# Climate change impact assessment on rainwater in Jordan

A. Dahamsheh [1], M. Wedyan [2, *], Mahmoud B. Alhasanat [1]

[1]*Department of Civil Engineering, College of Engineering, Al-Hussein bin Talal University, P.O. Box: 20, Ma'an – 71110, Jordan*
[2]*Biological Sciences and Biotechnology Department, The Hashemite University, Al Zarka, P O Box: 330127, Jordan*

A B S T R A C T

This article aims to investigate the possible trend in precipitation and temperature in the agricultural areas in Jordan. Six meteorological stations locate in the agricultural areas in Jordan were chosen to investigate the variation in precipitation, maximum and minimum temperature. In order to achieve accurate result, quality control was conducted for each station. Also the homogeneity test was conducted using Standard Normal Homogeneity Test, Pettitt and Von Neumann ratio tests. All stations passed the quality and homogeneity tests. Data were analyzed using the recommended software RClimDex to determine 27 climate indices. The obtained results indicated significant trend in many indices. The most significant trend was found for cool days, warm days, warm nights, cool nights, summer days, diurnal temperature range, and the tropical night indicators. Further studies to quantify the climate change in Jordan were recommended.

## 1. Introduction

Jordan population has increased rapidly from 0.58 million in 1950 to more than 5.6 million in 2006 (DOS, 2006). As a result of population growth and development projects, water consumption also increased, while the available sources are limited and decreasing year after year. The water consumption in the year of 2006 was about 160 $m^3$/capita/y and it is expected to fall to 90 m3/capita/y in 2020, which is very low in comparison with the international water poverty level of 1000 $m^3$/y (Barjenbruch and Alzboon, 2010). By the year of 2025, it is expected that Jordan will be in the category of having an absolute water scarcity (Smadi and Zghoul, 2006). The total water demand in the country is as almost twice as that of the conventional water supply which includes the safe yield of all available groundwater and surface water resources (Dahamsheh and Aksoy, 2007). The agricultural demand of water is estimated to be 73% of the total water consumption, while 22% of water is used for domestic needs and only 5% is used for industrial sector (Al Zboon and Ananzah, 2008).

The total average precipitation volume is about 8.5 billion/y; however 92% of this quantity is lost through evaporation (Barjenbruch and Alzboon,

2010). About 5% of the rainwater infiltrates into the ground and replenishes the aquifers while 3% is transformed into direct flood flow (Taha, 2006). Rainfall exceeding the limit for reliable rain fed agriculture (300 millimeters annually) covers only 4% of the land area in the North, North Western Highlands and Jordan Valley. Rain falls during the winter months, and it is of sporadic nature especially in the desert areas (Taha, 2006).

Most agricultural activities were concentrated in two areas. In rain-fed northern and central areas of higher elevation where wheat, barley, and other field crops such as olives, tobacco, lentils, barley, and chick-peas are. Rain-fed agriculture in Jordan is the most important mode of employment and food production (Smadi and Zghoul, 2006). Due to the fact of periodic drought and limited area, the rain-fed uplands did not support sufficient output of cereal crops to meet the domestic demands. Rainfall is highly sensitive to variations in weather and climatic change.

In the last two decades, great interest in the evaluation of possible future environmental changes due to global warming and their implications for society have evolved worldwide. The conducted studies reveals strong global indicators of climate change such as the rise in sea level on the order of 1 to 2 mm/year over the last century (Parker, 1991), increased of mean annual temperature (Parker, 1991; Aguilar et al., 2005; Gruza et al., 1999), especially during summer time (Parker, 1991), decrease in the total precipitation (Gruza et al., 1999), snow melting (Kaiser, 2000), decreased in

cloudiness cover (Kaiser, 2000), influence on clinical malaria rates (Yé et al., 2007), and increased the patient's admissions due to many prevalent human diseases, such as cardiovascular mortality and respiratory illnesses due to extreme heat waves (Patz et al., 2005).

The potential long term effect of climate change on the environment is the focus of much ongoing researches. The possible future impacts include variation in rainfall (Francis, 2001), disappearance of ice and snow on the mountainous areas (Ngaira, 2007), stress on plants and diversity (DECC, 2008), increase incidences of insect-borne infections (Smadi and Zghoul, 2006), fishing and human settlement and submerge of coastal areas (Ngaira, 2007).

Water resources and agriculture are the main sectors that will be affected by climate change, so there is much concern over the possible impacts of climatic changes on these sectors. Due to the expected warmer conditions and increase of evapotranspiration rate, more stresses on available water resources (Lane et al., 1999), high agricultural potential areas will become arid and increase variability and unpredictability in plant productivity and community composition (Harmsen, 2009; Ngaira, 2007). Moreover, a radical shift in the location of agricultural production, particularly of cereals, would be likely to occur (Hossell et al., 1996). Such impacts of climate change will affect the economic and social life (Smadi and Zghoul, 2006), and declining the economic development (Chhibber and Laajaj, 2008). Due to the importance of agriculture sector in food security and water balance, this study is conducted to evaluate the potential variation in climate change in the agricultural areas of Jordan.

## 2. Methodology

### 2.1. Data

Six meteorological stations operated by the Jordan Meteorological Department were selected (Fig. 1) to evaluate the effect of climate change on temperature and precipitation on the selected agricultural areas. These stations are located in a narrow strip area in the western region of Jordan. Stations were chosen based on the longest records over a common period and their coverage of agricultural fed rain areas form the North to the South of Jordan.
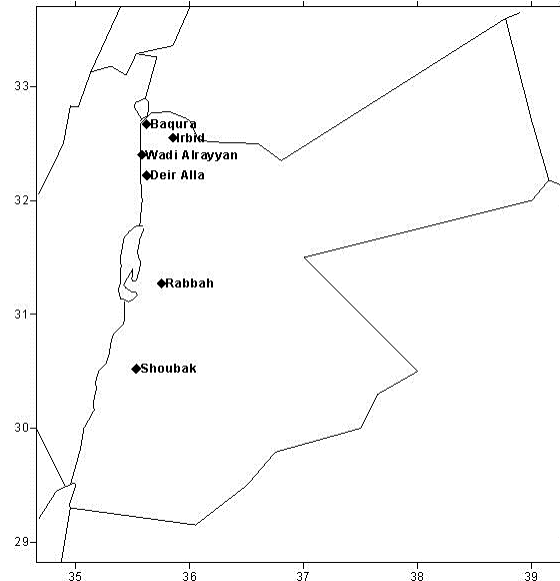


**Fig. 1:** Locations of the metrological stations

Three stations are located in the Ghor area (Baqura, Dier Alla), and three in the mountainous area (Irbidand Wadi Alrayyan, Rabba, Shoubak). The availability of data varies from one station to other, but all stations have full record data since 1976, covering the period from 1976 to 2007 for further analyses and discussion.

The stations are heterogeneously scattered throughout the country with elevation ranges from 224m below sea level represented by Dier Alla in the Ghor to 1365m above sea level represented by Shoubak in the mountainous region. Daily maximum and minimum temperatures varies from 48.5 Co (Deir Alla in the ghor area) to -14 Co (Shoubak in the mountainous area). Statistical characteristics of maximum and minimum temperature data used in the study are given in Tables 1 and 2.

**Table 1:** Stations statistical characteristics of maximum temperature

| Station | Period | Lon. | Lat. | Elev. (m) | Max. (C°) | Min. (C⁰) | $C_v$ | $C_s$ |
|---|---|---|---|---|---|---|---|---|
| Baqura | 1967-2007 | 35.62 | 32.67 | -170 | 47.7 | 7.6 | 0.27 | -0.28 |
| Irbid | 1955-2007 | 35.85 | 32.55 | 616 | 41.0 | -1.2 | 0.33 | -0.24 |
| Wadi Alrrayan | 1961-2007 | 35.58 | 32.40 | -200 | 47.5 | 8.4 | 0.27 | -0.25 |
| Deir Alla | 1952-2007 | 35.62 | 32.22 | -224 | 48.5 | 8 | 0.27 | -0.25 |
| Rabbah | 1961-2007 | 35.75 | 31.27 | 920 | 41.0 | 0.0 | 0.36 | -0.30 |
| Shoubak | 1965-2007 | 35.53 | 30.52 | 1365 | 38.2 | -3.4 | 0.41 | -0.36 |

**Table 2:** Stations statistical characteristics of minimum temperature

| Station | Period | Lon. | Lat. | Elev. (m) | Max. (C°) | Min. (C⁰) | $C_v$ | $C_s$ |
|---|---|---|---|---|---|---|---|---|
| Baqura | 1967-2007 | 35.62 | 32.67 | -170 | 29.8 | -3.0 | 0.39 | -0.10 |
| Irbid | 1955-2007 | 35.85 | 32.55 | 616 | 29.0 | -5.0 | 0.48 | -0.17 |
| Wadi Alrrayan | 1961-2007 | 35.58 | 32.40 | -200 | 31.0 | -2.8 | 0.43 | 0.07 |
| Deir Alla | 1952-2007 | 35.62 | 32.22 | -224 | 36.3 | 0.5 | 0.31 | -0.15 |
| Rabbah | 1961-2007 | 35.75 | 31.27 | 920 | 28.5 | -5.2 | 0.56 | -0.03 |
| Shoubak | 1965-2007 | 35.53 | 30.52 | 1365 | 25.2 | -14.0 | 1.1 | 0.0 |

## 2.2 Quality control

Quality control involved carefully evaluating numerous detailed graphs of daily data to detect evidence of possible quality issues as well as statistically identifying outliers (Sensoy et al., 2008). For this reason quality control data is a prerequisite for indices calculations. RClimDex was used for quality control of data on the bases of replace all missing values (coded as -99.9) and replace all unreasonable values into NA. These values include automated checking for negative precipitation and it is assumed as missing value (-99.9); if maximum temperature less or equal to minimum temperature, it is assumed as missing value (-99.9); automated searches for outliers, where a limit of mean ± 3.5*STD was taken as a borders of outlier data and visual checks of data plots were made for temperature parameter.

## 2.3. Data homogeneity

Homogeneous climate time series is defined as where the variations are caused only by climate variations (Sensoy et al., 2008). Inhomogeneity occurs when one or more factors are change during the observation period. The relocation of a station most often involves change in the inter-station distance, the altitude and the surface characteristics. These changes will normally lead to abrupt inhomogeneity. Testing homogeneity requires a method that distinguishes artificial from natural changes. In order to detect any possible variations in the available data, three homogeneity tests are used. They are Standard Normal Homogeneity Test (Alexanderson), Pettitt and Von Neumann Ratio Tests. In addition to Buishand range, these tests were used by the European Climate Assessment (ECA) project to detect the usefulness of daily time series in evaluating the results of the homogeneity tests.

## 2.4. Indices calculation

Data were analyzed using the well-known package RClimDex. This program was used by many investigators to determine the indices of climate change in different countries (Aguilar et al., 2005; Haylock et al., 2006; New et al., 2006; Rusticucci and Renom, 2008). RClimDex is capable of computing all 27 core indices listed in Table 3.

## 3. Results and discussions

### 3.1. Homogeneity and quality control

Table 4, illustrates the results of homogeneity test for the selected stations. All stations passed Von Neumann and Pettitt test, while only one station (Baqura) failed in Alexanderson test. The result of RClimDex quality control indicated that all stations passed the quality control tests.

**Table 3:** Climate indices

| ID | Indicator name | Definitions | UNITS |
|----|----------------|-------------|-------|
| SU25 | Summer days | Annual count when TX(daily maximum)>25ºC | Days |
| TR20 | Tropical nights | Annual count when TN(daily minimum)>20ºC | Days |
| TN10p | Cool nights | Percentage of days when TN<10th percentile | Days |
| TX10p | Cool days | Percentage of days when TX<10th percentile | Days |
| TN90p | Warm nights | Percentage of days when TN>90th percentile | Days |
| TX90p | Warm days | Percentage of days when TX>90th percentile | Days |
| WSDI | Warm spell duration indicator | Annual count of days with at least 6 consecutive days when TX>90th percentile | Days |
| DTR | Diurnal temperature range | Monthly mean difference between TX and TN | ºC |

**Table 4:** Results of homogeneity tests

| Station | Von Neumann Test | | | Pettitt Test | | | Alexandersson Test | | |
|---------|------|-------|--------|------|-------|--------|-------|-------|--------|
| | V | $V_c$ | Remark | K | $K_c$ | Remark | $T_0$ | $T_c$ | Remark |
| Baqura | 1.54 | 1.48 | Ok | 82.0 | 129.9 | Ok | 11.5 | 7.3 | Not Ok |
| Irbid | 2.25 | 1.48 | Ok | 65.0 | 129.9 | Ok | 1.6 | 7.3 | Ok |
| Wadi Alrrayan | 2.23 | 1.48 | Ok | 80.0 | 129.9 | Ok | 2.6 | 7.3 | Ok |
| Deir Alla | 2.72 | 1.48 | Ok | 45.0 | 129.9 | Ok | 0.9 | 7.3 | Ok |
| Rabbah | 2.28 | 1.48 | Ok | 81.0 | 129.9 | Ok | 3.4 | 7.3 | Ok |
| Shoubak | 2.52 | 1.48 | Ok | 77.0 | 129.9 | Ok | 4.3 | 7.3 | Ok |

## 3.2. Temperature

### 3.2.1. Cold extremes (TX10p and TN10p)

For indices of cold days (TX10), two stations (Rabbah and Shoubak) showed significant decreasing trend (p=0) as shown in Fig. 2. The rate of decrease ranged from -0.197 to -0.237 with average value of -0.217. This result indicated that the percentage of cold days decreased by 11.7% during the last thirty years. Three stations (Dier Alla, Irbid, and Wadi Alrayyan) showed significant decreasing trend in cool nights (TN10), where the slope of trend ranged from -0.14 to -0.298, and Baqura station showed significant increasing in cool night (TN10p), whereas the slope of the trend is 0.15 as shown in Fig. 3. Concerning the temperatures of the coldest days and coldest nights in each year (TX10p and TN10p), significant trend was shown for all stations.

### 3.2.2. Diurnal temperature range (DTR)

Three stations indicated significant increasing trend (Shoubak, Baqura, and Rabbah) in DTR indices,

where the slope of trend ranged from +0.024 for Shoubak station to 0.042 For Rabbah station with average value of +0.033, and three stations showed significant decreasing trend (Irbid, Deir Alla, and Wadi Alrayyan) with average slope 0.024 as shown in Fig. 4.

The results indicated that the average variation in the daily temperature (TX-TN) increased by 1.35°C during the study period. The maximum variation was noticed in Rabba station while the lowest was for Irbid station.


(a)


(b)
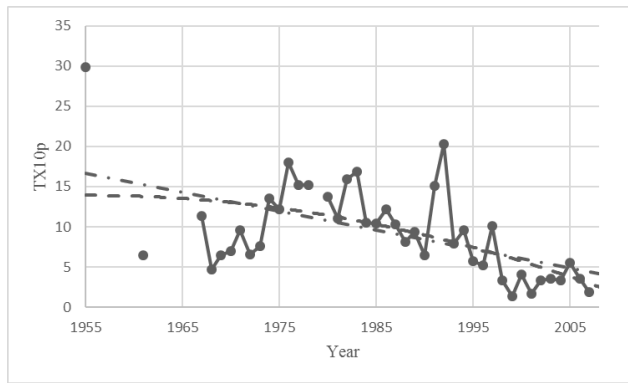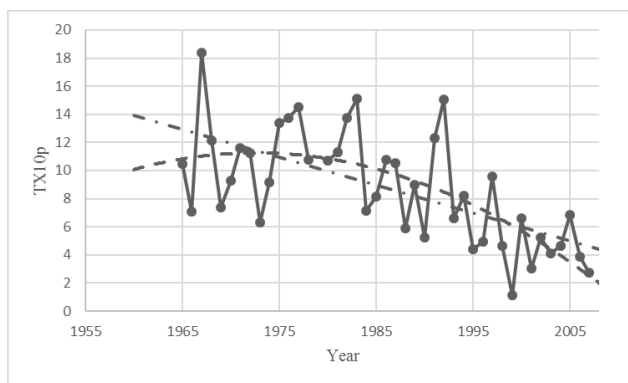
**Fig. 2:** TX10p for (a) Rabba and (b) Shoubak station

### 3.2.3. Hot Extremes (TX90p, TN90p, TXx, TNx, TR20, SU25 and WSDI)

The percentage of days exceeding the 90th percentiles (TX90p) is the most noticeable indices, where three stations showed significant positive trend (Baqura, Rabbah, and Shoubak). Very small values of p were obtained and ranged from 0 to 0.0105, while the slope of trend ranged from +0.163 for Shoubak station to +0.33 for Baqura station with an average value of 0.236 as given in Fig. 5.

This result indicated that a significant shift occurred in the daily temperature where the number of the hot days increased by 5.7 days during the study period. Moreover, a significant increase in the percentage of nights exceeding the 90th percentiles temperature (TN90p) was observed for three stations (Baqura, Deir Alla, Irbid, and Wadi Alrayyan) as shown in Fig. 6.


(a)


(b)


(c)


(d)
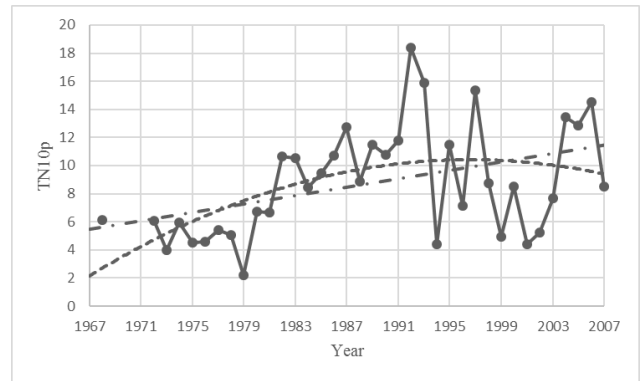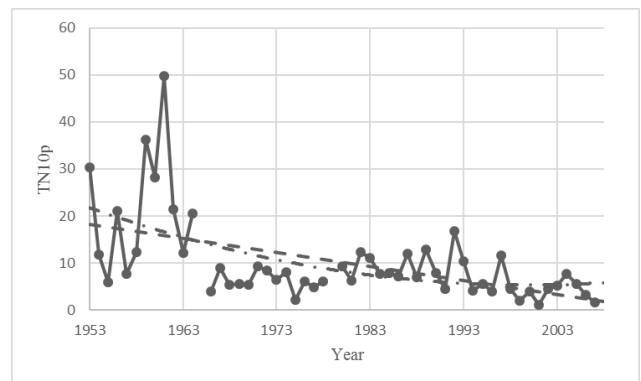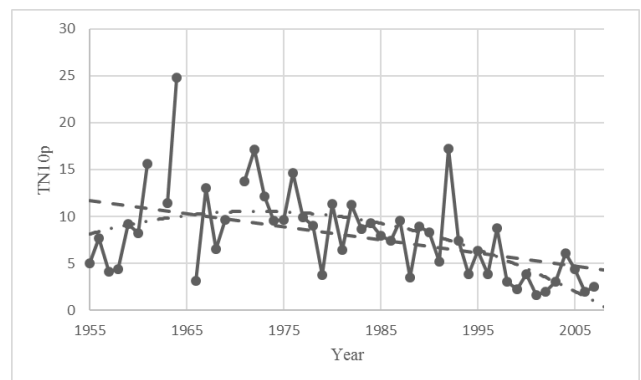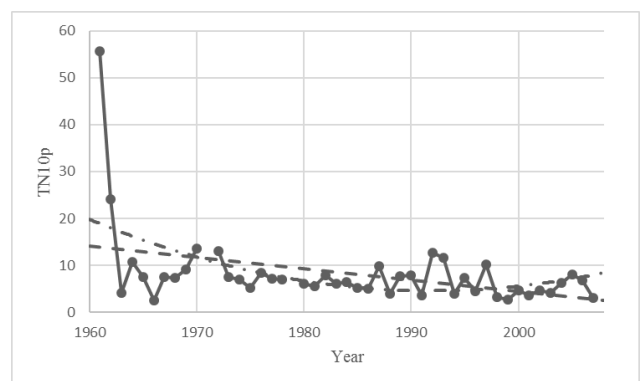
**Fig. 3:** TN10p for (a) Baqura, (b) Deir Alla, (c) Irbid, and (d) Wadi Alrayyan stations

Three stations (Deir Alla, Irbid and Wadi Alrayyan) shows increasing trend in tropical nights (TR20), three stations (Baqura, Rabbah, and Shoubak), and two stations (Rabbah and Shoubak) shows increasing trend in warm spell duration
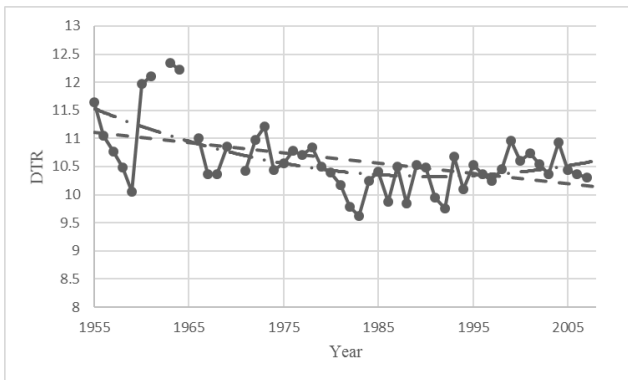
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(WSDI), and summer days (SU25), respectively (Figs. 7, 8, and 9). Shoubak is the only station which showed increasing trend in the two parameters, while Deir Alla station showed insignificant trend for these parameters.
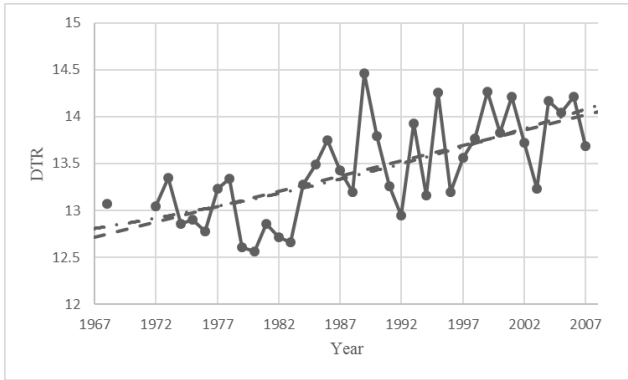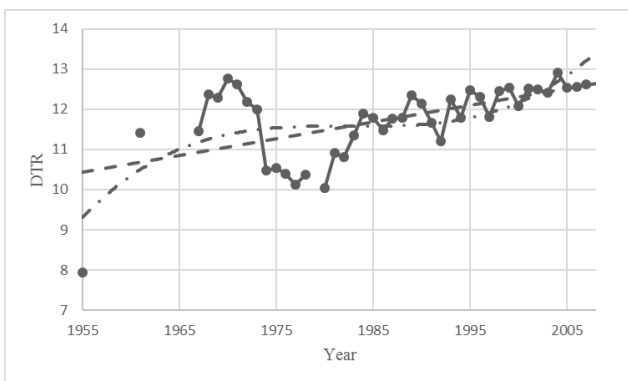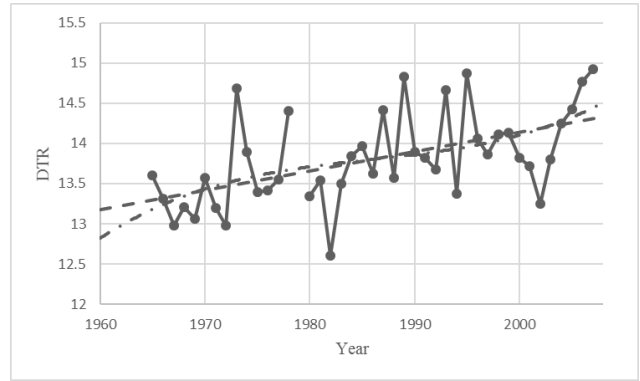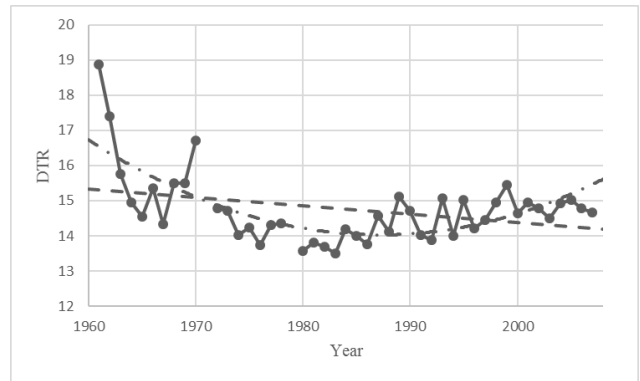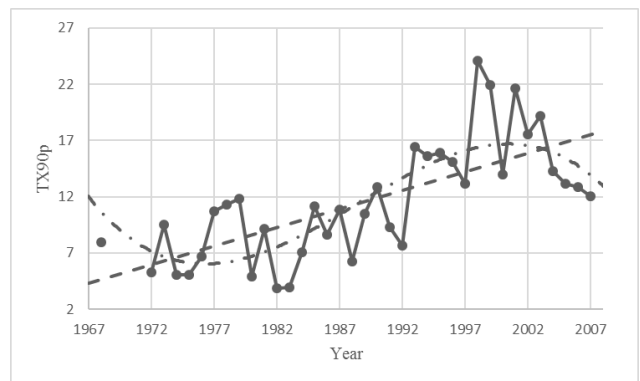


(a)
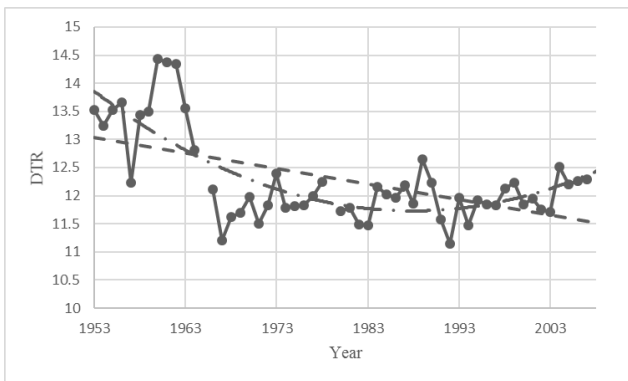


(b)



(c)



(d)



(e)



(f)

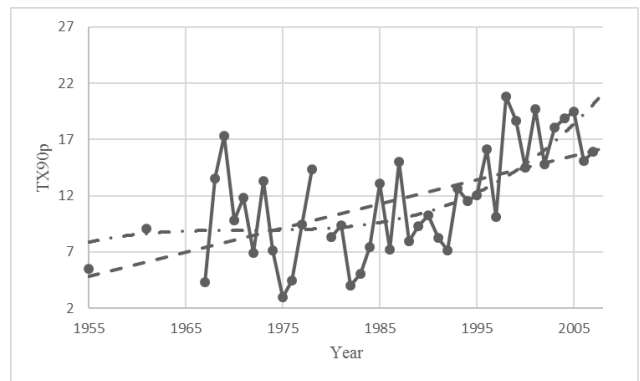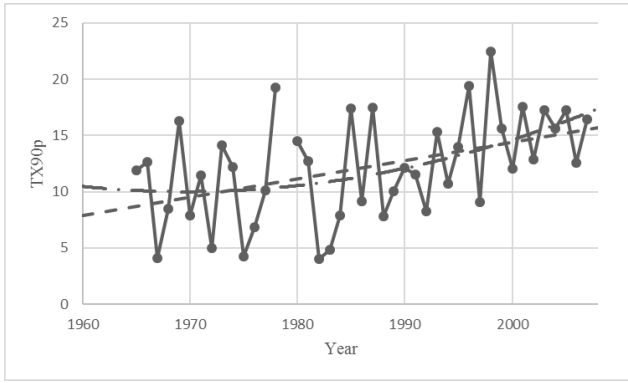**Fig. 4:** DTR for (a) Baqura, (b) Deir Alla, (c) Irbid, (d) Rabba, (e) Shoubak, and (f) Wadi Alrayyan stations
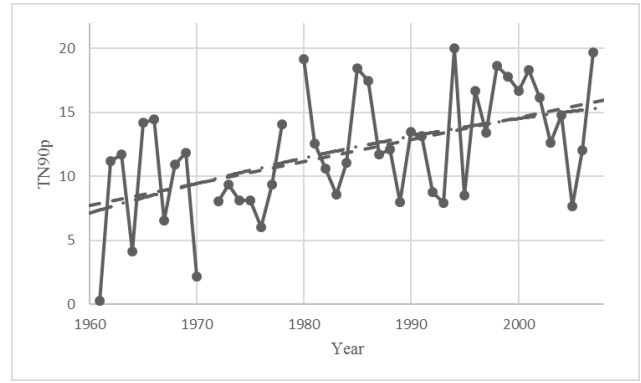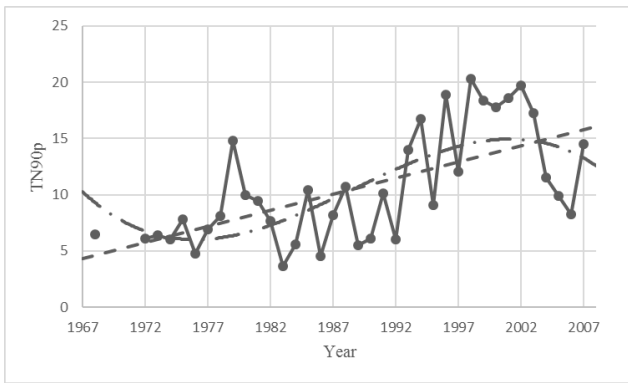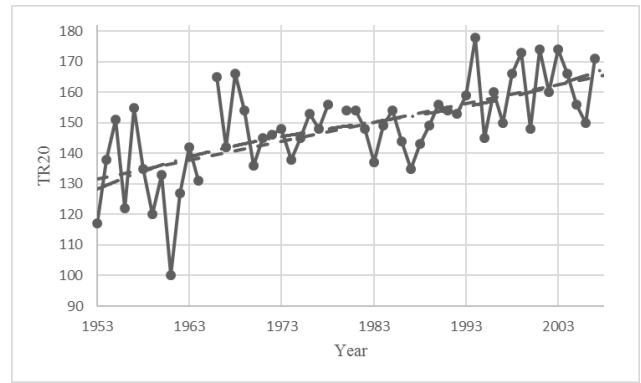


(a)



(b)

(c)

**Fig. 5:** TX90p for (a) Baqura, (b) Rabba, and (c) Shoubak stations
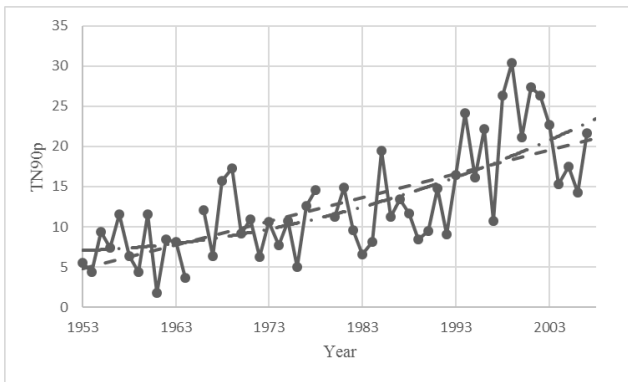


(d)

**Fig. 6:** TN90p for (a) Baqura, (b) Dier Alla, (c) Irbid, and (d) Wadi Alrayyan stations
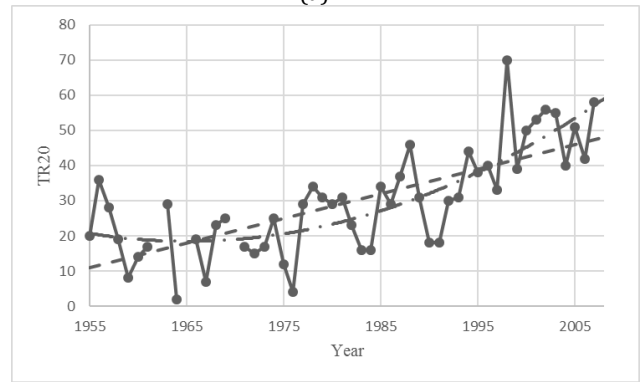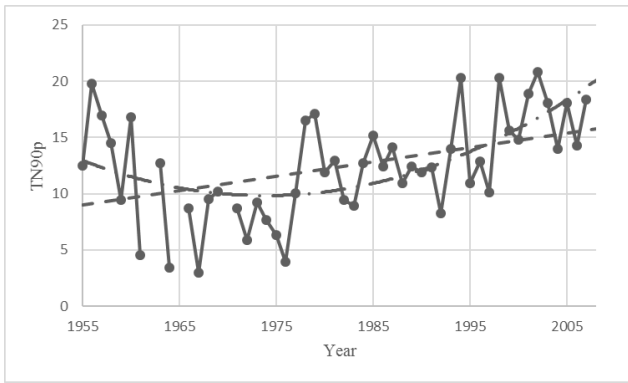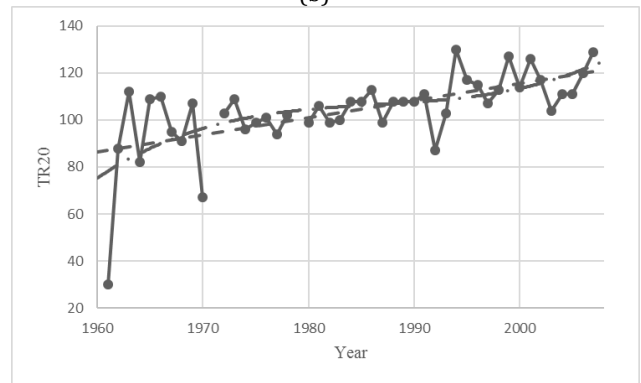


(a)



(b)



(c)



(a)



(b)



(c)

**Fig. 7:** TR20 for (a) Dier Alla, (b) Irbid and (c) Wadi Alrayyan stations
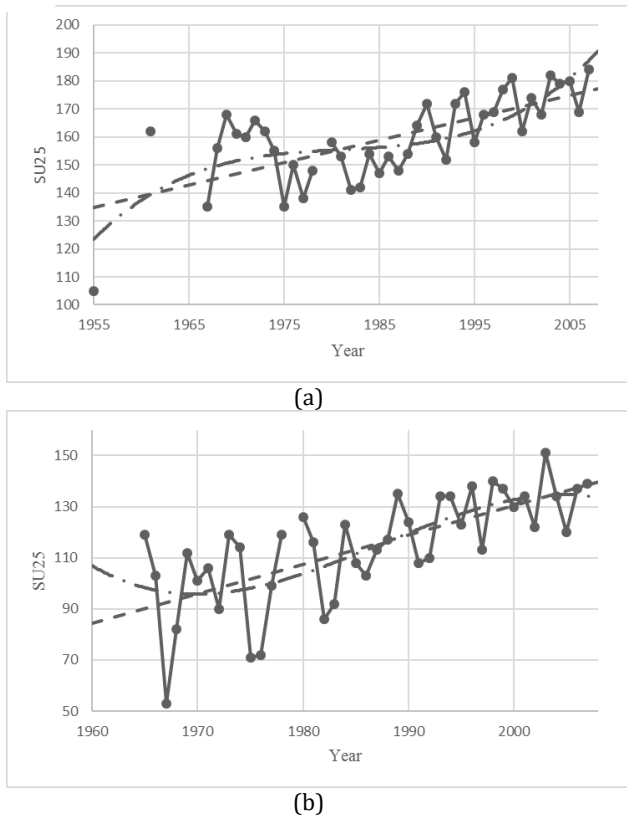
(a)



(b)

**Fig. 8**: SU25 for (a) Rabba and (b) Shoubak stations

### 3.2.4. Comparison of hot and cold extremes

The magnitude of the averaged trend in TX10p is about twice that of TX90p, where all stations have larger magnitude trends in terms of TX10p. The trend ratios of TX10/TX90 were 100%, 120%, 120%, 100%, 100% and 100% for Baqura, Dier Alla, Irbid, Rabba, Shoubak, and Wadi Alrayyan, respectively. The result indicated that 11.76 days were shifted from the cold extreme (<10p) during the study period, while only 6.7 days were shifted to the hot extreme (>90%).

For both indices (TX10p, and TX90p), Rabbah and Shoubak showed significant trend as such, which indicated that the change in temperature profile appeared as increasing in the number of warm days (increase in TX90p and decrease in TX10p), for indices (TN10p, and TN90p), Baqura, Deir Alla, Irbid, and Wadi Alrayyan showed significant trend as such, which indicated that the change in temperature profile appeared as increasing in the number of warm night (increase in TN90p), and three stations showed decrease in cool night (decrease in TN10p). Baqura station, have a positive trend for warm daytime and nighttime hot and cold extremes (TX90p, TN90p, and TN10p), while the other stations showed significant trends in two parameters or more.

### 4. Conclusion

The obtained results showed that it has significant trends in temperatures indices especially for cool days, warm days, warm nights, cool nights, summer days, diurnal temperature range, and the

tropical nights indicators. For indices of diurnal temperature range (DTR), all stations showed significant trend, where the percentage of the cold days decreasing by 11.7% during the last thirty years. Baqura, Deir Alla, Irbid, Rabbah, Shoubak, and Wadi Alrayyan stations showed significant trend for five, four, four, five, five, four indices respectively.
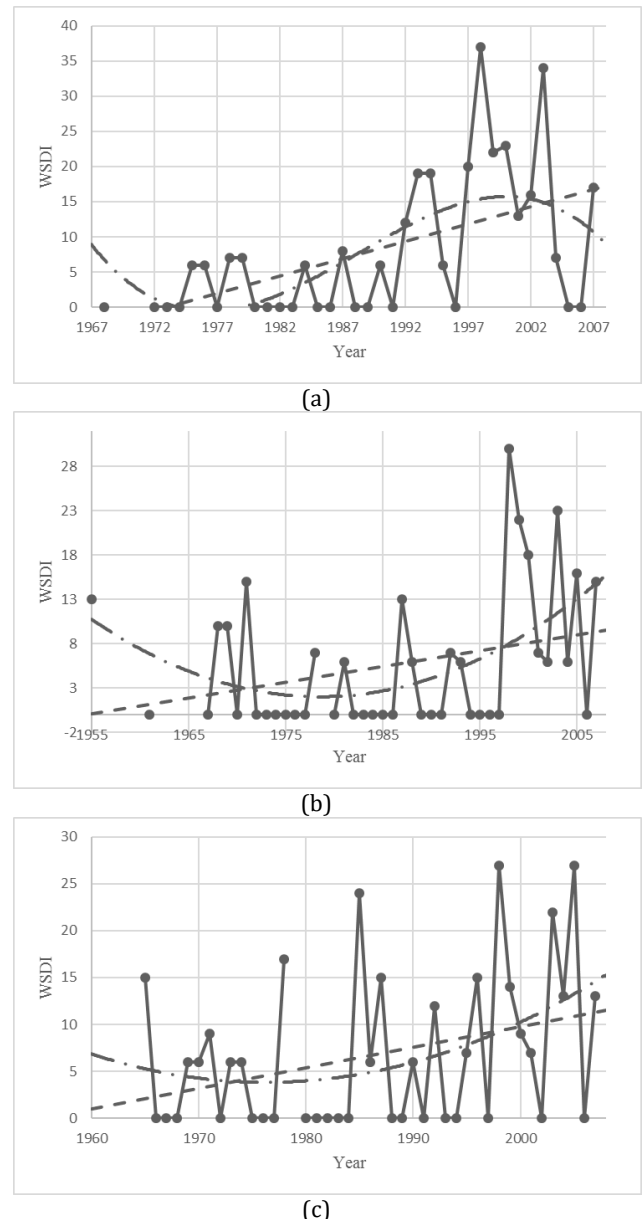


(a)



(b)



(c)

**Fig. 9:** WSDI for (a) Baqura, (b) Rabbah, and (c) Shoubak stations

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