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Change point of river streamflow in Turkey

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Abstract. The present study aims to determine the hydrological change-year by evaluating the homogeneity of average annual streamflow data in Turkey. Pertaining to the years 1936-2005, change-year streamflow data from 74 streamflow gauging stations, which have no regulatory structure on the source side, and possessing a minimum of 39 years of data, from streamflow gauging stations located on 26 streamflow basins in Turkey, have been collected. By using the employed homogeneity tests, it has been attempted to detect the change year. Employed methods are the Buishand test, the Pettitt test, the Standard Normal Homogeneity test and the Von Neumann test. By comparing the results obtained from tests, it is aimed to detect the consistency of the change years in gauging stations. The change year could be detected in 16 gauging stations using three tests each every year, and 18 stations using 2 tests in the same year. It has also been ascertained that change years of streamflow are geographically closer to each other in western Turkey in comparison to the east. The reason for values in the west to be closer, with respect to both location and time, might be attributed to the precipitation characteristics and uniformity of measured data.

1. Introduction

Climate change corresponds to short or long term changes exhibited by climate indicators. This interval of change might vary between decades to millennia. This particular change can emerge upon the change of average values, as well as the widening gap of change between averages. Climate change can differ with respect to physically small territory to huge areas of land that might affect the entire earth. The studies aiming to use water resources effectively should focus on the changes in climate parameters. Climate changes might depend on several factors: natural changes on earth, industrialization, urbanization, land use and agricultural water usage, which increased after the 19th century. Data that is employed in hydrological modeling which is feasible for detecting climatic change years will demonstrate more valid results. For the model studies to be implemented, it is known that the main resource is the accumulated hydrological-meteorological data [1,2]. In any issues concerning nature, the length and reliability of input parameters are directly proportional to the result.

In its statistical meaning, homogeneity implies that the series under inspection belongs to a main group, and, thus, has an average value that remains constant over the course of time. Nonetheless rapid changes witnessed in the mid-1900s brought forth the necessity to reexamine the homogeneity of hydrological-meteorological series. Changes experienced in streamflow, which is one of the hydrological indicators, diminish homogeneity and cause effects that limit the validity of classical hydrological measurements. For instance, disruption of homogeneity in flood records undermines the reliability of predicting design floods. Changes in climate conditions or basins turn hydrological data into some kind of data incom-

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patible with the modeling method to be employed. It is acknowledged that in hydrological analyses, the data series is stationary [3]. Due to meteorological, topographic and human-based changes, disruption of stationarity in hydrological data causes the failure of streamflow predictions to reflect reality and to obtain correct predictions. In order to detect the extent to which changes in physical processes affect data, the data need to be statistically tested. Provided that the effect of the changes in measured data is high, prior to conducting the analyses, this change should be taken into account. The planning and operation of any water structure can only be initiated upon a correct statistical analysis of streamflow data. Hence, in all planning related to water streamflow, data that contain input parameters bear great importance [4].

It is possible to investigate the existence of any change points in the series via statistical homogeneity tests [5]. To detect change points by investigating homogeneity, a number of non-parametric methods have been developed. The survey interval of these methods could be monthly, seasonal or annual. It is feasible to identify the change point by examining the homogeneity of a series. Four methods have been utilized towards this end: the Von Neumann Test (VNT), the Pettitt Test (PT), the Buishand Test (BT) and the Standard Normal Homogeneity Test (SNHT). These four methods, also utilized in various other fields, have provided brilliant results in homogeneity research (see, for example [5-14]). Of all these nonparametric methods, only the Von Neumann method identifies if the series is homogenous, while other methods can also detect the change point of the series if there is one.

For a great number of meteorological indicators, both globally and in Turkey, statistical analysis has been employed in an attempt to detect the change points. Türkeş [15] (1996) examined annual precipitation changes in Turkey, with respect to time and space, and detected the 1970 -1980 interval. By employing SNHT and an identical method, Alexadersson and Moberg [16] (1997) analyzed Swedish temperature data and compared the obtained findings. Wijngaard et al. [11], in their 2003-dated research, examined the homogeneity of the temperature and precipitation series for Europe and compared the methods with respect to research findings. Xiong and Guo [17] (2004), by statistically analyzing annual streamflow data, probed into trends and change points and detected that the change point in Yichang hydrologic station on the Yangtze River was in 1968. Mazvimavi and Wolski [18] (2006), in their study covering South Africa streamflow between years 1924-2004, detected the change points as years 1973-74 and 1980-81. Toreti et al. [19] (2008) determined the change years of precipitation data in Italy that classified change years with respect to geographical position. Rasol et al. [20] (2008) have studied temperature data in Croatia, and, by employing different methods, they obtained approximate change years. Costa and Soares [21] (2008), by conducting homogeneity research with precipitation data for South Portugal, drew a comparison between PT, BT and SNHT methods. Dikbaş et al. [13] (2010), in their research based on temperature data in Turkey, determined 1976-1994 time interval as the change point. Gao et al. [22] (2010), in their trend-change point research conducted with streamflow and sediment data between years 1950-2005, employed a variety of statistical methods, and for the four gauging stations on the Yellow River, China, detected change years as 1979 and 1985.

In the present study, the change point in the annual average streamflow data in Turkish Rivers between years 1936-2005 has been examined. The key objective of research is to test the homogeneity of streamflow data and designate what kind of relation this homogeneity has with climate change. The focus has been on interpreting change points of annual streamflow tested via different methods in Turkey, which possesses a vast surface area and rich water potential. Through this analysis, it is aimed to compare the applicability of the methods and see if there is any common (shared) change year for annual streamflow averages. Findings obtained via methods employed in searching the change point of river streamflow in Turkey have been compared with each other, and the consistency of the results has been analyzed. What distinguishes this particular research from other relevant studies is that the homogeneity tests utilized in identification of the change point have been applied, for the first time, on all streamflow gauging stations in Turkey. This method, previously applied to a variety of meteorological data, has been applied, for the first time, on annual average streamflow on the basis of the entire country.

2. Study area and data

The total area of Turkey is 783,562 km^2, of which 755,688 km^2 are in Southwest Asia and 23,764 km^2 are in Europe. Turkey lies between latitudes 35° and 43° N, and longitudes 25° and 45° E. The area situated on the Asian continent is called Anatolia, which is a peninsula surrounded by sea on three sides: the Black Sea on its north side, the Mediterranean Sea on its south side and the Aegean Sea on its west side.

Turkey is located between a tropical climate belt and a temperate belt. However, on account of its geographical position and land forms, it is possible to witness a variety of climatic forms in Turkey. In coastal regions, the temperature is warmer due to the effect of the sea. The position of the mountains prevents the passage of the warming effects of the sea towards the inner regions. Hence, a continental climate is prevalent throughout these regions. In coastal regions, precipitation takes the form of rainfall, whereas at inner and higher regions, it transforms into snow.

In this study, data obtained from streamflow gauging stations operated by the State Hydraulic Works (DSİ) are utilized. With respect to its river streamflow, Turkey is divided into 26 basins. Measurements initiated in 1935 are still in effect. In identification of the stations whose data will be employed, particular care is rendered to see if there is any regulatory structure on the source side, if the measurement location remained stationary throughout the gauging process and if the data set had sufficient length. Hydro-climatologists are concerned with analyzing time series by concentrating on differences in 30-year normal values during the whole period of recording [23]. This is why a period of 30 years is assumed sufficient for a valid mean statistic. It also amounts to describing the hydro-climatic time series as non-stationary, with local periods of stationary [24]. Streamflow data employed in the current study cover a minimum of 39 years, which is a sufficient length of time to detect climatic changes, if there are any. Burn and Elnur [25] (2002) stated that the selection of stations in climate change research is substantial in the initial step, and that a minimum record length of 25 years ensures the validity of the trend results, statistically. 75 streamflow gauging stations identified to possess these qualities have been marked with their numbers in Figure 1. In these 75 stations, annual average streamflow is detected via monthly annual streamflow. A closer look at the map in Figure 1 demonstrates that in the central and southeastern parts of the Anatolian peninsula, the number of stations is fewer compared to the other regions. This might be due to the fact that the Central Anatolian region is an endorheic basin. Available stations lack streamflow series possessing sufficient length, whilst the Southeastern Region lacks unchanged raw data due to the implementation of large-size water projects.

In Table 1, the positions of the stations employed in these measurements and information on measurement records are summarized. The shortest measurement (39 years) has been recorded from the Dereli streamflow gauging station (station no: 328) on the Susurluk Basin, and the longest measurement (70 years) from the Beşdeğirmen streamflow gauging station (station no: 1203) on the Sakarya Basin and the Himmetli streamflow gauging station (station no: 1801) on the Seyhan Basin. The records of stations from which research measurements have been gathered started in 1936 with 2 stations and reached 75 stations in 1968. In Figure 2, the annual increase of stations whose streamflow data have been used is provided. In the streamflow series of particular stations, there are minor level gaps, which are completed by the linear regression method, as done in some other studies [26-28].

3. Methodology

The four methods selected in testing annual average streamflow are the Buishand test [5], the Pettitt

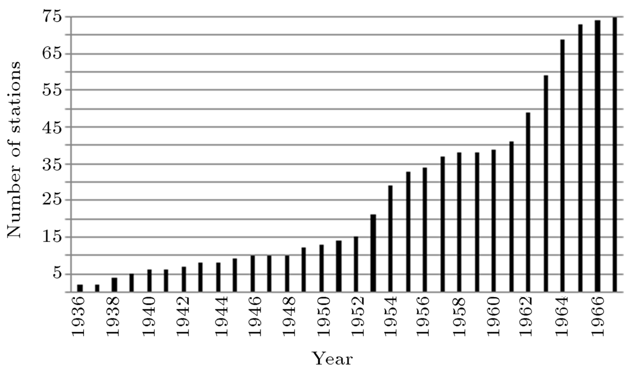

Figure 2. Number of stations for the corresponding year.

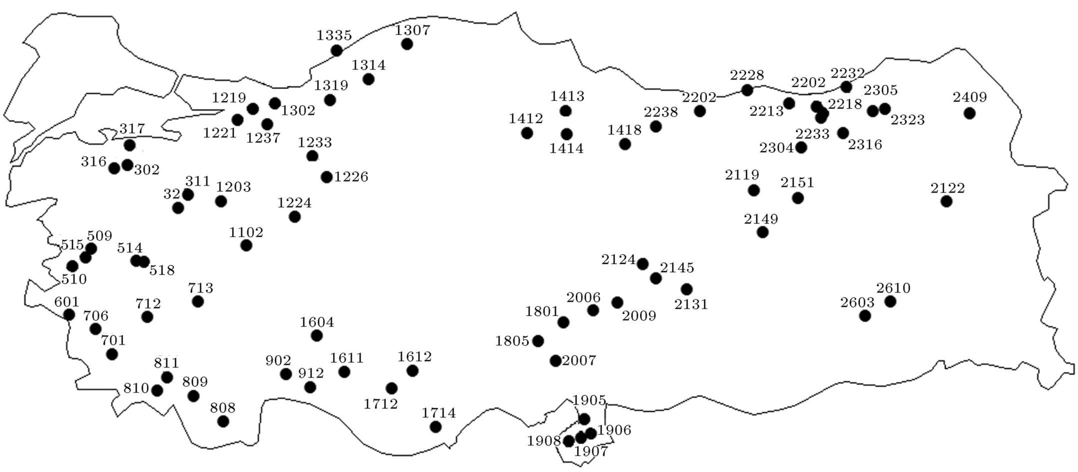

Figure 1. Location of streamflow gauging stations used in the study.

Table 1. Some facts of streamflow gauging stations and change point analysis results.

Basin	Station	No	Latitude	Longitude	Start year	Range year	VNT	BT	PT	SNHT
Susurluk	Döllük	302	39°57′41″	28°30′58″	1938	67	1.54	1982	1982	1984
	Küçükilet	311	39°37′31″	29°27′52″	1945	60	1.54	1984	1987	1987
	Yahyaköy	316	39°59′10″	28°10′34″	1953	52		198	198	1982
	Akcasusurluk	317	40°15′51″	28°24′21″	1953	52	1.48	1982	1982	1982
	Dereli	328	39°27′44″	29°15′30″	1968	37	1.08	1984	1987	1984
Gediz	Kayalıoğlu	509	38°53′25″	28°46′09″	1962	43		1982	1982	1968
	Killik	510	38°46′12″	27°40′02″	1961	44	1.23	1984	1984	1984
	Dereköy	514	38°41′58″	28°42′00″	1964	41	1.24	1986	1987	1986
	Deliiniş Dere	515	38°43′24″	28°33′18″	1966	39		1987	1987	1988
	Topuzdamları	518	38°38′41″	27°26′30″	1962	43	0.86	1984	1984	1984
L. Mend.	Selçuk	601	37°58′45″	27°22′46″	1953	52	1.17	1984	1984	1984
B. Mend.	Kayırlı	701	37°25′16″	28°07′50″	1938	67	0.79	1971	1971	1955
	Aydın Köp.	706	37°47′00″	27°50′25″	1950	55	0.55	1985	1985	1985
	Burhaniye	712	37°56′54″	28°44′37″	1951	54	0.56	1985	1985	1985
	Çıtak Köp	713	38°09′25″	29°38′24″	1952	53	0.63	1985	1985	1971
W. Mediter	Çatallar	808	36°29′27″	30°04′28″	1963	42	0.3	1985	1988	1988
	Kavaklıdere	809	36°49′34″	29°33′44″	1957	48	1.22	1984	1985	1985
	Suçatı	8011	37°05′38″	29°06′12″	1962	43	0.67	1985	1985	1985
	Akköprü	812	36°55′05″	28°56′04″	1964	41	0.58	1984	1985	1984
M. Mediter	Beşkonak	902	37°08′30″	31°11′19″	1940	65	1.05			
	Sinanhoca	912	36°58′46″	31°36′31″	1964	41	1.41			
Afyon	Gazlıgöl	1102	38°56′09″	30°30′07″	1957	48		1986	1986	1986
Sakarya	Beşdeğirmen	1203	39°31′43″	30°02′56″	1936	69	0.91	1985	1985	1987
	Yağbsan	1219	40°46′31″	30°36′02″	1953	52				
	Doğançay	1221	40°37′31″	30°19′50″	1953	52	1.03	1984	1987	1987
	Aktaş	1224	39°19′18″	31°20′11″	1963	42	0.58	1985	1985	1985
	Meşecik	1226	39°49′08″	31°56′01″	1963	42	1.04	1907	1978	1970
	Karaköy	1233	40°11′16″	31°39′28″	1958	47		1987	1987	1987
	Dokurcun	1237	40°34′31″	30°51′37″	1956	49	1.52	1987		
W. Black Sea	Yakabaşı	1302	40°51′22″	30°59′09″	1953	52				
	Azdavay	1307	41°10′11″	32°38′35″	1963	42				
	Karabük	1314	41°10′11″	28°10′34″	1963	42			1984	
	Gökcesu	1319	40°53′47″	31°58′02″	1965	40				
	Derecikviran	1335	41°32′53″	32°04′45″	1964	41				
Yesilırmak	Şeyhoğlu	1412	40°27′06″	35°25′03″	1954	51	1.34	1993	1993	1993
	Durucasu HES	1413	40°44′40″	36°06′43″	1995	50	1.12	1993	1993	1993
	Sütlüce	1414	40°26′03″	36°07′05″	1955	50	1.03	1989	1989	1993
	Gömelönü	1418	40°18′42″	37°07′34″	1963	42				

Table 1. Continued.

Basin	Station	No	Latitude	Longitude	Start year	Range year	VNT	BT	PT	SNHT
M. Anatolia	Beyşehir	1604	37°41′00″	31°44′09″	1964	43	1.11			
	Bozkır	1611	37°10′24″	32°12′34″	1962	43				
	Denircik	1612	37°12′07″	33°24′20″	1962	43	1.2	1983	1983	1983
E. Mediter	Bucakkışla	1712	36°56′56″	33°02′21″	1962	43		1985	1985	1985
	Karanacılı	1714	36°24′13″	33°48′56″	1962	69	1.37	1989	1989	1989
Seyhan	Himmetli	1810	37°51′59″	36°03′32″	1936	66	1.39			
	Gökdere	1805	37°37′07″	35°36′52″	1939	51				
Hatay	Torun Köp.	190	36°30′12″	36°24′40″	1954	51	1.17			
	Müşrürlü	1906	36°18′25″	36°32′38″	1954	56	0.91			
	Demirköprü	1907	36°15′05″	36°21′12″	1949	56	0.81	1982	1981	1982
	Antakya	1908	36°11′52″	36°09′25″	1949	51	0.75	1982	1982	1989
Ceyhan	Karaahmet	2006	38°01′55″	36°34′11″	1954	51	1.21			
	Çukurköprü	2007	37°20′29″	35°55′03″	1954	51				
	Poskoflu Köp.	2009	38°08′55″	37°00′04″	1954	51	1.15			
Euphrates	Kemah Boğazı	2119	39°41′02″	39°23′37″	1954	43	1.44		1982	1988
	Tutak	2122	39°32′19″	42°46′49″	1962	42				
	Yazıköy	2124	38°40′23″	37°26′35″	1963	48	0.77		1984	
	Kılayık	2131	38°19′47″	38°12′38″	1957	42	1.37		1982	
	Hisarcık	2145	38°28′34″	37°41′08″	1963	42	1.11		1982	
	Miskisağ	2149	39°06′37″	39°32′23″	1963	41	1.43			1961
	Sansa Boğazı	2115	39°34′45″	40°10′05″	1964	62	1.5			
E. Black Sea	Ağnas	2202	40°50′58″	40°00′25″	1943	43	0.99	1969	1968	1968
	Dereli	2213	40°44′52″	38°26′44″	1962	40				
	Dereköy	2215	40°43′44″	40°35′52″	1965	50				
	Şimşirli	2218	40°48′56″	40°29′33″	1955	43	1.5			1956
	Bahadırlı	2228	41°01′51″	39°16′43″	1962	41			1981	
	Topluca	2232	41°03′58″	41°00′28″	1964	41				
	Tozköy	2233	30°39′57″	40°34′44″	1964	41				
	Arıcılar	2238	40°32′58″	37°40′32″	1964	63				
Coruh	Byburt	2304	40°15′32″	40°13′36″	1942	42	1.59		1962	1963
	Peterek	2305	40°44′38″	41°29′05″	1963	40	1.36			
	İspir Köp.	2316	40°27′37″	40°57′53″	1965	40				
	İşhan Köp.	2323	40°46′50″	41°41′54″	1965	45				1964
Aras	Güvercinkaya	2409	40°43′23″	43°10′30″	1960	59				1961
Tigris	Beşiri	2603	37°57′54″	41°20′45″	1946	50			1969	
	Baykan	2610	38°09′41″	41°46′57″	1955					

test [7], the Standard Normal Homogeneity test [8] and the Von Neumann test [6]. Null hypothesis (H0) assumes that the analyzed series are homogenous, while the opposite condition is an alternative hypothesis (H1). For BT, PT and SNHT, null hypothesis obtains the year when the homogeneity of annual average streamflow is disrupted; VNT only detects if or not the series are homogenous. Despite their similarities, three tests locating the change point exhibit certain variations. In his 2003-dated work, Wijngaard et al. [11] reported that SNHT is more sensitive in detecting change points in the beginning and end of a series, while PT and BT are more sensitive in detecting change points in mid series. Also, while BT and SNHT assume that the series is in normal distribution, there is no such acknowledgment in PT.

3.1. Buishand test

In his 1982-dated article, Buishand [5] stated that in the investigation of the homogeneity of any series, it is feasible to manipulate this method. In this method, suggested by Buishand for the x series, adjoint partial summations are calculated:

$$S'_k = \Sigma_i^k (X_i - \bar{X})^2, \quad k = 1, 2, ..., N, \quad S'_o = 0.$$

In the event that time series (X_i) exhibits deviations around averages, the series is homogenous, and, in that case, S'_k values shall oscillate around zero. In the event that a fracture takes place in year k, the value of S'_k reaches a maximum or minimum value. Rescaled adjusted partial sums are obtained by dividing S'_k by the sample standard deviation:

$$S''_k = S'_k / S_d,$$

where S_d is the standard deviation,

$$S_d = \Sigma_i^N (X_i - \bar{X})^2 / N.$$

A statistic which is sensitive to departures from homogeneity is:

$$Q = \max_{0 \leq k \leq N} |S''_k|.$$

High values of Q are an indication of a change in level. Critical values for the test statistics can be found in Table 2 [5].

3.2. Von Neumann test

Von Neumann is a nonparametric test where the statistic is defined as the ratio of the mean square successive (year-to-year) difference to the variance [6]. The

Table 2. 5% critical values for the statistic of Buishand range test as a function of n.

n	20	30	40	50	70	100
5%	1.43	1.50	1.53	1.55	1.59	1.62

Table 3. 5% critical values for N of the Von Neumann ratio test as a function of n .

n	20	30	40	50	70	100
5%	1.30	1.42	1.49	1.54	1.61	1.67

Von Neumann test assumes that under the alternative hypothesis, the series is not randomly distributed. This test is not location specific, which means that it does not give information on the year of the break. The von Neumann test is complementary to the other three tests because of its sensitivity to departures of homogeneity that are of a nature other than strict step-wise shifts [5]:

$$N = \Sigma_{i=1}^{n-1} (Y_i - Y_{i+1})^2 / \Sigma_{i=1}^{n} (Y_i - \bar{Y})^2.$$

Critical values for N are given in Table 3. When the series is homogeneous, then the expected value is $E(N) = 2$. When the sample has a break, then the value of N must be lower than 2, otherwise we can imply that the sample has rapid variation in the mean.

3.3. Pettit test

The Pettitt test is a nonparametric test and analyzed from a point that will change over time [7]. The null hypothesis is that the data are independent, identically distributed random quantities, and the alternative is that a stepwise shift in the mean is present. The Pettit test is more sensitive to breaks in the middle of a time series [11]. The Pettitt test cuts the main series of N elements into two sets at each time, t, between 1 and $N-1$. This test is a non-parametric rank test. The ranks, $r_1, ..., r_n$, of the $Y_1, ..., Y_n$ are used to calculate the statistics:

$$X_k = 2\Sigma_{i=1}^{k} r_i - k(n+1), \qquad k = 1, 2, ..., n.$$

If a break occurs in year K, then the statistics are maximal or minimal near the year $k = K$:

$$X_K = \max_{1 \leq k \leq n} |X_k|.$$

The significance level is given by Pettitt [7]. Critical values for X_K are given in Table 4.

3.4. Standard normal homogeneity test

Alexandersson [8] developed the Standard Normal Homogeneity Test (SNHT), which is widely used and taken as a reference in the hydrological and climatic sciences. The null hypothesis is that the data are independent, identically normally distributed random quantities, and the alternative is that a step-wise shift

Table 4. 5% critical values for X_E of the Pettitt test as a function of n.

n	20	30	40	50	70	100
5%	57	107	167	235	393	677

in the mean (a break) is present. The SNHT for a single break is capable of locating the period (month or year) where a break is likely, and it detects breaks near the beginning and end of a series relatively easily [11]. Alexandersson [8] describes statistics, $T(k)$, to compare the mean of the first k years of the record with that of the last $n-k$ years:

$$T(k) = k.\bar{z}_1^2 + (n-k).\bar{z}_2^2, \qquad c = 1, ..., n,$$

where:

$$\bar{Z}_1 = \Sigma_{i=1}^{k}(y_i - \bar{y})/s,$$

and:

$$\bar{Z}_2 = \Sigma_{i=1+k}^{n}(y_i - \bar{y})/s.$$

If a break is located in the year K, then, $T(k)$ reaches a maximum near the year $k = K$. The $T(k)$ is depicted in the graphs representing the results of this test. The test statistics, T_0, are defined as:

$$T_0 = \max_{1 \le k \le n} T(k),$$

The test has further been studied by Jaruskova [29] (1994). The relationship between her test statistics, $T(n)$ and T_0, is:

$$T_0 = (n.(T(n))^2)/(n - 2 + (T(n))^2).$$

The null hypothesis will be rejected if T_0 is above a certain level, which is dependent on the sample size. Critical values are given in Table 5.

4. Result and discussion

As illustrated, the results are obtained from homogeneity research conducted by utilizing annual average streamflow data received from the annual average data of different streamflow gauging stations in Turkey, with a rich potential of water. According to the Von Neumann test, of the annual average streamflow series belonging to 74 streamflow gauging stations, 46 are non-homogenous, and 26 of these 46 streamflow gauging stations with no homogeneity are scattered, partially homogenously, with respect to geographical position, in the western part of Turkey. The remaining 20 streamflow gauging stations are condensed into a belt in the northeast and above the eastern part of the Mediterranean. Non-homogenous streamflow gauging stations have been indicated with their numerical values in Table 1. 29 stations with no corresponding numerical values are, according to the VNT method, homogenous.

Table 5. 5% critical values for the statistic T_0 of SNHT as a function of n.

n	20	30	40	50	70	100
5%	6.95	7.65	8.10	8.45	8.80	9.15

According to the analysis with the Buishand test, of the total 74 streamflow gauging stations there are change points available in 35 stations. Obtained findings demonstrate that during the first half of the 1980s, in particular, streamflow data went through a change (Figure 3(a)). 24 streamflow gauging stations that have a change year in a 95% confidence interval are situated in the western part of Turkey (Figure 4(a)).

In 35 (84%) stations, whose change year is detected by the Pettitt test, this change year is between 1980 and 1990 (Figure 3(b)). Findings related to the data analyzed by PT are marked on the map in Figure 4(b). In 42 stations out of 74 streamflow gauging stations analyzed by PT, the change year has been detected at a 95% confidence interval. Of all the analyzed stations, 15 are located in the eastern part of Turkey and 28 are in the western part of Turkey (Figure 4(b)).

In 30 (76%) stations, whose change year is identified by the Standard Normal Homogeneity test, the change year is between 1980 and 1990 (Figure 3(c)). In the analysis based on SNHT, parallel to the findings obtained via the other two methods, similar change years are identified. Of all the 74 stations analyzed, 40 have been detected to be meaningful at a 95% level. Of all the 40 stations providing results, 14 are in the eastern part of Turkey, whereas 26 are in the western part (Figure 4(c)).

It can be seen that the change year of annual average streamflow detected by the Buishand [5] homogeneity test varied particularly intensely between years 1982 and 1989. Besides, the change points of 47.2% of the stations were found to be in 1984-1985 time period. that change points detected via the PT method are centered between 1981 and 1989, and in years 1984 and 1985, 33% of the stations changed. Change years detected via the SNHT method varied densely between 1982 and 1989, while the change year in 32% of the stations pointed to the years 1984-1985 (Figure 3(a)-(c)). Streamflow gauging stations which have been used to detect the change year for mean annual streamflow in this study are almost in the same locations as the station trends determined by Kahya and Kalayci [23] in their study.

In the assessment of change year, results obtained for the annual average streamflow findings of previous hydrological and meteorological research are utilized. It should be particularly emphasized that change point research is mostly focused firstly on meteorological values (temperature, humidity etc.), but recently they have also been applied to hydrological data such as precipitation and streamflow.

Fırat et al. [30] (2010), in their research, utilizing

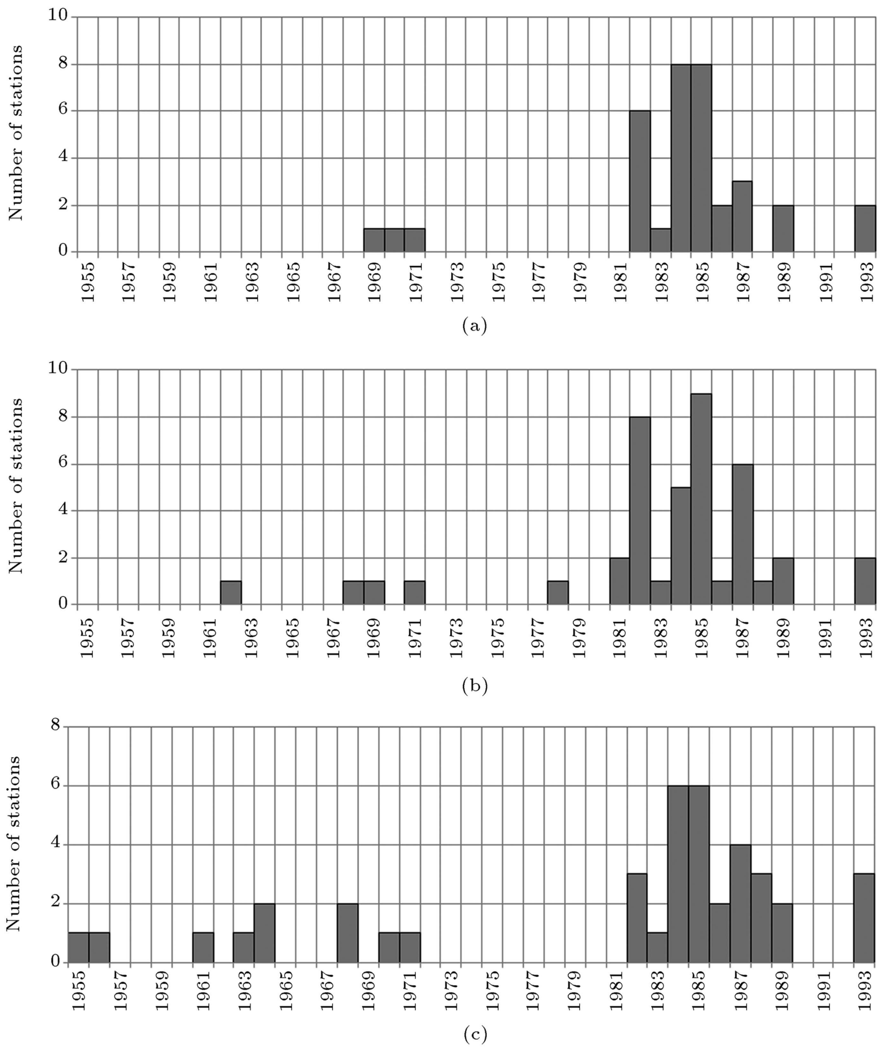

Figure 3. Detected number of streamflow gauging stations by years: a) For Buishand test; b) for Pettitt test; and c) for standard normal homogeneity test.

data obtained from 229 precipitation stations in Turkey between years 1968-1998, determined the years that disrupted homogeneity in 50 stations. Change years detected by PT on 27 precipitation stations are between 1983-1988, change years detected by SNHT on 34 precipitation stations are between 1969-1973 and 1995-1996. It is a known fact that there is positive correlation between precipitation and streamflow. In that case, it goes without saying that the change years of these two climate indicators shall also be similar. If we are to compare change years of annual total precipitation detected by Fırat et al. [30] with the change years of annual average streamflow obtained in this research, we can claim that the results obtained by PT demonstrate that both indicators go through changes in similar years and in approximate geographical locations (in the western part of Turkey in particular). As the results obtained in both studies by SNHT methods are compared, it can be claimed that for the southwest part of Turkey, there are similar change years in geographically nearby stations.

However, using the same method in the present study, the change years for streamflow in the northeast part of Turkey was determined whereas in Fırat et al. (2010) study the change years for precipitations in the southeastern part of Turkey was detected. This finding might prove, once again, that large-size water projects operating in the southeastern region have an effect on streamflow.

Şahin and Cığızoğlu [31] (2010), in their study, employed meteorological data collected between years 1974-2002 from 232 stations in Turkey, and provided a homogeneity analysis. For total precipitation data, by employing SNHT, BT, PT and VNT, change years are detected at 99% confidence intervals throughout a total of 12 stations. As seen in the study of Şahin and Cığızoğlu [31], the geographical locations of the stations in which precipitation homogeneity is disrupted are physically close to these research stations,

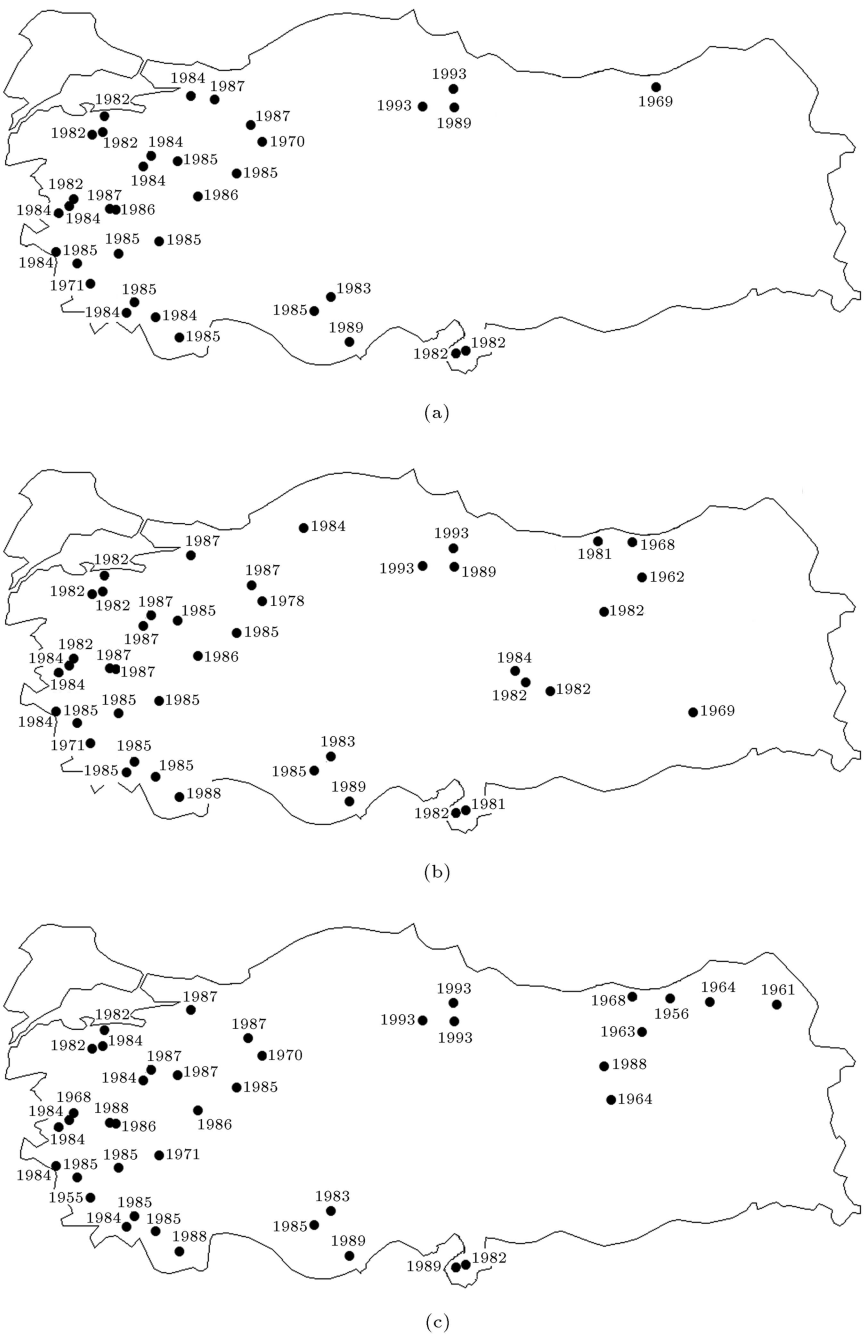

Figure 4. Geographical locations of streamflow gauging stations and detected changing years: a) For Buishand test; b) for Pettitt test; and c) for standard normal homogeneity test.

whose change years of annual average precipitation have been detected. Türkeş [15], in his study, examined the monthly precipitation data of 91 Turkish stations, whose data length varied between 54 years and 64 years, and identified that a drought period corresponded to the onset of 1970 and 1980. Furthermore, as classification based on the seasonal precipitation regime in Türkeş's [15] study is compared with the regions whose change years are obtained in this study, it surfaces that in those regions where the dominant type of precipitation is rainfall, it is possible to detect the change years. Aksoy [32] tested 1961 - 2000 period data from two streamflow gauging stations on the European part of Turkey, and identified that the change years corresponded to 1982 and 1997. As can be seen, there are similarities between the findings obtained from the above-summarized research and the change year interval identified in the present research (first half of the 1980s).

Stations in which the change year is obtained by BT, PT and SNHT are the same as summarized in Table 6. The number of stations detecting the same

Table 6. Streamflow gauging stations which detected same changing year by test methods.

	BT-PT-SNHT	BT-PT	PT-SNHT	BT-SNHT
1969	-	-	2202	-
1970	-	-	-	1226
1971	-	1971	-	-
1982	316-317	302-509-1908	-	1907
1983	1612	-	-	-
1984	510-518-601	-	-	328-812
1985	706-712-811-1224-1712	713-1203	809	-
1986	1102	-	-	514
1987	1233	515	311-1221	-
1988	-	-	808	-
1989	1714	1414		-
	-	-	-	-
1993	1412-1413	-	-	-

year by employing the three methods used to identify the change year is 16. The number of stations in which the same change year has been identified by BT and PT methods is 8; the number of stations in which the same change year has been identified by PT and SNHT methods is 5; the number of stations in which the same change year has been identified by BT and SNHT methods is 5. 1984 and 1985 are the most frequent change years detected by these methods. Stations in which the same change year is detected by all three methods are stations in the western part of Turkey where the dominant precipitation form is rainfall.

5. Conclusion

Within the scope of the present research, an attempt is made to detect the climate change points of 74 streamflow gauging stations in Turkey by analyzing their annual average streamflow between years 1938-2005. Nonparametric statistical methods, namely, Von Neumann, Pettitt, Buishand, and Standard Normal Homogeneity methods, are utilized. Analyses are conducted on, statistically, a 95% confidence interval. Compared to the eastern part of Turkey, the western part is climatically warmer, which enabled us to conduct further systematic streamflow measurements. In the western part of Turkey, where climate conditions resemble a Mediterranean climate, the climatic change year has been identified as the first half of the 1980s. In geographically higher locations where precipitation characteristics turn into snow, it becomes substantially harder to find both raw data and also to obtain a common change year with the obtained data. In the southeastern Anatolia region where no common change year could be detected, large-size water projects for agricultural and energy purposes have been implemented in the aftermath of the 1970s. The eastern Anatolia region is the highest geographical region in Turkey with, approximately, 1500 meters of altitude, and is another region where no common change year could be detected. This high altitude created long and harsh winters with snowfall, which, in turn, makes it harder to make sensitive and systematic measurements. The failure to obtain a common change year in eastern Anatolia might be attributed to both the type of climate and challenges in measurement conditions. As regards the Black Sea region, the scarcity of habitable areas plays a role in the condensing of settlements near water resources. The industrial progress witnessed in the 19th century and agricultural needs triggered a change of course in water resources, which, in turn, caused the transformation or disruption of the streamflow gauging stations that could be utilized. As the number of stations in which changes took place is taken into account, the method that detected the change year in the highest number of stations is PT (42 stations), followed by SNHT (40 stations) and BT (35 stations) in turn. All three methods are basically obtained from the western part of Turkey and detected change years mostly correspond to the first half of the 1980s.

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Biography

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