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Climate Change Indicators in Jordan: A New Approach Using Area Method

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ABSTRACT

Climate change is considered as one of the main environmental challenges which occurred during the last five decades. Climate change poses an additional heavy pressure on Jordan's limited water resources and the environment. This paper aimed to assess climate change in Jordan using many temperature indicators (max. T>25, max. T>30, min. T>10 and min. T<10°C). Also, the area method was used as a new approach to assess the trend in the mentioned indicators. The data collected for 30 years in 10 stations was used for calculation and analysis. The results indicated that two stations recorded a noteworthy increase in temperature above 25 and 30°C, while the others showed an insignificant increase/decrease. Only one station showed a significant increase in the min. T>10°C with an irrelevant change in the other stations. Analysis of monthly data revealed that 50, 60 and 30% of the stations showed an increase in the max. temp. (>25) in June, July and August, respectively, with a notable increase for two stations. In comparison with the minimum temperature >15°C, six of the 10 stations showed increases during June, four in July and four in August, with a significant trend in two stations in two different months. Regarding the coldest days (min.<10°C), 6 of 8 stations and 8 of 10 stations showed a decrease in the average min. monthly temperature<10°C in November and December, respectively, which indicated late commencement of the winter season and a significant change in the season's pattern. By comparing the results of the area method with those of the linear regression method, a high agreement was found between the trends in both approaches, while a substantial difference in R^2 value was found. Based on the obtained results, it was concluded that the climate change in temperature is pronounced and can be determined successfully by the area method.

KEYWORDS: Climate change, Jordan, Temperature pattern, Area method, Max. temp., Min. temp.

INTRODUCTION

Climate change is considered as one of the major environmental problems which occurred during the last five decades. A dramatic increase in population as well as industrial revolution have resulted in a sharp increase in resource consumption and an extreme generation of contaminants, particularly greenhouse gases (EPA, 2017).

Climate change evidences have been reported in many countries in terms of an increase in atmospheric temperature, high evaporation, harsh weather, flood, drought in some areas, melting of ice glaciers in the northern hemisphere, the spread of diseases, extinction of some species, an increase in the concentration of CO_2 and CH_4 in the atmosphere and rising sea level.

It has been reported that CO_2 concentration increased from 280ppm in the 18th century to about 400ppm in 2015. Methane (CH_4) increased to about 1800ppb which represents double the reference level of preindustrial times. Similarly, NO_2 increased to an extreme level, where it exceeded 328 ppb in 2014 (EPA, 2018).

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In the USA, temperature has increased by 0.29-0.46°F per decade since the 1970s in comparison with a lower rate of 0.14°F between 1901 and 1970. Regarding the warmest years, eight of the ten warmest years occurred after 1998 and the years 2012 and 2015 are considered the warmest. Globally, based on records, 2006-2015 is considered the warmest decade and the year 2015 the warmest year.

In terms of precipitation, from the year 1901, the global rate increased by 0.08 inch/decade in comparison with 0.17 inch/decade in the USA. Since 1993, the average sea level has risen by 0.11-0.14inch/y, which is double the normal rate (EPA, 2018).

In addition to the environmental impacts, climate change has destructive impacts on both the global economy and human welfare. In EU countries, it is expected that an increase in temperature by 2.5°C will cause a reduction in the GDP by €20 billion, while an increase of 5.4°C might cause a reduction of €65 billion. Similarly, the annual welfare losses will be 0.2% and 1% for both temperatures, respectively (Juan-Carlos et al., 2011). Also, land losses due to the rise in sea level will reach 12% in Malta and 3.5% in Greece, resulting in indirect losses in GDP in addition to lower food security (Bosello et al., 2012).

In Africa, it is predicted that food production could be reduced by up to one half (50%) due to climate change phenomenon (Richard, 2018). For example, in Mali, a significant reduction in forage yields up to 36% is expected and the livestock animal weight will be reduced by 14-16%, resulting in a loss estimated at €70-142 million/y. The sharp impact of climate change on the economy and food production could significantly increase the risk of hunger by 30-38% (Butt et al., 2005).

A review on the impact of climate change on the south of Asia and Africa reported that in 2050, the crop yield in Africa will be reduced by 17, 5, 15 and 10% for wheat, maize, sorghum and millet, respectively, whereas in the south of Asia, the reduction will be 16% and 11% for maize and sorghum, respectively.

Locally, Jordan has limited water resources and is considered as one of the three poorest countries in this essential resource. High evaporation, high population growth rate, consecutive waves of refugees, limited financial sources and drought are the main driving forces of water stress in Jordan (AlZou'by et al., 2017; Al-Zboon and Al-Suhaili, 2009). Climate change poses an additional pressure on water resources, the environment and the national GDP. It has been reported that there was a significant increase in the annual minimum temperature during 1999-2009 (Hamdi et al., 2009). A significant decrease in rainfall in December and January up to 40% is expected, combined with a reduction in the annual number of rainy days, while an insignificant change during February and March is predicted (Emily, 2009; Abdulla and Malkawi, 2020). Wheat and barley are considered the most planted rain-fed crops in Jordan and are the most affected crops by rainfall variation and change of rainfall pattern. The application of a crop simulation model revealed that a reduction in rainfall by 10-20% will cause a reduction in wheat and barley yield by 10–20% and 4–8%, respectively (Al-Bakri et al., 2011). Al Qatarneh et al. (2018) found that there was an increase in the number of days with max. temp. >38 and with min. temp. >20°C. The increase in temperature resulted in an increase in evaporation rate by 4.74 - 5.32% for Azraq basin –Jordan.

Different models have been used to determine the impact of climate change and to assess its indicators. The RClimDex model is recommended by the World Metrological Organization for the prediction of 27 climate change indices. The Soil and Water Assessment Tool (SWAT) model was used to determine the impacts of climate change on water, sediment, soil and agricultural yield (Al Qatarneh et al., 2018). Dynamic and Interactive Vulnerability Assessment (DIVA) model was developed to predict the environmental and social impacts of climate change on coastal areas and to predict the rise in sea-level. The Global Trade Analysis Project (GATP) model was used to predict indirect economic impacts (Bosello et al., 2012). The Decision Support System for Agrotechnology Transfer (DSSAT) model was intensively used to predict the effect of climate change on agriculture and crops (Al-Bakri et al., 2011). Also, many statistical approaches have been used to assess climate change indicators, such as linear regression, Mann-Kendall, rank difference and rank sum approaches (Hamdi et al., 2009).

In this research, the linear regression approach was used to determine the possible climate change in the atmospheric temperature of Jordan. Five temperature indicators were used: max. temp.>25°C(TX>25), max. temp.>30°C(TX>30), min. temp.>15°C(TN>25), min. temp.>10°C(TN>10) and min. temp.<10°C(TN<10). For

30 years, the data of ten stations was utilized to determine the mentioned indices. Also, the area approach method was applied to obtain the same indicators; thereafter, the agreement of the results of both methods was evaluated. To the best of the authors' knowledge, this is the first time the area method is used to find climate change indices, which proves the novelty of this work.

METHODOLOGY

Data

The data of the max. and min. temperatures of ten stations was collected from the Ministry of Water and Irrigation of Jordan. Figure (1) illustrates the location of the selected stations.

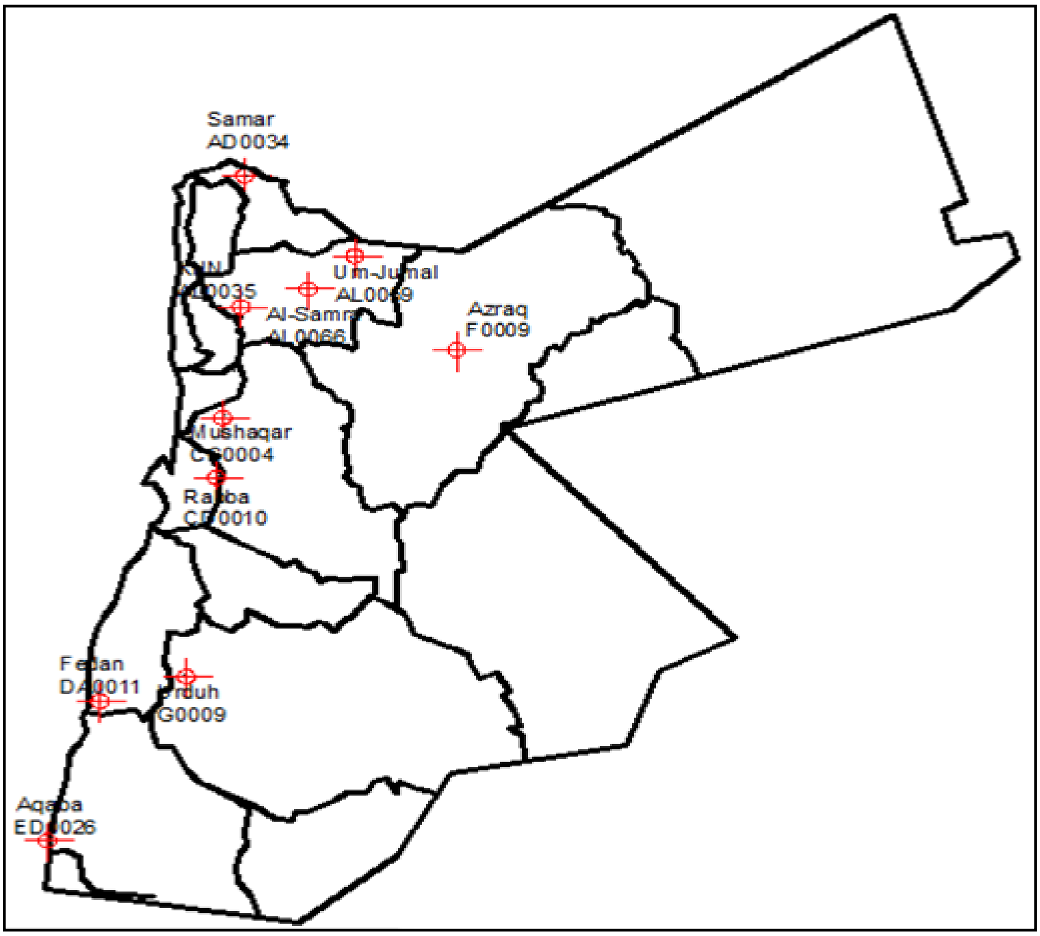

Figure (1): Location of the meteorological stations

In some cases, there were errors in the collected data due to many factors, such as the need of calibration for instruments, improper calibration, change of the instrument location, errors related to data collection and recording, incorrect coding of data and errors of telecommunication and data transfer. Human activities in the area, such as urbanization and the development of irrigation systems, could be possible sources of error. To avoid the impact of errors on the collected data, analysis and decision making, many homogeneity tests have been developed and applied worldwide. In this research, three homogeneity tests for data were used; namely: 1) Von Neumann's test, 2) Pettit's test and 3) standard normal homogeneity test (SNHT) (Al-Qatarneh et al., 2018). The results of the homogeneity tests showed that eight of the ten stations passed the three tests, while the other two stations (Udrah, Rabba) passed two tests only.

Calculated Indices

In this research, five indices were considered and presented as indicators of climate change; namely:

a. Average max. monthly temperature >30°C, which was expected to occur during the months of April-October. In some stations, most temperatures were below 30°C, which affected the quality of data analysis. So, other analysis were carried out based on max. temp. >25°C.

b. Average max. monthly temperature >25°C, which was expected to occur during the months of March-November.
c. Average min. monthly temperature >10°C, which was mostly recorded during the months of April-October and was implemented to assess the possible increase in the min. temperature and tendency to a warmer climate.
d. Average min. monthly temperature >15°C, which was mostly recorded during the months of May – October. Also, it was used to obtain the tendency of temperature to warmer conditions.
e. Average min. monthly temperature <10°C, which was used as an indicator of the coldest months.

Area Method

MATLAB software has been used in many environmental applications, such as contaminant transport in groundwater, water quality model, forecasting of hydrological parameters, assessment of eutrophication in lakes and rivers, air quality monitoring and sewage monitoring systems.

The trend (increase or decrease) of the area above or below the reference level was considered as an alternative indicator of climate change instead of using linear regression. The area for a certain month was calculated as follows:

$$A = \int_{1}^{n} (f(T) - Tr) dt \qquad (1)$$

where A is the area of the temperature curve above or below the reference temperature for a certain month, n refers to the number of months in which the temperature was above or below the reference, $f(T)$ is a polynomial function of temperature, Tr is the reference temperature (TX>25, XT>30, TN>15, TN>10 and TN<10) and *t =1,2,3,…….,n.*

Figure 2.a shows the maximum temperatures for station CD0010, where the blue line, the polynomial equation, is connected between the points, representing the maximum temperature above a certain level (index) and in this case, the value of the index was 25°C. Thereafter, the area between the curve and the index was calculated and the area value recorded for all the years, where the figure illustrates some of the fitting results. Figure 2.b shows the minimum temperature readings for the same station and the blue line represents the polynomial equation for temperatures below the index, which is 10°C; then, the area between the reflex line and the curve was calculated. The results of the area method were compared with those of the linear regression method to determine the applicability of the area method as an indicator of climate change.

RESULTS

Annual Trend of the Max. Monthly Temp.

The values of the average TX> 25 for the selected stations showed variable trends. Two stations (Al0035, ED0026,) showed an insignificant positive trend with R^2 = 0.002 and 0.004, respectively, while Al0066 and CC004 stations revealed a considerable increase with R^2= 0.417 and 0.474, respectively. In contrast, six stations (AD0034, Al0059, CD0010, DA0011, F0009 and G0009) showed insignificant decreases with R^2= 0.11, 0.07, 0.21, 0.15, 0.096 and 0.001, respectively. Similarly, the TX>30 showed a minimal increase for Al0035, while Al0066 and CC004 showed a considerable increase with R^2= 0.331 and 0.466, respectively. CD0010 and G0009 recorded a limited number of days with T>30°C; so, the trend for both stations was not calculated. The other stations (AD0034, Al0059, DA0011, ED0026 and F0009) showed a minor decrease with R^2= 0.169, 0.018, 0.263, 0.003 and 0.116, respectively. Considering the results above, it can be confirmed that there is an irrelevant trend in the average max. temperature. The monthly temperature data showed an insignificant trend for all stations except for Al0066 (Al-Samra) and CC004 (Mushaqar). Al-Samra area has the largest wastewater treatment plant in Jordan with a daily flow of 328,000 m^3. During the winter season, influent wastewater to the plant has warmer temperatures than the ambient air, which results in an increase in the atmospheric temperature of the surrounding area. Also, Al-Samra area is located 5km to the east of the two major emission sources in Jordan, the Jordan Petroleum Refinery and Al-Hussein Thermal Power Plant. Both sources of emission are considered the main reason for temperature increase in the area. Mushaqar station is located at about 20km to the west of

Amman, the capital and largest city of Jordan, where the high population and dense industries in the surrounding areas have resulted in a gradual increase in the max. temperature.

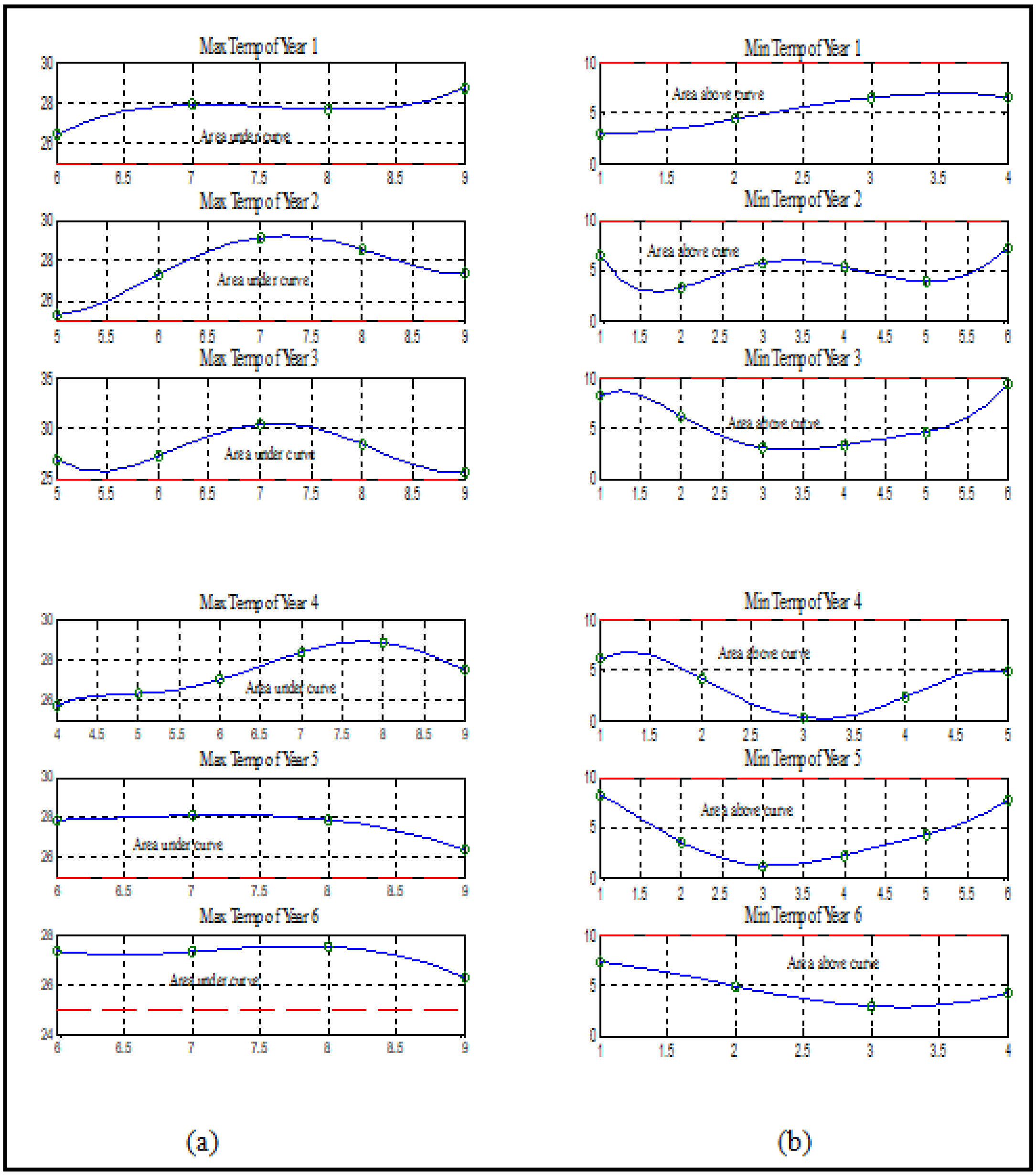

Figure (2): Maximum and minimum temperature fitting with polynomial

Monthly Trend of the Max. Temperature

The max. temperature >25°C showed an insignificant correlation coefficient (R^2) in 9 of 11 stations. The trend varied from negative to positive signs for all stations. In this study, 50, 60 and 30% of the stations showed increments in the max. temp. in June, July and August, respectively. In terms of seasonal variations, only two stations showed a notable positive trend during the summer season (June, July and August); namely: Al-Samra and Mushaqar stations. In contrast, Samar, Um- Jumal, Rabba and Fedan stations showed negative trends for all the summer months (June, July and August), as shown in Table 1.

Table 1. R^2 of monthly trend of max. temp.>25°C

Station	Name	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
AD0034	Samar	*	-0.029	-0.029	-0.007	-0.006	-0.068	-0.351	*	*
N. of data, months		2	27	30	30	30	30	30	2	0
Al0035	KHN	*	-0.027	+ 0.011	+ 0.024	+ 0.055	-0.004	- 0.0004	-0.005	*
N. of data, months		0	8	25	25	25	25	25	25	0
Al0059	Um-Jumal	*	-0.027	-0.004	-0.004	-0.002	-0.034	- 0.170	-0.116	*
N. of data, months		1	20	30	30	30	30	30	28	1
Al0066	Al-Samra	*	+ 0.036	+ 0.207	+ 0.419	+ 0.322	+ 0.445	+ 0.292	+ 0.386	+ 0.042
N. of data, months		4	24	30	30	30	30	30	30	10
CC0004	Mushaqar	*	*	+0.041	+ 0.638	+ 0.406	+ 0.331	+ 0.519	+ 0.102	*
N. of data, months		0	3	20	20	25	25	25	17	0
CD0010	Rabba	*	*	+ 0.027	-0.088	-0.051	-0.202	- 0.005	+ 0.018	*
N. of data, months		0	1	10	21	23	23	19	5	0
G0009	Udruh	*	*	*	+ 0.029	+ 0.001	-0.042	- 0.181	*	*
N. of data, months		0	0	2	22	25	24	18	0	0
DA0011	Fedan	+ 0.006	+ 0.154	-0.053	-0.051	-0.371	-0.003	- 0.146	+ 0.187	*
N. of data, months		6	9	15	15	15	15	15	15	3
F0009	Azraq	*	-0.018	-0.009	+ 0.006	+ 0.001	- 0.036	- 0.297	+ 0.002	*
N. of data, months		2	27	29	29	29	29	29	29	2
ED0026	Aqabaa	+ 0.227	+ 0.053	+ 0.003	-0.032	+ 0.134	+ 0.009	- 0.017	-0.001	+ 0.001
N. of data, months		15	26	26	26	26	26	26	26	20
* Number of months with T>25 is very low and not suitable to determine R^2.										

Table 2 illustrates the coefficients of correlation for the average max. monthly temp. based on a reference temperature of 30°C for all stations. Similar to the trend of max. temp.>25, Al-Samra and Mushaqar stations showed a positive trend during the summer season for T>30°C that ranged from 0.261 in July to 0.445 in August for Al-Samra station and from 0.199 in August to 0.681 in June for Mushaqar station. This result indicated that the max. temperature in both stations increased notably during the summer season. During July, Aqaba station (in the south) reported a noticeable increase. In contrast, Fedan station showed a significant decrease in July, while Samar station showed an insignificant decrease for all months. The number of times in a month when the average max. temp. exceeded 30°C varied from 5 times for Rabba station to 170 times for Aqaba station.

Table 2. R^2 of monthly trend of max. temp.>30°C

Station	Name	Apr.	May	June	July	Aug.	Sept.	Oct.
AD0034	Samar	*	- 0.07	-0.007	-0.006	-0.068	- 0.351	- 0.090
N. of data , months		1	25	30	30	30	30	7
Al0035	KHN	*	+ 0.005	+ 0.001	+ 0.055	-0.002	-0.043	*
N. of data, months		1	7	24	25	23	22	2
Al0059	Um-Jumal	*	+ 0.014	-0.004	-0.002	-0.034	- 0.170	- 0.391
N. of data, months		1	19	30	30	30	30	6
Al0066	Al-Samra	*	+ 0.09	+ 0.371	+ 0.261	+ 0.445	+ 0.292	+ 0.0003
N. of data, months		6	23	29	28	29	29	17
CC0004	Mushaqar	*	*	*	+ 0.343	+ 0.199	+ 0.707	*
N. of data, months		0	1	6	18	19	6	0
CD0010	Rabba	*	*	*	*	*	*	*
N. of data, months		0	0	0	3	2	0	0
G0009	Udruh	*	*	*	*	*	*	*
N. of data, months		0	0	0	4	4	0	0
DA0011	Fedan	*	-0.053	-0.051	-0.371	-0.003	-0.146	+ 0.004
N. of data, months		4	15	15	15	15	15	9
F0009	Azraq	*	- 0.070	+ 0.006	+ 0.001	-0.036	-0.297	- 0.090
N. of data, months		1	26	29	29	29	29	7
ED0026	Aqaba	+ 0.003	+ 0.003	-0.032	+ 0.134	+ 0.009	-0.017	+ 0.001
N. of data, monthsee		14	26	26	26	26	26	25

Annual Trend of the Min. Monthly Temperature

The annual trend of the average min. monthly temperature indicated that six stations had an increased number of months with min. temperature >10°C and these were: Al0035, Al0059, CC0004, DA0011, ED0026 and G0009 with R^2 of 0.261, 0.19, 0.642, 0.178, 0.013 and 0.085, respectively. Based on the coefficients of correlation, except for CC0004 (Mushaqar), all stations showed insignificant correlations. The increase in the min. temperature >10°C indicated that the climate in these stations tends to be hot. In contrast, four stations (AD0034, Al0066, CD0010 and F0009) showed a decrease in the min. temperature >10 with R^2= 0.259, 0.008, 0.034 and 0.245, respectively. For min. temperature >15°C, AL0035, AL0059, CC0004, DA0011 and ED0026 showed an increase with R^2 = 0.403, 0.069, 0.102, 0.098 and 0.048, respectively. Stations AD0034, CD0010 and F0009 showed a negative trend (decrease) with R^2 of 0.137, 0.006 and 0.175, respectively, whereas AL0066 had an R^2 of about zero and all the min. temperatures in the G0009 station (Azraq) were <15°C, except for two values.

Monthly Trend of the Min. Temperature

Table 3 shows the values of R^2 for the min. temp. >10°C for all stations. While all stations have records of the min. temp. >10 during May-Sept., only Aqaba station recorded such temperature for all months and Fedan station has records for March-October. Samar, Azraq and Rabba stations showed a decrease in the min. temp. >10°C for all months, indicating a general trend to colder weather. In contrast, KHN, Um-Jumal, Mushaqar, Udruh and Aqaba showed a positive trend (increase) during the summer season (June-August). Mushaqar and Udruh stations recorded medium R^2 values for June (0.511 and 0.498, respectively), while the trends of the other stations were insignificant. The number of months with the average min. temp. >10°C during the period of March-October varies from 90 times for Udruh station up to 200 times for Aqaba station.

Table 3. R^2 of monthly trend of min. temp. > 10°C

Station	Name	Apr.	May	June	July	Aug.	Sept.	Oct.
AD0034	Samar	*	- 0.07	-0.007	-0.006	-0.068	- 0.351	- 0.090
N. of data , months		1	25	30	30	30	30	7
Al0035	KHN	*	+ 0.005	+ 0.001	+ 0.055	-0.002	-0.043	*
N. of data, months		1	7	24	25	23	22	2
Al0059	Um-Jumal	*	+ 0.014	-0.004	-0.002	-0.034	- 0.170	- 0.391
N. of data, months		1	19	30	30	30	30	6
Al0066	Al-Samra	*	+ 0.09	+ 0.371	+ 0.261	+ 0.445	+ 0.292	+ 0.0003
N. of data, months		6	23	29	28	29	29	17
CC0004	Mushaqar	*	*	*	+ 0.343	+ 0.199	+ 0.707	*
N. of data, months		0	1	6	18	19	6	0
CD0010	Rabba	*	*	*	*	*	*	*
N. of data, months		0	0	0	3	2	0	0
G0009	Udruh	*	*	*	*	*	*	*
N. of data, months		0	0	0	4	4	0	0
DA0011	Fedan	*	-0.053	-0.051	-0.371	-0.003	-0.146	+ 0.004
N. of data, months		4	15	15	15	15	15	9
F0009	Azraq	*	- 0.070	+ 0.006	+ 0.001	-0.036	-0.297	- 0.090
N. of data, months		1	26	29	29	29	29	7
ED0026	Aqaba	+ 0.003	+ 0.003	-0.032	+ 0.134	+ 0.009	-0.017	+ 0.001
N. of data, months		14	26	26	26	26	26	25

In comparison with the min. temperature >15ºC, six of 10 stations showed increases in June, four in July and five in August. Three stations (KHN, UM-Jumal and Aqaba) showed increases for all months of the summer season (June-August), while Samar station showed a negative trend (decrease) in the min. temp.>15°C for all the summer months. Azraq, Fedan and Samar stations showed a positive trend (increase) in May, indicating an early summer season in these areas, as shown in Table 4.

Table 4. R^2 of monthly trend of min. temp.>15°C

Station	Name	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
AD0034	Samar	*	*	0.019	-0.212	-0.038	-0.184	-0.215	*	*
N. of data, months		0	0	12	22	30	30	30	1	
Al0035	KHN	*		*	0.094	0.457	0.211	0.232	-0.162	
N. of data, months		0	0	5	21	25	25	24	12	
Al0059	Um-Jumal	*		*	0.026	0.168	0.077	-0.005	*	
N. of data, months		0	0	5	23	25	24	23	5	
Al0066	Al-Samra	*	*	*	0.058	-0.001	0	0.001	*	
N. of data, months		0	0	2	15	29	29	15	2	
CC0004	Mushaqar	*	*	*	*	0.239	0.098	-0.027		
N. of data, months		0	0	0	3	24	25	13	0	
CD0010	Rabba	*	*	*	0.059	-0.001	-0.013	-0.196	*	*
N. of data, months		0	0	1	10	23	24	10	0	0
G0009	Udruh	*	*	*	*	*	*	*	*	*
N. of data, months		0	0	0	1	1	2	0	0	*
DA0011	Fedan		*	0.077	0.046	-0.023	0.044	0.066	0.228	*
N. of data, months		0	3	15	15	15	15	15	15	*
F0009	Azraq	*	*	0.019	-0.234	-0.055	-0.204	-0.238	*	*
N. of data, months		0	0	11	29	29	29	29	1	*
ED0026	Aqaba	-0.098	0.025	-0.013	0	0.124	0.110	0.066	0.048	0.005
N. of data, months		5	24	25	25	25	25	25	25	20

Monthly Trend of the Coldest Days

Regarding the coldest days (min.<10°C), 6 of 8 stations and 8 of 10 stations showed a decrease in the average min. monthly temperature<10°C in November and December, respectively, announcing a late start of the winter season and a significant change in the season's pattern. In March, six of nine stations showed an increase in the average monthly min. temp.<10ºC, indicating late extension of winter season and supported the previous result of late winter start. Samar station showed a negative trend for all months, while Mushaqar station showed increases for most months, as shown in Table 5.

Table 5. R^2 of monthly trend of min. temp.<10°C

Station	Name	Jan.	Feb.	March	Apr.	May	June	Sept.	Oct.	Nov.	Dec.
AD0034	Samar	-0.311	-0.125	-0.113	-0.09	*	*	*	*	-0.186	-0.371
N. of data, months		29	30	30	16	0	0	0	1	30	30
Al0035	KHN	0.22	0.121	0.104	-0.013	*	*	*	*	-0.002	0.008
N. of data, months		25	25	24	15	0	0	0	0	6	25
Al0059	Um-Jumal	-0.245	-0.056	-0.015	0.275	*	*	*	*	-0.03	-0.03
N. of data, months		25	25	25	16	0	0	0	1	22	25
Al0066	Al-Samra	-0.081	-0.068	0.001	-0.015	0.102	*	*	1	-0.064	-0.148
N. of data, months		30	30	29	27	0	0	0	2	28	30
CC0004	Mushaqar	0.059	0.017	0.159	0.355	0.314	*	*	*	0.002	-0.027
N. of data, months		25	25	25	23	6	0	0	0	23	25
CD0010	Rabba	-0.05	-0.015	0.034	0.067	*	*	*	*	-0.009	-0.021
N. of data, months		24	24	24	19	0	0	0	0	22	23
G0009	Udruh	-0.006	0.233	0.335	0.264	0.077	-0.337	-0.191	0.22	0.18	0.137
N. of data, months		25	25	25	25	22	8	3	20	25	25
DA0011	Fedan	-0.092	-0.044	0.001	*	*	*	*	*	*	-0.012
N. of data, months		15	14	6	0	0	0	0	0	1	15
F0009	Azraq	-0.288	-0.083	-0.116	-0.09	*	*	*	*	-0.206	-0.411
N. of data, months		29	29	29	16	0	0	0	1	28	29
ED0026	Aqaba	-0.024	0.09	*	*	*	*	*	*	*	-0.147
N. of data, months		16	7	0	0	0	0	0	0	0	4

Results of the Area Method

Figure 3 presents the relationship between the max. and min. temperatures, years and months. The horizontal plane represents a certain reference temperature (index). The levels above and below the index represent the temperature profile for max. and min. temperature, respectively. The area method is used to describe the possible change in the max. temp.>25°C, min. temp.>10 °C and min. temp.<10ºC, as shown in the different parts of Figure 3. The area represents the integration of the temp. difference (T-Tr) over certain months, while the horizontal flat surface represents the reference temp. (10, 15, 25, 30°C). The area method indicated that there are increases in the area above 25°C for four stations, while six stations showed decreases. Four stations showed an increase in the area above 30°C, while four stations showed decreases. For T>10°C, six stations showed increases in the area and four stations showed decreases. For T<10°C, six stations showed a positive trend (increase in temp.) with a significant R^2 for two stations (Samar and Azraq), while three stations showed insignificant decreases and Aqaba station had a limited number of months with TMN<10°C.

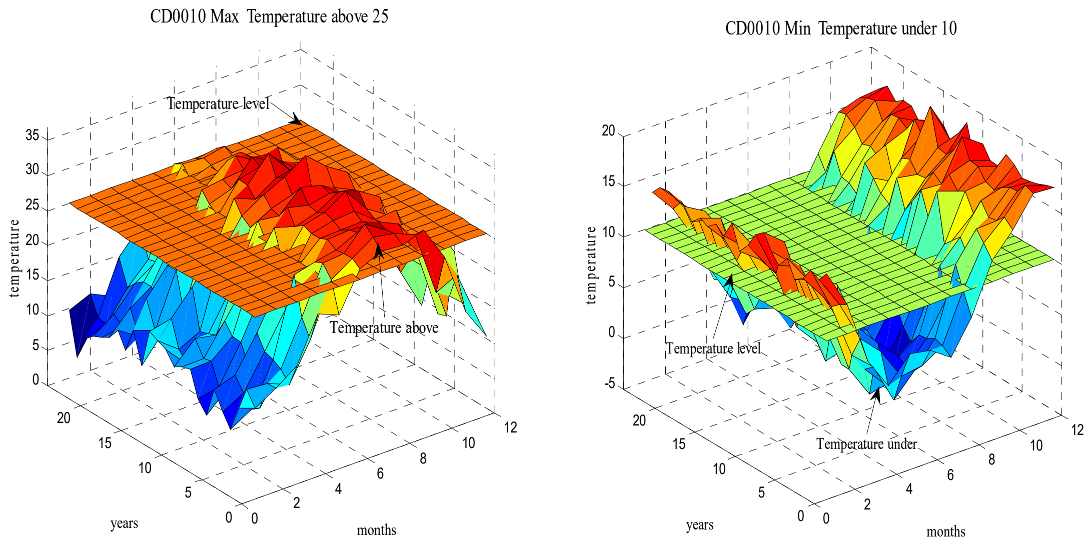

Figure (3a): Surface temperature profile with a reference level (>25°C and <10°C) for station CD0010

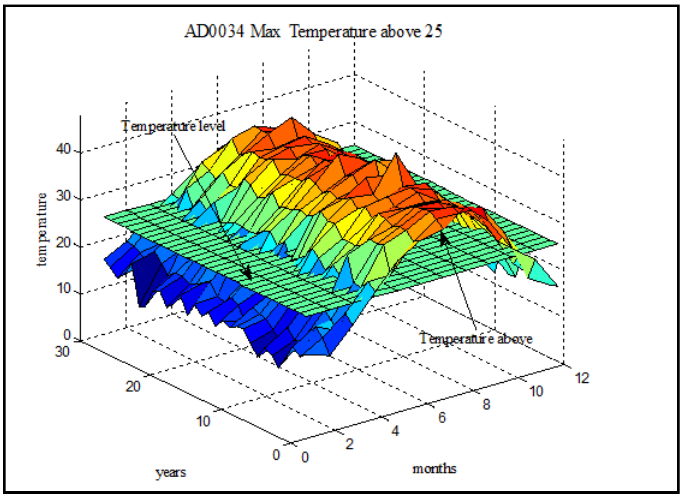

Figure (3b): The area profile of max. T>25 for station AD0034

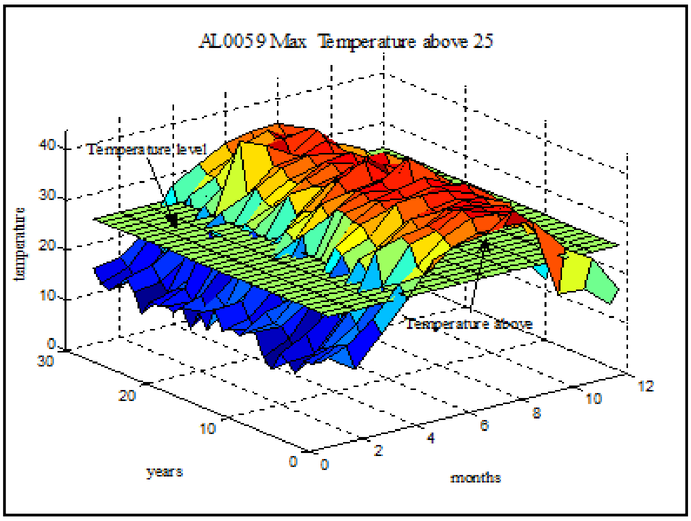

Figure (3c): The area profile of max. T>25 for station Al0059

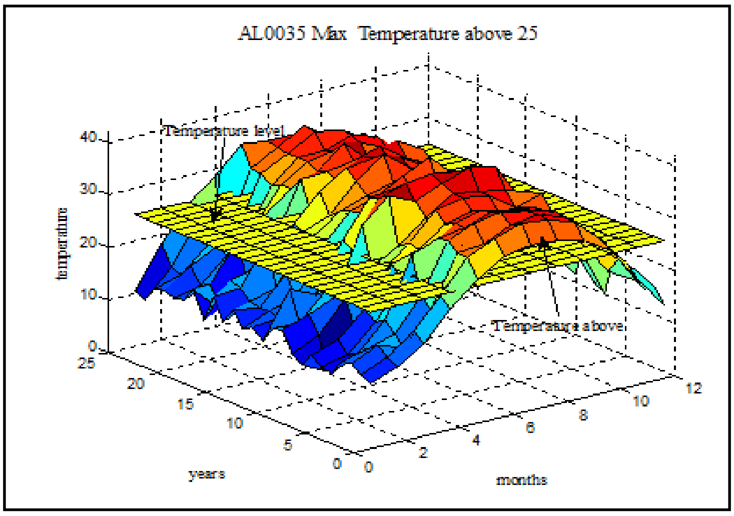

Figure (3d): The area profile of max. T>25 for station Al0035

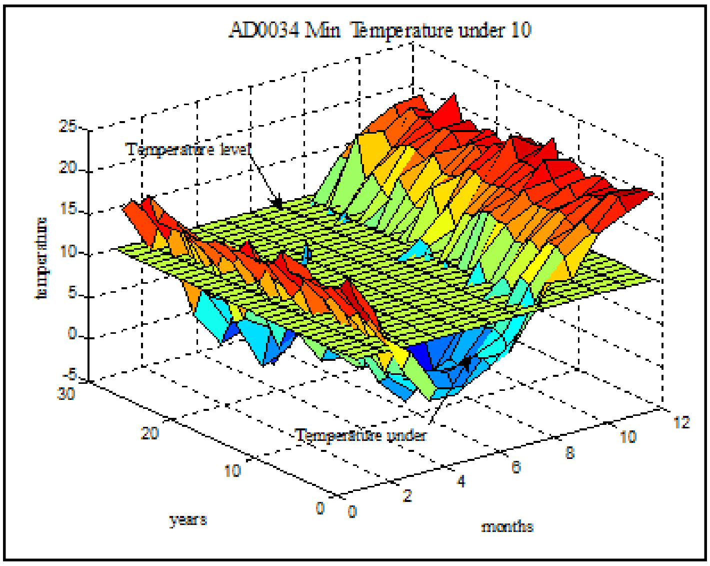

Figure (3e): The area profile of min. T<10 for station AD0034

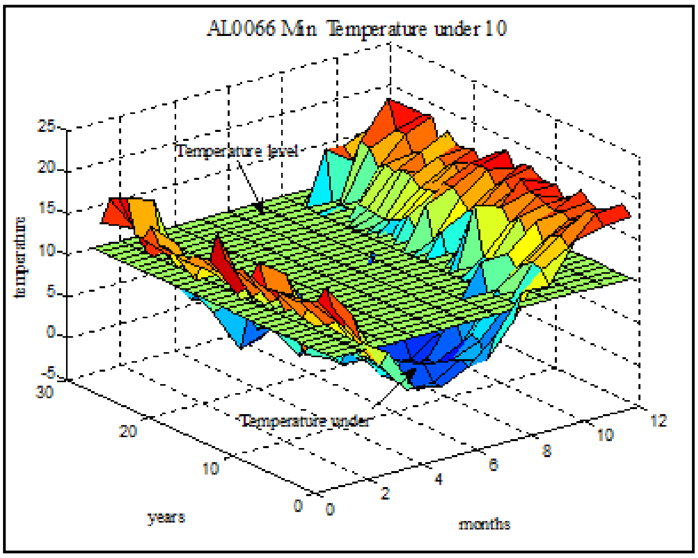

Figure (3f): The area profile of min. T<10 for station Al0066

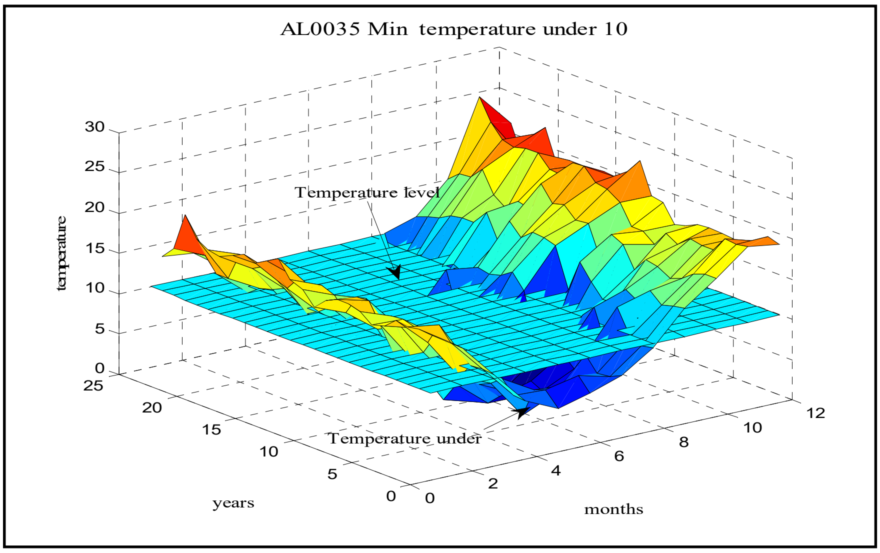

Figure (3g): The area profile of min. T<10 for station Al0035

Comparing the Results of Area Method with Those of the Linear Regression Method

Table 6 shows a comparison between the results of the two methods used, expressed in terms of the trend (+, -) and R^2 for both methods. It is clear that there is a fit agreement between the trends of both methods for all stations. Some stations showed a slight difference in the value of R^2 between the two methods, while other stations showed a significant variation. The difference in R^2 value between the two methods is attributed to the difference in the calculation method. While the linear regression method depends on the number of months with temperature above or below the reference level, the area method depends on the integration of the area under/above the curve connecting the value of (T-Tr) between the centerlines of months.

Table 6. Comparison between the results of area method (AM) and linear regression method (LR)

Station code	Name	T>25		T>30		T>10		T<10	
		AM	LR	AM	LR	AM	LR	AM	LR
AD0034	Samar	-0.103	-0.114	-0.08	-0.169	-0.238	-0.259	0.394	0.119
Al0035	KHN	0.013	0.002	0.008	0.022	0.209	0.261	-0.203	-0.036
Al0059	Um-Jumal	-0.051	-0.071	-0.052	-0.018	0.031	0.19	0.234	0.042
Al0066	Al-Samra	0.387	0.417	0.464	0.331	-0.097	-0.008	0.190	-0.043
CC0004	Mushaqar	0.644	0.474	0.577	0.466	0.096	0.642	-0.01	-0.138
CD0010	Rabba	-0.254	-0.209	*	*	-0.199	-0.034	0.07	-0.01
G0009	Udruh	-0.061	-0.001	*	*	0.129	0.086	-0.21	-0.138
DA0011	Fedan	0.032	-0.15	-0.089	-0.263	0.072	0.178	0.087	0.033
F0009	Azraq	-0.021	-0.096	-0.026	-0.116	-0.292	-0.245	0.424	0.277
ED0026	Aqabaa	0.003	0.004	0.022	-0.003	0.001	0.013	7 below	0.019

CONCLUSION

Due to the high pressure of climate change on the environment, research in this field has become a very important approach which might help in decreasing its impact. In this research, many indicators were used to assess the possible climate change in Jordan, using many temperature indicators. The results of the analysis indicated that there are significant trends in the mean max. monthly temperature for some stations, while others showed insignificant trends (positive or negative). One station showed an increase in the average min. temperature >10ºC, but insignificant trends were recorded for other stations. Analysis of the monthly temperature indicated that there is a change in the temperature pattern, where late start and late extension of winter were noticed. The area method was used as an alternative method to assess possible changes in temperature trends. The results showed that the area method could be used for this purpose. The results of this research may help decision makers in planning for the management of climate change and the associated impacts as well. Additional research related to climate change in Jordan should be conducted.

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