Nevşehir Bilim ve Teknoloji Dergisi Cilt 6(ICOCEE 2017 Özel Sayı) 333-340 2017
DOI: 10.17100/nevbiltek.323640
URL: http://dx.doi.org/10.17100/nevbiltek.323640

Trend Analysis of Hydro-Meteorological Variables of Kızılırmak Basin

Burcu ERCAN [1,*] , Mehmet İshak YÜCE [2]

[1]*Kilis 7Aralık Üniversitesi, Mühendislik Mimarlık Fakültesi, İnşaat Mühendisliği Bölümü, Kilis*

[2]*Gaziantep Üniversitesi, Mühendislik Mimarlık Fakültesi, İnşaat Mühendisliği Bölümü, Gaziantep*

Abstract

Trend analysis of annual precipitation and temperature are essential in water resources management, developing hydraulic engineering projects, environment protection and sustainable urbanization. In this study, trend analyses were performed to determine whether there are any increase or decrease in the total annual precipitation and annual average temperature data of 36 stations located in and around Kızılırmak Basin, Turkey. Mann-Kendall test, which is a non-parametric trend analysis method, was utilised in order to conduct an investigation for a period of about 40 years ranging from 1975 to 2015. Although no-trend was perceived in the total annual precipitation in the most of the stations, an increasing trend was observed in the average annual temperature in the majority of the stations, with a significance level of 95%.

Keywords: Trend Analysis, Mann-Kendall, Precipitation, Temperature, Kızılırmak Basin.

Kızılırmak Havzasının Hidrometeorolojik Verilerinin Trend Analizi

Öz

Yıllık yağış ve sıcaklığın trend analizi; su kaynakları yönetimi, hidrolik mühendislik projeleri geliştirme, çevre koruma ve sürdürülebilir kentleşmede önemli bir yere sahiptir. Bu çalışmada, Türkiye'de yer alan Kızılırmak Havzasında ve çevresinde bulunan 36 istasyonun yıllık toplam yağış ve yıllık ortalama sıcaklık verilerinde herhangi bir artış ya da azalış trendi olup olmadığını belirlemek için eğilim analizleri yapılmıştır. Parametrik olmayan bir eğilim analiz yöntemi olan Mann-Kendall testi, 1975 ile 2015 yılları arasında değişen yaklaşık 40 yıllık bir periyodun verilerinin eğilim hareketlerinin araştırılabilmesi için kullanılmıştır. İstasyonların çoğunda toplam yıllık yağışta bir trend eğilimi gözlenmemesine rağmen, ortalama yıllık sıcaklık değerlerinde % 95'lik önem aralığına göre artan bir eğilim gözlendi.

Anahtar Kelimeler: Trend Analiz, Mann-Kendall, Yağış, Sıcaklık, Kızılırmak Havzası.

[*]e-mail: burcuercan@kilis.edu.tr

1. Introduction

Among others, industrialisation and consumption of fossil fuel causes harmful greenhouse gases emissions to the environment. Increase in the amount of these harmful greenhouse gases in the atmosphere, leads to global warming. Thus, average annual temperature increase. Global or local average annual temperature increase may cause environmental, social, economic and health problems. According to Intergovernmental Panel on Climate Change (IPPC), in 2007, the average global surface temperature has been increased by 0.74°C from the beginning of the 20th century to today. The hottest year recorded so far was noted to be 1998, while the period of between 1990 and 2002 is marked as the hottest years. The average temperature in Turkey is expected to increase between 2.5 - 4°C in the following years, which may be higher in Aegean and Eastern regions of Anatolia [1-4]. Studies indicate that there are significant changes in the temperature and precipitation values in Turkey, which are expected to continue in following years. The increase in temperature and the decrease in rainfall may lead to the problem of drought [5]. It is perceived that the number and the severity of meteorological disasters such as floods and droughts will increase in Turkey. Long-term and severe droughts may cause a widespread desertification in some areas.

Turkey's spatial rainfall variability distribution is steadily decreasing from north to south. Since the coefficient of variation is 25% higher in Mediterranean and south-eastern regions of Anatolia, there are frequent droughts due to the differences in precipitation over many years. In the trend analyses studies performed on the hydro-meteorological parameters, the runoff trends show a statistically significant decrease in western, southern and south-eastern parts of Turkey. Nonetheless, the runoff trends do not present statistically significant increase in the south and eastern Anatolia [6, 7]. Both in meteorological and hydrological data recorder in black sea region, in the majority of the stations statistically significant trends were not observed. Whereas in southern part of the country, including Seyhan and Ceyhan river basins which supply irrigation water to Çukurova, decreasing trends were noted in annual total rainfall and annual average stream flow [8-12].

In general, trend analyses present an increase in long-term temperature records in Kızılırmak River Basin, while the precipitation data shows a downward trend in the watershed. Stream flow trend in the basin is usually decreasing in almost all sub-basins [13]. In this study, the trend analyses are performed on annual average temperature and annual total precipitation in the Kızılırmak River Basin by Mann-Kendall method, under the influence of climate change.

2. Data and Methods

The Kızılırmak River Basin is located between 37° 58´N -41° 44´N latitude and 32° 48´E -38° 22´E longitude in the eastern part of Central Anatolia. The Kızılırmak is the longest river situated entirely within Turkey, with a total drainage area of about 78 180 km2. The river flows for a total length of 1355 km, rising in Eastern Anatolia around 39.8°N 38.3°E, at an altitude of around 2000 m above sea level. It is joined by the Delice River at 40.47°N 34.14°E, then it confluences with the Devrez River at 41.10°N 34.42°E. Kızılırmak joins the Gökırmak before finally flows through its delta into the Black Sea at 41.72°N 35.95°E, with a long-term mean annual discharge of 184 m3/s. A number of dams are located on the river including the Boyabat, Altınkaya and Derbent. The basin generally reflects the Central Anatolian continental climate, while a small section has the effect of climate of the Black Sea. The river reaches its highest level of the water regime in April, while it flows in the lowest water level between February and July [14, 15]. The basin boundaries and the meteorological stations used in this study are given in Figure 1.

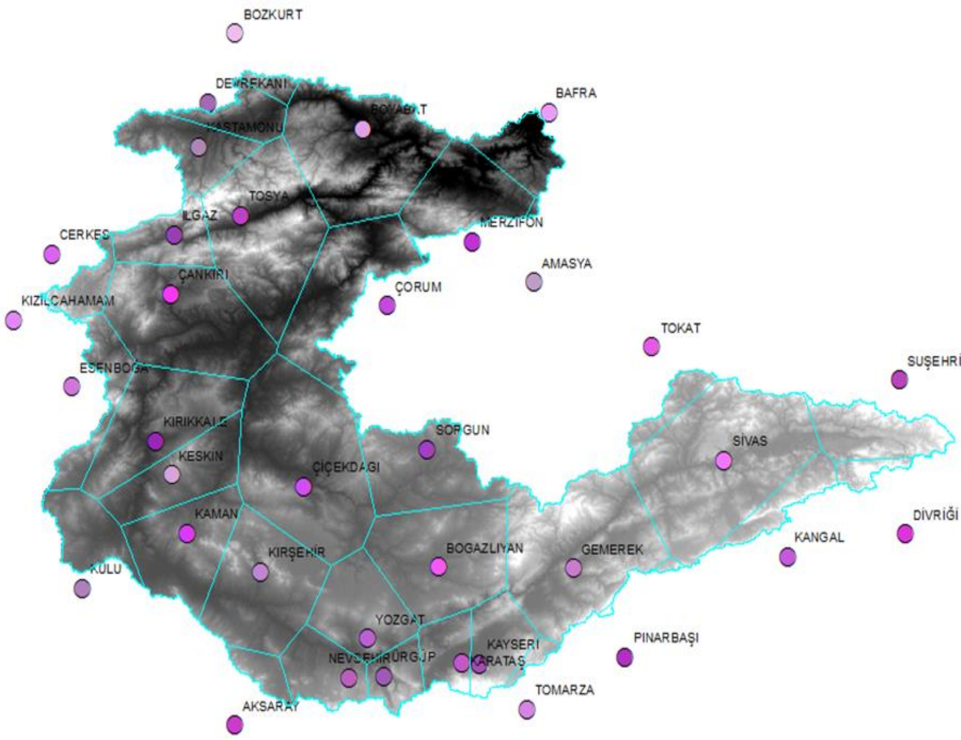

Figure 1. Basin Boundaries of Kızılırmak and rainfall-Temperature Stations.

Annual total precipitation and annual average temperature data of 36 meteorological stations in and around Kızılırmak River Basin were employed in the analyses. The characteristics of these stations are given in Table 1.

The Mann-Kendall test is a non-parametric test used to examine whether there is any monotonic trend in time series data. The method compares the relative magnitudes of sample data rather than the data values themselves [16]. One advantage of this method is that the data does not need to follow any particular distribution. Furthermore, data stated as non-detects can be included by assigning them a common value which is smaller than the smallest measured value in the data set. The procedure assumes that there exists only one data value per time period. When multiple data points exist for a single time period, the median value is used. The data values are evaluated as an ordered time series. Each data value is compared to all subsequent data values. The initial value of the Mann-Kendall statistic, S, is assumed to be 0 (e.g., no trend). If a data value from a later time period is higher than a data value from an earlier time period, S is increased by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, S is decreased by 1. The net result of all such increments and decrements produces the final value of S [17].

Let x_1, x_2 , … x_n characterize n data values where j x represents the data value at time j. Then The Mann-Kendall test statistic is calculated by Equation 1:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \text{sign}(x_j - x_k) \tag{1}$$

Where:

If $x_j - x_k$	k>0	$\text{sign}(x_j - x_k)=1$
If $x_j - x_k$	k=0	=0
If $x_j - x_k$	k<0	=-1

A large positive value of S is an indicator of an increasing trend, and a small negative value specifies a decreasing trend. Nevertheless, it is necessary to calculate the probability associated with S and the sample size, n, to statistically quantify the significance of the trend. The following procedures are performed in order;

- Calculate S by Equation 1.
- Calculate the variance of S, VAR(S), by the following Equation 2.

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

Where n is the number of data values, g is the number of tied grups, and tp is the number of data points in the pth group.

- Normalized test statistic Z is calculated by Equation 3.

$$Z = \frac{S-1}{[VAR(S)]^{1/2}} \quad \text{if } S>0$$
$$= 0 \quad \text{if } S=0 \tag{3}$$
$$= \frac{S+1}{[VAR(S)]^{1/2}} \quad \text{if } S<0$$

- The probability associated with this normalized test statisticis estimated. The probability density function for a normal distribution with a mean of 0 and a standard deviation of 1 is given by the following Equation 4.

$$f(z) = \frac{1}{\sqrt{2\pi}} e^{\left(-\frac{z^2}{2}\right)} \tag{4}$$

It is checked according to the 95% confidence interval whether the trend curve of the function value (f(z)) is increasing, no-trend or decreasing for temperature and rainfall [18]. Described above the Mann-Kendall trend analysis steps were applied to the precipitation and temperature values used in this study (Table 1). The trend is said to be decreasing if Z is negative and the estimated probability is greater than the level of significance. The trend is said to be increasing if the Z is positive and the calculated probability is greater than the level of significance. If the computed probability is less than the level of significance, there is no trend.

3. Results and Discussion

In this study, trend analyses were performed to determine if there is any increase or decrease in the total annual precipitation and annual average temperature data of 36 stations situated in and around Kızılırmak River Basin, Turkey. A non-parametric trend analysis test, namely; Mann-Kendall method, was employed to perform an examination for a period of around 40 years ranging from 1975 to 2015. Station codes, coordinates and elevations of the stations are evaluated separately. The results are given considering the probability values for 95% confidence interval in Table 1. A decreasing trend is occured at only 4 rainfall stations according to 95% confidence interval. However, this number is up to 12, when examined according to 85. When an assessment is made for the temperature stations: there is increasing trend in 26 stations for 95% confidence interval, this number is up to 30 for 85%. Looking at the general picture (according to 95%), 1/9 ratio of stations show decreasing trend behavior in the rainfall stations, while the temperature stations show an increasing trend more than 2/3 ratio. In 85% confidence interval, the number of rainfall stations which are show decreasing trend behavior are 1/3 of all stations, while the number of temperature stations was 5/6 of all stations.

Table 1. The trend analysis values of Rainfall and Temperature stations.

Station Code	Station Name	Lat.	Long.	Elevation (m)	Service Range for Rainfall	Service Range for Temperature	Rainfall	Temperature	Rainfall			Temperature		
									S statistic	Z	P-value	S statistic	Z	P-value
17756	Kaman	39,3652	33,7064	1075	1975-2011	1975-2015	No Trend	Increasing	333	4,34	0,60	342	3,83	1
17760	Boğazliyan	39,1897	35,2532	1070	1975-2011	1975-2015	No Trend	Increasing	-142	-1,84	0,93	280	3,13	1
17802	Pinarbaşi	38,7224	36,3924	1542	1975-2005	1975-2013	No Trend	No Trend	-96	-1,69	0,91	120	1,44	0,86
17734	Divriği	39,3618	38,1142	1121	1975-2005	1975-2013	No Trend	Increasing	-27	-0,46	0,64	240	2,89	1
17684	Suşehri	40,1623	38,0752	1164	1975-2005	1975-2013	No Trend	No Trend	89	1,57	0,88	88	1,05	0,77
17086	Tokat	40,3312	36,5577	611	1975-2005	1975-2013	No Trend	Increasing	63	1,11	0,78	181	2,18	0,96
17084	Çorum	40,5461	34,9362	776	1975-2005	1975-2013	No Trend	Increasing	-57	-1	0,76	228	2,75	0,99
17080	Çankiri	40,6086	33,6102	755	1975-2015	1975-2015	No Trend	Increasing	-23	-0,25	0,61	253	2,83	1
17606	Bozkurt	41,9597	34,0037	167	1975-2009	1975-2013	No Trend	Increasing	47	0,82	0,72	239	2,88	0,99
17622	Bafra	41,5515	35,9247	103	1975-2011	1975-2015	No Trend	Increasing	-116	-1,5	0,87	288	3,22	1
17160	Kirşehir	39,1639	34,1561	1007	1975-2015	1975-2015	Decreasing	Increasing	-221	-2,47	0,98	279	3,12	1
17135	Kirikkale	39,8433	33,5181	751	1975-2015	1975-2015	Decreasing	Increasing	-180	-2,01	0,95	256	2,86	0,99
17192	Aksaray	38,3705	33,9987	970	1975-2005	1975-2015	No Trend	Increasing	-61	-1,07	0,78	273	3,06	1
17730	Keskin	39,6682	33,6118	1140	1975-2011	1977-2015	No Trend	No Trend	-61	-0,78	0,71	84	1	0,76
17754	Kulu	39,0788	33,0657	1005	1975-2005	1975-2013	No Trend	Increasing	-105	-1,86	0,93	261	3,15	1
17140	Yozgat	38,8205	34,8159	1301	1975-2015	1975-2015	Decreasing	Increasing	-191	-2,13	0,96	391	4,38	1
17196	Kayseri	38,687	35,5	1094	1975-2015	1975-2015	No Trend	Increasing	-97	-1,08	0,78	395	4,43	1
17193	Nevşehir	38,6163	34,7025	1260	1975-2015	1975-2015	No Trend	Increasing	-169	-1,89	0,93	360	4,03	1
17732	Çiçekdaği	39,6067	34,4235	900	1975-2011	1975-2015	No Trend	Increasing	2	0,01	0,6	257	2,88	0,99
17712	Sorgun	39,8016	35,1805	1116	1984-2009	1984-2015	No Trend	No Trend	-63	-0,81	0,71	118	1,99	0,94
17835	Ürgüp	38,6218	34,9144	1068	1975-2011	1975-2015	Decreasing	Increasing	-214	-2,79	0,99	216	2,41	0,98
17981	Karataş	38,6895	35,3894	22	1975-2005	1975-2013	No Trend	Increasing	-15	-0,25	0,61	286	3,45	1
17090	Sivas	39,7437	37,002	1294	1975-2015	1975-2015	No Trend	Increasing	-171	-1,91	0,94	280	3,13	1
17162	Gemerek	39,185	36,0805	1182	1975-2015	1975-2015	No Trend	Increasing	-144	-1,61	0,89	218	2,44	0,98
17837	Tomarza	38,4522	35,7912	1402	1975-2005	1975-2013	No Trend	No Trend	-37	-0,64	0,68	129	1,55	0,88
17762	Kangal	39,2428	37,389	1521	1975-2005	1975-2013	No Trend	No Trend	-25	-0,43	0,64	100	1,2	0,8
17085	Amasya	40,6668	35,8353	409	1975-2005	1975-2013	No Trend	Increasing	57	1	0,76	193	2,32	0,97
17083	Merzifon	40,8793	35,4585	754	1975-2005	1975-2013	No Trend	Increasing	75	1,32	0,83	206	2,48	0,98
17620	Boyabat	41,463	34,7853	350	1975-2005	1975-2015	No Trend	No Trend	-30	-0,52	0,65	-5	-0,04	0,6
17074	Kastamonu	41,371	33,7756	800	1975-2015	1975-2015	No Trend	Increasing	-69	-0,76	0,7	248	2,77	0,99
17128	Esenboğa	40,124	32,9992	959	1975-2005	1975-2006	No Trend	Increasing	-31	-0,54	0,65	157	1,89	0,93
17646	Çerkes	40,815	32,8831	1126	1975-2005	1975-2013	No Trend	Increasing	68	1,2	0,8	261	3,15	1
17664	Kizilcahamam	40,4729	32,6441	1033	1975-2005	1975-2013	No Trend	No Trend	10	0,16	0,61	146	1,75	0,91
17650	Tosya	41,0132	34,0367	870	1975-2011	1975-2015	No Trend	Increasing	-90	-1,16	0,8	193	2,16	0,96

4. Conclusion

In this study, Even though increasing trends were observed in the average annual temperature in the majority of the stations, no-trend was perceived in the total annual precipitation in the most of the stations, with a significance level of 0.05%. The trend in the average annual temperature at nine meteorological stations was found to have no-trend, while at twenty-seven stations an upward trend was noted. The total annual precipitation time series show a downward trend in four out of thirty-six stations, whereas no-trend was observed in thirty-two stations. Typically there is a relationship between the hydrological and the meteorological parameters. If the average annual temperature increases, it is expected to cause a rise in evaporation, thus, increase in the total annual precipitation. An increasing trend in the average annual temperature and a decrease trend in the total annual precipitation could be an indication of drought.

5. References

[1] Intergovernmental Panel on Climate Change (IPCC), "Climate Change 2007: Impacts, Adaptation and Vulnerability" (Eds. Parry M. L., Canziani O. F., Palutikof J. P., Van Der Linden P. J., Hanson C. E.), *Cambridge University Press*, 987s, UK, 2007.

[2] Altın T. B., Barak B., "Seyhan havzasında 1970-2009 yılları arasında yağış ve hava sıcaklığı değerlerindeki değişimler ve eğilimler" ***Türk Coğrafya Dergisi***, 58, 21-34, 2012.

[3] Kadıoğlu M., "Küresel iklim değişikliğine uyum stratejileri" *Kar Hidrolojisi Konferansı* 27-28 March, Symposium Book, 69s, Erzurum, Turkey, 2008.

[4] İçel G., Ataol M., "Türkiye'de yıllık ortalama sıcaklıklar ile yağışlarda eğilimler ve NAO arasındaki ilişkileri (1975-2009)" ***Coğrafya Dergisi***, 28, 55-68, 2014.

[5] Ercan B., Yüce M. İ., "Delineation of Watershed Boundaries by GIS: Case of the Kızılırmak Basin" *International Conferance on Natural Science Engineering (ICNASE'16)* 19-20 March, Symposium E-book, 2627s, Kilis, Turkey, 2016.

[6] Ölgen K., "Türkiye'de yıllık ve mevsimsel yağış değişkenliğinin alansal dağılım" ***Ege Coğrafya Dergisi,*** 28, 155-174, 2010.

[7] Kahya E., Kalaycı S., "Trend analysis of streamflow in Turkey" ***Journal of Hydrology,*** 289, 128-144, 2004.

[8] Oğuz İ., Öztekin T., Akar Ö., "Tokat Kazova'daki uzun yıllık yağış ve sıcaklık gidişlerinin kuraklık açısından irdelenmesi" ***GOÜ Üniversitesi, Ziraat Fakültesi Dergisi,*** 25, 71-79, 2008.

[9] Douglas E. M., Vogel R. M., Kroll C. N., "Trends in floods and low flows in the United States; Impact of spatial correlation" ***Journal of Hydrology,*** 240, 90-105, 2000.

[10] Eriş E., Ağıralioğlu N., "Homogeneity and trend analysis of hydrometeorological data of the eastern Black Sea region, Turkey" ***Journal of Water Resource and Protection,*** 4, 99-105, 2012.

[11] Altın T. B., Barak B., "Seyhan havzasında 1970-2009 yılları arasında yağış ve hava sıcaklığı değerlerindeki değişimler ve eğilimler" ***Türk Coğrafya Dergisi,*** 58, 21-34, 2012.

[12] Özgür E., Efe B., Akbayır İ., "Güneydoğu Anadolu Projesi (GAP) illerinin aylık ve yıllık toplam yağış analizi" *II. Uluslararası Katılımlı Kuraklık ve Çölleşme Sempozyumu* 16-18 September, Konya, Turkey, 2014.

[13] Bahadır M., "Kızılırmak Nehri akım değişimlerinin istatistiksel analizi" ***Turkish Studies-International Periodical For The Languages, Literature and History of Turkish or Turkic,*** 6/3, 1339-1356, 2011.

[14] Ercan B., "Determination of the rainfall-runoff relationship for Kızılırmak basin" *MSc Thesis*, Department of Civil Engineering, Graduate School of Natural and Applied Sciences, Gaziantep University, Turkey, 2016.

[15] Yüce M. İ., Ercan B., "Kızılırmak Havzası Yağış Akış ilişkisinin Belirlenmesi" *4. Su Yapıları Sempozyumu* 19-21 November, Symposium book 410s, Antalya, Turkey, 2015.

[16] Gilbert R. O., "Statistical Methods for Environmental Pollution Monitoring" John Willey and Sons Inc., New York, 1987.

[17] Muratoğlu A., Yüce M. İ., "Trend Analysis of Tigris River Basin Stream Flow Data" *10th International Congress on Advances in Civil Engineering*, Ankara, Turkey, 2012.

[18] Khambhammettu P., "Appendix Mann-Kendall Analysis for the Fort Ord Site" *Annual Groundwater Monitoring Report*, California, 2005.