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RESEARCH ARTICLE

RAINFALL AND RAINY DAYS TRENDS IN CONTEXT OF CLIMATE CHANGE OVER SAUDI ARABIA : A CASE STUDY OF HA'IL REGION

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ABSTRACT

This study used the recorded daily rainfall, available and monitored during 38 years (from January 1, 1978 to December 31, 2015) in total of 8 rain stations and the meteorology station of Ha'il. The purpose of this study is to analyze the variations and trends of rainfall events through a statistical analysis of data recorded. The analyze the rainfall variability has been processed using the coefficient of variation (CV) and Standardized Analyze Index (SAI) and plotted. While the rainfall trends have been analyzed by three statistically methods widely used: Simple Moving-Average (SMA), Homogeneity of variance (Hartley's $F_{max\text{-}ratio}$) and Semi-averages. The trends analysis of rainfall show that the fluctuations or variations in climatic parameters is a recurring phenomena in the studied stations. Inter-annual variability of rainfall and the cumulative frequency of rainy days are characterized by the high coefficients of variation. In addition, the values of Chi square test reveals the significant Standardized Anomaly Index (SAI) of rainfall. Accordingly, the results contain a total of 18 increasing trends (37.5%) and 30 decreasing trends (62.5%). These results indicate that the aspects of climate change in Ha'il region accelerating in recent decades. This situation may have severe socioeconomic repercussions in many sectors especially the agriculture and surface water resources.

KEYWORDS

Annual rainfall, Daily rainfall, Rainy days, Statistic tests, Ha'il region, Saudi Arabia.

1. INTRODUCTION

Now, the water resource has the prime concern for any future planning and development including flood control, flood protection and sustainable water resources management in Saudi Arabia. The rainfall available is an important factor for determining the availability of water to full file the different demand mainly for agriculture, domestic demand, groundwater, etc. Global climate changes affect the long-term rainfall pattern causes availability of water and may danger of occurrence of serious drought and flood. Global warming affects the rainfall change which influence the stream flow rate, hydrologic cycle, water demand requires review in planning, design and management of hydraulic structures (Nalley, 2012). Changes in run-off and its distribution will depend on likely future climate scenarios. The trend analysis of rainfall and other climatic variables on different spatial scales will help in understanding the future climate scenarios (Ganguly et al., 2015).

Since rainfall and temperatures trends will have significant impact on climate change (Rutkowska, 2013). Consequently, any rise or fall in rainfall has several consequent implications in water resources development projects (Serrano et al., 1998). In the same concept, this study has been attempted to investigate the trend of rainfall for Ha'il area in Northern central part of Saudi Arabia. There are two main variables which are critical in studies of climatic change: rainfall and temperature. So, changes in temperature will impact directly the various hydrological and climatic processes such as rainfall pattern and their sequences (Basistha, et al., 2008).

The trend analysis of rainfall time series includes determination of increasing and decreasing trend and magnitude of trend and its statistical significance by using parametric and non-parametric statistical methods (Jain and Kumar, 2012). Trend analysis in various study shows that there are generally Hartley's F-max, Moving averages, Semi-averages and Straight linear regression methods were used and preferred by various researchers (Machiwal and Jha, 2008; Dong et al., 2020). The main goal of this study is to analyze the rainfall trends as indicators of climate change in Ha'il region, using four rain indicators (Annual rain, Daily maximum rain, Actual average of daily rain, Number of rainy days).

Scientific knowledge and literature relating to the climate and climate change in Saudi Arabia is scattered, incomplete and limited (Hasanean and Almazroui, 2015). The analysis of daily mean, maximum and minimum temperature and daily total rainfall records from a meteorological data collection station in Dhahran, Saudi Arabia over a period of 37 years spanning from 1970 to 2006 indicated a warming trend of the local air and the total annual rainfall values showed almost a constant trend during the reporting period (Rehman, 2010). The climatic datasets from 27 ground observations for the period 1978-2009, showed a significant decreasing trend (47.8 mm per decade) of the observed annual rainfall in the last half of the analyzed period (Almazroui et al., 2012).

The recent studies indicate that Saudi Arabia recorded extreme temperature, and some regions were exposed to the strong rainstorms, also characterized by the extreme daily rain (Abdou, 2014). The detailed features of dry and wet spell durations and rainfall intensity series available (1971-2012) on daily basis for the Jeddah area (Western Saudi Arabia), show trend changes in annual and seasonal analyses confirm that

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the rainy seasons are tending to have more intense rainfall while the seasons are becoming drier (Subyani and Hajjar, 2016). The future trends of temperature and rainfall assessed for several regions in Saudi Arabia showed the increase of temperature and variable pattern of rainfall may increase uncertainty in developing sustainable water resource management strategies (Tarawneh and Chowdhury, 2018). The analysis of extreme rainfall trends indicate that the warming climate of Saudi Arabia is accelerating in recent decades, which may have severe socioeconomic repercussions in many sectors of the country (Almazroui, 2020).

2. MATERIALS AND METHODS

2.1 Study area and Data used

The study area covered a geographical area of about 120000 km², occupying 5% of the Saudi Arabia area. The study area extends from 25°30' to 29° 15' North latitudes and 39°30' to 44°15' East longitudes in the middle part of the Northern Saudi Arabia. It is bordered to the North by the regions of Al-Jawf and the Northern borders, to the East by Al Qasim region and the Eastern Province, to the South by Al Madinah Al Munawwarah region, and to the West by Tabuk region (Figure 1).

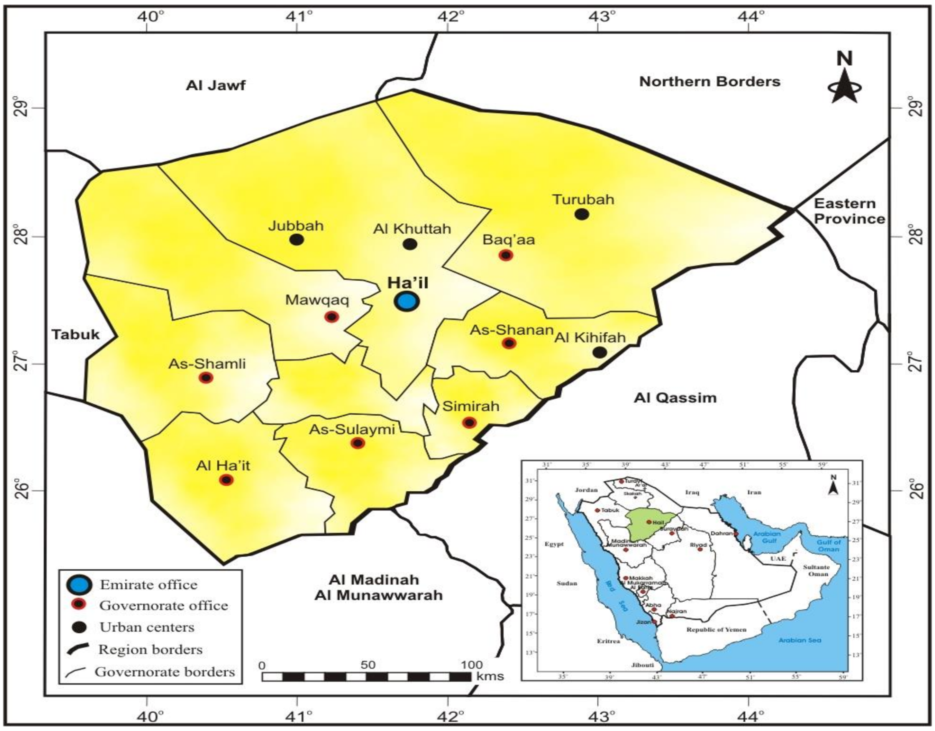


Figure 1: Geographic location of Ha'il region.

Consequently, Ha'il area, is classified under a hot desert climate (BWh) of the Köppen-Geiger climate classification, with hot summers and cool winters. It has a somewhat milder climate than other Saudi cities due to its higher altitude. Geologically, Ha'il province is divided into two main parts: Arabian shield in the west, and the Arabian shelf in the east. The Arabian shield consists of igneous and metamorphic rocks, and the Arabian shelf consists of a different group of sedimentary rocks, and different geological formations deposited in oblique sedimentary layers to East and North-East. Therefore, the thickness of the sediments increases gradually in the same direction. It has a varied relief composed mainly by three major components: Salma and Aja mountains, in the West, Ha'il plain in the middle and East; and Wadi Ad Dayri', which cross the region, from the South west to the North East. In general, Ha'il region is dominated by two air masses, namely, the Polar Continental that occurs from December to February and Tropical Continental that occurs in summer from June to September. Both systems are affected by minor incursions of Polar Maritime and Tropical Maritime air (Fisher and Membery, 1998).

All of the climatic conditions, soil properties and relief topography are clearly contributed to the presence of abundant plant diversity in Hail region. So, the mountainous of Salma and Aja are famous for the widespread of (Dianthus cyri). While the (Haloxylon salicornicum), Calligonum comosum), (Ephedra alata) and (Panicum turgidum) are the main plants of the sand dunes environment. However, (Suaeda) is the most widespread plant clans in the Sabkhas environment. In the plains environment, two major plants clans, namely (Rhanterium epapposum) and (Haloxylon salicornicum) are widely spread. The water courses are also an important environment for a number of plants mainly (Lycium shawii) and (Acacia gerrardii). In addition, the main agricultural activity of Ha'il province is the date production and vegetable cultivation. These two sectors is undergoing considerable development as it is the fundamental resource of several farmers. At the same time, these activities include camels breeding and livestock.

Datasets of rainfall were obtained from 8 rain stations and the meteorological station of Ha'il airport for the period of 1978-2015 (Table 2, 3 and Figure 2).

Table 1: Geographic coordinates of studied rain stations.

Station	Latitude (N)	Longitude (E)	Height (m)	Code	Station No.	Data collection years	Data collection period
Ha'il	27°15'	41°34'	990	101 H	**191**	1978-2015	38
Baq'aa	27°52'	42°23'	755	103 H	**193**	1978-2015	38
Jubbah	28°01'	40°56'	920	106 H	**196**	1978-2015	38
Faydat ibn Suwaylim	27°04'	40°25'	910	108 H	**198**	1978-2015	38
Simirah	26°29'	42°07'	950	105 H	**793**	1978-2015	38
Al Ha'it	25°59'	40°27'	1064	111 H	**797**	1978-2015	38
Al Uqlat	27°06'	41°17'	1215	208 H	508	1978-2015	38
Al Ghazalah	26°47'	41°21'	980	215 H	**812**	1978-2015	38
Ha'il meteorology	27°26'	41°42'	1001.5	40394		1978-2015	38

Table 2: Observed annual rainfall at the studied stations.

Year	1	2	3	4	5	6	7	8
1978	2.0	20.0	28.6	31.0	42.4	22.2	4.3	9.0
1979	131.5	25.8	15.5	102.2	63.6	89.6	2.2	35.6
1980	38.6	31.5	71.0	67.6	31.1	75.0	92.8	19.0
1981	82.0	53.4	98.5	90.2	41.5	90.2	130.6	20.5
1982	212.6	134.8	100.0	76.0	35.0	120.2	157.9	68.8
1983	21.5	43.5	49.5	57.8	26.6	62.2	37.4	14.9
1984	2.0	58.9	189.0	142.8	65.7	202.8	232.6	36.8
1985	101.0	91.7	158.2	105.8	48.7	122.6	97.7	27.3
1986	85.5	105.2	132.5	141.4	65.0	177.2	86.4	36.4
1987	81.6	31.3	14.5	50.2	23.1	36.2	38.0	12.9
1988	92.5	105.2	37.0	45.0	20.7	43.0	45.0	11.6
1989	103.6	70.5	108.5	100.6	46.3	93.8	62.0	25.9
1990	23.7	28.4	25.0	34.6	15.9	52.4	20.8	8.9
1991	119.2	79.9	92.0	126.6	76.9	134.1	98.5	43.1
1992	107.5	35.4	75.5	22.0	15.7	26.4	54.8	8.8
1993	282.8	69.4	113.5	139.7	64.3	27.6	216.2	36.0
1994	179.5	30.5	93.0	78.2	36.0	31.2	95.5	20.1
1995	143.7	38.8	86.0	31.5	14.5	16.6	61.0	8.1
1996	71.0	18.0	113.6	21.0	9.7	59.8	64.1	5.4
1997	158.0	41.7	90.0	51.5	23.7	9.8	127.4	13.3
1998	68.2	26.7	95.0	46.6	21.4	34.6	76.0	12.0
1999	120.0	9.1	40.0	14.2	6.5	40.2	41.5	3.7
2000	64.0	66.0	44.0	85.5	23.0	18.2	3.5	12.9
2001	99.0	62.8	32.0	57.5	9.0	56.4	55.5	5.0
2002	14.2	13.8	49.6	40.5	44.0	30.0	105.0	4.0
2003	7.0	8.4	39.6	23.5	25.0	23.0	30.0	14.0
2004	30.5	16.5	22.0	47.5	24.0	61.0	9.5	30.0
2005	10.0	19.5	15.0	15.0	65.0	45.0	154.5	42.0
2006	37.0	110.5	83.0	11.5	76.0	74.0	125.0	85.0
2007	10.6	10.0	12.9	8.0	12.0	10.0	20.5	23.0
2008	74.5	68.5	82.0	15.0	65.6	64.0	116.5	87.0
2009	90.0	16.5	84.0	32.0	65.5	102.0	127.5	94.0
2010	52.0	53.0	56.5	66.0	13.0	74.0	63.0	27.0
2011	19.5	15.0	30.5	7.0	10.0	6.0	20.5	10.0
2012	6.0	27.5	45.0	42.4	35.0	41.5	7.9	19.6
2013	33.0	20.0	62.0	76.2	63.0	74.7	34.6	35.3
2014	17.0	37.0	60.0	37.5	31.0	36.8	11.0	17.4
2015	28.0	22.0	52.0	41.1	34.0	40.3	22.0	19.0

1- Simirah, 2 – Al Ha’t, 3- Faydat Ibn Suwaylim, 4- Al Ghazalah, 5- Ha’il, 6- Al Uqlah, 7- Baq’aa, 8- Jubbah.

Table 3: Observed rainy days at the studied stations

Year	1	2	3	4	5	6	7	8
1978	1	1	5	10	7	7	1	2
1979	15	1	3	22	9	22	1	5
1980	12	5	13	21	17	20	7	1
1981	10	3	6	10	18	13	9	10
1982	23	8	16	20	38	37	22	3
1983	5	3	4	9	13	13	7	6
1984	1	2	9	16	16	21	12	4
1985	10	7	7	3	21	11	6	7
1986	18	14	10	18	30	19	7	6
1987	19	4	3	8	16	7	4	4

Table 3: Observed rainy days at the studied stations

1988	14	6	3	11	5	5	5	5
1989	18	7	8	24	26	11	5	4
1990	6	1	2	11	14	8	2	5
1991	18	12	7	23	31	28	10	5
1992	13	8	11	15	14	16	7	7
1993	35	17	11	19	22	6	18	1
1994	29	12	10	17	24	4	13	2
1995	20	8	8	4	8	4	6	2
1996	22	10	9	3	10	17	8	9
1997	28	9	15	23	15	2	12	2
1998	11	8	8	10	9	20	5	3
1999	8	2	5	5	5	15	1	2
2000	6	8	5	7	6	3	7	2
2001	9	11	5	8	2	3	8	1
2002	5	6	6	8	6	1	10	1
2003	3	2	7	5	4	4	8	3
2004	9	2	3	9	3	3	4	4
2005	2	4	2	1	10	2	10	6
2006	7	9	5	2	11	7	15	2
2007	2	1	2	1	2	1	5	7
2008	10	12	4	2	7	7	15	9
2009	11	9	5	5	12	11	18	5
2010	8	7	7	7	2	6	13	3
2011	5	4	4	1	3	4	11	3
2012	2	6	4	4	8	7	6	6
2013	5	9	6	4	6	4	17	7
2014	8	31	8	3	6	1	24	5
2015	8	8	6	3	4	5	9	2

1- Simirah, 2 – Al Ha’t, 3- Faydat Ibn Suwaylim, 4- Al Ghazalah, 5- Ha’il, 6- Al Uqlah, 7- Baq’aa, 8- Jubbah.

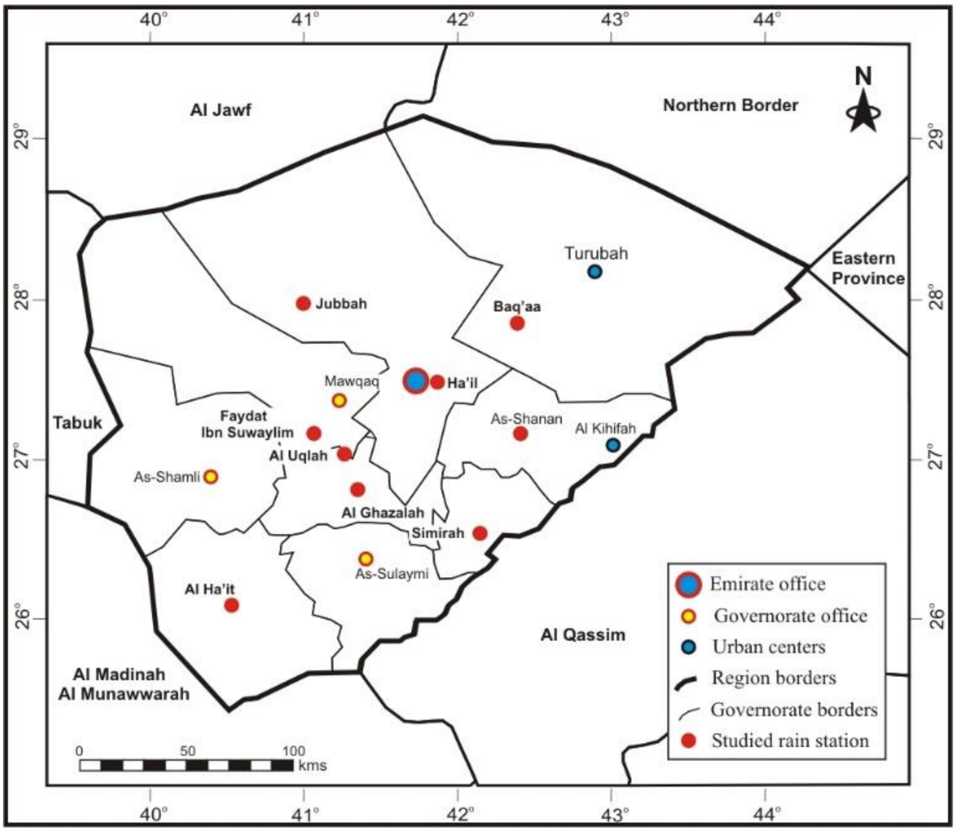


Figure 2: Geographic location of studied stations.

2.2 Rainfallnd Temperature variability

2.2.1 Coefficient of variation (CV)

The coefficient of variation (CV) determines the variability of the rainfall or temperature in specific region. A high value of (CV) indicates that the rainfall or temperature variability is greater, where a lower value means the opposite. The (CV) is computed by the following equation :

$$CV = \frac{\sigma}{\mu}$$

Where (σ) is the standard deviation and (μ) is the mean of chosen temporal scale. (CV) is used to classify the degree of variability events into three categories : (Asfaw et al., 2018).

- Low CV (less than 20%)

- Moderate CV (from 20% to 30%).

- High CV (Above 30%).

2.2.2 Standardized Anomaly Index (SAI)

The Standardized Anomaly Index (SAI) was introduced by E.B. Kraus in the mid-1970s and was examined closely by Katz and Glantz at the National Center for Atmospheric Research, United States, in the early 1980s. SAI was developed for identifying drought events, especially in areas frequented by drought. The SAI can be computed by applying the follow equation :

$$SAI = \frac{X_i - X'}{Sd}$$

Where, (X_i) is the annual rainfall of the particular year, (X') is the long-term mean annual rainfall over a period of observation and (Sd) is the standard deviation of annual rainfall over that period of observation. So, positive value suggest a time of wet situation relative to the period of reference chosen, while the negative value ones imply a drought condition (Table 4).

Table 4: SAI values classification (McKee et al., 1993).

SAI value	Category
Above 2.0	Extremely wet
1.5 – 1.99	Very wet
1.0 – 1.49	Moderately wet
(-0.99) – 0.99	Near normal
(-0.1) – (-1.49)	Moderately dry
(-1.50) – (-1.99)	Severely dry
(-2) or less	Extremely dry

2.3 Rainfall trend analysis

2.3.1 Simple Moving Averages (SMA) method

The formula for Simple Moving Average is written as follows:

$SMA = (A_1 + A_2 + \ldots\ldots\ldots A_n) / n$

Where A is the average in period n; and **n** is the number of periods.

2.3.2 Homogeneity of variance test

Hartley proposed a homogeneity of variances test which is based on a F_{max} statistic used the ratio of the largest variance to the smallest variance (Hartley, 1950). The exact distribution of Hartley's F-max statistic is known under homogeneity of variances with equal sample sizes and Hartley has given a table of the upper 5 % points of this statistic. David gave corrections to this table (David, 1952).

This is one of the most popular statistics for comparing the semi averages. In this paper, Hartley's F_{max} statistic for testing the homogeneity of variances used the equal sample sizes for 19 years; with the first part (1978-1996) and the second part (1997-2015) of the time-series. Hartley's F_{max} statistic is not robust when the underlying distribution is not normal or unequal sample sizes (Conover et al., 1981; Rivest, 1986). However, the reasons for using F_{max} statistic are as follows. Firstly, the rain data recorded during a continuous and common time series (38 years) available at every studied station. Secondly, the rainfall data is in general, normally distributed. Thirdly, Hartley's statistic is still easy to compute using an equal sample sizes (Gupta, 1987 ; Chu and Sutradhar, 1995). Fourthly, also with the increase of usage and availability of several computer software, it is easier to apply F_{max} ratio with a high accuracy. To apply F_{max} method, the time-series were divided into two equal parts with respect to time. However, the dataset is homogeneous if the computed F_{max} value is smaller than the critical F_{max} value at the level 0.05 and degree of freedom [d.f = n – 1].

2.3.3 Semi-averages method

To apply the semi-averages method, the time-series were divided into two equal parts with respect to time. And then we compute the arithmetic mean of the two parts. The trend values can then be read from the ratio between the semi-averages of the first and the second parts (X_1', X_2') of every period (T_1, T_2). So, the ratio value greater than 1 indicates the increasing trend and the ratio value less than 1 represents the decreasing trend. The trend indicator "b" was defined as the ratio of the difference between the semi-averages and the difference between the middle of the two parts, expressed as follows:

$$b = \frac{X'_2 - X'_1}{T_2 - T_1}$$

Where, X'_1 and X'_2 are the semi-averages of the first and the second parts (T_1, T_2) the middle of every part. The estimated straight trend line passes through the two points (X'_1, X_2'). The level significance of trend can be determined by comparison between the difference of the semi-averages ($X'_2 - X'_1$) and the standard error (SE), expressed as follows:

$$S.E|X'_1 - X'_2| = \left[\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}\right]^{0.5}$$

Where, (σ_1^2 , n_1) are the variance and the number of time units (years) covered by the first part; (σ_2^2 , n_2) are the variance and the number of time units (years) covered by the second part. So, the T-student test can be computed using the following equation:

$$t = \frac{|X'_1 - X'_2|}{\left[\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}\right]^{0.5}}$$

However, the trend is significant at the level 0.05 and degree of freedom [d.f = (n_1+n_2) – 2], if : (Gregory, 1970 ; Oliver, 1981).

a- The computed T-student value is greater the critical T value b- The absolute difference IX'_1 – X'_2I > 2 SE or 3 SE, at the same level 0.05 and degree of freedom.

3. Results and Discussion

3.1 Annual rainfall variability

The variability of annual and daily rainfall is analyzed using two statistical parameters; coefficient of variation (CV) and standardized anomaly index (SAI).

3.2 Coefficient of variation (CV)

The mean annual rainfall varies from 26.4 mm in Jubbah station to 74.2 mm in Simirah station. But, the annual rainfall is ranged for extremely dry years from 2.0 mm (1978) at Simirah to 12.9 mm (2007) at Faydat Ibn Suwaylim. However, it is ranging for relatively rainy years from 76.9 mm (1991) at Ha'il to 282.8 mm (1993) at Simirah. Interannual variability of rainfall is characterized by the high coefficients of variation, from 0.59 at Ha'il to 0.87 at Jubbah. So, the range of annual rainfall varies from 70.4 mm to 280.8 mm at Ha'il and Simirah, respectively (Table 5 & Figure 3).

In the same context, the cumulative frequency of rainy days during the period of 1978-2015 (38 years) shows that the maximum is observed with 460 days at Ha'il and the minimum with 161 days at Jubbah (Table 7 & Figure 4). Consequently, the of rainy days varies from 5 days/year at Jubbah to 13 days/year at Ha'il. But during the extremely dry years, the total of rainy days don't exceed 2 days/year. However, during the relatively rainy years, the total of rainy days is ranging from 10 to 38 days/year at Jubbah and Ha'il, respectively. So, the actual mean of daily rainfall obtained by the proportion of the cumul of annual rainfall and the cumulative frequency of rainy days during the studied period varies from 4.1 to 10.5 mm/day at Ha'il and Faydat Ibn Suwaylim, respectively. But the maximum of daily rainfall increases from 10.5 mm/day (2013) to 42.5 mm/day (2006) and the difference between the upper and lower mean varies from 9.6 to 41.9 mm/day at Ha'il and Jubbah, respectively.

So the actual mean of daily rainfall is characterized by the high coefficients of variation, with 0.44 to 1.11 at Faydat Ibn Suwaylim and Jubbah, respectively (Table 5 & Figure 5). Accordingly to the variability of daily rainfall, the maximum daily rainfall observed during the studied period, varies from 11.4 to 25.2 mm/day at Jubbah and Al Ha'it, respectively (Table 5 & Figure 6). Consequently, the range values show that the maximum is observed with 73.5 mm/day at Faydat Ibn Suwaylim and the minimum with 30.9 mm/day at Ha'il. So, the variability of maximum daily rainfall is characterized by the high coefficients of variation, ranged between 0.47 at Al Hait to 0.71 at Jubbah.

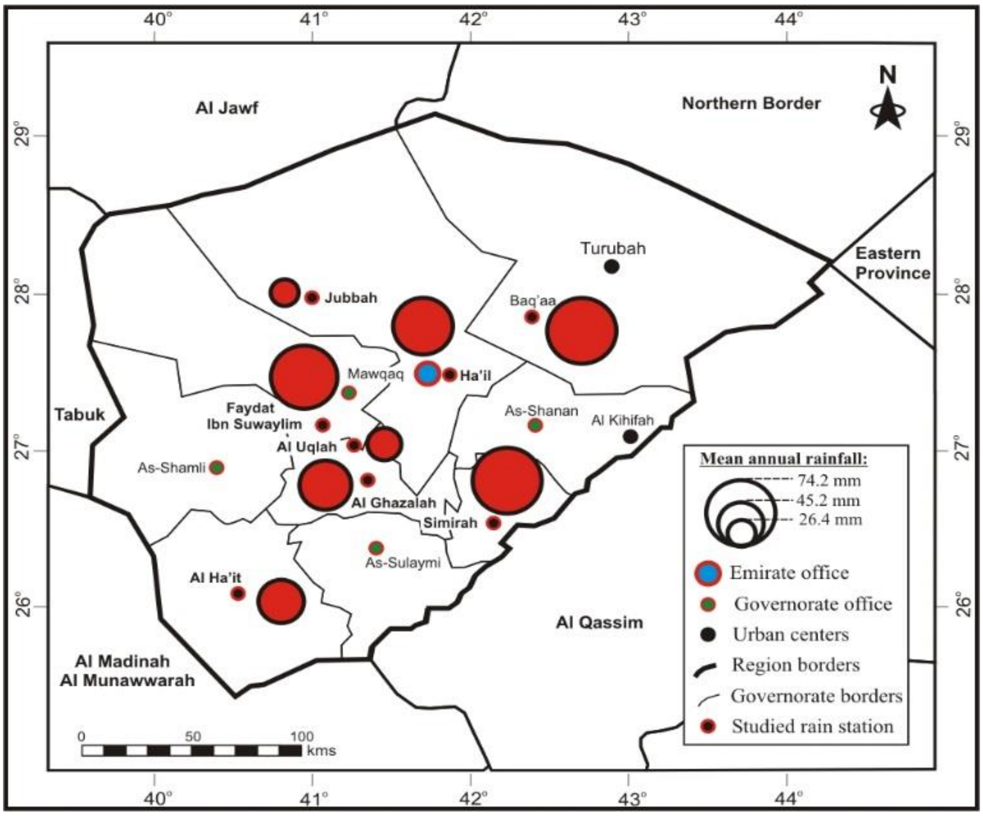


Figure 3: Spatial distribution of mean annual rainfall

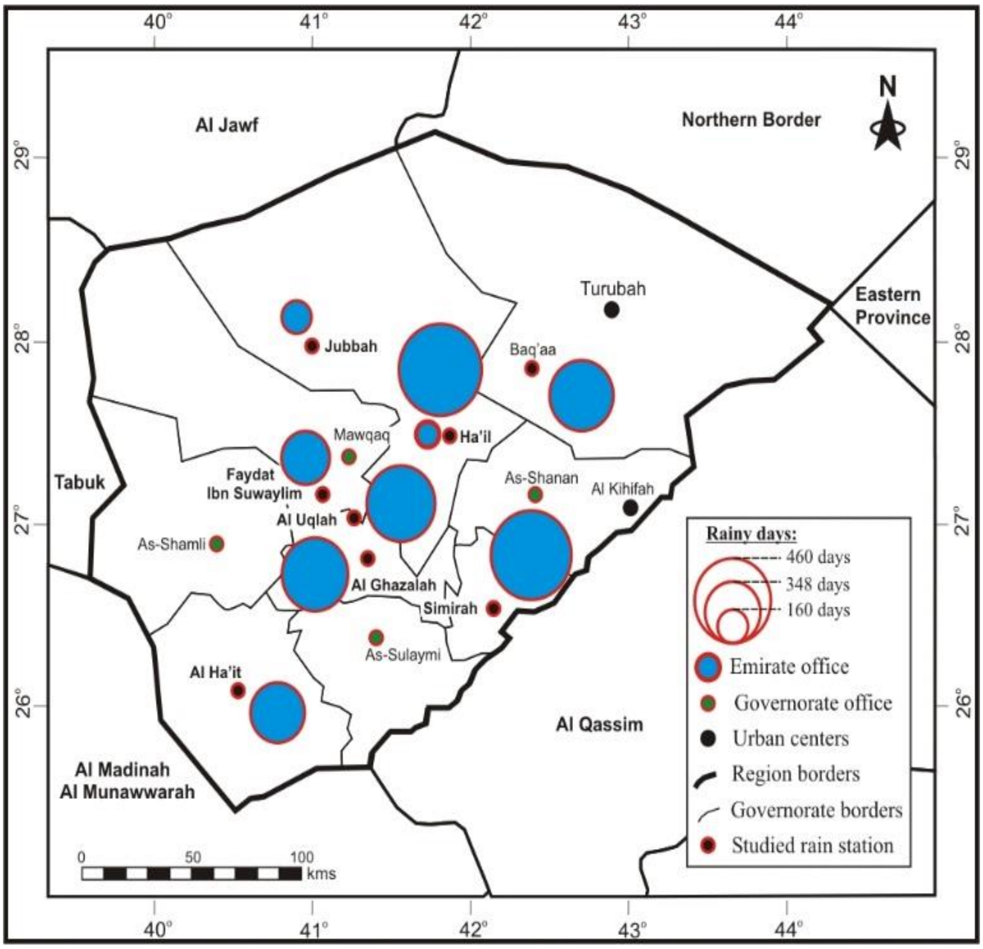


Figure 4: Spatial distribution of cumulative rainy days

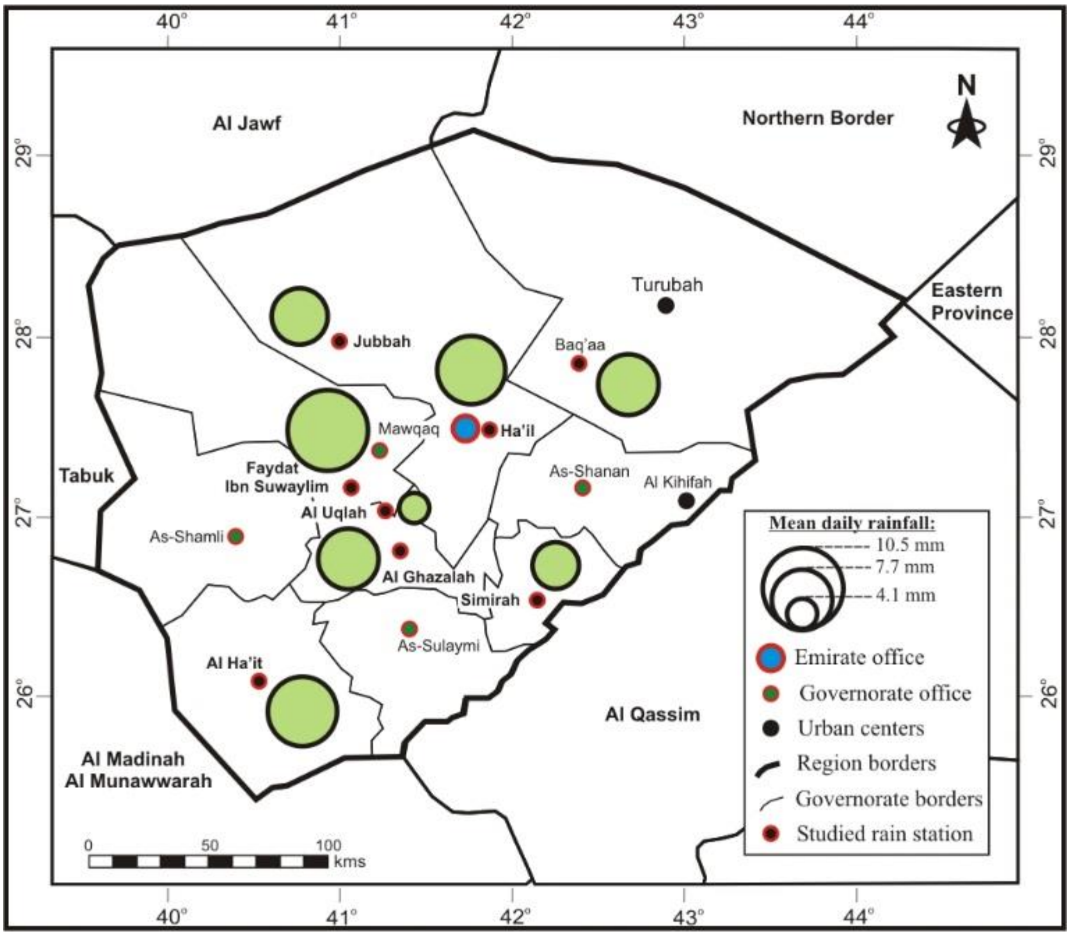


Figure 5: Spatial distribution of mean daily rainfall

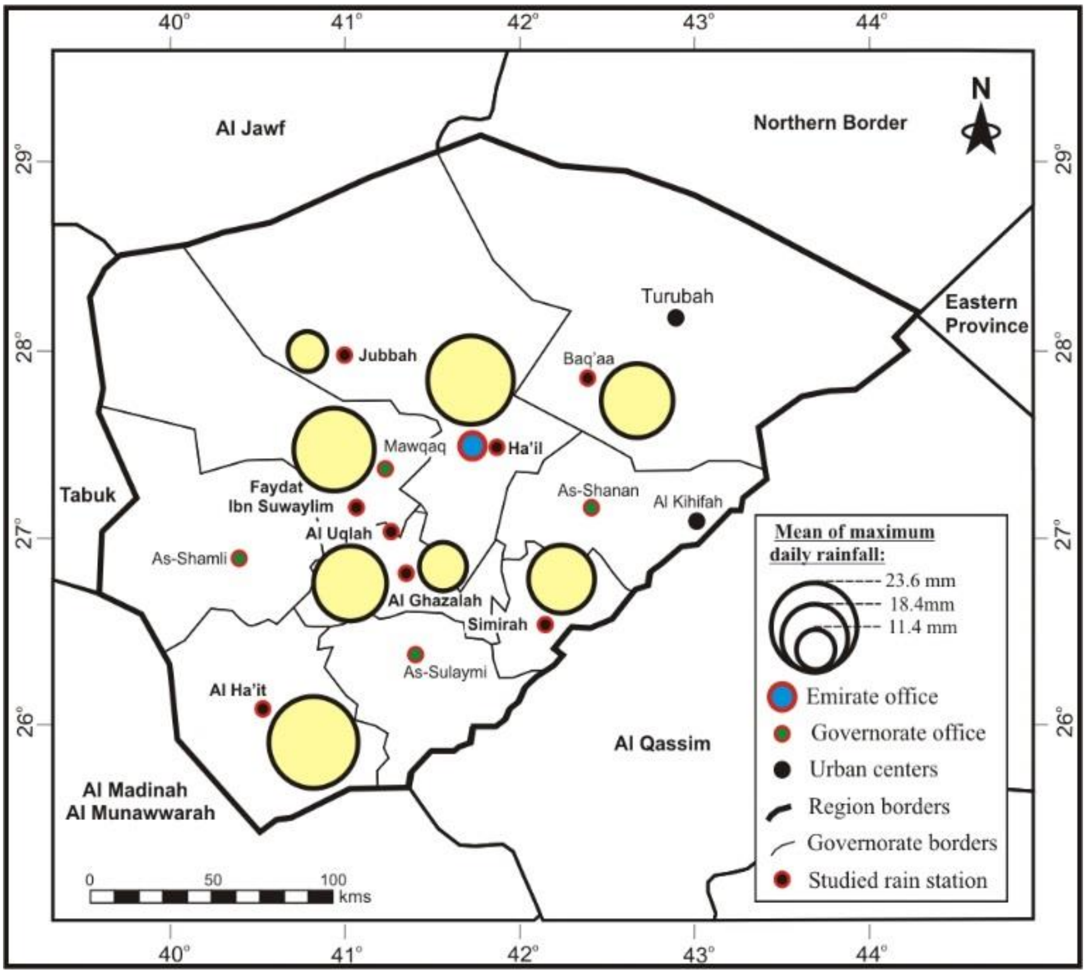


Figure 6: Spatial distribution of mean maximum daily rainfall

Table 5: Averages of annual and daily rainfall for 1978-2015 at studied stations.

Variables		Simirah	Al Ha'it	Faydat Ibn Suwaylim	Al Ghazalah	Ha'il	Al Uqlah	Baq'aa	Jubbah
Mean annual Rainfall (mm)	**X'**	74.2	45.2	68.3	57.4	36.6	61.2	72.3	26.4
	Sd	63.5	32.2	41.2	38.8	21.4	44.8	57.7	22.9
	Max	282.8	134.8	189.0	142.8	76.9	202.8	232.6	94.0
	Min	2.0	8.4	12.9	7.0	6.5	6.0	2.2	3.7
	Range	280.8	126.4	176.1	135.8	70.4	196.8	230.4	90.3
	CV	0.86	0.71	0.60	0.68	0.59	0.73	0.80	0.87
Rainy days	**X'**	11	7	7	10	12	10	9	4
	Sd	8	6	3	7	9	8	6	2
	Max	35	31	16	24	38	37	24	10
	Min	1	1	2	1	2	1	1	1
	Range	34	30	14	23	36	36	23	9
	CV	0.72	0.77	0.52	0.74	0.74	0.84	0.61	0.57
Mean daily Rainfall (mm)	**X'**	6.0	8.9	10.5	7.7	4.1	9.1	8.9	8.1
	Sd	2.9	7.5	4.6	5.9	2.7	7.8	7.3	8.9
	Max	15.0	29.5	22.6	35.3	10.5	36.8	41.5	42.5
	Min	2.0	1.2	4.8	1.5	0.9	1.5	0.5	0.6
	Range	13.0	28.3	17.8	33.8	9.6	35.3	41.0	41.9
	CV	0.49	0.84	0.44	0.77	0.65	0.85	0.81	1.11
Maximum daily rainfall (mm)	**X'**	18.4	25.2	22.7	20.6	11.8	23.6	20.4	11.4
	Sd	12.6	11.8	13.6	13.3	7.5	13.8	12.6	8.1
	Max	53.0	53.4	81.0	56.0	34.0	61.6	53.8	35.3
	Min	2.0	7.2	7.5	6.5	3.1	4.0	2.2	2.1
	Range	51.0	46.2	73.5	49.5	30.9	57.6	51.6	33.2
	CV	0.68	0.47	0.60	0.65	0.64	0.59	0.62	0.71

3.3 Standardized Anomaly Index (SAI) of rainfall

Positive values that suggest wet years relative to the period of reference increase from 14 years at Al Hait and Jubbah, 15 years at Ha'il, 16 years at Al Ghzalah, Al Uqlah and Baq'aa to 18 years at Simirah and Faydat Ibn Suwaylim. While the negative ones imply a drought condition during the dry years vary from a station to another with the maximum of 24 years at Al Hait and Jubbah to the minimum of 20 years at Simirah and Faydat Ibn Suwaylim. SAI value classification is presented in Table 6.

Table 6: Distribution of SAI positive and negative at the studied stations.

Station	SAI positive	%	SAI negative	%
Simirah	18	47.4	20	52.6
Al Hait	14	36.8	24	63.2
Faydat Ibn Suwaylim	18	47.4	20	52.6
Al Ghazalah	16	42.1	22	57.9
Ha'il	15	39.5	23	60.5
Al Uqlah	16	42.1	22	57.9
Baq'aa	16	42.1	22	57.9
Jubbah	14	36.8	24	63.2

To analyze the statistical significance of the SAI variance, the Chi square test was computed. The Chi square values are presented in Table 7. The test Chi square distribution has been used for detecting the statistical significance of the SAI variance. The null hypothesis indicating that the variance data don't have any outliers is accepted if the computed value of Chi square test is greater than the critical value at 0.05 significance level corresponding to the degree of freedom (n - 1). While the null hypothesis is rejected and the alternative hypothesis is accepted on the contrary case. So, from the table 8, the Chi square values are smaller than the critical values at 0.05 significance level and at the different degrees of freedom.

Table 7: Chi square test of SAI variance at the studied stations.

Station	Xc2	df	N	Xt2	H = 0
Simirah	5.158	4	5	9.488	Rejected
Al Hait	6.211	4	5	9.488	Rejected
Faydat Ibn Suwaylim	5.292	5	6	11.040	Rejected
Al Ghazalah	5.927	5	6	11.040	Rejected
Ha'il	4.657	5	6	11.040	Rejected
Al Uqlah	3.705	5	6	11.040	Rejected
Baq'aa	4.022	5	6	11.040	Rejected
Jubbah	3.842	4	5	9.488	Rejected

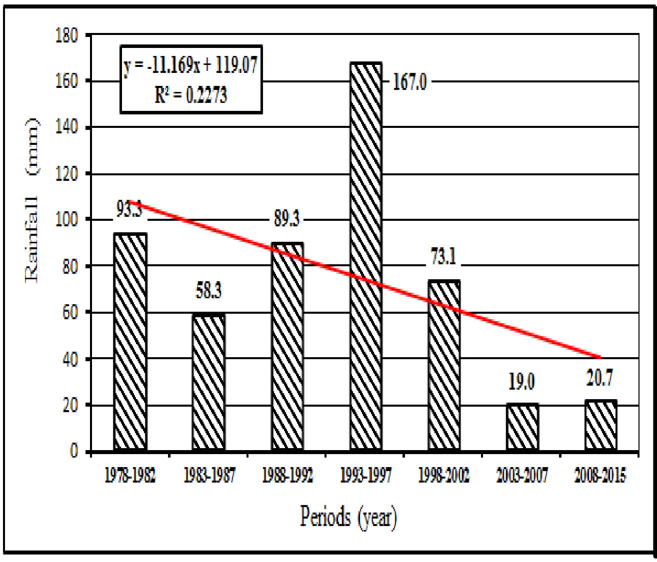
3.4 Trends analysis of annual rainfall

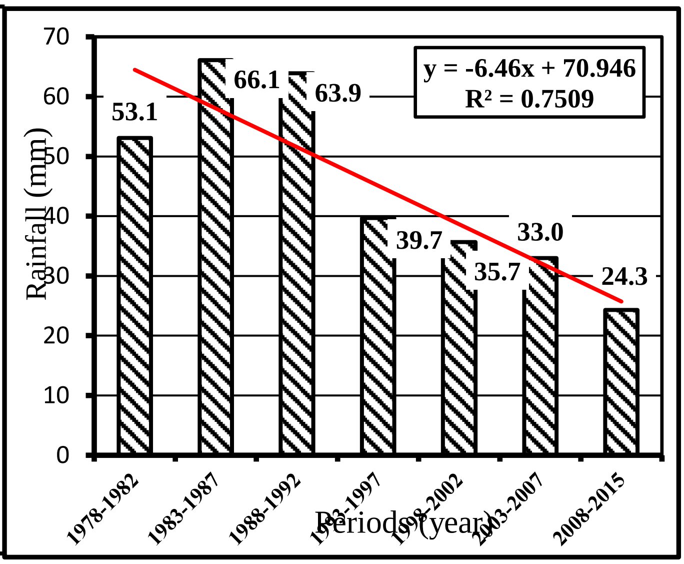
3.4.1 Moving-averages of annual rainfall

The analysis of the annual rainfall for 1978-2015, indicates downward trend with a decrease ranged from 4 mm to 167 mm in 38 years at Jubbah and Simirah, respectively. So, a decreasing annual mean varies from 0.1 mm/year at Jubbah to 1.8 mm/year at Simirah. Accordingly, the decreasing trends of annual rainfall were analyzed using the Moving averages method. So, the time-series of dataset was divided into seven periods: 1978-82, 1983-87, 1988-92, 1993-97, 1998-2002, 2003-2015. The table 8 and figure 7 present the moving-averages of the named periods. The table 10 shows a contrast of temporal and spatial distributions of the increasing and decreasing trends. So, that there is no homogeneous trends characterizing the same period at all station. But, in general, the results contain a total of 18 increasing trends (37.5%) and 30 decreasing trends (62.5%). From these various trends, it is clear the difficulties to determine the main trend of annual rainfall in all stations using the moving-average method. However, the semi-averages method was applied to analyze the annual rainfall trends.

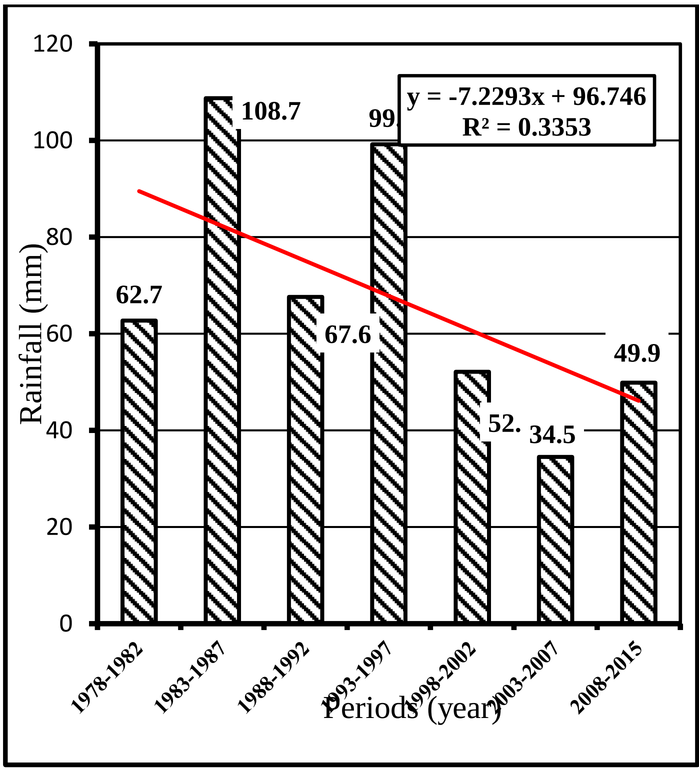
Table 8: The moving-averages at the studied rain stations.

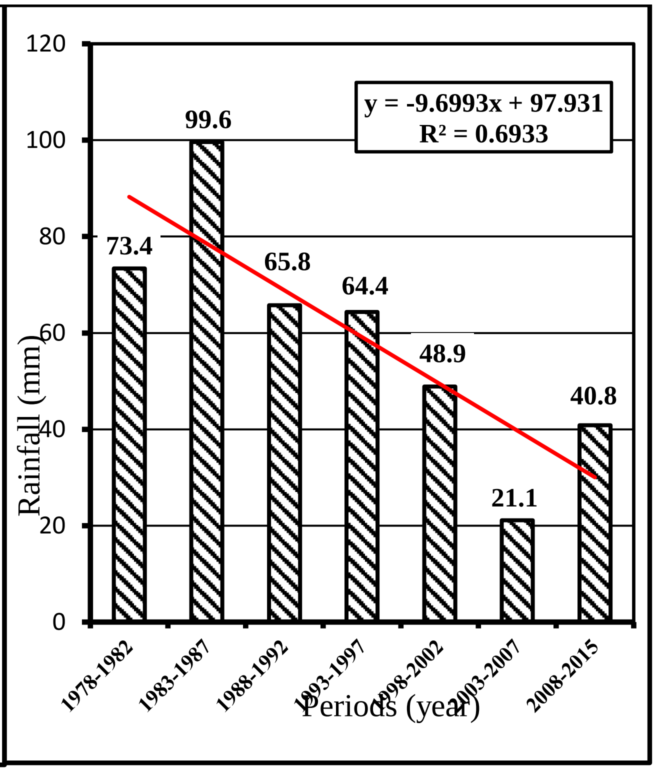
Station	1978-1982	1983-1987	1988-1992	1993-1997	1998-2002	2003-2007	2008-2015
Simirah	93.3	58.3	89.3	167.0	73.1	19.0	20.7
Al Ha'it	53.1	66.1	63.9	39.7	35.7	33.0	24.3
Faydat Ibn Suwaylim	62.7	108.7	67.6	99.2	52.1	34.5	49.9
Al Ghazalah	73.4	99.6	65.8	64.4	48.9	21.1	40.8
Ha'il	42.7	45.8	35.1	29.6	20.8	40.4	34.6
Uqlat Ibn Jibrin	79.4	120.2	69.9	29.0	35.9	42.6	39.9
Baq'aa	77.6	98.4	56.2	112.8	56.3	67.9	19.2
Jubbah	30.6	25.7	19.7	16.6	7.5	38.8	20.3



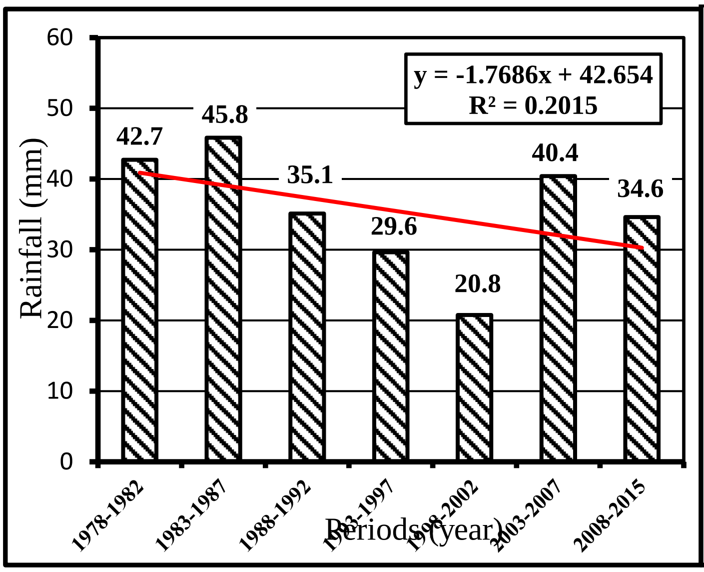


A : Simirah. **B : Al Hait.**

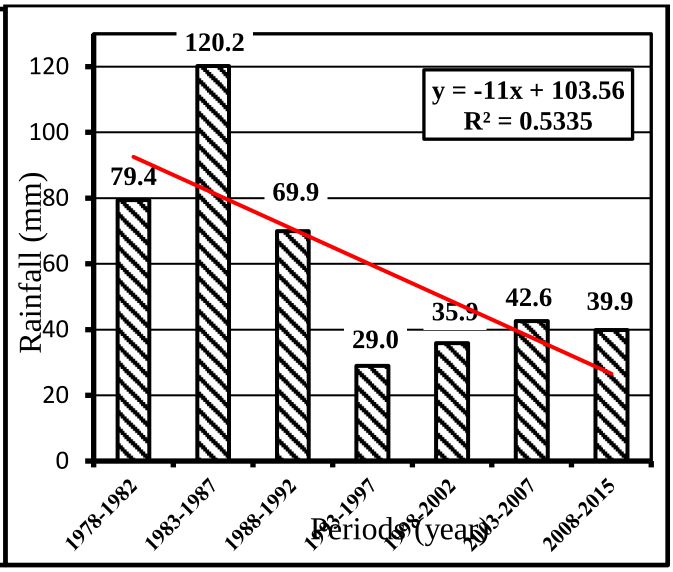




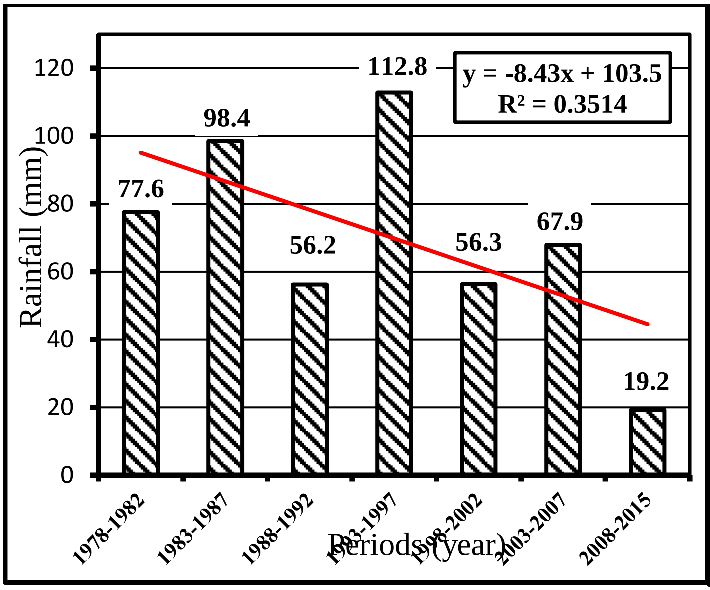
C : Faydat Ibn Suwaylim. **D : Al Ghazalah.**



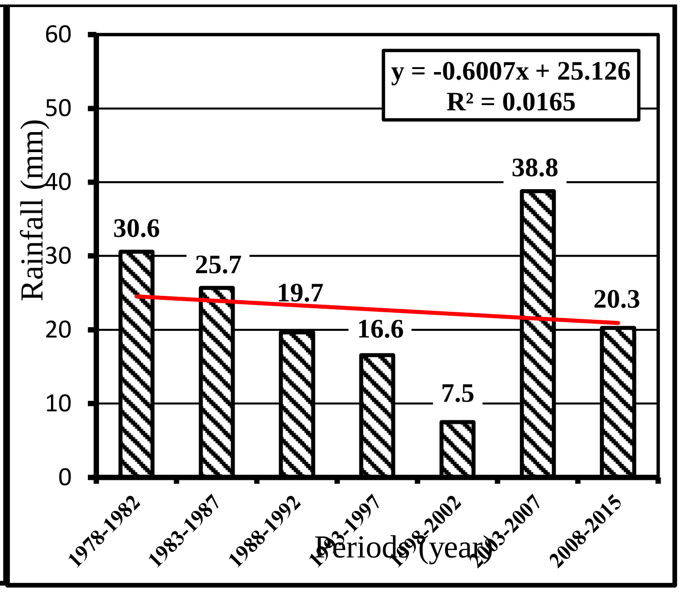
E : Ha'il.



F : Al Uqlah.



G : Baq'aa.



H : Jubbah.

Figure 7: Moving averages of annual rainfall.

3.4.2 Homogeneity of variance of annual rainfall

The variance is homogeneous if the calculated F_{cmax} value is small than the critical F_{tmax} value at the degree of freedom (n-1) and significance level 0.05. It is clear from the data of table 9 that the calculated F_{max} values are greater than the critical F_{max} value 2.46 at the statistical significance level 0.05 and the degree of freedom 18. The results of this test indicate that the variance is homogeneous at all stations, except at Baq'aa station.

Table 9: Results of F_{max}-Hartley's test for annual rainfall.

Station	S_1^2	S_2^2	F_{max-c}	F_{max-t}	Variance
Simirah	5137.2	1847.2	2.781	2.46	Not homogeneous
Al Hait	5998.8	1864.3	3.218	2.46	Not homogeneous
Faydat Ibn Suwaylim	2368.8	675.4	3.507	2.46	Not homogeneous
Al ghazalah	1745.0	482.3	3.618	2.46	Not homogeneous
Ha'il	1022.0	3127.7	3.060	2.46	Not homogeneous
Al Uqlah	2853.3	719.6	3.965	2.46	Not homogeneous
Baq'aa	4050.7	2849.2	1.422	2.46	Homogeneous
Jubbah	256.3	830.0	3.239	2.46	Not homogeneous

3.4.3 Semi-averages of annual rainfall

Trend analysis of a series of observed annual rainfall using the semi-averages method can indicate if the rainfall pattern and distribution is changing in due course of time or remains stable (Borse and Agnihorti, 2017). Various researchers have contributed to the study of climate change over Saudi Arabia using rainfall and temperature trends. So, the analysis of different time series data have proved that rainfall trend is decreasing and temperature trend is increasing (AlSarmi and Washington, 2013). The rainfall and temperature have a direct impact on the scarcity of the surface water resources over Saudi Arabia (Amin et al., 2016).

In general, some measures of central tendency (mean, mode, median); measures of position (location) (Q_1, Q_1, Q_3); and measures of dispersion (Sd, IQR, Range, …) are used to describe the amount or rate of the variability of meteorological events. In this study, the whole data of rainfall is divided into equals periods (parts) : (1978-1996) and (1997-2015). After the data has been divided an average (arithmetic mean) of each part is calculated in order to obtain 2 points. On the graphic of rainfall distribution, every point is plotted against the middle of each part. Then, the straight line joining these 2 points gives the trend line. So, the table 10 and figure 8 summarize the annual rainfall trends using the semi-averages method.

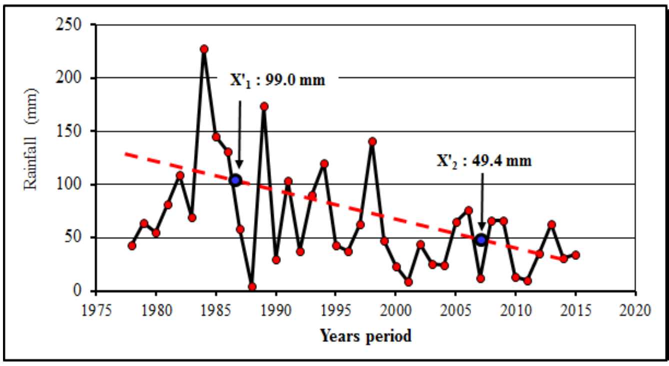
Table 10: Statistical parameters of semi-averages of annual rainfall at the studied stations.

Statistical parameters	Simirah	Al Ha'it	Faydat Ibn Suwaylim	Al Ghazalah	Ha'il	Al Uqlah	Baq'aa	Jubbah
X'1	99.0	112.2	84.7	77.1	78.1	85.4	84.1	22.5
X'2	49.4	60.7	50.9	32.2	42.8	44.5	81.4	32.7
T'1	1987	1987	1987	1987	1987	1987	1987	1987
T'2	2006	2006	2006	2006	2006	2006	2006	2006
b	-2.611	-2.711	-1.779	-2.363	-1.858	-2.153	-0.142	0.537
SE	19.2	20.3	12.7	10.8	14.8	13.7	19.1	7.6
2SE	38.3	40.7	25.3	21.7	29.6	27.4	38.1	15.1
IX1'-X2'I	49.6	51.5	33.8	44.9	35.3	40.9	2.7	10.2
T-student	2.587	2.532	2.670	4.147	2.389	2.983	0.142	1.349
df	36	36	36	36	36	36	36	36
Tt0.05	1.688	1.688	1.688	1.688	1.688	1.688	1.688	1.688
H=0	Rejected	Rejected	Rejected	Rejected	Rejected	Rejected	Accepted	Accepted

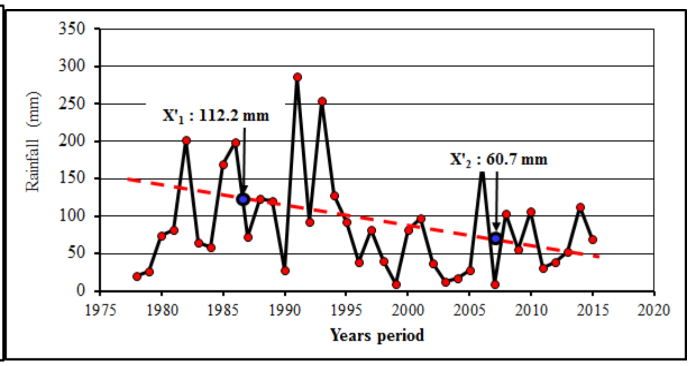
Table 10 and figure 8 represent the annual rainfall trends using the semi-averages of rain (X_1,X_2) were calculated for each half period (n_1,n_2) and the slope estimator (b) of the trend line. The line trend joins the two points of semi-averages.

From the data of Table 12, we find that the annual rainfall amounts have decreasing rain trends in all stations, except Jubbah. It was found that all trends had simple negative regression values ranged between (-2.711) in Al Hait and (-0.142) in the Baq'aa, while it reached 0.537 in Jubbah. The statistical significance was determined using the standard error method S.E|X'_1-X'_2| for the two semi-averages. There are statistically significant differences between the two semi-averages in all stations, at the 5% significance level, except Baqa'a and Jubbah stations. So that, all the differences between them were greater than twice the standard error. These differences are statistically significant because the probability of their occurrence exceeds 5%. For the difference to be statistically significant and therefore substantial and real, it is required that it exceed (2S.E) or (3S.E). Otherwise it is considered statistically insignificant and rejected (Gregory, 1970; Crowe, 1971). Accordingly, all the rain trends represented the regression lines between the negative semi-averages are statistically significant. But, the increasing trend in the Jubbah station is considered to be due to the randomness of the annual rainfall system.

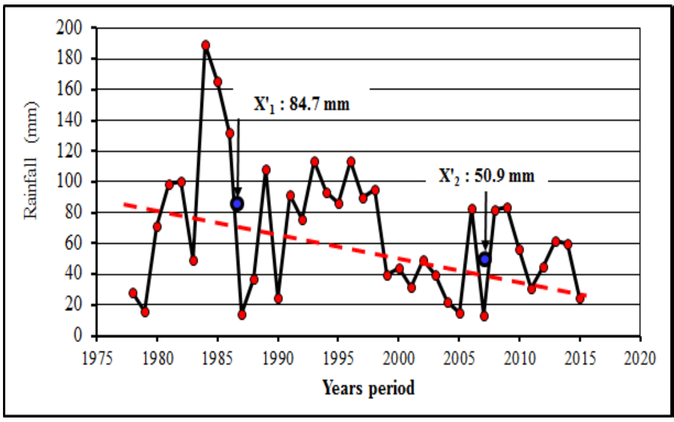
Student's t-statistic test of the difference between the semi-averages also confirmed these results. From the data of Table 10, we find that the calculated “t” values are greater than the critical “t” value (1.688) at the significance level 0.05, at the degree of freedom (n-2) 36 in all stations except Baq’aa and Jubbah.



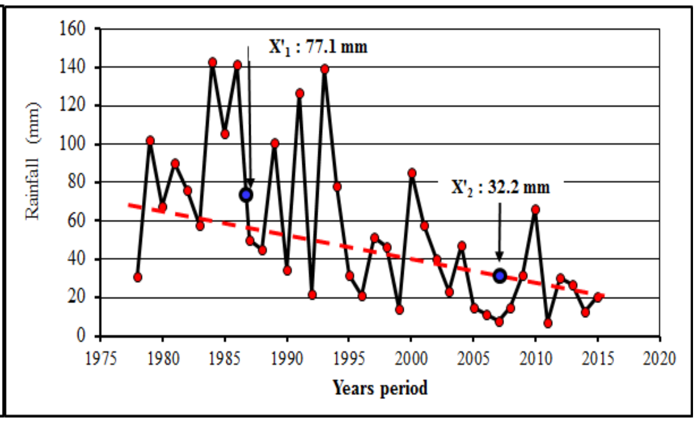
A : Simirah



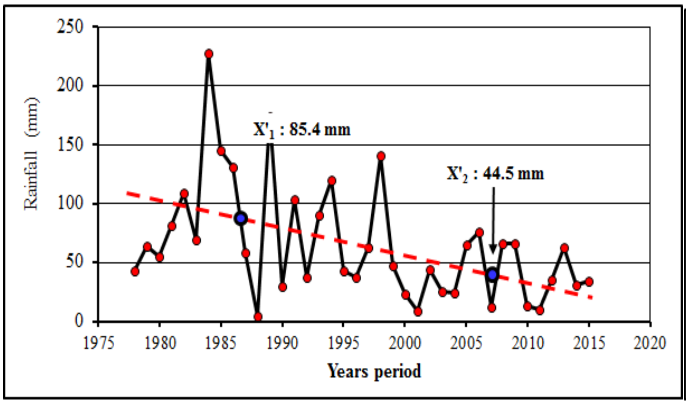
B : Al Hait



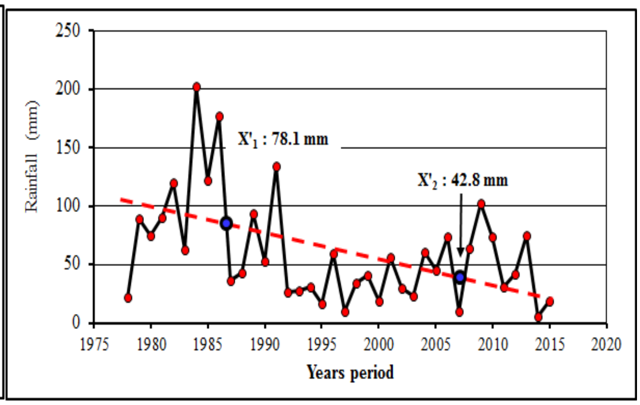
C : Faydat Ibn Suwaylim



D : Al Ghazalah



E : Ha'il



F : Al Uqlah

So, the difference between the semi-averages of annual rainfall can to be significant, if the calculated "t" value is greater than the critical "t" value at the significance level of 0.05 and the degree of freedom at the station. Accordingly, the decreasing rain trends are significant and can be relied upon in analyzing the temporal and spatial changes of annual rainfall in Hail region, except the rain trends in Baq'aa and Jubbah stations**.**

4. Conclusions

Ha'il region is susceptible to climate variability and change like various regions in Saudi Arabia. the trends analysis of annual rainfall show that the fluctuations or variations in climatic parameters is a recurring phenomena in the studied stations. The effects of climate variability exacerbate existing social and economic activities, because people are sensitive to climate variability. Rainfall is the most determinant climatic parameters in the arid zones such as Ha'il region. The present study used the rainfall of the meteorological data and the time series for the period (1978-2015), to conducting descriptive statistics and trend analysis.

The variability analysis, is conducted using the coefficient of variation **(CV).** The range of annual rainfall varies from 70.4 mm to 280.8 mm at Ha'il and Simirah, respectively. Inter-annual variability of rainfall is characterized by the high coefficients of variation, from 0.59 at Ha'il to 0.87 at Jubbah. In the same context, the cumulative frequency of rainy days during the period of 1978-2015 (38 years) shows that the maximum is observed with 460 days at Ha'il and the minimum with 161 days at Jubbah. Consequently, the rainy days varies from 5 days/year at Jubbah to 13 days/year at Ha'il. So the actual mean of daily rainfall is characterized by the high coefficients of variation, with 0.44 to 1.11 at Faydat Ibn Suwaylim and Jubbah, respectively. In addition, the values of Chi square test reveals the significant Standardized Anomaly Index (SAI) of rainfall.

The trend analysis of rainfall, using Moving-averages indicates downward trend with a decrease ranged from 4 mm to 167 mm in 38 years at Jubbah and Simirah, respectively. A decreasing annual mean varies from 0.1 mm/year at Jubbah to 1.8 mm/year at Simirah. Accordingly, the results contain a total of 18 increasing trends (37.5%) and 30 decreasing trends (62.5%). In the same context, The Homogeneity of variance using Fmax-Hartley's ratio indicates the homogeneous variance with the calculated F_{max} values greater than the critical F_{max} value 2.46 at the statistical significance level 0.05 and the degree of freedom 18 in all stations, except at Baq'aa station**.** The results of the Semi-averages method also show a significant decreasing trends in all stations, except Jubbah. It was found that all trends had simple negative regression values ranged between (-2.711) in Al Hait and (-0.142) in the Baq'aa, while it reached 0.537 in Jubbah.

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