

Changes and trends of seasonal total rainfall in the province of Istanbul, Turkey

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Abstract: Several studies revealed that climate change can affect local and regional precipitation patterns. Long term trends and cycles in precipitation is important for the health of ecosystems in the region. The possible impacts in near future can affect the forest and water resources of Istanbul. In this study, daily, monthly, seasonal and annual precipitation analyses for the different meteorology stations were examined for the İstanbul province. Northern and southern different climatic conditions of İstanbul have been effective selection of the station. The Mann-Kendall test results showed that there is positive statistically significant trend in some meteorology stations. According to Mann-Kendall results the increased fall precipitation trend were found in Florya, Kireçburnu ve Kumköy meteorology stations and decreased summer precipitation trend were found in Göztepe meteorology stations.

Keywords: Mann-Kendall trend analysis, precipitation time series, the regional precipitation reactions analysis, the climate change

İstanbul ilinde mevsimsel toplam yağışların değişimleri ve eğilimleri

Özet: İklim değişikliğinin bölgesel ve yöresel ölçekte yağış rejimi üzerinde etkileri olabileceği birçok araştırma ile ortaya konulmuştur. Yağış serilerindeki uzun dönemli yönelimler ve döngüler yöredeki ekosistemlerin sağlığı ve geleceği açısından büyük önem arz etmektedir. İstanbul ilinde önümüzdeki dönemde gerçekleşebilecek etkiler ise hem su kaynakları hem de ormanlar üzerinde önemli sonuçlar ortaya çıkarabilir. Bu çalışmada İstanbul iline ait farklı meteoroloji istasyonlarının uzun dönemli mevsimlik verileri araştırılmıştır. Çalışmadaki amacımız ileriye dönük tahminlerdeki belirsizlikleri belli oranda ortadan kaldırabilecek geçmişe dönük veriler yardımıyla istatistiksel analizleri gerçekleştirmektir. İstasyon seçiminde İstanbul'un kırsal ve kentsel bölgelerindeki farklı iklim koşulları etkili olmuştur. Mann-Kendall testi sonuçlarına göre Florya, Kireçburnu ve Kumköy Meteoroloji İstasyonları'nda seçilen sonbahar mevsimi yağışlarında, Göztepe Meteoroloji İstasyonu'nda ise yaz mevsimi yağışlarında istatistiksel anlamda artan bir trend bulunmuştur.

Anahtar kelimeler: Mann-Kendall trend analizi, yağış zaman serileri, iklim değişikliği

1. INTRODUCTION

Fossil fuel usage, which have increased dramatically after the Industrial revolution, brought with it an increase in greenhouse gasses emitted into the atmosphere (Rustad et al., 2000). The increase in the amount of greenhouses gasses in the atmosphere (CO₂, CH₄, N₂O, HFCs, PFCs, SF₆) have led to changes in the dynamic balances on earth. In the studies conducted, it was indicated that greenhouse gasses accumulated in higher layers of the atmosphere have led to / will lead to higher temperatures on earth and changes in precipitation dynamics (Wentz et al., 2007; Meinshausen et al., 2009). The changes in atmospheric balances are not limited to changes in average values of climate parameters. It may be observed that recent studies

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focus rather on the reflections of the change in atmospheric dynamics created by climate change on local and regional climatic conditions.

In addition to systemic problems caused by the increase in the usage of fossil fuels, the balance between terrestrial and atmospheric areas may also be changed by factors such as the decrease in the amount of efficient forests and forest fires, irresponsible usage of wetland areas, and construction of dams. The effects of these changes may be seen especially in local areas. Especially the land usage in favor of urbanization in metropolitan cities like Istanbul, leads to even higher surface temperatures (Kalnay and Cai, 2003). It is expected that this terrestrial warming situation also affects atmospheric conditions and leads to changes in precipitation mechanisms. In this context, especially in cities like Istanbul where there is an intense urbanization pressure, the prominent purpose is to determine the direction of long term precipitation data. In addition to the surface temperature increase caused by urbanization, introduction of artificial wetlands in a watershed (such as dams, etc.) may increase the total amount of evaporation in the area. The increase in the total amount of evaporation will affect precipitation dynamics, based on the suitability of frontal movements (Pielke, 2005). An increase in heavy rainfalls may be caused by energy flow changes especially in the boundary layers of the atmosphere (Feddema et al., 2005) and this situation may increase the amount of overflows and floods by triggering strong storms. The temperature increase caused by the greenhouse effect in the atmosphere and urbanization may change the humidity holding capacity of the atmosphere. According to IPCC, a 0.75 0C increase in temperature leads to a 5-6% higher amount of moisture held in the atmosphere (Van Vuuren et al., 2011). Therefore, an increased amount of humidity may mean that more intense precipitation will be experienced. In addition to the amount of precipitation, it is expected that this abnormal change in the humidity balance of the atmosphere will affect the time and frequency of precipitation (Ferguson and Suckling, 1990). Thus, it is possible to experience longer draught periods more frequently.

In models with global or local scopes developed on climate change (for example, the HadGEM2-ES model with a global scope or the RegCM 4.3.4 model with a local scope), the word 'scenario' is more prominent than the word 'forecast' as opposed to the situation in other models (IPCC, 2000). The scenarios, as outputs of these models, should not be seen as predicting the future. Here, it is important to determine possible situations that may be foreseen in the future (Turkes, 2012). Climate change scenarios are seen as the most important factors the research by the Intergovernmental Panel on Climate Change (IPCC) focuses on. The IPCC has published 5 evaluation reports so far. The four main SRES scenarios in climate change (A1, A2, B1 and B2) may be seen in evaluation reports 3 and 4. In the 5th IPCC report, instead of SRES scenarios, a new type of concentration scenarios called RPC (Representative Concentration Pathways) was published (Van Vuuren et al., 2011). In studies conducted for Turkey with local scopes, precipitation projections were produced by using HadGEM2-ES in the basis of the RCP4.5 scenario (Demircan et al., 2014). For instance, according to these projections, while an increase in precipitation is predicted between 2016-2040 for Coastal Aegean, Eastern Black Sea and Eastern Anatolia regions in Winter months, a decrease in precipitation by about 20% is expected for every region except Coastal Aegean and Eastern Anatolia regions in Spring (Turkes, 2012). Against this dramatic decrease in precipitation, the role of soils in forests as water tanks will help increase the efficiency of usable water in the area and the importance of forests for the future years will be emphasized. In addition to the projections in these climate models, the analyses of current climate parameters may also provide clues about trends reaching up to today.

It may be seen that one of the important parameters of climate, precipitation, have been measured by the Turkish State Meteorological Service in our country since the beginning of 1900s. In connection to the advancements in technology, measurement and monitoring stations have improved since the beginning of 2000s. Today, with the help of automated monitoring stations, data are automatically stored and saved in the computers at the offices. The evaluations on the precipitation data in the data sets up to now can provide us with significant clues about climate change. Especially in our country where all four seasons are experienced, wet and dry periods may be separated by clear lines. Especially the graphical representation of precipitation data fluctuates between these periods. In the graphs, fluctuation averages and trend lines may provide information about the trends of the data. However, some special time series analyses are needed in order to see if these trends are statistically significant. The most frequently used one among these methods is the Mann-Kendall test which is not parametric. There are numerous studies where precipitation

data are evaluated with the Mann-Kendall test (Serrano et al., 1999; Zhang et al., 2000; Gemmer et al., 2004; Chinchorkar et al., 2015; Kızılelma et al., 2015; Sutgibi, 2015). The most important advantage of this technique is that it removes the correlation effect of the series in itself and provides results (Zhang and Zwiers, 2004). Therefore, this test helps determine the direction of statistical trends in precipitation data. The precipitation data evaluated with this test may set a basis on a locally conducted climate change study.

While Turkey is not located on a core center of an air mass, precipitation in our country is known to be caused by air movements coming from outside (Atalay, 2010). These air movements come from the south in Summer, and the north in Winter. In our country located in the Mediterranean climate area, it is known that different warming zones occur in different seasons. Therefore, it may be argued that precipitation is affected by atmospheric instability conditions (Komuscu et al., 2009). Additionally, it was reported that the occurrence of precipitation in our county is affected by seasonal pressure patters in the Atlantic Ocean and Europe (Temucin, 1990). It is also known that precipitation is affected by land forms in some areas in addition to frontal air masses. For example, when the air masses coming from the Black Sea encounter Istranca Mountains, this encounter leads to orographic precipitation in the area. The varying topography in the borders of the province of Istanbul, and the humid air masses encountering this uneven topography may also lead to orographic precipitation. In this case, it leads to local differences in precipitation. In addition to these types of precipitation, the precipitation in the Marmara region may also be caused by air masses which are under the effect of cold weather and low pressure, meeting with areas under the effect of warm weather (Kocman, 1993). Therefore, especially in the northern parts of Istanbul, it is known that precipitation is rooted in the Black Sea precipitation regime (Ikiel, 2005). In the southern parts of Istanbul, the climate becomes more moderate and diverts away from the Black Sea climate. This situation creates precipitation differences in northern and southern parts of Istanbul. It will be possible to determine the precipitation trends in these two different parts by analyzing the trends of precipitation data gathered from meteorology stations located in the north and the south of Istanbul. This study is considered to address this purpose, rather than determining the reasons for seasonal changes and trends in precipitation.

In the climate change adaptation process, the concept “water management” is prominent. For an efficient water management strategy, firstly the current inventory information should be acquired. In addition to climate analyses, this information is created by land usage information of watersheds, as well as water resources and water reserve information. The climate analyses which may be done with this purpose may also provide indicator aspects showing climate change. However, before going into these studies, firstly the current climatic situation should be analyzed. In this study, the daily precipitation data starting with 1960 taken from certain meteorology stations in Istanbul were subjected to a set of statistical analyses. Therefore, seasonal precipitation trends were shown for these stations.

2. MATERIALS AND METHODS

2.1 Study Area

In order to analyze the precipitation data, a set of meteorology stations in the rural and urban areas of the province of Istanbul among ones owned by the State Meteorology Stations. Kumköy and Kireçburnu Meteorology Stations located in the district of Sarıyer were chosen to represent the rural areas in the province of Istanbul. The other three meteorology stations in Florya, Göztepe and Kartal were chosen to represent the urban areas of the province of Istanbul.

As it may be seen in Figure 1, the north of Istanbul was generally classified as rural areas in this study, as it is generally covered in forests, while the south of Istanbul generally consists of residential areas. Moreover, it is also known that northern areas are under the effect of the Black Sea, while there is a more moderate climate in southern areas because of the effects of the Marmara Sea. The differences in the amount of precipitation are thought to be caused by these two effects.

As the data set of this study, daily total precipitation data taken from these 5 meteorology stations were used. Table 1 contains information about these meteorology stations. There is no lack of information in the data set. Therefore, the process of completing missing data was not needed for this study. The measurement

of precipitation up to today has been made in meteorology stations with devices called pluviograph and rain gauge. While rain gauges measure precipitation directly, pluviographs save the information on an embedded diagram. With the developments in technology, pluviographs are replaced by rain gauges, and this situation will lead to a certain amount, however tiny, of difference based on the differences in measurement.



Figure 1. The General view of the surveyed meteorology stations
Şekil 1. Araştırmada değerlendirilen meteoroloji istasyonlarının genel görünümü

Table 1. The information of meteorology stations in the study
Tablo 1. Araştırmadaki meteoroloji istasyonlarına ait bilgiler

Meteorology stations	Evaluated monthly rainfall data	The highest amount of rainfall (month)	n	The Coordinates of The Meteorology Stations	Elevation (m)
Kartal	January 1960 - September 2015	278.4 mm (October 2010)	21157	40°54'42.25"K 29° 9'24.44"D	18
Florya	January 1960 - August 2015	298.6 mm (October 1997)	21127	40°58'29.12"K 28°47'9.66"D	36
Göztepe	January 1960 - November 2007	286.2 mm (December 1963)	18487	40°59'22.80"K 29° 3'7.70"D	33
Kireçburnu	January 1960 - September 2015	337.8 mm (December 2001)	21157	41° 8'49.01"K 29° 3'3.60"D	58
Kumköy	January 1960 - September 2015	339.3 mm (September 2009)	21157	41°15'2.21"K 29° 2'18.06"D	30

As it may be seen in Table 1, there are no dramatic differences in the altitudes of the stations. This prevents abnormalities based on differences of altitudes.

2.2 Statistical Analyses

2.2.1 Regression Analysis

Regression analysis is a method to statistically analyze the relationship among dependent and independent variables and the performance of this relationship. In this method, the value of the dependent variable in units of independent variables is found based on an equation. In the simple linear regression of $Y = a + b \cdot X$, the values of Y represent the dependent variable, while the values of X represent the independent variable. In the equation, the value of a is where the line intersects the Y axis, while the value of b denotes the slope of the line, which denotes the amount of change in Y against a 1-unit change in X. In the study, the precipitation series was firstly subjected to a regression analysis in order to determine the state of the trend and the slope of the line.

2.2.2 Homogeneity Analysis of the Data Series

When the series in the precipitation data is evaluated over graphs, it may be seen that it fluctuates. If there are not significant changes in these fluctuations, this means the series is homogenous (Firat et al., 2012). If the fluctuations do not happen in a standard area, but showing significant changes, the data set is defined to be heterogeneous. Besides graphs, whether data series are homogenous in themselves or not may be determined by various parametric and non-parametric tests. In this study, whether the data belong to the same set or not is determined by the Run (Swed-Eisenhart) test.

Before starting the Run test, a critical threshold value should be determined. In general, it is found suitable to take the median value as the threshold value in the Run test. In the method, meteorology stations are assigned Run values for the number of values under and over this value. The calculated value is compared to the value in the frequency table in order to determine whether the data belongs to the same data set (is homogenous) or not (Swed ve Eisenhart, 1943). The Run test is defined with the equation below.

$$z = \frac{r - \frac{2N_k N_b}{N_k + N_b} + 1}{\sqrt{\frac{2N_k N_b (2N_k N_b - n)}{n^2 (n - 1)}}$$

Here, z = Run test value, r = Run number, Nb= the number of data higher than the median, Nk = the number of data lower than the median and n= the number of data. If the value “z” is lower than the value on the table, the data are determined to be homogenous. When the frequency table is observed, the 95% and 90% confidence intervals are described with the values 1.96 and 2.54. Therefore, if the value of z is higher than 1.96, it may be determined that the data are not homogenous within the 95% confidence interval.

2.2.3 The Mann-Kendall Test

A frequently used test to determine the trends of precipitation data in a given time and the trend’s magnitude is the Mann-Kendall test which is not parametric. It is a preferred method to test the direction (increase, decrease, or no change) or statistical significance of the trend in hydrological and meteorological research.

In this test, instead of the actual data, ordering of the data in the series (yi) is used. In the test, for each yi, the values higher than the previous order are counted and a number like ni is defined. The test statistic t is found by the summation of ni values (Sneyers, 1990).

$$t = \sum_{i=1}^n n_i$$

The average variance of this is defined as;

$$E(t) = \frac{n(n-1)}{4} \text{ ve } var t = \frac{n(n-1)(2n+5)}{72}$$

Respectively, The Mann-Kendall test statistic value u(t), which is an important output, may be calculated with the following formula.

$$u(t) = \frac{[t - E(t)]}{\sqrt{var t}}$$

In cases where there is not statistical change over time, it is seen that u(t) takes values that are closer to zero. In cases where u(t) takes high values, it is determined that there is a change in the time series. The u(t) value reaching ± 1.96 means that the significance level reaches 95% (Toros, 2012).

2.2.4 The Pettitt Test

In the Mann-Kendall test, a graphical approach may be taken in determining the changing point of a data series. In this approach, the intersection point of u(t) and u'(t) denotes the point where the change starts. In addition to the graphical approach, in finding the changing point of a series, some homogenous tests like the Pettitt test, the Standard Normal Homogeneity Test, the Buishand test and the von Neumann test are also used. A frequently used one among these is the Pettitt test. This test was developed by Pettitt in 1979

in order to determine the changing point (Pettitt, 1979). In the test, H_0 indicates that the series has an independent and random distribution, while H_A indicates that there is a sudden change. According to Pettitt (1979), Y_1, \dots, Y_n values are ordered as r_1, \dots, r_n in the test. The changing point is the absolute maximum value of X_k , and this value is,

$$X_k = 2 \sum_{i=1}^k r_i - k(n+1) \quad k = 1, 2, 3, 4, \dots, n$$

The X_k as a result of the equation may be graphically shown. The absolute maximum value of X_k (X_E) is indicated as the following,

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

If the p value found using the Monte Carlo simulation is lower than 0.05, H_0 is rejected and H_A is accepted.

3. RESULTS

Besides computing the daily, monthly and annual averages of precipitation and long term precipitation data of the meteorology stations, precipitation trends for different seasons were also analyzed. Average daily, monthly and annual precipitation values for the meteorology stations and their standard deviations are shown in Table 2.

Table 2. The results of long term daily, monthly and yearly average precipitation in meteorology stations
Tablo 2. Meteoroloji istasyonlarının uzun dönemli günlük, aylık ve yıllık yağış ortalamaları

Meteorology stations	Daily avg. rainfall (mm) and std. deviation	Monthly avg. rainfall (mm) and std. deviation	Annual avg. rainfall (mm) and std. deviation
Kartal	1.79 ± 5.26	54.70 ± 44.07	652.4 ± 140.7
Florya	1.77 ± 5.24	53.98 ± 44.77	647.7 ± 122.1
Göztepe	1.87 ± 5.42	57.08 ± 47.05	691.3 ± 120.9
Kireçburnu	2.26 ± 6.39	69.04 ± 53.68	827.9 ± 157.1
Kumköy	2.21 ± 6.61	67.32 ± 56.28	809.5 ± 172.1

Considering the average precipitation amounts, it may be seen that particularly the two stations located in the north of Istanbul (Kireçburnu and Kumköy) received higher amounts of precipitation in comparison to other stations. According to the results of the Run (Swed-Eisenhart) test, the z value for each station was lower than the value that corresponded to the 95% confidence interval on the Run test table. This revealed that the precipitation series of each station is homogenous (Table 3).

Table 3. The results of Run (Swed-Eisenhart) test
Tablo 3. Run (Swed-Eisenhart) testi sonuçları

Meteorology stations	z (calculated value)	Run test table value (95% confidence level)	The results of Run test
Kartal	-0.368	1.96	Homogeneous
Florya	-0.854	1.96	Homogeneous
Göztepe	-0.957	1.96	Homogeneous
Kireçburnu	-0.781	1.96	Homogeneous
Kumköy	-1.021	1.96	Homogeneous

According to the Mann-Kendall test results of the meteorology stations in Istanbul, if we look at the precipitation series graphs of the seasons where there are statistical trends, although the data series is homogenous, it is seen that the trend shows irregular fluctuations based on the effect of extreme occasions of precipitation (Figure 2). If we look at the regression curves of the series, the sign of R^2 (+ or -) may generally provide information about the direction of the tendency. However, the regression curve may not provide the direction and magnitude of the statistical tendency in time series analyses. Therefore, conducting of the Mann-Kendall test will provide the statistical assessment and the magnitude of the trend.

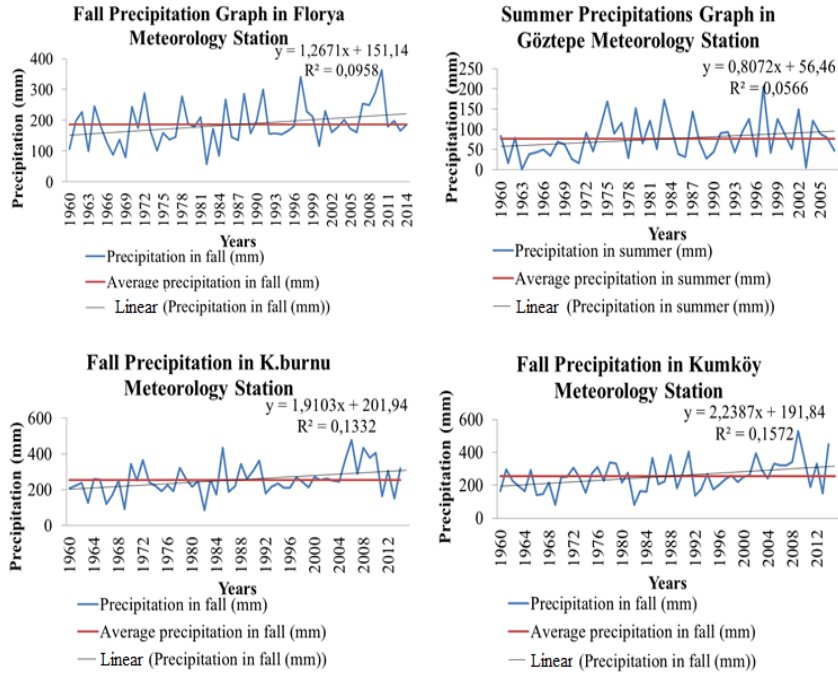


Figure 2. The trend of seasonal rainfall in some meteorology stations belongs to seasons which has a trend
 Şekil 2. Bazı meteoroloji istasyonlarının trend bulunan mevsimlere ait mevsimlik yağış serisi grafikleri

The graph above may not determine whether there is a statistical trend or not. Therefore, the seasonal trends of the precipitation records gathered from 5 different meteorology stations located in Istanbul were statistically evaluated by the Mann-Kendall correlation test. In addition to the direction of the trend, the trend's magnitude $u(t)$ was also computed by each station separately (Table 4).

Table 4. The results of Mann-Kendall correlation test
 Tablo 4. Mann-Kendall korelasyon testi sonuçları

Seasons	Parametre	Kartal	Florya	Göztepe	Kireçburnu	Kumköy
Winter	n	51.00	56.00	48.00	56.00	55.00
	t	702.00	692.00	531.00	787.00	736.00
	E (t)	637.50	770.00	564.00	770.00	742.50
	var (t)	3789.58	5005.00	3164.67	5005.00	4743.75
	u (t)	1.05	-1.10	-0.59	0.24	-0.09
Spring	n	51.00	56.00	48.00	56.00	56.00
	t	647.00	679.00	548.00	740.00	740.00
	E (t)	637.50	770.00	564.00	770.00	770.00
	var (t)	3789.58	5005.00	3164.67	5005.00	5005.00
	u (t)	0.15	-1.29	-0.28	-0.42	-0.42
Summer	n	51.00	56.00	48.00	56.00	56.00
	t	666.00	827.00	694.00	864.00	789.00
	E (t)	637.50	770.00	564.00	770.00	770.00
	var (t)	3789.58	5005.00	3164.67	5005.00	5005.00
	u (t)	0.46	0.81	2.31	1.33	0.27
Fall	n	49.00	55.00	48.00	55.00	55.00
	t	688.00	913.00	615.00	917.00	937.00
	E (t)	588.00	742.50	564.00	742.50	742.50
	var (t)	3364.67	4743.75	3164.67	4743.75	4743.75
	u (t)	1.72	2.48	0.91	2.53	2.82

According to Table 4, the values of $u(t)$ (values written in red) over ± 1.96 show that there is a trend. It was seen that there is a precipitation trend in at least one season in each station except the Kartal Meteorology Station. It was observed that there is an increase in Summer precipitation amounts at Göztepe Meteorology Station. At the meteorology stations located in Florya, Kireçburnu and Kumköy, it was observed that there is an increase in Fall precipitation amounts. These determined trends were statistically significant in the 95% confidence interval. The value 1.96 is the critical level for the Mann-Kendall analysis and a trend may be considered if the values reach this level. Based on the information on the table, it may be seen that there is a trend of increase in at least one season for each of the 4 meteorology stations' precipitation time series. The highest magnitude of a trend was found at the Kumköy Meteorology Station ($u(t)$: 2.82).

In graphically determining the changing point, $u(t)$ and $u'(t)$ graphs are needed for the stations where there are trends, and the seasons which are found statistically significant. Therefore, the $u(t)$ and $u'(t)$ graphs of the Fall season precipitation trends from the Florya, Kireçburnu and Kumköy locations and the Summer season precipitation trend from the Göztepe location were given in the figure below.

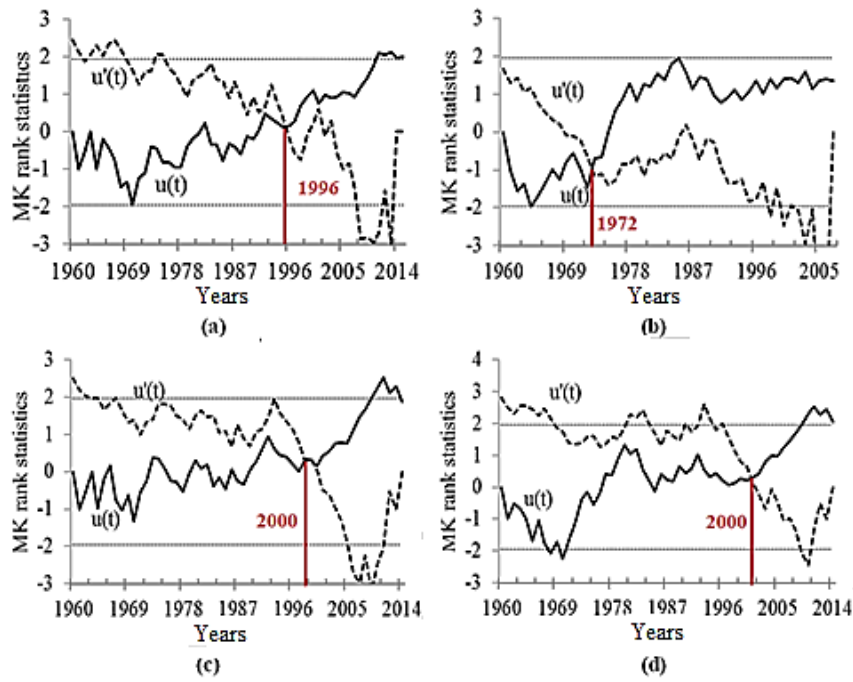


Figure 3. Change point of precipitation trends in Florya (a), Göztepe (b), Kireçburnu (c) ve Kumköy (d) meteorology stations

Şekil 3. Florya (a), Göztepe (b), Kireçburnu (c) ve Kumköy (d) meteoroloji istasyonlarının mevsimlik yağış trendlerinin değişim noktaları

The points where $u(t)$ and $u'(t)$ values intersect in Figure 3 may be seen as points where the change starts. The points where the change starts are the year 1996 the Florya Meteorology Station, 1972 for the Göztepe Meteorology Station, and 2000 for the Kireçburnu and Kumköy Meteorology Stations. The Pettitt Test, which aims to find the changing point is a widely used statistical test outside graphical evaluation. The H_0 for the Pettitt test is that “there are not changing points in the seasonal trend curves of the stations”. The alternate hypothesis H_A is the opposite of the H_0 . The results of this test may be seen in Table 5.

Tablo 5. Pettitt testi sonuçları
Table 5. The results of Pettitt test

Florya (Fall)		Göztepe (Summer)	
t	36	t	12
P value	<0.0001	P value	<0.0001
alfa	0.05	alfa	0.05
Kireçburnu (Fall)		Kumköy (Fall)	
t	40	t	40
P value	<0.0001	P value	<0.0001
alfa	0.05	alfa	0.05

According to the Pettitt Test table, the changing points of the particular seasonal trends of the stations resulted in similar values to the graphical evaluation. The “t” value on the table shows how long it took the changing point to emerge after the first evaluated year (1960). This value is 26 years for the Florya Meteorology Station, 12 years for the Göztepe Meteorology Station, and 40 years for the Kireçburnu and Kumköy Meteorology Stations. These years are 1996, 1972 and 2000 respectively. As the “p” value for each station was lower than the alpha value of 0.05, the null hypothesis (H_0) was rejected and the alternate hypothesis (H_A) was accepted. Therefore, that there was a diffraction in the trend curve (there is a changing point) was statistically proven.

4. DISCUSSION

In this study where the effects of climate change on the seasonal precipitation trends were investigated, the times series of each of the 5 different meteorology stations selected in Istanbul was statistically analyzed. Considering there are two different transition climates effective in Istanbul, the stations were selected to represent different climate types in this study. The variability of precipitation is considered to be caused by atmospheric movements effected by these two different transition climates. According to Olgen (2010), the atmospheric movements effective in the country are influential in precipitation variability in Turkey. In the same study, the depressions influential in the Mediterranean basin caused by air masses that are effective in the precipitation variability, lead to higher amounts of precipitation in the Marmara Region in Winter. Erinç (1957) refers to three different precipitation regimes in Turkey; Black Sea, Mediterranean, and Continental regimes. However, the researcher talks about two different transition types as Central Anatolia and Marmara, while reporting that the maximum amount of precipitation in Winter is seen in the Marmara transition type, and there is a higher amount of precipitation in Spring relative to the coasts of the Mediterranean. Colasan (1960), while indicating that there are three main precipitation regimes as coastal, interior and Black Sea (as it is different from the Mediterranean), asserts that the Marmara Region is located on a transitional belt. Temucin (1990) in their study, classified the precipitation in the Marmara Region in two classes as the Marmara precipitation regime (Black Sea coasts of Istanbul) and the Mediterranean-Marmara transitional type (Marmara Sea coasts of Istanbul), while emphasizing that the Mediterranean-Marmara transitional type is particularly effective in Summer precipitation, and precipitation is influenced by the mobile depressions coming from the Mediterranean Region encountering subtropical high pressures.

The air masses moving from the Azores high pressure to the Basra low pressure in the Marmara Region, gather humidity while passing over the Black Sea and bring Summer rains particularly to the coasts of the Black Sea. That there were no increases in precipitation in Summer especially in the Kireçburnu and Kumköy Meteorology Stations shows that there have been no changes in these high and low pressure air movements. It is thought that the increasing atmospheric pressure differences and abnormalities brought by the increasing temperatures in sea water and territorial areas based on the effects of climate change may be effective in the seasonal precipitation trend changes. Therefore, the existence of an increasing trend especially in Fall and Summer months found in our study may be explained by the high rates of frontal activity in the Fall season or the increasing transitional frequency of depressions in these seasons. Turkes (2012) indicates that the long term humid conditions observed in the negative stage of the North Atlantic Fluctuation (the fluctuation caused by the broad-scaled pressure fluctuation between Azores high and Iceland low pressures) are effective on the increase in precipitation in the Fall season. In Efe et al.’s study (2015) where meteorology stations in the entire country of Turkey were evaluated, it was reported that there

are trends of increase in the Marmara Region and especially in the coastal areas generally the total amount of annual precipitation. As reported in the 6th National Climate Change Declaration (MEU, 2016), it was projected according to the RCP4.5 scenario that there will be a 100-150 mm decrease in precipitation abnormalities in the Marmara Region in the period 2015-2040, while there will be an increase of 100-400 mm in total annual precipitation in the period 2071-2099. In the same declaration, according to the projections made using the HadGEM2-ES global data of the RCP8.5 scenario, it was estimated that the amount of precipitation in the Marmara Region will increase in Summer months. In our study, a statistical trend of increase was found for the Göztepe Meteorology Station only.

In the study, the diffraction and starting points of the trend of stations where we found trends were analyzed graphically, as well as using the Pettitt Test. Graphical assessment and the Pettitt Test showed that the Fall precipitation trends in locations Kireçburnu and Kumköy changed in the year 2000. Among the other stations subjected to assessment, the points where trends of increase started for precipitation in Summer was the year 1972 for the Göztepe Meteorology Station, and the year 1996 for the Florya Meteorology Station. It may be seen that the stations located in the south of Istanbul started their trends of increase earlier than those located in the north. It is thought that, besides the atmospheric movements explained above, factors such as differences in land usage, increase in population, etc. were effective in this situation. In looking for the reasons for the changes in precipitation trends, it is necessary to observe air movements, as well as the effects of land usage which may change the climate of the region on a local-scale along with other factors. As opposed to assessment on a global scale, the studies conducted on a local level may set a basis for research that will evaluate the effects of climate change and land usage more effectively. It may be evaluated as a significant hypothesis that the surface temperature increase caused by urbanization and population increase or the heat island effect may lead to any kind of influence by causing a change in the amount of evaporation. The report by the IPCC (2000) was utilized as a source of this hypothesis. A temperature increase of 0.75 °C leads to a 5-6% increase in the humidity held in the atmosphere. The easiest way to test this hypothesis is to observe the trends in precipitation series on a regional-scale along with other factors. Istanbul is city with an increasing population and high urbanization pressure. It is known that new industrial and residential areas have been established in Istanbul and the amount of urban areas have increased (Yuzer and Yuzer, 2014). It was projected that the increased surface temperature led by this change in land usage may lead to a change in the balance between territorial areas and the atmosphere (Pielke, 2005). Additionally, the increasing population and the concept of urbanization may lead to a change in precipitation and temperature dynamics by increasing the amount of greenhouse gasses emitted into the atmosphere (IPCC, 2000). In addition to climate change and changes in land usage increasing the territorial surface temperatures, the possible effects of these on sea water temperatures, pressure differences centered in Europe, and the fluctuations in the Atlantic Ocean may be effective on the diffraction points of the precipitation trends generally in our country, and specifically in the Marmara Region.

5.CONCLUSIONS

In this study, which may be utilized as a basis for other regional climate change studies, whether there were tendencies in trends of seasonal precipitation data was investigated. The Mann-Kendall Test is an important statistical test which may show such precipitation trends. The trends of increase in precipitation in some seasons is a positive development for a city like Istanbul with a rapidly increasing population density. It is known that especially the soil in forest areas is able to hold more water than that of open areas or urbanized areas, and feed the streams in a regular regime (Balci, 1996). This situation helps the optimal utilization of rainfalls without the risk of floods and overflows in forests and the watersheds they are located in. Hence, for effective water management, besides techniques and solutions such as dams and storage areas, vegetation/forest management should also be utilized as a part of water management plans.

REFERENCES (KAYNAKLAR)

- Atalay, I., 2010. Applied Climatology. Meta Publication. Izmir (in Turkish).
- Balci, N., 1996. Soil Conservation. Istanbul University Publishing Center, Istanbul (in Turkish).

- Browning, K.A., 1964. Airflow and precipitation trajectories within severe local storms which travel to the right of the winds. *Journal of the Atmospheric Sciences* 21(6): 634-639.
- Chinchorkar, S.S., Sayyad, F. G., Vaidya, V. B., Pandye, V., 2015. Trend detection in annual maximum temperature and precipitation using the Mann Kendall test–A case study to assess climate change on Anand of central Gujarat. *Mausam* 66(1): 1-6.
- Colasan, U.E., 1960. The Climate of Turkey. TC Ziraat Bank Printing House (in Turkish).
- MEU, 2016. Sixth National Communication of Turkey. Republic of Turkey Ministry of Environment and Urbanization, Directorate General of Environmental Management. AFS Media, Ankara (in Turkish).
- Demircan, M., Demir, O., Atay, H., Eskioglu, O., Tuvan, A., Akcakaya, A., 2014. Climate change projections for Turkey with new scenarios. The Climate Change and Climate Dynamics Conference-2014–CCCD2014. Istanbul. 8–10 September 2014. pp. 8-10.
- Efe, B., Toros, H., Deniz, A., 2015. Temperature and Precipitation Trends for Turkey. 7th Atmospheric Sciences Symposium, Istanbul, 28-30 April 2015, pp. 791-800.
- Erinc, S., 1957. Applied Climatology and Climate of Turkey. ITU Institute of Hydrogeology, Istanbul (in Turkish).
- Feddema, J.J., Oleson, K.W., Bonan, G.B., Mearns, L.O., Buja, L.E., Meehl, G.A., Washington, W.M., 2005. The importance of land-cover change in simulating future climates. *Science* 310(5754): 1674-1678.
- Firat, M., Dikbas, F., Koc, A. C., Gungor, M., 2012. Analysis of temperature series: estimation of missing data and homogeneity test. *Meteorological Applications* 19(4): 397-406.
- Gemmer, M., Becker, S., Jiang, T., 2004. Observed monthly precipitation trends in China 1951–2002. *Theoretical and Applied Climatology* 77(1-2): 39-45.
- IPCC (Intergovernmental Panel on Climate Change), 2000. Land use, land-use change and forestry. Cambridge University Press, Cambridge, U.K.
- Ikiel, C., 2005. Rainfall Regime Regions in Turkey (A Statistical Climate Study). Forest Impact on Hydrological Process and Soil Erosion. October 2005, Yundola, Bulgaria.
- Kalnay, E., Cai, M., 2003. Impact of urbanization and land-use change on climate. *Nature* 423(6939): 528-531.
- Kızılelma, Y., Celik, M. A., Karabulut, M., 2015. Trend analyses of temperature and precipitations in Central Anatolia. *Turkish Geographical Review* 64: 1-10 (in Turkish).
- Kocman, A., 1993. The Climate of Turkey. Ege University, Faculty of Literature Publications, No. 72 (in Turkish).
- Komuscu, A.U., Celik, S., Ceylan, A., 2011. Rainfall analysis of the flood event that occurred in Marmara Region on 8-12 September 2009. *Turkish Journal of Geographical Sciences* 9(2): 209-220 (in Turkish).
- Meinshausen, M., Meinshausen, N., Hare, W., Raper, S.C., Frieler, K., Knutti, R., Frame, D.J., Allen, M.R., 2009. Greenhouse-gas emission targets for limiting global warming to 2 C. *Nature* 458(7242): 1158-1162.
- Olgen, M.K., 2010. Spatial distribution of annual and seasonal rainfall variability over Turkey. *Aegean Geographical Journal* 19(1): 85-95 (in Turkish).
- Pettitt, A.N., 1979, A non-parametric approach to the change-point detection. *Applied Statistics* 28: 126-135.
- Pielke, R.A., 2005. Land use and climate change. *Science* 310(5754): 1625-1626.
- Rustad, L.E., Huntington, T.G., Boone, R.D., 2000. Controls on soil respiration: implications for climate change. *Biogeochemistry* 48(1): 1-6.
- Serrano, A., Mateos, V.L., Garcia, J.A., 1999. Trend analysis of monthly precipitation over the Iberian Peninsula for the period 1921–1995. *Physics and Chemistry of the Earth Part B: Hydrology, Oceans and Atmosphere* 24(1): 85-90.
- Sneyers, R., 1990. On The Statistical Analysis of Series of Observations. WMO Technical Note 143. p. 192. Genova.
- Sutgibi, S., 2015. Variations and trends in temperature, precipitation and stream-flow series in the Buyuk Menderes River Basin. *Marmara Geographical Journal* (31): 398-414 (in Turkish).

Swed, F.S., Eisenhart, C., 1943. Tables for testing randomness of grouping in a sequence of alternatives. *Annals of Mathematical Statistics* (14): 66-87.

Temucin, E., 1990. According to monthly rate of change the types of precipitation regimes in Turkey. *Aegean Geographical Journal* 5(1): 160-183 (in Turkey).

Toros, H., 2012. Spatio-temporal variation of daily extreme temperatures over Turkey. *International Journal of Climatology* 32(7): 1047-1055.

Turkes, M., 2012. Observed and projected climate change, drought and desertification in Turkey. *Ankara University Journal of Environmental Sciences* 4(2): 1-32 (in Turkish).

Van Vuuren, D.P., Edmonds, J., Kainuma, M., Riahi, K., Thomson, A., Hibbard, K., Hurtt, G.C., Kram, T., Krey, V., Lamarque, J.F., Masui, T., Meinshausen, M., Nakicenovic, N., Smith, S.J., Rose, S.K., 2011. The representative concentration pathways: an overview. *Climatic Change* 109: 5-31.

Van Vuuren, D.P., Stehfest, E., den Elzen, M.G., Kram, T., van Vliet, J., Deetman, S., Isaac, M., Goldewijk, K.K., Hof, A., Beltran, A.M., Oostenrijk, R., van Ruijven, B., 2011. RCP2. 6: exploring the possibility to keep global mean temperature increase below 2 C. *Climatic Change* 109(1-2): 95-116.

Wentz, F.J., Ricciardulli, L., Hilburn, K., Mears, C., 2007. How much more rain will global warming bring? *Science* 317(5835): 233-235.

Yuzer, M.A., Yuzer, A.S., 2014. Changes in land-use preferences of small-medium- and large-scale industries located in metropolitan areas (Case study in Istanbul). *European Planning Studies* 22(6): 1127-1142.

Zhang, X., Vincent, L.A., Hogg, W.D., Niitsoo, A., 2000. Temperature and precipitation trends in Canada during the 20th century. *Atmosphere-Ocean* 38(3): 395-429.

Zhang, X., Zwiers, F.W., 2004. Comment on "Applicability of prewhitening to eliminate the influence of serial correlation on the Mann-Kendall test" by Sheng Yue and Chun Yuan Wang. *Water Resources Research* 40(3): 1-5.