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TEMPERATURES TRENDS ANALYSIS IN CONTEXT OF CLIMATE CHANGE USING MANN-KENDALL AND SEMI-AVERAGE TESTS: A CASE STUDY OF IMAM TURKI BIN ABDULLAH ROYAL NATURE RESERVE (ITBA, SAUDI ARABIA)

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ABSTRACT

Temperatures trend analysis, on different spatial and temporal scales, has been used by the scientific community during the past century as the indicate of global climate change. According to some recent studies, the Nature Reserve (ITBA) has been suffering a Temperatures increase, especially in the second half of the studied period (1993-2018). The aim of the present study is to analyze the Temperatures trends using the time series of 41 years in Qaysumah, Rafha and Al Jawf and 39 in Ha'il stations surrounding the Nature Reserve of (ITBA) that extended on area of about 91500 km^2 in the Northeast of Saudi Arabia. This study applied the Mann-Kendall test and the Semi-averages method to determine the temperatures trends using the recorded data. So, the main results obtained revealed the highest temperatures at Qaysumah and the lowest temperatures at Ha'il and Al Jawf. The variance, Chi square test shows that the variance of the maximum daily temperatures was significant in Qaysumah and Ha'il, the variance of the mean daily temperature was significant in only Qaysumah, and the variance of the minimum daily temperature was significant in all studied stations. The $F_{max\text{-}ratio}$ shows the variance of the maximum daily temperatures is not homogeneous in the total of studied stations, and the variance of the mean daily temperature is not homogeneous in Al Jawf and Rafha. While the variance of the minimu daily temperature is not homogeneous in only Qaysumah. As for the trends analysis, the T-student and Mann-Kendall tests show the significant increased trends of the maximum daily temperatures at only Ha'il and Al Jawf, the significant increased trends of the mean daily temperatures in all of the studied stations at 5% level of significance and 39 and 37 degree of freedom, respectively.

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INTRODUCTION

Climate change can affect significantly the variability in surface water resources with a decreased Temperatures and high temperature and evaporation (Wang *et al*. 2020). So, the Temperatures variability is considered as the most important hydro-meteorological component of the water cycle and Its variability is highly correlated with flood and drought, especially in arid zones (Wang *et al*. 2017). The Temperatures trends are directly related to the climate change they have a several acute impacts on the environment, society, economy and agriculture. Their impact can caused the psychological disorders, economic disruption, biodiversity loss, loss of crop production, malnutrition, livelihood disruption, decreased social-cultural function, environmental degradation (Miah *et al*. 2017; Hossain *et al*. 2019). Therefore, over the last four decades, the estimation of long-term Temperatures variability and trend has become the main active research worldwide (Sun *et al*. 2018; Praveen *et al*. 2020; Wang *et al*. 2020). In this context, many studies have been used several methods for estimating the long-term Temperatures trend and variabilities, especially Mann-Kendall test, Spearman's rho, Şen-Theli estimator, and linear regression (Mann 1945; Furl *et al*. 2014; Cui *et al*. 2017; Tosunoğlu 2017; Sanikhani *et al*. 2018; Ahokpossi 2018; Al Balasmeh *et al*. 2019; Caloiero 2020; Gao *et al*. 2020; Wang *et al*. 2020). Temperatures modeling or Temperatures trend is used in assessment for the water balance in Saudi Arabia (Al Sarmi and Washington 2011; Al-Ahmadi and Al-Ahmadi 2013a; Almazroui *et al*. 2015). Many previous literature on global climate change reported Saudi Arabia as a highly water-scarce region (Rahman and Islam 2019). Saudi Arabia is considered as a Temperatures deficit region. The studies and researches using the Temperatures to detect climate change are rare (El Kenawy and McCabe 2016). Hence, before proposing any environmental management plans in (ITBA), it is of paramount importance to detect Temperatures trends and their distribution characteristics in recorded data. Previous literature reported that many statistical techniques are available for trend detection. In the present study, Moving averages and Semi-averages methods were used to detect the variability and trends of the annual Temperatures, rainy days and actual mean of the daily Temperatures data for the period 1697-2018 (52 years). The present study area, the Imam Turki Bin Abdullah Royal Nature Reserve (ITBA), is arid region of Saudi Arabia and very limited study on the Temperatures

has been conducted. The future trend of Temperatures in the Nature Reserve of (ITBA) needs to be known for long-term sustainable planning. So, no studies have been analyzed the long-term Temperatures trends and variability in the study area. Therefore, the present study is the first to use in the study area, the coefficient of variation (CV), Standardized Anomaly Index (SAI) for analyzing the variability of the Temperatures data, Hartley's index for analyzing the homogeneity of the semi averages method and T-student for determining the performance of the Semi averages method. The findings of the present study would help to update the Temperatures trends detected in the study area by finding the best methods for estimating accurate Temperatures trends. These objectives would help to propose high-precision and accurate plans for water resources and environment management in the Imam Turki Bin Abdullah Royal Nature Reserve (ITBA).

MATERIALS AND METHODS

Study area: The study area is located in Northeastern of Saudi Arabia, covered a geographical area of about 91500 km^2 (Fig. 1). are known as Imam Turki Bin Abdullah Royal Nature Reserve (ITBA).

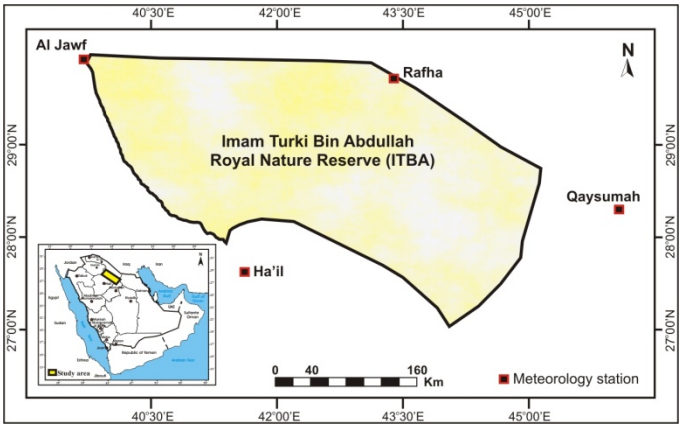


Figure 1. Geographic location of study area

The study area extends from 26°45' to 30°15' North latitudes and 40° to 45° East longitudes in the Northeastern of Saudi Arabia. It is bordered to the Northewest by the regions of Al-Jawf, in the North by the Northern borders, in the South by Ha'il , in the South by Al Qasim area and in the east by the Eastern Province. Consequently, the Nature Reserve (ITBA) 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 sites due to its higher altitude. Geologically, Nature Reserve (ITBA) is extended over Four main administrative regions; Ha'il, Northern boundaries, Al Qasim area and Al Jawf. In general, the study area 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 & Membery, 1998). All of the climatic conditions, soil properties and relief topography are clearly contributed to the presence of abundant plant diversity. So, At-Taysiah and Al Hijra plateaus 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 wide spread plant clans in the Sabkhas environment. In the plateaus 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 the population in west ITBA is the date production and vegetable cultivation. These two sectors are undergoing considerable development as it is the fundamental resource of several farmers. At the same time, these activities include camels breeding and livestock.

Data used: Datasets of Temperatures were obtained from 3 meteorology stations for the period of 1978-2018 in Al Jawf, Qaysumah and Rafh and for the period 1978-2015 in Ha'il (Tab. 1 & Fig. 2). The dataset is summarized in the Tables 2.

Table 1. Coordinates of the meteorology stations

Station	Code	Latitude (N)	Longitude (E)	Height (m)
Ha'il	40394	27°26'04"	41°41'28"	1001.5
Qaysumah	40373	28°19'08"	46°07'49"	357.6
Rafha	40362	29°37'17"	43°29'41"	444.1
Al Jawf	40361	29°47'19"	40°05'55"	668.1

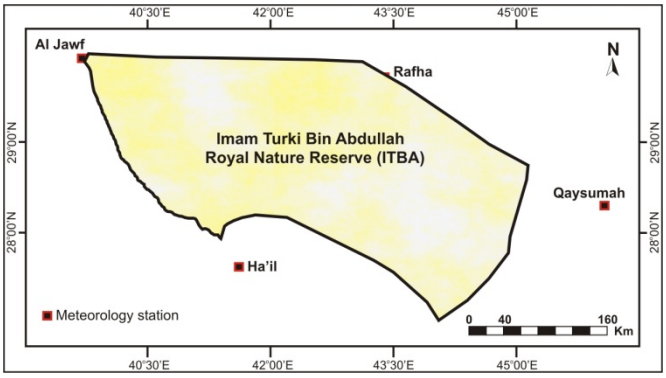


Figure 2. Geographic location of studied stations

METHODOLOGY ANALYSIS

The methodology analysis used several statistical analysis as follows:

(1) Temperatures variability analysis: To analyze the temperature variability, this study uses the Central tendency (mean, coefficient of variation) and the Dispersion measurements (Standard deviation, Variance, Range, Minimum, Maximum, Standard Error of mean) available in frequency statistics tools of SPSS23 software.

(2) Temperatures trends analysis: To analyze the temperature trends, this study uses the following methods:

Mann-Kendall test

$$S = \sum_{j=i+1}^{n} [\text{sgn}(R_i - R_j)]$$

Where,

sgn (x) = 1 for x > 0.
sgn (x) = 0 for x = 0.
sgn (x) = 01 for x < 0.

If the null hypothesis is true, then S is approximately normally distributed.

The Mann-Kendall (Z) statistic is written as:

$$Z = \frac{S-1}{\sqrt{\text{Var}(S)}}, \text{if } S > 0$$

$$Z = 0, \text{if } S = 0$$

$$Z = \frac{S+1}{\sqrt{\text{Var}(S)}}, \text{if } S < 0$$

Where,

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

n : number of data points,
g : number of tied groups.
tp : number of observations in the p^{th} group.
A positive (negative) value of Z indicates that the data trend to increase (decrease) with time.

every studied station. Secondly, the Temperatures data is in general, normally distributed. Thirdly, Hartley's statistic is still easy to compute using an equal sample sizes (Gupta, 1987 ; Chu & 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

Table 2. Daily extreme temperatures recorded at the studied stations

Year	Ha'il			Rafha			Qaysumah			Al Jawf		
	Tx	T'	Tm	Tx	T'	Tm	Tx	T'	Tm	Tx	T'	Tm
1978	37.4	28.8	-2.2	39.2	31.3	-0.1	44.0	32.4	-3.5	37.0	28.6	0.0
1979	35.3	29.1	-5.0	38.7	32.2	-2.6	46.2	33.5	0.2	35.9	29.4	-1.8
1980	36.4	29.2	-5.6	39.0	30.9	-5.4	40.3	32.6	-2.0	36.8	28.6	-4.7
1981	35.2	28.8	-2.8	39.7	31.1	0.0	41.4	32.4	1.0	38.1	28.7	-0.2
1982	34.1	27.4	-6.2	37.0	29.6	-3.2	38.1	30.4	0.0	34.1	27.2	-3.4
1983	36.1	28.0	-3.8	37.7	30.5	-4.2	39.3	31.1	0.4	36.2	27.6	-2.6
1984	33.3	28.3	-3.8	43.5	30.4	-0.6	37.6	31.6	0.9	33.3	28.1	-1.0
1985	35.0	28.5	-2.2	37.4	31.6	-2.0	39.0	32.2	0.0	35.9	28.4	-1.0
1986	36.5	28.3	-2.5	38.6	30.9	-1.7	39.9	32.3	-0.8	34.3	28.5	-1.0
1987	37.4	30.1	-2.6	40.1	31.2	-2.0	42.0	33.4	0.4	40.3	29.5	-1.0
1988	35.8	29.2	-3.6	38.7	30.2	-3.0	39.7	32.8	-1.0	39.8	28.5	-1.0
1989	36.3	28.5	-9.4	41.0	30.5	-5.8	38.6	32.3	-4.0	38.6	28.5	-7.0
1990	36.2	29.7	-1.1	39.1	31.5	-3.5	40.3	32.8	0.2	37.4	29.1	-2.0
1991	38.6	29.2	-5.2	38.1	30.8	-3.0	40.1	32.4	-3.0	35.7	28.6	-4.4
1992	34.4	27.5	-9.3	35.8	29.2	-5.8	38.4	30.7	-4.0	36.5	27.2	-5.8
1993	35.2	28.9	-4.2	38.6	30.8	-4.7	39.8	31.6	-1.3	34.3	28.6	-6.0
1994	36.5	28.8	-2.4	37.2	30.9	-4.0	38.2	32.0	-2.0	35.5	28.6	-3.4
1995	35.9	29.2	-1.0	36.3	30.6	2.0	38.2	32.2	3.2	36.9	28.8	2.0
1996	36.7	29.8	0.0	39.0	31.7	1.3	41.3	33.4	2.8	37.2	30.0	1.0
1997	34.6	28.6	-3.0	37.8	30.1	-3.2	39.6	32.0	-1.0	34.4	28.3	-3.0
1998	37.5	30.5	-2.2	40.3	32.3	-1.0	41.9	34.2	0.0	38.4	30.4	0.0
1999	36.8	30.6	-4.9	37.5	32.1	-0.9	39.5	33.9	0.6	37.4	30.0	-1.2
2000	37.3	30.0	-3.2	39.0	31.2	-0.9	41.0	33.1	0.0	38.2	28.9	-2.0
2001	37.6	30.6	-3.2	39.3	32.1	-3.0	41.6	33.9	0.0	38.4	29.8	-1.0
2002	36.9	30.3	-3.0	37.6	31.3	-3.5	40.5	33.5	1.4	35.9	29.1	-0.1
2003	38.1	30.6	-3.4	39.8	31.4	-0.7	40.9	33.5	1.6	38.9	29.4	-2.0
2004	36.4	30.4	-1.2	36.9	31.5	-5.6	39.4	33.2	-0.5	36.4	29.1	-3.6
2005	38.0	30.1	-4.4	39.1	31.2	-3.0	40.5	32.9	0.3	37.4	28.9	-2.6
2006	38.4	30.1	-5.6	40.2	31.4	-4.2	40.4	33.3	-2.4	37.3	29.5	-3.0
2007	37.5	30.5	-6.2	40.0	31.7	-3.9	40.5	33.6	-3.0	39.0	30.0	-2.3
2008	36.5	29.9	-10.0	38.7	31.0	-5.0	40.2	33.7	-4.2	38.0	29.9	-5.0
2009	37.7	30.4	-7.0	38.5	31.0	-5.6	40.0	33.7	-4.0	37.5	29.8	-3.6
2010	38.4	31.8	-3.0	40.0	33.2	-1.8	62.8	35.3	0.5	39.7	32.3	0.6
2011	37.2	29.9	-2.0	39.6	30.9	-1.7	42.0	33.2	-1.0	39.0	29.7	0.0
2012	37.7	30.7	-5.4	40.4	31.6	-3.5	41.4	33.9	-2.0	38.9	30.1	-1.3
2013	36.4	30.1	-4.4	38.3	30.6	-2.0	40.2	33.4	0.2	37.4	29.5	-2.0
2014	37.3	30.4	-2.8	40.0	31.3	-1.4	40.1	34.1	1.3	37.4	30.2	0.0
2015	37.3	31.1	-7.8	39.4	31.8	-3.0	42.0	34.3	0.2	39.8	30.4	-2.7
2016	---	---	---	40.8	31.7	-2.9	42.4	34.1	-1.4	39.6	30.7	-1.7
2017	---	---	---	41.0	32.3	-3.4	42.5	34.8	-2.4	40.1	31.1	-3.5
2018	---	---	---	41.0	33.0	-3.4	42.5	35.3	-2.4	40.1	31.8	-3.5

Homogeneity of variance test: Hartley (1950) 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 as follows:

$$F_{max} = \frac{\sigma^2 max}{\sigma^2 min}$$

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 (1952) gave corrections to this table. 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 26 years; with the first part (1967-1992) and the second part (1993-2018) 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 (52 years) available at

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].

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.

RESULTS AND DISCUSSION

Daily Temperatures variability: To analyze the temperature variability, this study uses the Central tendency (mean, coefficient of variation) and the Dispersion measurements (Standard deviation, Variance, Range, Minimum, Maximum, Standard Error of mean) available in frequency statistics tools of SPSS23 software. The table 3 summarizes the results. The coefficient of variation (CV) determines the variability of the Temperatures in specific region. A high value of (CV) indicates that the Temperatures variability is greater, where a lower value means the opposite. The (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%).

The Table 3, shows the law coefficient of variation of the daily maximum and the daily average of temperatures and the high coefficient of variation of the daily minimum temperatures.

Table 3. Descriptive statistics of the daily temperatures

Statistic parameters		Ha'il	Rafha	Qaysumah	Al Jawf
Daily Maximum (T_x)	X'	36.6	39.0	41.1	37.4
	SD	1.3	1.5	3.9	1.8
	CV	0.03	0.04	0.09	0.05
	Maximum	38.6	43.5	52.8	40.3
	Minimum	33.3	35.8	37.6	33.3
	Range	5.3	7.7	15.2	7.0
Daily Minimum (T_m)	X'	-4.1	-2.7	-0.7	-2.1
	SD	2.4	1.9	1.9	2.0
	CV	-0.58	-0.69	-2.47	-0.93
	Maximum	0.0	2.0	3.2	2.0
	Minimum	-10.0	-5.8	-4.2	-7.0
	Range	10.0	7.8	7.4	9.0
Daily Mean (T')	X'	29.6	31.2	33.0	29.3
	SD	1.0	0.8	1.1	1.1
	CV	0.03	0.03	0.03	0.04
	Maximum	31.8	33.2	35.3	32.3
	Minimum	27.4	29.2	30.4	27.2
	Range	4.4	4.0	4.9	5.0

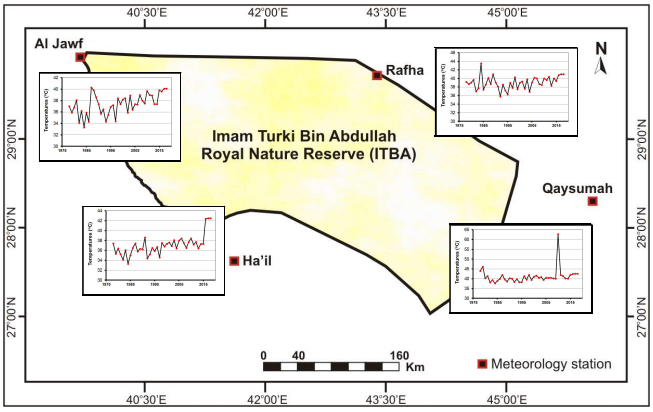


Figure 3. The spatial distribution of the daily maximum of temperatures during 1978-2018

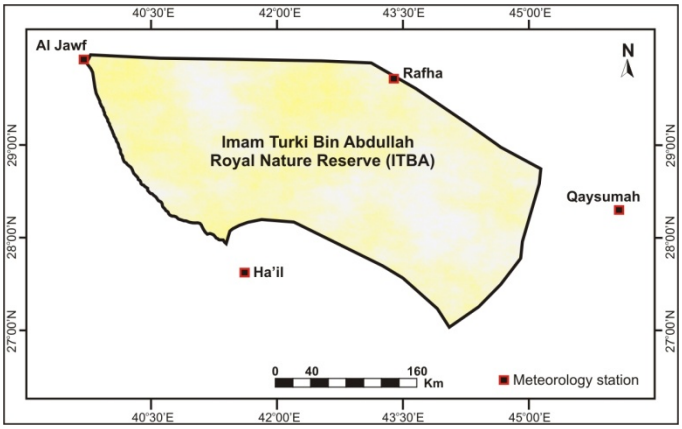


Figure 4. The spatial distribution of the daily mean of temperatures during 1978-2018

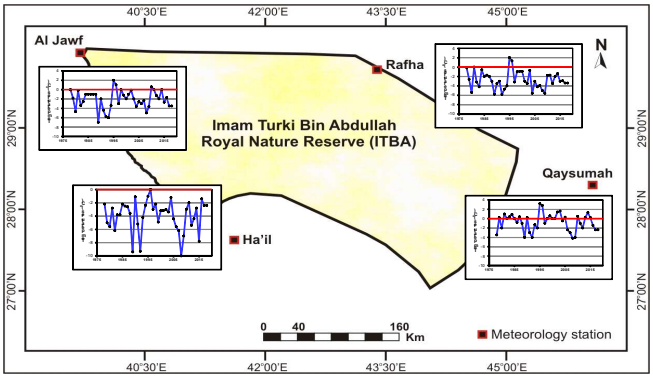


Figure 5. The spatial distribution of the daily minimum of temperatures during 1978-2018

To analyze the statistical significance of the temperatures variance, the Chi square test was computed (Table 4). The null hypothesis indicates 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 4, the Chi square values for maximum daily temperatures are greater than the critical values at 0.05 significance level and at the degrees of freedom 3 in Al Jawf and Rafha stations. This result show that the variance of the maximum daily temperatures is only significant at Ha'il and Qaysumah stations. In the other hand, the Chi square values for minimum daily temperatures are smaller than the critical values at 0.05. So, the null hypothesis was accepted indicating that the variance of the minimum daily temperature was not significant in the fourth studied stations. The null hypothesis of the daily mean temperature was accepted in only Qaysumah, indicating the significant variance in Ha'il, Al Jawf and Rafha stations.

Table 4. Chi square test of annual rainfall variance at the studied stations

Station		X_c^2	df	N	X_t^2	H = 0
Daily Maximum (Tx)	Ha'il	8.842	4	38	9.488	Accepted
	Rafha	20.951	3	41	7.815	Reject
	Qaysumah	3.024	4	41	9.488	Accepted
	Al Jawf	8.073	3	41	7.815	Reject
Daily Minimum (Tm)	Ha'il	5.579	3	38	7.815	Accepted
	Rafha	6.707	3	41	7.815	Accepted
	Qaysumah	3.000	3	41	7.815	Accepted
	Al Jawf	0.463	3	41	7.815	Accepted
Daily Mean (T')	Ha'il	10.421	3	38	7.815	Reject
	Rafha	19.000	3	41	7.815	Reject
	Qaysumah	7.683	3	41	7.815	Accepted
	Al Jawf	10.024	3	41	7.815	Reject

Table 5. Results of F_{max}-Hartley's test

Variable	Station	S_1^2	S_2^2	$F_{max\text{-}c}$	Variance
Daily Maximum (Tx)	Al Jawf	3.5	1.5	2.347	Not Homogeneous
	Rafha	2.9	1.4	2.120	Not Homogeneous
	Qaysumah	4.4	8.0	1.830	Not Homogeneous
	Ha'il	1.6	2.0	2.015	Not Homogeneous
Daily Minimum (Tm)	Al Jawf	5.7	2.2	2.637	Not Homogeneous
	Rafha	4.8	2.2	2.212	Not Homogeneous
	Qaysumah	3.9	3.1	1.236	Homogeneous
	Ha'il	6.4	1.3	1.296	Homogeneous
Daily Mean (T')	Al Jawf	0.6	0.8	1.376	Homogeneous
	Rafha	0.6	0.4	1.292	Homogeneous
	Qaysumah	0.8	0.4	1.858	Not Homogeneous
	Ha'il	0.5	1.4	1.352	Homogeneous

Trends analysis of Temperature

Homogeneity of variance: 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 5 that the calculated F_{max} values are greater than the critical F_{max} value 1.67 at the statistical significance level 0.05 and the degree of freedom 40 at Qaysumama, Rafha and Al Jawf and 37 at Ha'il, for the maximum daily temperatures. It is also greater than 1.67 for the minimum daily temperatures in Al Jawf and Rafha; and for the mean daily temperature in Qaysumah. Consequently, the variance of the maximum daily temperatures is not homogeneous in the total of the stations, and the variance of the minimum daily temperature is not homogeneous in Al Jawf and Rafha. The variance of the mean daily temperature is not homogeneous in only Qaysumah.

Temperatures trends by Mann-Kendall test: The trends of temperatures were analyzed using Mann-Kendall test. This method tests whether there is a trend in the time series data. It is a non-parametric test and it eliminates the outliers. The n time series values (X1, X2, X3,….., Xn) are replaced by their relative ranks (R1, R2, R3,….., Rn) (starting at 1 for the lowest up to n). The positive value of the Sen's slope (S) and Mann-Kendall (Z) statistic indicate that the data trend to increase (decrease) with time. The critical test statistic values for various significance levels for observations are 1.645, 1.97 and 2.57 at 90, 95 and 99 % probability levels, respectively. This test is applied to the temperature data for detecting the trends and to quantify the change both spatially and temporally. The table 6 summarizes the results. The Mann-Kendall (MK) and Sen's slope (S) estimator were applied to the time series 1978-2017 for Al Jawf, Rafha and Qaysumah and for 1978-2015 for Ha'il. In the MK test, the Sen's slope and Z statistic were computed to determine the positive or negative trend of temperature in the studied stations. The table 6 shows the maximum daily temperature (Tx) and their trend during the study period. The mean of (Tx) was ranged from 36.6 °C to 40.8 °C with the range of 5.3 °C and 15.2 °C in Ha'il and Qaysumah, respectively. The regression line slope is about 0.5 °C and 0.85 °C per decade, at 95% and 99.9% levels of significance for Rafha and Al Jawf, respectively. These results reflect the increased trends of the (Tx) during the last 41 years in Qaysumah, Rafha and Al Jawf; and for 39 years in Ha'il. The mean daily temperature was ranged from 29.3 °C and 33.0 °C with the range of 5.1 °C and 4.9 °C in Al Jawf and Qaysumah, respectively. The regression line slope is about 0.024 °C and 0.067 °C at 95% and 99.9% levels of significance in Rafha and Ha'il, respectively. These trends concorde with the similar trends of the maximum daily temperatures. While the minimum daily temperature are not significant in the studied stations.

Semi-averages trends: Trend analysis of daily temperatures using the semi-averages method can indicate if these variables pattern and distribution are changing in due course of time or remains stable (Borse & Agnihorti, 2017). Various researchers have contributed to the study of climate change over Saudi Arabia using Temperatures trends. So, the analysis of different time series data has proved that Temperatures trend is increasing (Al Sarmi & Washington, 2013). The Temperatures has a direct impact on the scarcity of the surface water resources over Saudi Arabia (Amin *et al*., 2016). In this study, the whole data of Temperatures is divided into equals periods (parts): (1978-1998) and (1999-2017) in Qaysumah, Rafha and Al Jawf; and (1978-1996) and (1997-2017) in Ha'il. After, the average (arithmetic mean) of each part is calculated in order to obtain 2 semi averages (Table 7). On the graphic of data distribution, every point is plotted against the middle of each part. Then, the straight line joining these 2 semi-averages points gives the trend line. So, the table 7 and figures 4, 5 and 6 summarize the Temperatures trends using the semi-averages method. From the data of Table 7 and Figure 4, we find that the maximum daily Temperatures have increasing trends in the studied stations, with the simple positive rate of (0.2°C/decade) in Rafha, (0.3°C/decade) in Qaysumah and Ha'il, and (0.4°C/decade) in Al Jawf. While the minimum daily Temperatures have also an increasing trends with the simple positive rate of (0.2°C/decade) in Rafha, (0.3°C/decade) in Al Jawf and (0.4°C/decade) in Qaysumah and Ha'il. The statistical significance was determined using the standard error method $S.E|X'_1\text{-}X'_2|$ for the two semi-averages. There are a significant increasing trends of the maximum daily Temperatures at the 5% significance level only in Al Jawf and Ha'il. These two trends 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). Student's t-statistic test of the difference between the semi-averages also confirmed these results.

Table 6. Basic statistics and Mann-Kendall analysis of Temperature in the studied stations

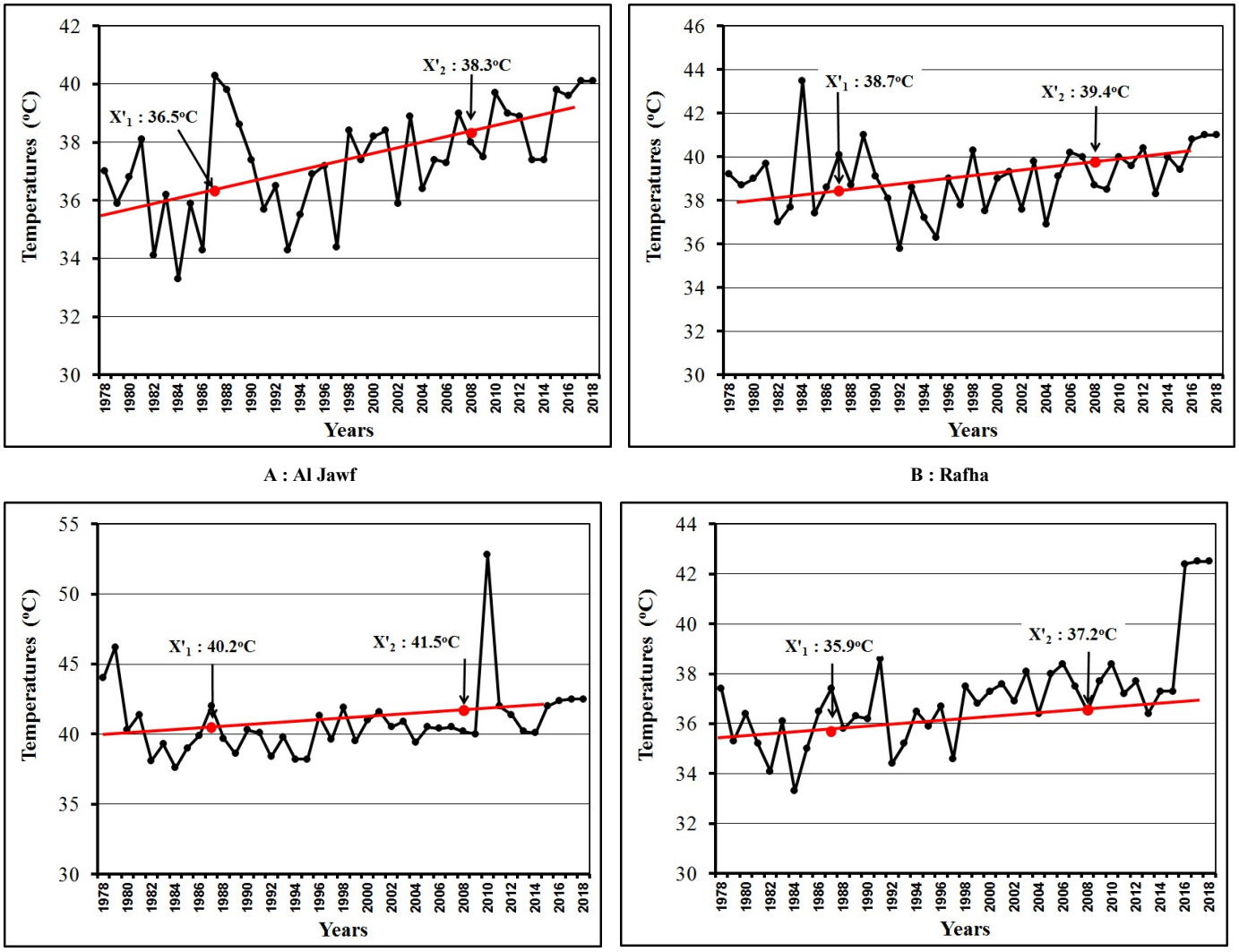
Statistics	Al Jawf	Rafha	Qaysumah	Ha'il
	Maximum daily temperature			
N	41	41	41	39
Range	7.0	7.7	15.2	5.3
Minimum	33.3	35.8	37.6	33.3
Maximum	40.3	43.5	52.8	38.6
Mean	37.4	39.0	40.8	36.6
Standard deviation	1.8	1.5	2.5	1.3
Skewness	(-0.34)	0.29	2.86	(-0.65)
Kurtosis	(-0.52)	1.01	12.05	0.04
Z	3.51	1.88	2.08	3.47
Sen's slope	0.085	0.036	0.050	0.061
Significance	0.999	---	0.95	0.999
Statistics	Mean daily temperature			
N	41	41	41	39
Range	5.1	4.0	4.9	4.4
Minimum	27.2	29.2	30.4	27.4
Maximum	32.3	33.2	35.3	31.8
Mean	29.3	31.2	33.0	29.8
Standard deviation	1.1	0.8	1.1	1.0
Skewness	0.52	0.04	(-0.25)	(-0.25)
Kurtosis	0.76	0.81	0.11	(-0.47)
Z	5.18	2.37	4.65	4.80
Sen's slope	0.060	0.024	0.063	0.067
Significance	0.999	0.95	0.999	0.999
Statistics	Minimum daily temperature			
N	41	41	41	39
Range	9.0	7.8	7.4	10.0
Minimum	(-7.0)	(-5.8)	(-4.2)	(-10.0)
Maximum	2.0	2.0	3.2	0.0
Mean	(-2.1)	(-2.7)	(-0.7)	(-4.0)
Standard deviation	2.0	1.9	1.9	2.4
Skewness	(-0.39)	0.38	(-0.19)	(-0.87)
Kurtosis	0.03	(-0.00)	(-0.47)	0.49
Z	(-0.023)	(-0.64)	(-0.53)	(-0.86)
Sen's slope	0.000	(-0.019)	(-0.009)	(-0.027)
Significance	---	---	---	---

Table 7. Statistical parameters of semi-averages trends at the studied stations

Variable	Statistical parameters	Al Jawf	Rafha	Qaysumah	Ha'il
Daily Maximum (Tx)	X'_1	36.5	38.7	40.2	35.9
	X'_2	38.3	39.4	41.5	37.2
	T'_1	1987.5	1987.5	1987.5	1987
	T'_2	2008.5	2008.5	2008.5	2006
	b	0.086	0.033	0.062	0.060
	SE	0.492	0.456	0.781	0.341
	2SE	0.983	0.912	1.561	0.682
	$IX_1'-X_2'I$	1.8	0.7	1.3	1.3
	T-student	3.662	1.535	1.665	3.814
	df	39	39	39	39
	$T_{t0.05}$	1.645	1.645	1.645	1.645
	H=0	Rejected	Accepted	Accepted	Rejected
Daily Minimum (Tm)	X'_1	28.6	30.9	32.3	28.8
	X'_2	30.0	31.6	33.8	30.4
	T'_1	1987.5	1987.5	1987.5	1987
	T'_2	2008.5	2008.5	2008.5	2006
	b	0.067	0.033	0.071	0.074
	SE	0.262	0.220	0.241	0.209
	2SE	0.524	0.441	0.482	0.419
	$IX_1'-X_2'I$	1.4	0.7	1.5	1.6
	T-student	5.346	3.176	6.223	7.644
	df	39	39	39	39
	$T_{t0.05}$	1.645	1.645	1.645	1.645
	H=0	Rejected	Rejected	Rejected	Rejected
Daily Mean (T')	X'_1	-2.2	-2.5	-0.6	-3.8
	X'_2	-2.0	-3.0	-0.9	-4.4
	T'_1	1987.5	1987.5	1987.5	1987
	T'_2	2008.5	2008.5	2008.5	2006
	b	0.010	-0.024	-0.014	-0.028
	SE	0.618	0.582	0.584	0.741
	2SE	1.235	1.164	1.167	1.483
	$IX_1'-X_2'I$	1.4	0.7	1.5	1.6
	T-student	2.267	1.203	2.570	2.158
	df	39	39	39	39
	$T_{t0.05}$	1.645	1.645	1.645	1.645
	H=0	Rejected	Accepted	Rejected	Rejected

The calculated "t" values are greater than the critical "t" value (1.645) at the significance level 0.05, at the degree of freedom (n-2) 36 in Ha'il and 39 in Al Jawf. And on the contrary, the T-student value of the mean daily temperatures trends is greater than the critical value (1.645) and the differences $IX_1'-X_2'I$ is greater than the 2SE in all the studied stations. Consequently, the null hypothesis was rejected and the increasing trends of the mean temperatures are significant in the study area. On the other hand, the T-student values of the minimum daily Temperatures are greater than the critical value (1.645) and the differences $IX_1'-X_2'I$ are greater than the 2SE in all the stations, except Rafha. So, the increasing trends of the mean daily Temperatures are significant in the study area, except Rafha.

Mann-Kendall test: The results of Mann-Kendall test are consistent with the T-student results (Table 8). So, the maximum daily temperatures are characterized by the significant increasing trends in Al Jawf and Ha'il, at the significance level of 99.9%. the increasing rate is ranged between 0.61 °C/decade in Ha'il and 0.82 °C/decade in Al Jawf. The daily mean of temperatures shows a significant increasing trends with a rate of 0.6 °C/decade in Al Jawf, 0.63 °C/decade in Qaysumah and 0.63 °C/decade in Ha'il. The maximum daily temperature in Qaysumah and the mean daily temperature in Rafha show the increasing trends at the significance level of 95%, with a rate of 0.5 °C/decade and 0.24 °C/decade, respectively.



A : Al Jawf

B : Rafha

C : Qaysumah

D : Ha'il

Figure 4. The variations of maximum daily temperature from 1978 to 2017

Table 8. Mann-Kendall test of the temperatures trends

Temperature	Station	First year	Last year	n	Z Test	Sig.	Sen's slope estimate (Q)
Daily Maximum (°C)	Al Jawf	1978	2018	39	3.51	0.999	0.085
	Rafha	1978	2018	39	1.88	+	0.036
	Qaysumah	1978	2018	39	2.08	0.95	0.050
	Ha'il	1978	2018	37	3.47	0.999	0.061
Daily Mean (°C)	Al Jawf	1978	2018	39	5.18	0.999	0.060
	Rafha	1978	2018	39	2.37	0.95	0.024
	Qaysumah	1978	2018	39	4.65	0.999	0.063
	Ha'il	1978	2018	37	4.80	0.999	0.067
Daily Minimum (°C)	Al Jawf	1978	2018	39	-0.23	---	0.000
	Rafha	1978	2018	39	-0.64	---	-0.019
	Qaysumah	1978	2018	39	-0.53	---	-0.009
	Ha'il	1978	2018	37	-0.86	---	-0.027

CONCLUSIONS

This study applied the Mann-Kendall test and the Semi-averages method to determine the temperatures trends in 4 meteorology stations surrounding the Royal Nature Reserve (Imam Turki Bin Abdullah) using the data recorded from 1978 to 2017 at Qaysumah, Rafha and Al Jawf stations and during 1978-2017 in Ha'il station. So, the main results obtained can be summarized in the following:

- The highest temperatures was recorded at Qaysumah and the lowest temperatures at Ha'il and Al Jawf.
- Regarding the variance, Chi square test shows that the variance of the maximum daily temperatures was significant in Qaysumah and Ha'il, the variance of the mean daily temperature was significant in only Qaysumah, and the variance of the minimum daily temperature was significant in all studied stations.
- The $F_{max\text{-}ratio}$ shows the variance of the maximum daily temperatures is not homogeneous in the total of studied stations, and the variance of the mean daily temperature is not homogeneous in Al Jawf and Rafha. While the variance of the minimu daily temperature is not homogeneous in only Qaysumah.
- As for the trends analysis, the T-student and Mann-Kendall tests show the significant increased trends of the maximum daily temperatures at only Ha'il and Al Jawf, the significant increased trends of the mean daily temperatures in all of the studied stations at 5% level of significance and 39 and 37 degree of freedom, respectively.

From the foregoing, it is difficult to infer the general trends of the Temperatures as an indicate for confirming the aspects of the climate change in the Royal Nature Reserve (Imam Turki Bin Abdullah). So, it is recommended to comparing these results with the Temperatures trends in more meteorology stations and auditing the results of the obtained trends by adding the analysis of more climatic variables over Saudi Arabia.

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