Sürdürülebilir Mühendislik Uygulamaları veTeknolojik Gelişmeler Dergisi
Journal of Sustainable Engineering Applications and Technological Developments
2022, 5(2): 123-137

Homogeneity Analysis of Turkish Rainfall Intensity Series

Türkiye Yağış Şiddeti Serilerinin Homojenlik Analizi

Utku Zeybekoğlu[1], Aslı Ülke Keskin[2]
[1]Sinop University, Boyabat Vocational School of Higher Education, Department of Construction, Sinop Turkey
[2]Ondokuz Mayıs University, Engineering Faculty, Department of Civil Engineering, Samsun Turkey

Doi: 10.51764/smutgd.1097444
Geliş Tarihi :02.04.2022
Kabul Tarihi :08.08.2022

ABSTRACT

In this study, homogeneity checking the annual maximum rainfall intensity series for periods ranging from 30 to 78 years were obtained from 103 stations operated by the Turkish State Meteorological Service. Absolute homogeneity tests (AHT) namely Standard Normal Homogeneity Test (SNHT), Buishand Range Test (BRT), Pettitt Test (PT), and Von Neumann Ratio Test (VNRT) were applied at a confidence level of 95%. Stations were classified inhomogeneous if at least one of the standard durations data classified suspect or doubtful. Assuming that the factor destabilizing the homogeneity is the trend, a detrended methodology (DFA) was performed. After the implementation of DFA, absolute homogeneity tests were reapplied to the series of rainfall intensity. As a result of this study 49 of 103 stations called useful all 14 standard durations. 45 of the remaining 54 stations classified useful all standard durations after trend components separated from rainfall intensity series. As a result of the analysis, it was determined that the remaining 8 of 103 stations had inhomogeneous values after the trend components were separated.

Keywords: Homogeneity analysis, Turkey, Rainfall Intensity

ÖZET

Bu çalışmada, Meteoroloji Genel Müdürlüğü tarafından işletilen 103 istasyondan 30 ile 78 yıl arasında değişen periyotlar için yıllık maksimum yağış şiddeti serilerinin homojenlik kontrolü yapılmıştır. Mutlak homojenlik testleri olarak bilinen Standart Normal Homojenlik Testi (SNHT), Buishand Aralık Testi (BRT), Pettitt Testi (PT) ve Von Neumann Oran Testi (VNRT) %95 güven aralığında uygulanmıştır. Standart süre verilerinden en az biri şüpheli veya sorunlu ise, istasyon homojen değil olarak sınıflandırılmıştır. Homojenliği bozan faktörün muhtemel trend bileşenleri olduğu varsayılarak, trend bileşenleri ayrılmıştır. Daha sonra, yağış şiddeti serilerin mutlak homojenlik testleri yeniden uygulanmıştır. Analizler sonucunda 103 istasyonun 49'u 14 standart sürenin tamamında kullanılabilir olarak sınıflandırılmıştır. Kalan 54 istasyonun 45'i, trend bileşenlerinden sonra tüm standart süreleri kullanılabilir olarak sınıflandırılmıştır. 103 istasyondan geriye kalan 8'inin ise trend bileşenleri ayrıldıktan sonra da homojen olmayan değerlere sahip olduğu tespit edilmiştir.

Anahtar Kelimeler: Homojenlik analizi, Türkiye, Yağış Şiddeti

Utku Zeybekoğlu, Orcid:0000-0001-5307-8563, utkuz@sinop.edu.tr, Corresponding author
Aslı Ülke Keskin, Orcid: 0000-0002-9676-8377, asli.ulke@omu.edu.tr

INTRODUCTION

Rapidly melting of ice masses in the poles, rising seawater level, and occurring large irregularities in the rain are powerful indicators of world ecosystem deterioration and global warming. These reasons might lead to water-related problems in the future. To date, researches have been conducted intensively by scientists to determine climate change. In these studies, they first tried to understand atmospheric events. The most basic study to understand atmospheric events are meteorological measurements. The main purpose of these measurements is to show the similarities and to make the necessary predictions by considering the occurrences and the situations that may occur in the future (Salarijazi et al., 2012; Zeybekoglu & Ulke Keskin, 2020).

Homogeneous climate series is defined as the series where changes are caused only by weather and climatic changes (Conrad & Pollak, 1950; Sahin, 2009; Sahin & Cigizoglu, 2010). It is essential for climate and hydrological studies to have long-term, homogeneous, and continuous precipitation series (Bickici Arikan, 2018; Bickici Arikan & Kahya, 2018). The homogeneity of precipitation series employed in climate change and hydrological studies poses a major problem in this respect (Em et al., 2007). The reliability of hydro meteorological observation data should be carefully investigated (Agha et al., 2017). The measurements made, the methods employed, the tools, and environmental factors disrupt the homogeneity. For this reason, measurements must be made with suitable devices and methods. In precipitation measurements, the technological development of the measuring devices can create an artificial and systematic increase (Hanssen-Bauer & Førland, 1994). Therefore, long-term climate changes and trends must be interpreted carefully. To achieve accurate results from climate analysis, it should be examined whether the data have homogeneous and non-homogeneous series, which must either be removed or homogenized (Sahin, 2009; Sahin & Cigizoglu, 2010). Many researchers around the world have investigated the quality and homogeneity of various climatic parameters (Peterson & Easterling, 1994; Tayanc et al., 1998; Gonzalez-Rouco et al., 2001; Yesilirimak et al., 2008; Suhaila et al., 2008; Mair & Fares, 2010; Eris & Agiralioglu, 2012; Sonmez, 2013; Pirnia et al., 2019; Ay 2020, 2021; Khalil, 2021; Ahmed et al., 2021; Demir et al., 2021; Aksu et al., 2022).

Hanssen-Bauer and Førland (1994**)** made a homogeneity analysis for the precipitation data of 165 precipitation stations in Norway by using the SNHT. Alexandersson and Moberg (1997) tested the homogeneity of monthly temperature series for Sweden by using a new method developed by them from the SNHT. Serra et al. (2001) examined the homogeneity of daily, monthly, seasonal, and annual temperature series of the 1917-1998 period of Barcelona in Spain with the VNRT. Wijngaard et al. (2003) examined the homogeneity of the temperature and precipitation series of the European geographical area by applying the SNHT, PT, BRT and VNRT, which are called the Absolute Homogeneity Tests (AHT), and classified the homogeneity of the stations according to the results of these four tests. Feng et al. (2004) examined and classified the homogeneity of daily, temperature, humidity, and wind speed values recorded between 1951-2000 in meteorological observation stations in China with the AHT. Kang and Yusof (2012) analyzed the homogeneity of the precipitation data of Peninsular Malaysia by using the SNHT, BRT, PT, and VNRT. Talaee et al. (2014) examined homogeneity of the annual and monthly precipitation datasets throughout Iran covering the years 1966–2005. Agha et al. (2017) used the AHT and reported that the annual, winter and spring precipitation series of stations in Northern Iraq were not homogeneous. Zaifoglu et al. (2017) examined the daily precipitation series of Northern Cyprus with the AHT. Tsega and Tibebe (2018) applied the AHT to the daily precipitation series of 54 stations in Ethiopia and reported that 42 stations were not homogeneous. Suhaila and Yusop (2018) examined the homogeneity of annual and seasonal temperature series of 10 stations in Malaysia by using the PT and Mann-Kendall test; and reported that there were breaks in the homogeneity of the precipitation series in 1996, 1997, and 1998.

Turkes (1996) analyzed the homogeneity of annual precipitation data of 91 stations in Turkey by using the Kruskal-Wallis test for the 1930-1993 period. Turkes et al. (1996) made the homogeneity analysis of seasonal and annual temperature series of 80 stations for the 1940-1993 period across Turkey by using the Kruskal-Wallis Method. As a result of the Kruskal-Wallis Homogeneity Test, they reported that 59 stations had homogeneous data. the homogeneity of monthly and annual temperature and precipitation series recorded between 1951-1990 of 82 meteorological observation stations in Turkey were examined by Tayanc et al. (1998) using the Kruskal-Wallis and Wald-Wolfowitz tests. They reported that the tests were an important means in testing the homogeneity of time series. Karabork et al. (2007) examined the homogeneity and breaking points of the precipitation series of 212 stations for the 1973-2002 period with SNHT and PT. They reported that 43 stations were not homogeneous. Gokturk et al. (2008) applied the SNHT and PT to the precipitation series of 267 stations in Turkey for the 1930-2004 period and found the years when the homogeneity was disrupted. Firat et al. (2010) examined the homogeneity of precipitation series for the 1968-1998 period of 229 meteorological observation stations in Turkey by using the SNHT and PT, and reported that 179 stations were not homogeneous. Sahin and Cigizoglu (2010) applied the AHT to precipitation series between 1974-2002 in Turkey; and as a result of the AHT, they reported that 5 out of 232 stations were not homogeneous. Haktanir and Citakoglu (2014) examined the homogeneity of the maximum precipitation series of Turkey for the 1938-2010 period by using the VNRT and Mann-Whitney Homogeneity Test. They reported that the precipitation series was 90% homogeneous according to the Von Neumann Test, and 84% according to the Mann-Whitney test. Bickici Arikan and Kahya (2018) examined the homogeneity of 160 meteorological stations with the AHT and concluded that 5 stations were not homogeneous. They achieved homogeneity by applying the double additive curve method to inhomogeneous stations. Zeybekoglu and Ulke Keskin (2020) examined the homogeneity of the rainfall intensity series of 14 standard durations that were measured between 1965 and 2010 at Artvin in the Eastern Black Sea region of Turkey by using the SNHT and PT and examined their trends by using the Mann Kendall and Spearman's Rho tests. They reported that homogeneity was achieved when the trend component was eliminated from the intensities of the 5', 10', 15', and 30' duration rainfalls, and the trend disrupted the homogeneity.

In this study, the purpose was to determine the homogeneity of the maximum rainfall intensity series of 103 stations operated by the Turkish State Meteorological Service (TSMS) throughout Turkey. For this purpose, firstly, the quality and usability of the data that were obtained from Turkish State Meteorological Service (TSMS) were checked with the BRT, PT, SNHT, and VNRT, which are called AHT. The classes of the data will be identified at this stage with AHT. As a result of the AHT, the rainfall intensity series of the non-homogeneous stations were separated from possible trend components by applying the detrended methodology. Then, the data were classified by re-applying AHT.

STUDY AREA

In the present study, the maximum rainlfall intensity series of a 103 stations that had different observation periods between a minimum of 42 years (1974-2015) and a maximum of 78 years (1938-2015), operated by the TSMS, distributed homogeneously in geographical terms in Turkey as given in Figure 1. The latitude, longitude, altitude, and observation periods of these stations are given in Table 1.

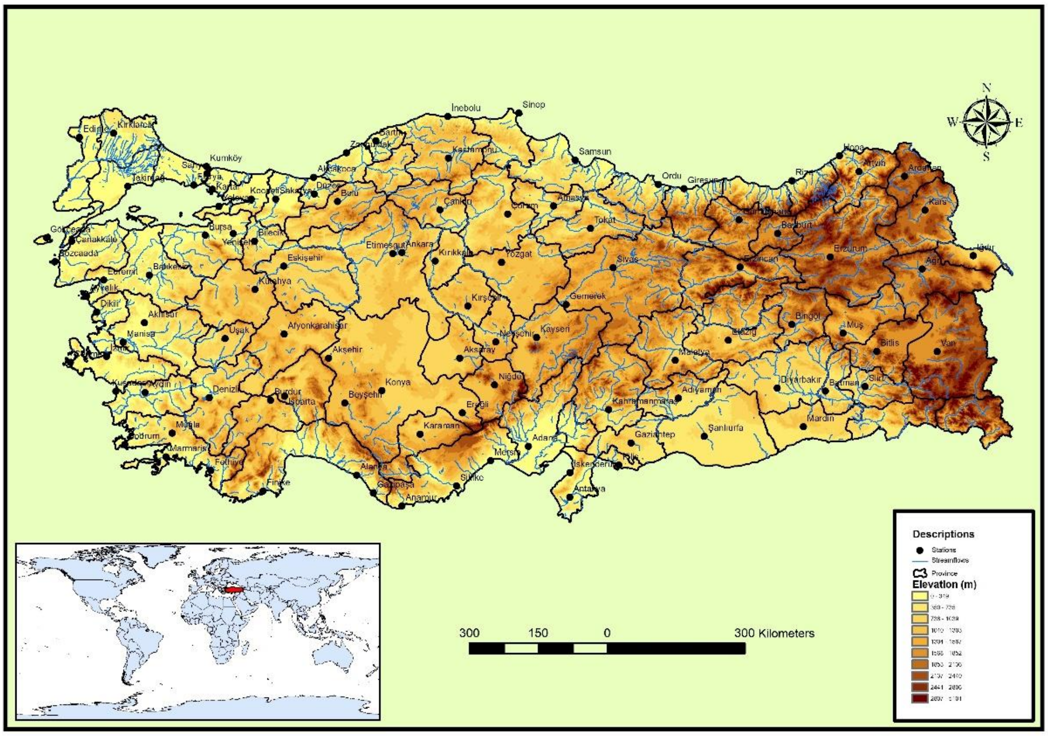

Figure 1. Geographical distribution of meteorological stations

Table 1. List of meteorological stations and geographical details

ID	Name	Period	Elevation (m)	Lat. (N)	Long. (E)
17015	Akçakoca	1968-2015	10	41.0895	31.1374
17020	Bartın	1966-2015	33	41.6248	32.3569
17022	Zonguldak	1945-2015	135	41.4492	31.7779
17024	İnebolu	1959-2015	64	41.9789	33.7636
17026	Sinop	1965-2015	32	42.0299	35.1545
17030	Samsun	1957-2015	4	41.3435	36.2553
17033	Ordu	1965-2015	5	40.9838	37.8858
17034	Giresun	1966-2015	38	40.9227	38.3878
17040	Rize	1940-2015	3	41.04	40.5013
17042	Hopa	1965-2015	33	41.4065	41.4330
17045	Artvin	1965-2015	613	41.1752	41.8187
17046	Ardahan	1967-2015	1827	41.1061	42.7055
17050	Edirne	1949-2015	51	41.6767	26.5508
17052	Kırklareli	1966-2015	232	41.7382	27.2178
17056	Tekirdağ	1963-2015	4	40.9585	27.4965
17059	Kumköy	1965-2015	38	41.2505	29.0384
17061	Sarıyer	1955-2015	59	41.1464	29.0502
17064	Kartal	1974-2015	18	40.9113	29.1558
17066	Kocaeli	1945-2015	74	40.7663	29.9173
17069	Sakarya	1962-2015	30	40.7676	30.3934
17070	Bolu	1949-2015	743	40.7329	31.6022
17072	Düzce	1965-2015	146	40.8437	31.1488
17074	Kastamonu	1948-2015	800	41.371	33.7756
17080	Çankırı	1959-2015	755	40.6082	33.6102
17084	Çorum	1958-2015	776	40.5461	34.9362
17085	Amasya	1965-2015	40	40.6668	35.8353
17086	Tokat	1966-2015	611	40.3312	36.5577
17088	Gümüşhane	1966-2015	1216	40.4598	39.4653
17089	Bayburt	1966-2015	1584	40.2547	40.2207
17090	Sivas	1958-2015	1294	39.7437	37.002
17094	Erzincan	1957-2015	1216	39.7523	39.4868
17095	Erzurum	1956-2015	1860	39.9058	41.2544
17097	Kars	1965-2015	1777	40.6042	43.1073
17099	Ağrı	1967-2015	1646	39.7253	43.0522
17100	Iğdır	1966-2015	856	39.9227	44.0523
17110	Gökçeada	1970-2015	79	40.191	25.9075
17111	Bozcaada	1970-2015	30	39.8326	26.0728
17112	Çanakkale	1958-2015	6	40.141	26.3993
17116	Bursa	1951-2015	100	40.2308	29.0133
17118	Yenişehir	1986-2015	238	40.2552	29.5624
17119	Yalova	1962-2015	4	40.6589	29.2796
17120	Bilecik	1960-2015	539	40.1414	29.9772
17126	Eskişehir	1940-2015	801	39.7656	30.5502
17129	Etimesgut	1968-2015	806	39.9558	32.6854
17130	Ankara	1940-2015	891	39.9727	32.8637
17135	Kırıkkale	1967-2015	751	39.8433	33.5181
17140	Yozgat	1960-2015	1301	39.8243	34.8159
17145	Edremit	1965-2015	19	39.5592	27.0253
17150	Balıkesir	1957-2015	102	39.6326	27.9201
17155	Kütahya	1941-2015	969	39.4171	29.9891
17160	Kırşehir	1942-2015	1007	39.1639	34.1561
17162	Gemerek	1966-2015	1182	39.185	36.0805
17172	Van	1956-2015	1675	38.4693	43.346
17175	Ayvalık	1967-2015	4	39.3113	26.6861
17180	Dikili	1959-2015	3	39.0737	26.888
17184	Akhisar	1965-2015	92	38.9118	27.8233
17186	Manisa	1958-2015	71	38.6153	27.4049
17188	Uşak	1941-2015	919	38.6712	29.404
17190	Afyonkarahisar	1957-2015	1034	38.738	30.5604
17192	Aksaray	1965-2015	970	38.3705	33.9987
17193	Nevşehir	1965-2015	1260	38.6163	34.7025
17196	Kayseri	1950-2015	1094	38.687	35.5
17199	Malatya	1958-2015	950	38.3367	38.2173
17201	Elazığ	1957-2015	989	38.6443	39.2561
17203	Bingöl	1966-2015	1139	38.8847	40.5007
17204	Muş	1966-2015	1322	38.7509	41.5023
17208	Bitlis	1966-2015	1785	38.475	42.1625
17210	Siirt	1959-2015	895	37.9319	41.9354
17220	İzmir	1938-2015	29	38.3949	27.0819
17221	Çeşme	1966-2015	5	38.3036	26.3724
17232	Kuşadası	1966-2015	25	37.8597	27.2652
17234	Aydın	1959-2015	56	37.8402	27.8379
17237	Denizli	1959-2015	425	37.762	29.0921
17238	Burdur	1964-2015	957	37.722	30.294
17239	Akşehir	1964-2015	1002	38.3688	31.4297
17240	Isparta	1957-2015	997	37.7848	30.5679
17242	Beyşehir	1965-2015	1141	37.6777	31.7463
17245	Konya	1950-2015	1029	37.8687	32.4713
17246	Karaman	1965-2015	1018	37.1932	33.2202
17248	Ereğli	1970-2015	1046	37.5255	34.0485
17250	Niğde	1959-2015	1211	37.9587	34.6795
17255	Kahramanmaraş	1966-2015	572	37.576	36.915
17261	Gaziantep	1957-2015	854	37.0585	37.351
17262	Kilis	1966-2015	640	36.7085	37.1123
17265	Adıyaman	1965-2015	672	37.7553	38.2775
17270	Şanlıurfa	1959-2015	550	37.1608	38.7863
17275	Mardin	1966-2015	1040	37.3103	40.7284
17281	Diyarbakır	1940-2015	680	37.9094	40.2133
17282	Batman	1969-2015	610	37.8636	41.1562
17290	Bodrum	1965-2015	26	37.0328	27.4398
17292	Muğla	1944-2015	646	37.2095	28.3668
17296	Fethiye	1960-2015	3	36.6266	29.1238
17298	Marmaris	1966-2015	16	36.8395	28.2452
17310	Alanya	1964-2015	6	36.5507	31.9803
17320	Anamur	1965-2015	2	36.0686	32.8649
17330	Silifke	1964-2015	10	36.3824	33.9373
17340	Mersin	1958-2015	7	36.7808	34.6031
17351	Adana	1944-2015	23	37.0041	35.3443
17370	İskenderun	1965-2015	4	36.5924	36.1582
17372	Antakya	1957-2015	104	36.2048	36.1513
17375	Finike	1966-2015	2	36.3024	30.1458
17636	Florya	1938-2015	37	40.9758	28.7865
17974	Gazipaşa	1983-2015	21	36.2715	32.3045

Since the final observation year of the data employed in this study was 2015, the data that include the maximum rainfall intensities recorded until this date, and the place and dates of the observations are given in Table 2.

Table 2. Summary of historical maximum rainfall intensity series (TSMS)

Duration	Intensity (mm/min)	Location	Date
5'	10.10	Hopa	07.07.1988
10'	6.06	Hopa	07.07.1988
15'	4.71	Hopa	07.07.1988
30'	3.03	Hopa	07.07.1988
60'	2.18	Antalya	03.11.1995
120'	1.50	Antalya	03.11.1995
180'	1.28	Marmaris	11.12.1992
240'	1.38	Antalya	03.11.1995
300'	1.25	Antalya	03.11.1995
360'	1.08	Antalya	03.11.1995
480'	0.86	Antalya	03.11.1995
720'	0.59	Antalya	03.11.1995
1080'	0.43	Marmaris	10-11.12.1991
1440'	0.32	Marmaris	10-11.12.1991

As seen in Table 2, the highest values at 5', 10', 15' and 30' rainfall intensities were measured at

Hopa(07.07.1988); 180', 1080' and 1440' rainfall intensities were measured at Marmaris (10-11.12.1991); and 60', 120', 240', 300', 360', 480' and 720' rainfall intensities were measured at Antalya (03.11.1995). It was also seen that the rainfall intensities decreased as the duration increased.

ABSOLUTE HOMOGENEITY TESTS (AHT)

The Standard Normal Homogeneity Test (SNHT), Buishand Rank Test (BRT), Pettitt Test (PT), and Von Neuman Ratio Test (VNRT), which are called AHT were used for the quality of meteorological data. These tests perform homogeneity analysis after examining the distributions of the data, and its logic is to identify the deviations from the means in the data. According to the results of the AHT, the data are analyzed in three classes as shown in Table 3 (Schonwiese & Rapp, 1997; Wijngaard, et al., 2003).

Table 3. Classes suggested by absolute homogeneity test results

Class	Code	Information
Useful	I	one or zero tests reject the null hypothesis (H_0) at the selected level.
Doubtful	II	two tests reject the null hypothesis (H_0) at the selected level.
Suspect	III	three or four tests reject the null hypothesis (H_0) at the selected level.

Standard Normal Homogeneity Test (SNHT)

This method, which was developed by Alexandersson (1986), was used successfully in testing many climatic and hydrological variables (Alexandersson, 1986). According to the H_0 the hypothesis that was accepted for the test, the data were distributed independently and randomly. The test is sensitive to detect the breaks or distortions at the beginning and end of the data series (Kahya et al., 2006). With let Y_i be the value at any instant, $\bar{Y}$ be the mean, and *s* the standard deviation, Alexandersson (1986) identified a $T(k)$ statistic comparing the mean of the first k years with the last n-k years and is shown in *Eq. 1*.

$$T(k) = k\bar{z}_1^2 + (n-k)\bar{z}_2^2; k = 1, \ldots, n \quad (1)$$

The $\bar{z}_1$ and $\bar{z}_2$ values given in Eq. 1 are calculated by using Eqs. 2-3.

$$\bar{z}_1 = \frac{1}{k}\sum_{i=1}^{k}\left(\frac{Y_i - \bar{Y}}{s}\right) \quad (2)$$

$$\bar{z}_2 = \frac{1}{n-k}\sum_{i=1}^{k}\left(\frac{Y_i - \bar{Y}}{s}\right) \quad (3)$$

If the change occurs at a "k" point, $T_{(k)}$reaches its maximum value at $k = K$ point. T_0 test statistics is given in *Eq. 4*.

$$T_0 = \max_{1 \le k \le n} T_{(k)}. \quad (4)$$

The 95% Confidence Rank critical values for this test are given in Table 4 (Alexandersson, 1986; Jaruskova, 1996). If T_0 does not exceed the critical value, the H_0 hypothesis is accepted, in other words, it is considered to be homogenous (Alexandersson & Moberg, 1997).

Buishand Range Test (BRT)

The BRT assumes that the data are distributed normally, and according to the H_0 hypothesis, the data are distributed independently and randomly. This method is sensitive in detecting the distortions in the middle of the time series (Wijngaard et al., 2003). In this test, the partial sums are calculated as given in Eq. 5.

$$S_0^* = 0 \; and \; S_k^* = \sum_{i=1}^{k}(Y_k - \bar{Y}); k = 1, \ldots, n \quad (5)$$

When the data series is homogeneous, the S_0^* value will be “0” since there will be no systematic deviation of Y_i. The rate of the difference between the maximum and minimum S_k to the number of the data yields the *R* correction rate, which is calculated as the standard deviation as given in Eq. 6 (Wijngaard et al., 2003).

$$R = \frac{\max_{0\leq k\leq n} S_k^* - \min_{0\leq k\leq n} S_k^*}{s} \quad (6)$$

Buishand (1982) gave the critical $\frac{R}{\sqrt{n}}$ values that corresponded 95% Confidence Rank for this test in Table 4. If the $\frac{R}{\sqrt{n}}$ value does not exceed the critical value, the H_0 hypothesis is accepted, in other words, it is acceptable, and the data are homogenous.

Pettitt Test (PT)

This non-parametric method, which was developed by Pettitt (1979) to identify the change point in a time series, can find the change point on a monthly or annual scale (Pettitt, 1979). The null hypothesis denotes that the series has independent and random distribution, but the alternative hypothesis denotes that there is a sudden change. The test statistic is related to the Mann-Whitney Statistic (Wijngaard et al., 2003; Yerdelen, 2013). This test is least affected by outliers. Let the ranks of $Y_1, \ldots, Y_n$ series be $r_1, \ldots, r_n$, the test statistic is calculated according to Eq. 7;

$$X_k = 2\sum_{i=1}^{k} r_i - k(n+1)\,;\, k = 1, \ldots, n \quad (7)$$

The result of this test is shown as E chart. If there is a break in E year, the statistic is maximum or minimum when close to k=E year (Eq. 8).

$$X_E = \max_{1\leq k\leq n} |X_k| \quad (8)$$

The evaluation is made by considering the critical X_k values given in Table 4 identified for 95% Confidence Interval by Pettitt (1979) (Wijngaard et al., 2003).

Von Neumann Ratio Test (VNRT)

According to the H_0 hypothesis in the VNRT, the data are not randomly distributed. According to the opposite hypothesis; however, the time series considered is distributed randomly. This test does not detect a specific place where the homogeneity is disrupted and does not provide data on when the homogeneity is disrupted (Wijngaard et al. 2003).
Von Neuman Ratio N is calculated as in Eq. 9 and is defined as the ratio of the sum of the year-to-year mean values to the variance value (Von Neuman, 1941).

$$N = \frac{\sum_{i=1}^{n-1}(Y_i - \bar{Y}_{i+1})^2}{\sum_{i=1}^{n}(Y_i - \bar{Y})^2} \quad (9)$$

If the resulting value of the test is greater than the identified critical value, the dataset is considered to be homogeneous. The critical values at 95% confidence interval are given in Table 4 (Owen, 1962; Buishand, 1981).

Table 4. Critical values of AHT based on data count at 95% Confidence Interval

N	20	30	40	50	70	100
SNHT	6.95	7.65	8.10	8.45	8.80	9.15
BRT	1.43	1.50	1.53	1.55	1.59	1.62
PT	57	107	167	235	393	677
VNRT	1.30	1.42	1.49	1.54	1.61	1.67

RESULTS

It is required in hydrological studies that the data be homogeneous. However, meteorological data such as precipitation and temperature, the errors stemming from the tools and methods used during measurements, environmental factors, etc. sometimes have an inhomogeneous structure because of many factors. For this reason, the series of the stations must be tested with homogeneity analysis methods before the analyses (Sahin, 2009; Sahin and Cigizoglu, 2010). In this context, the results of the Absolute Homogeneity Test regarding the rainfall intensity series of the 103 stations across Turkey are evaluated and classified according to Table 3 (results are given in Table 5).

Table 5. AHT class results of the stations

ID	5'	10'	15'	30'	60'	120'	180'	240'	300'	360'	480'	720'	1080'	1440'
17015														
17020							III	III	III	III	III	III	III	
17022														
17024							III	III	III	III	III	III	III	III
17026						III	III	III	III					
17030								III	III	III	III	III		
17033														
17034														
17040									III	III	III	III	III	
17042							III	III	III	III	III	III	III	
17045	III	III	III	III	III									
17046														
17050							III	III	III	III	III			
17052														
17056							III			III		III	III	II
17059			III	III	III	III	III	III	III	III	III	III	III	II
17061	III	III	III		III	III	III	III	III	III	III	III	III	III
17064	III	III												
17066				III		III	III	III	III	III	III			
17069				III	III	III	III	III	III	III				
17070														
17072														
17074														
17080														
17084														
17085														
17086														
17088														
17089														
17090														
17094														
17095														
17097							III	III	III		III	III	III	III
17099														
17100														
17110												III	III	
17111														
17112														
17116														
17118														
17119	III													
17120						III	III	III	III	III	III			
17126														
17129	III			III	III	III	III	III	III	III	III	III	III	
17130	III	III												
17135														
17140														
17145														
17150	III													
17155													III	
17160				III	III	III	III	III	III	III	III	III	III	II
17162														
17172														
17175														
17180					III	III	III	III	III			III		
17184						III	III	III	III	III	III	III	III	
17186										III				
17188														
17190														II
17192								III						
17193														
17196		II											II	
17199	III													
17201								III	II	II	III	II	II	
17203														
17204														
17208					II							III	III	

ID	5'	10'	15'	30'	60'	120'	180'	240'	300'	360'	480'	720'	1080'	1440'
17210														
17220					II	III	III	III	III	III	III	III	III	II
17221							II	II	II	III	III		II	II
17232						II	III	III	III	III	III	III	III	III
17234			II	II	II	III	III	III	II	II	II	II	II	
17237														
17238														
17239	II													
17240										II	II			
17242														II
17245														
17246														
17248														
17250					II									
17255	II							II	III	II				II
17261														
17262														
17265														
17270														
17275														III
17281					II			II	II	III	III	II	III	
17282														
17290				II				II		II	III	III	II	II
17292			II			II	II							
17296		II	II	II	II	II	III	III	III	III	III	III	III	
17298						II	II		II	II	II	III	II	III
17310	II													
17320	III													
17330	II	II	II											
17340												II		
17351	III	II		II	II	III	III	III	II	II	II	II		
17370	II													
17372														
17375														
17636				II	III	III	III	III	III	III	III	III		
17974														
I	**88**	**95**	**96**	**92**	**88**	**85**	**78**	**75**	**75**	**74**	**77**	**77**	**79**	**88**
II	**5**	**4**	**4**	**5**	**7**	**4**	**3**	**4**	**6**	**7**	**4**	**5**	**6**	**9**
III	**10**	**4**	**3**	**6**	**8**	**14**	**22**	**24**	**22**	**22**	**22**	**21**	**18**	**6**

As a result of the AHT, the rainfall intensity series of 49 stations were classified to be useful. As it is seen in Table 5, the classification of all rainfall intensity series was obtained. The most appropriate series for using was at rainfall with 15' duration, the least series appropriate for using was determined at 360' rainfall with 74 stations. The geographical distribution of the stations identified to be homogeneous for 14 standard durations is given in Figure 2.

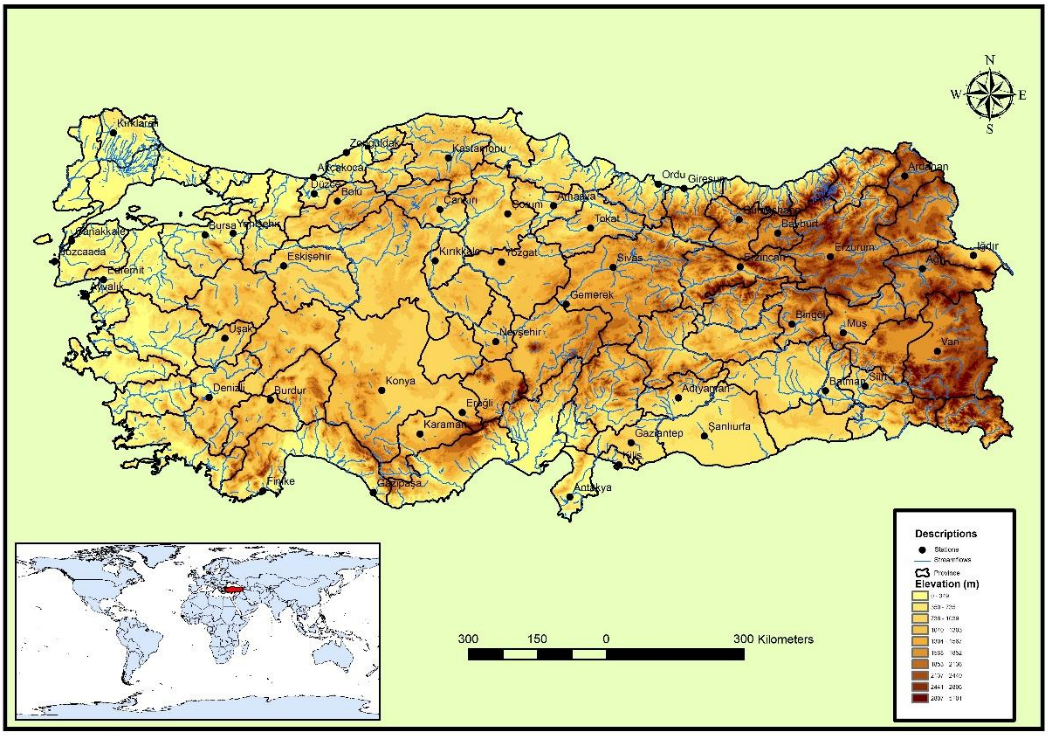

Figure 2. Geographical distribution of the useful stations

According to the results of AHT, the datas of the 54 meteorological observation stations were identified as doubtful or suspect for at least 1 standard duration. The station that had the lowest measurement quality was found to be Sariyer with 13 problematic series, which was followed by Kumköy and Fethiye with 12 problematic series. The geographical distribution of the stations that had doubtful/suspect values as a result of the AHT is shown in Figure 3.

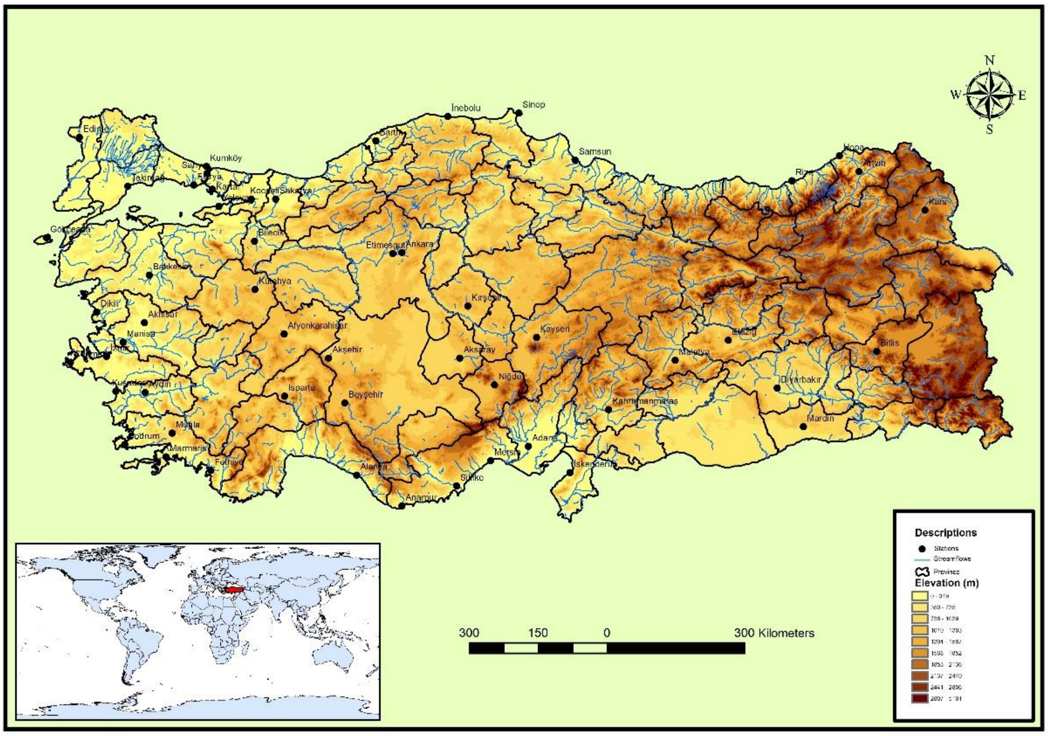

Figure 3. Geographical distribution of the doubtful/suspect stations

The disruption of the homogeneity in rainfall intensities of stations may occur because of a sudden rise or fall trends in temperatures with factors such as urbanization, as well as artificial reasons such as changing the location of the stations (Turkes et al., 2002; Sahin & Cigizoglu, 2010). For this reason, long-term climate changes and trends must be interpreted with care (Houghton et al., 1992; Sahin, 2009; Sahin & Cigizoglu, 2010). It was considered that the reason for the loss of homogeneity in stations with doubtful/suspect data of the 54 stations that were not suitable for use is possible trends, and therefore, the trend component in the time series was removed (Zeybekoglu & Ulke Keskin, 2020) by using the methodology suggested by Peng et al. (1994, 1995). The AHT were re-applied to the datasets which were free from the trend. The classes determined according to the results of the AHT of the series of the 54 stations that were not suitable for use at the end of the first stage and were separated from the trend component are given in Table 6.

Table 6. Absolute Homogeneity Test results of the stations that underwent DFA

ID	5'	10'	15'	30'	60'	120'	180'	240'	300'	360'	480'	720'	1080'	1440'
17020														
17024														
17026														
17030														
17040														
17042														
17045														
17050														
17056														
17059														
17061														
17064	III	III												
17066														
17069														
17097														
17110														
17119	II													
17120														
17129				II	II	II	II	II	II	II	II	II	II	
17130	III													
17150														
17155														
17160														
17180														
17184														
17186														
17190														
17192														
17196														
17199														
17201								II						
17208														
17220														
17221														II
17232														
17234														
17239														
17240														
17242														
17250														
17255														
17281														
17290										II	II	II	II	II
17292														
17296														
17298														
17310														
17320														
17330														
17340														
17351		II			II	III	II	II						
17370														
17636														
I	**51**	**52**	**54**	**53**	**52**	**52**	**52**	**51**	**53**	**52**	**52**	**52**	**52**	**52**
II	**1**	**1**		**1**	**2**	**1**	**2**	**3**	**1**	**2**	**2**	**2**	**2**	**2**
III	**2**	**1**				**1**								

When Table 6, which shows the Absolute Homogeneity Test results of the rainfall intensity series separated from the trend component by the DFA process is examined, it is found that Yalova (17119), Elazığ (17201), Çeşme (17221), and Ankara (17130) yielded doubtful/suspect values in 1 standard duration, Kartal (17064) yielded doubtful/suspect values in 2 durations, Bodrum (17290) and Adana (17351) in 5 standard durations, and Etimesgut (17129) in 10 standard durations. The rainfall intensity series of the 14 standard durations of the 46 stations other than these 8 stations were classified as useful as a result of AHT.

CONCLUSION

The reliability of the observation data that are employed in hydro-meteorological studies is evaluated before the water resources, hydrological processes, and climate change studies are conducted. In this study, the maximum rainfall intensity series of a total of 103 stations across Turkey were examined by employing AHT. In the application of the homogeneity tests, which was made in two stages, the rainfall intensity data of useful and non-useful (doubtful/suspect) periods for use at the stations were determined in the first stage. In the second stage, the trend component is allocated to the rainfall intensities of the stations that are not suitable for use. Homogeneity Tests were applied again. After the second stage, an approach was preferred to suggest that stations with problematic or suspicious data, in other words, inhomogeneous data, must not be employed in future studies in at least 1 standard duration.

The geographical distribution of the 95 stations, 49 of which were at the end of the first stage and 46 of which were at the second stage, is given in Figure 4. Yalova, Elazığ, Çeşme, Ankara, Kartal, Bodrum Adana, and Etimesgut were found to have doubtful/suspect values according to the results of the homogeneity analysis performed after the trend component was separated.

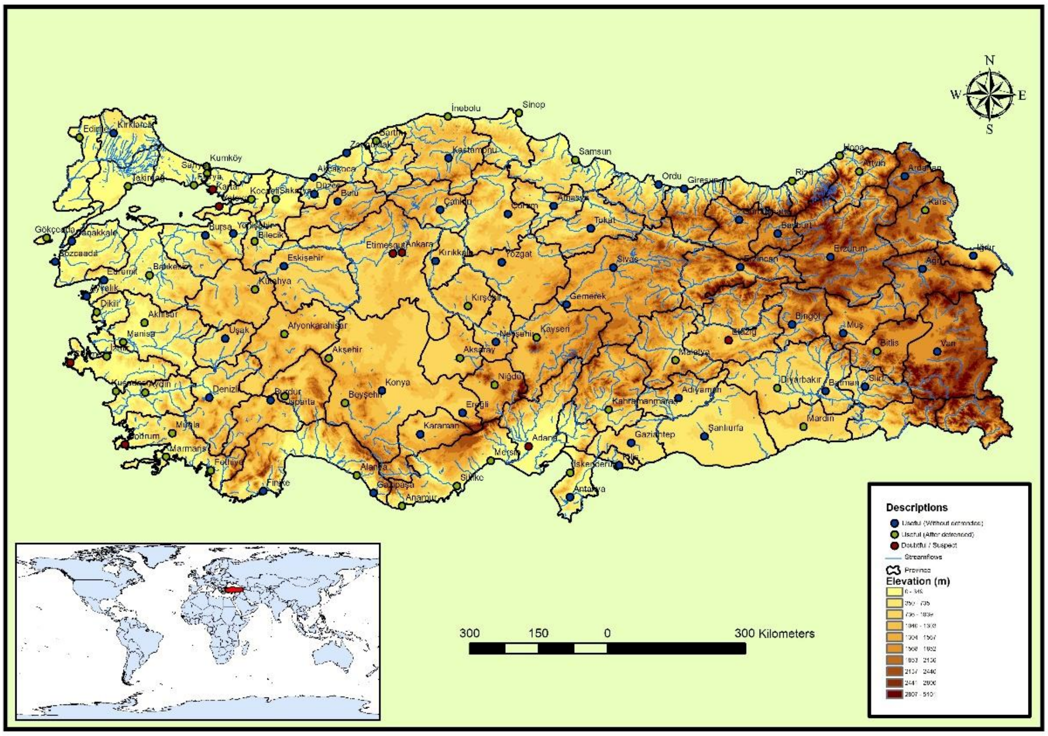

Figure 4. Geographical distribution of the station classes

The stations shown with black circles in Figure 4 are the stations that are suitable for use after the first stage, and the stations that are suitable for use after the second stage are indicated with black circles. The stations with a green circle show those that are recommended not to be used because of doubtful/suspect values in the AHT and DFA.

It is considered that the rainfall intensity series of 95 stations can be employed easily in climatic and hydrological studies. It is recommended that it would not be accurate to use the rainfall intensity series of the remaining 8 stations, and if they are used, it is recommended to carefullly investigate the reasons for the deterioration of homogeneity.

Acknowledgements

The Authors would like to thank the Turkish State Meteorological Service for providing the data. The authors also thank the anonymous reviewers who expressed their opinions on the development of the manuscript.

Conflict of İnterest

The authors declare no competing interests.

REFERENCES

Agha OMAM., Bagcaci SC., Sarlak N. Homogeneity analysis of precipitation series in North Iraq. IOSR Journal of Applied Geology and Geophysics 2017; 5(3) Ver. II: 57–63.

Ahmed K., Nawaz N., Khan N., Rasheed B., Baloch A. Inhomogeneity detection in the precipitation series: case of arid province of Pakistan. Environment, Development and Sustainability 2021; 23:7176–7192. https://doi.org/10.1007/s10668-020-00910-y

Aksu H., Cetin M., Aksoy H., Yaldiz SG., Yildirim I., Keklik G. Spatial and temporal characterization of standard duration-maximum precipitation over Black Sea Region in Turkey. Natural Hazards 2022; 111: 2379–2405. https://doi.org/10.1007/s11069-021-05141-6

Alexandersson H. A homogeneity test applied to precipitation data. Journal of Climate 1986; 6(6):661–675 https://doi.org/10.1002/joc.3370060607

Alexandersson H., Moberg A. Homogenization of Swedish temperature data. Part I: Homogeneity test for linear trends. International Journal of Climatology 1997; 17(1): 25-34. https://doi.org/10.1002/(SICI)1097-0088(199701)17:1<25::AID-JOC103>3.0.CO;2-J

Ay M. Trend and homogeneity analysis in temperature and rainfall series in western Black Sea region, Turkey. Theoretical and Applied Climatology 2020; 139: 837–848. https://doi.org/10.1007/s00704-019-03066-6

Ay M. Trend tests on maximum rainfall series by a novel approach in the Aegean region, Turkey. and Atmospheric Physics 2021; 133: 1041–1055. https://doi.org/10.1007/s00703-021-00795-0

Bickici Arikan B. Prediction of drought ındices based on hydroclimatological data. Istanbul Technical University PhD Thesis, Istanbul, Turkey, 2018.

Bickici Arikan B., Kahya E. Homogeneity revisited: analysis of updated precipitation series in Turkey. Theoretical and Applied Climatology 2018; 135(1–2): 1–10. https://doi.org/10.1007/s00704-018-2368-x

Buishand TA. The analysis of homogeneity of long-term rainfall records in the Netherlands. The Royal Netherlands Meteorological Institute, 1981

Buishand TA. Some methods for testing of rainfall records. Journal of Hydraulics 1982; 58(1-2): 11–27. https://doi.org/10.1016/0022-1694(82)90066-X

Conrad V., Pollak C. Methods in climatology. Cambridge: Harvard University Press, 1950.

Demir S., Karakaya K., Kavuncu O., Akdoğan, Y. trend analysis of climate parameters of Ordu province and determination of change point. Gaziosmanpasa Journal of Scientific Research 2021; 10(1): 128-141.

Em A., Hamidi N., Toprak, ZF. Variation in annual total precipitation and its homegeneous analysis at GAP Region. 1st Turkey Climate Change Congress, 11-13 April 2007, 379-393, Istanbul.

Eris E., Agiralioglu N. Homogeneity and trend analysis of hydrometeorological data of the Eastern Black Sea Region, Turkey. Journal of Water Resource and Protection 2012; 4(2): 99-105. https://doi.org/10.4236/jwarp.2012.42012

Feng S., Hu Q., Qian W. Quality control of daily meteorological data in China, 1951–2000: a new dataset.

International Journal of Climatology 2004; 24(7): 853–870. https://doi.org/10.1002/joc.1047

Firat M., Dikbas F., Koc AC., Gungor M. Missing data analysis and homogeneity test for Turkish precipitation series. Sadhana-Academy Proceedings in Engineering Sciences 2010; 35(6): 707–720. https://doi.org/10.1007/s12046-010-0051-8

Gokturk OM., Bozkurt D., Sen OL., Karaca M. Quality control and homogeneity of Turkish precipitation data. Hydrological Processes 2008; 22(16), 3210–3218. https://doi.org/10.1002/hyp.6915

Gonzalez-Rouca JF., Jimenez JL., Quesada V., Valero F. Quality control and homogeneity of precipitation data in the Southwest of Europe. Journal of Climate 2001; 14: 964-978. https://doi.org/10.1175/1520-0442(2001)014<0964:QCAHOP>2.0.CO;2

Haktanir T., Citakoglu H. Trend, independence, stationarity and homogeneity tests on maximum rainfall series of standard durations recorded in Turkey. Journal of Hydrologic Engineering 2014; 19(9): 1–13. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000973

Hanssen-Bauer I., Førland J. Homogenizing long Norwegian precipitation series. Journal of Climate 1994; 7: 1001–1013. https://doi.org/10.1175/1520-0442(1994)007<1001:HLNPS>2.0.CO;2

Houghton J., Callendar BA., Varney SK., Eds. (1992): Climate Change: The Supplementary Report to the IPCC Scientific Assesment. Cambridge University Press.

Jaruskova D. Change-point detection in meteorological measurement. Monthly Weather Review 1996; 124: 1535-1543. https://doi.org/10.1175/1520-0493(1996)124<1535:CPDIMM>2.0.CO;2

Kahya E., Cigizoglu HK., Dorum A., Karabork MC., Kömüşcü UA., Cengiz MT., Martı IA., Tarhan M. El Nino ve La Nina Olaylarının Etkileri ile Türkiye'deki Yağış Zaman Serilerinin Karakteristik Özelliklerindeki ve Dağılımlarındaki Değişkenlerin Analizi, YDABAG 102Y146, Research Project. The Scientific and Technological Research Council of Turkey (TUBITAK), Turkey (in Turkish), 2006.

Kang HM., Yusof F. Homogeneity tests on daily rainfall series in Peninsular Malaysia. International Journal of Contemporary Mathematical Sciences 2012; 7(1): 9-22.

Karabork MC., Kahya E., Komuscu AU. Analysis of Turkish precipitation data homogeneity and the Southern Oscillation forcings on frequency distributions. Hydrological Processes 2007; 21(23): 3203–3210. https://doi.org/10.1002/hyp.6524

Khalil A. Inhomogeneity detection in the rainfall series for the Mae Klong River Basin, Thailand. Applied Water Science 2021; 11:147. https://doi.org/10.1007/s13201-021-01474-6

Mair A., Fares A. Assessing rainfall data homogeneity and estimating missing records in Mākaha Valley, O'ahu, Hawai'i. Journal of Hydrologic Engineering 2010; 15(1): 61-66. https://doi.org/10.1061/(ASCE)HE.1943-5584.0000145

Owen DB. Handbook of Statistical Tables. Addison-Wesley, Reading, Mass: Addison-Wesley Pub. Co., 1962.

Peng CK., Buldyrev SV., Havtin S., Simons IM., Stanley HE., Goldberger AL. Mosaic organization of DNA nucleotides. Physical Review E 1994; 49(2): 1685–1689. https://doi.org/10.1103/physreve.49.1685

Peng CK., Havlin S., Stanley HE., Goldberger AL. Quantification of scaling exponents and crossover phenomena in nonstationary heartbeat time series. Chaos 1995; 5(1): 82-87. https://doi.org/10.1063/1.166141

Peterson, TC., Easterling DR. Creation of homogeneous composite climatological reference series.

International Journal of Climatology 1994; 14(6):671-679. https://doi.org/10.1002/joc.3370140606

Pettitt AN. A non-parametric approach to the change-point detection. Applied Statistics 1979; 28(2): 126–135. https://doi.org/10.2307/2346729

Pirnia A., Golshan M., Darabi H., Adamowski J., Rozbeh S. Using the Mann–Kendall test and double mass curve method to explore stream flow changes in response to climate and human activities. Journal of Water and Climate Change 2019; 10(4): 725–742. https://doi.org/10.2166/wcc.2018.162

Sahin S. Applying artificial neural networks on determining climate zones and comparison with the Ward's Method. Istanbul Technical University PhD Thesis, Istanbul, Turkey, 2009.

Sahin S., Cigizoglu HK. Homogeneity analysis of Turkish meteorological data set. Hydrological Processes 2010; 24(8): 981–992. https://doi.org/10.1002/hyp.7534

Salarijazi M., Akhond AA., Adib A., Daneshkhah A. Trend and change-point detection for the annual stream-flow series of the Karun river at the Ahvaz hydrometric station. African Journal of Agricultural Research 2012 7(32): 4540–4552. https://doi.org/10.5897/AJAR12.650

Schonwiese CD., Rapp J. Climate Trend Atlas of Europe Based on Observations 1891–1990. Dordrecht: Kluwer Academic Publishers, 1997.

Serra C., Burguen A., Lana X. Analysis of maximum and minimum daily temperatures recorded at Fabra Observatory (Barcelona, NE Spain) in the period 1917–1998. International Journal of Climatology 2001; 21(5): 617–636. https://doi.org/10.1002/joc.633

Sonmez I. Quality control tests for western Turkey Mesonet. Meteorological Application 2013; 20(3): 330–337. https://doi.org/10.1002/met.1286

Suhaila J., Deni SM., Jemain AZ. Detecting inhomogeneity in Peninsular Malaysian rainfall series. Asia-Pacific Journal of the Atmospheric Sciences 2008; 44(4): 369-380.

Suhaila J., Yusop Z. Trend analysis and change point detection of annual and seasonal temperature series in Peninsular Malaysia. Meteorology and Atmospheric Physics 2018; 130(5): 565–581. https://doi.org/10.1007/s00703-017-0537-6

Talaee PH., Kouchakzadeh M., Shifteh Some'e B. Homogeneity analysis of precipitation series in Iran. Theoretical and Applied Climatology 2014; 118(1–2): 297–305. https://doi.org/10.1007/s00704-013-1074-y

Tayanc M., Dalfes H., Karaca M., Yenigün O. A comparative assessment of different methods for detecting in homogeneities in Turkish temperature data set. International Journal of Climatology 1998; 18(5): 561–578. https://doi.org/10.1002/(SICI)1097-0088(199804)18:5<561::AID-JOC249>3.0.CO;2-Y

Tsega M., Tibebe D. Homogeneity tests on rainfall records for selected meteorological stations in Ethiopia. dvanced Journal of Agricultural Research and Reviews 2018; 2(3): 72–78.

Turkes M. Spatial and temporal analysis of annual rainfall variations in Turkey. International Journal of Climatology 1996; 16: 1057–1076. https://doi.org/10.1002/(SICI)1097-0088(199609)16:9<1057::AID-JOC75>3.0.CO;2-D

Turkes M. Spatial and temporal variations in precipitation and aridity index series of Turkey. In: Bolle HJJ. (ed.) Mediterranean Climate. Heidelberg: Springer Verlag 2002; 181-213. https://doi.org/10.1007/978-3-642-55657-9_11

Turkes M., Sumer UM., Kilic G. Observed changes in maximum and minimum temperatures in Turkey. International Journal of Climatology 1996; 16(4): 463-477. https://doi.org/10.1002/(SICI)1097-0088(199604)16:4<463::AID-JOC13>3.0.CO;2-G

Turkes M., Sumer UM., Kilic G. Persistence and periodicity in the precipitation series of Turkey and associations with 500 hPa geopotantial heights. Climate Research 2002; 21: 59-81. https://doi.org/10.3354/cr021059

Turkish State Meteorological Service (TSMS). Standart Zamanlardaki Maksimum Yağışlar ve Tekerrür Analizi. Ankara, Turkey. https://mgm.gov.tr/genel/hidrometeoroloji.aspx?s=6 .

Von Neumann J. Distribution of the ratio of the mean square successive difference to the variance. Annals of Mathematical Statistics 1941; 13: 367– 395. https://doi.org/10.1214/aoms/1177731677

Wijngaard JB., Klein Tank AMG., Konnen GP. Homogeneity of 20th century European daily temperature and precipitation series. International Journal of Climatology 2003; 23: 679–692. https://doi.org/10.1002/joc.906

Yerdelen C. Investigation of trend analysis and change point detection for annual mean streamflows of Susurluk Basin. Dokuz Eylul University Faculty of Engineering Journal of Engineering Sciences 2013; 15(44): 77-87.

Yesilirmak E., Akcay S., Dagdelen N., Gurbuz T., Sezgin F. Quality Control and Homogeneity of Annual Precipitation Data in Büyük Menderes Basin, Turkey. International Meeting on Soil Fertility Land Management and Agroclimatology. Turkey, 29 October - 01 November 2008; pp. 225-233, Aydin.

Zaifoglu H., Akintug B., Yanmaz AM. Quality control, homogeneity analysis and trends of extreme precipitation ındices in Northern Cyprus. Journal of Hydrologic Engineering 2017; 22(12): 1–14. https://doi.org/10.1061/(ASCE)HE.1943-5584.0001589

Zeybekoglu U., Ulke Keskin A. Detrended fluctuation analyses of rainfall intensities: a case study. International Journal of Global Warming 2020; 21(2): 141-154. https://doi.org/10.1504/IJGW.2020.108175