total precipitation in the eastern Mediterranean coast of Turkey. Turk Cografya Dergisi, no 55:1-12 (in Turkish).

[8] Bahadır, M. (2011) Southeastern Anatolia Project GAP trend analysis of temperature and precipitation in the field. Uluslararasi Sosyal Arastırmalar Dergisi no:4/16 46-59. (in Turkish)

[9] Bahadır, M. (2011) Climatic regions in Turkey in the reflection of climate change, change of north-south temperature and rainfall predictions. Akademik Bakıs Dergisi. 26, 1-18 (in Turkish).

[10] Gregory, G. (1956) Regional variations in the trends of annual rainfall over the British Isles. Geogr. J. 122.

[11] Suzuki, E. (1968) Secular variations of the rainfall in Japan. Pap. Met. Geophys. 19, 363-399.

[12] Jagannathan, P.and Parthasarathy, B. (1973) Trends and periodicities of rainfall over India. Mon. Weath. Rev. 101, 691-700.

[13] Parthasarathy, B. and Dhar, O. N. (1974) Secular variations of the rainfall over India. Quart. J. Roy. Met. Soc. 100, 245-257.

[14] Goswami, B.N. Venugopal, V. and Sengupta, D. (2006) Increasing trend of extreme rain events over India in a warming. Environment Science 314, 1442-1445.

[15] Sahai, A.K. Grimm, A.M. Satyan, V. and Pant, G.B. (2003) Long-lead prediction of Indian Summer Monsoon Rainfall from global SST evolution. Climate Dynamics 20 (7/8), 855-863.

[16] Plummer, D.A. Caya, D. Frigon, A. Cote, H. Giguere, M. Paquin, D. Biner, D.S. Harvey R. and De Ellia, R. (2006) Climate and climate change over North America as simulated by the Canadian RCM. J. Clim. 1913: 3112–3132.

[17] Mekis, E. and Hogg, W.D. (1999) Rehabilitation and analysis of Canadian daily precipitation time series. Atmosphere–Ocean, 371: 53–85.

[18] Stone, D.A. Weaver, A. J. and Zwiers, F.W. (2000) Trends in Canadian precipitation intensity. Atmosphere–Ocean, 382: 321–347.

[19] Zhang, X. Vincent, L.A. Hogg, W.D. and Niitsoo, A. (2000) Temperature and precipitation trends in Canada during the 20th century. Atmosphere–Ocean, 383: 395–429.

[20] Groleau, A. Mailhot, A. and Talbot, G. (2007) Trend Analysis of Winter Rainfall over Southern Québec and New Brunswick Canada Atmosphere–Ocean, 45 3 2007, 153–162.

[21] Tabari, H. Somoe, B. S. and Zadeh M. R. (2011) Testing for long-term trends in climatic variables in Iran. Atmospheric Research 100, 132–140.

[22] He, B. Miao, C. and Shi, W. (2013) Trend, abrupt change, and periodicity of streamflow in the mainstream of Yellow River. Environ Monit Assess 185 (7), 6187-6199.

[23] E.İ.E. (2011) Monthly averages of water currents, the General Directorate of Electrical Power Resources Survey Turkey (in Turkish).

[24] Mann, H. B. (1945) Non-parametric Test Against Trend. Econometrika, Vol. 13, pp. 245-259.

[25] Kendall, M. G. (1975) Rank Correlation Methods. Charles Griffin. London.

[26] Mondal, A. Kundu, S. Mukhopadhyay, A. (2012) Raınfall trend analysıs by mann-kendall test: a case study of north-

eastern part of cuttack dıstrıct, Orıssa, Vol. 2 (1) January-April, pp.70-78.

[27] Yue, S. Zou S. and Whittemore, D. (1993) Non-parametric Trend analysis of Water Quality Data of Rivers in Kansas. Journal of Hydrology. 37.

[28] Tongal, H. (2012) The examination of nonlinearity, stochasticity and uncertainty properties of streamflows with the mathematical based methods. Natural and Applied Sciences, Süleyman Demirel Uni. Isparta, Turkey. (in Turkish).

[29] Şen, Z. (2012) Innovative trend analysis methodology. Journal of Hydrologic Engineering, 17(9), 1042-1046.

[30] Şen, Z. (2013) "Trend Identification Simulation and Application". Journal of Hydrologic Engineering. doi: 10.1061/(ASCE)HE.1943-5584.0000811.

[31] Şen, Z. (2013) "Square Diagonal Trend Test Procedure". 6th International Perspective on Water Resources & The Environment. January, 07-09.

[32] Davidson, R. and MacKinnon J.G. (2003) Econometric Theory and Methods. Oxford University Press (New York)

[33] Saplıoğlu, M. (2010) An Accident Prediction Model For Urban Uncontrolled Intersections, Natural and Applied Sciences, Süleyman Demirel Uni. Isparta, Turkey. (in Turkish)

[34] Uzundurukan, S. (2001). A Study directed at determination of some geotechnical properties of fine graded soils with empirical expressions rely on SPT and DPT data, Master Thesis, Natural and Applied Sciences, Süleyman Demirel Uni. Isparta, Turkey. (in Turkish)

Received: May 27, 2013
Accepted: September 30, 2013

CORRESPONDING AUTHOR

Kemal Saplıoğlu
Engineering Faculty
Civil Engineering Department
Süleyman Demirel University
Isparta
TURKEY

E-mail: kemalsaplioglu@sdu.edu.tr