JJEES
Volume 7, (Number 2), Dec, 2015
ISSN 1995-6681
Pages 87 - 93
Jordan Journal of Earth and Environmental Sciences

Temporal and Spatial Analysis of Climate Change at Northern Jordanian Badia

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Received 8 February, 2015; Accepted 1 December, 2015

Abstract

Scientific evidence continues to mount that the earth's climate is changing rapidly. Global average surface temperatures have increased by about 0.7 degree Celsius since the beginning of the 20th century, and nine of the ten warmest years on record have occurred during the 21st century. Climate change is among the biggest threats that face humanity. As temperature and precipitation patterns change, the delicate balance of climate, weather events and life is disrupted. The present paper aims at investigating the impact of climate change on air temperature and annual precipitation in the Jordanian Badia, which has fragile environmental ecosystems. Meteorological data for six meteorological stations in the Badia (Mafraq, Safawi, Rwaished, Azraq, Um El-Jumal, and Ramtha) in addition to Dara'a at south Syria, and Turaif and Guriat at North Saudi-Arabia obtained from the Jordanian Ministry of Water and Irrigation and the USA national oceanic and atmospheric administration (NOAA) are used to identify the changes in air temperature and precipitation. The statistical package for the social sciences (SPSS) is utilized to retrieve a regression trend between atmospheric carbon dioxide and ambient air temperature and to project future air temperatures at the nine stations considered in this study. Findings indicate that air temperature is increasing at an annual rate of 0.02-0.06 °C/year and annual precipitation is decreasing at an annual rate 2.6-0.5 mm/year.

Keywords: carbon dioxide, global warming, climate change, precipitation, air temperature

1. Introduction

Meteorological data collected at Monalue Island indicate that air temperature has shown a steady and gradual increase especially in the past decades (IPCC, 2007). The Earth's average surface temperature has risen by 0.76° C since 1850 (IPCC, 2007). It is believed that the ongoing air temperature rise is attributed to the intensification of the greenhouse effect, which is primarily caused by carbon dioxide and other greenhouse gasses (Meehl et al., 2007).

One of the most important and immediate effects of the ongoing climate is the reduction in fresh water (Xu et al., 2005). Effects include the magnitude and timing of runoff, the frequency and intensity of floods and droughts, rainfall patterns, extreme weather events, and the quality and quantity of available water (Arora, 2001). Climate change is likely to alter the hydrological cycle through increasing the surface air temperature and rates of evapotranspiration. Changes in the total amount of precipitation and its frequency and intensity directly affect the magnitude and timing of run-off and the intensity of floods and droughts.

Jordan is vulnerable to the devastating impacts of climate change, especially in water and agriculture sectors that are linked to socio-economic conditions (UNFCCC, 2009). It is particularly important to detect any trends in air temperature and precipitation in Jordan, with particular emphasis on the Badia, which is becoming an important agricultural and residential area. Harrison (2009) argued that the major problem of biodiversity and conservation in Jordan due to climate change will be intensified drought. The author estimated that air temperature will increase by 3±0.5°C in winter and 4.5±1°C in summer by the end of the 21st century and there is little or no change in precipitation to offset these large increases in temperature.

Hammouri and El-Naqa (2007) conducted a research to assess drought conditions in Amman-Zarqa basin of Jordan and reported that the drought periods had repeatedly occurred in a regular manner during the last 50 years in the investigated catchment area. To the contrary, Dahamsheh and Aksoy (2007) did not find any trends in Jordanian precipitation data at 13 stations investigated for the years 1953–2002. Al-Qudah and Smadi (2011) reported that Jordan, which is part of a semi-arid zone, is vulnerable to climate change. Ghanem (2010) analyzed meteorological data of the rainy seasons from 1956/1957 to 2005/2006 at 11 stations distributed within Amman area and reported that annual precipitation is decreasing by about 0.4 mm/year, but with no statistical significance. He also reported that the running means show two wet periods (1962/1963–1973/1974 and 1987/1988–1993/1994) and two dry periods that occurred in the beginning and the end of the study period.

The Badia is the main source of summer vegetables and fruits, and most livestock is raised there. An emerging

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  - Volume 7, (Number 2), (ISSN 1995-6681)

humanitarian factor has also emerged due to the influx of a vast number of Syrian refugees who are anticipated to exceed two million persons if the Syrian civil war does not come to an end soon, which places an extra pressure on the stretched water resources in the Badia. For all these reasons, it is very important to better visualize how the climate change is going to impact the Jordan Badia, particularly in terms of air temperature and precipitation. Therefore, the main objective of this thesis is to study the temporal and spatial climate change in the Jordanian Badia and stations in neighboring territories.

2. Climate of Jordan

Jordan is situated at about 80 kilometers east of the Mediterranean Sea between 29º 11´ to 23º 22´ North, and 34º 19´ to 39º 18´ East. The area of land mass is approximately 88,778 Km^2 while the area of water bodies that includes both the Dead Sea and the Gulf of Aqaba is approximately 482 Km^2. Altitude ranges from about -415 m (below mean sea level) at the surface of the Dead Sea up to 1845 m at top of Jabal Um Ad Dani (MWI, 2009). Most of Jordanian territories (more than 80%) are either Badia or Desert; its climate is classified as arid to semi-arid (MWI, 2009). Jordan has three main topographic features; desert, mountains, and Jordan rift regions (MWI, 2009). The annual rainfall distribution varies with location from more than 600mm at Rasmuneef Summit in the northern highlands to less than 50mm in the eastern and southern deserts (MWI, 2009). The long term average accumulative precipitation of Jordan in last decades (1937 - 2006) averages around 8325 mcm/year, which is equivalent to about 93 mm per square meter per year.

North-Western parts of the country enjoy a Mediterranean climate, while eastern and southern deserts exhibit a sub-Sahara climate. The climate is hot and dry in summer months but mild and wet in winter. The rainy season extends from October to April. Most of the precipitation falls in the form of rain or drizzle. However snow may fall on highlands and hail is not unusual but it is associated with atmospheric instabilities during winter fronts or thunderstorms, which occur during warm spring days (UNFCCC, 2009).

According to Freiwan and Kadioglub (2008), Jordan can be divided into three regions based on annual precipitation:

(1) Wet region which includes Northern Heights, Western Amman, Assalatune, Jerash, Ajloon, and Irbid in addition to the northern Jordan Valley (Baqura). The total annual rainfall in this region varies between 400 and 600 mm.

(2) Semi-arid region which includes central part of Jordan such as East- and South-Amman, central heights (Shoubak and Rabba), and the middle Jordan Valley (Deir Alla). This region has annual rainfall in the range of 250-350 mm/year.

(3) Dry region which includes Eastern Hills and Badia plateau such as Wadi Duleil, Zarqa, Mafraq, Azraq, the eastern parts of Safawi and Ruwaished, southern and southeastern parts (Ma'an and Jafr) and southern Jordan Valley that extends to Aqaba. Annual precipitation in these regions varies between 140–170 mm in the central west, 70–90 mm in the east, and 30–50 mm in the south.

3. Study Area

The Badia area extends from north to south in the eastern part of Jordan, covering about 80% of the country's total area. The total population of the Badia represents about 5% of the whole population of the country. Only 5% of the Badia population is still nomadic (MWI, 2002). The total area of the northern Badia is 25,950 km^2 (Figure 1), which constitutes 36% of the total area of the Jordanian Badia. According to 2007 census, the total population of the northern Badia is 160 thousands living in 110 different urban settlements. This area is characterized by its unique location (Mafraq governorate) where it shares its borders with three Arab countries (Syria, Iraq and Saudi Arabia). Administratively, the northern Badia is divided into 3 districts (Ruwayshid, northern Badia, and northwestern Badia) and 7 sub districts (Sama As-sarhan, Hosha, Dair Al-kahf, Sabha, Um alJimal, Um Al-Quttain, Al-Khaldiyah). The Badia holds numerous and rich natural resources in quantities adequate for overall developmental requirements. Beside the vast area available for development, resources include mineral deposits, surface and groundwater, touristic sites, sunny weather, renewable natural range and cultivable land suitable for improved agriculture and livestock production. The area also has a potential for the development of non-pollutant renewable energy sources, namely solar and wind energy. As the Badia extends into the borders of neighboring countries, there is an additional benefit of its being a junction for export-import activities at the regional level.

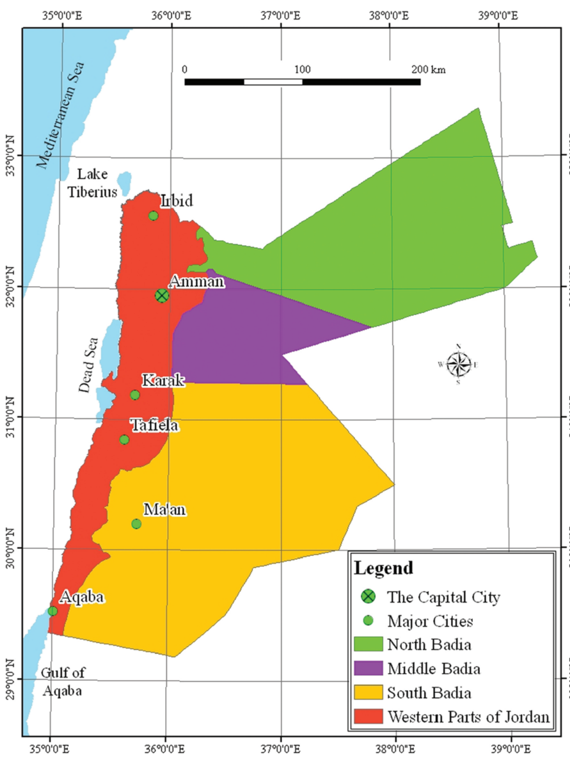

Figure 1. Study area.

4. Statistical Data Analysis

4.1. Data Collection

Nine meteorological stations are selected to study the impact changes in the northern Badia (Table 1). Compiled database includes meteorological parameters such maximum and minimum daily air temperature, mean daily air temperature and daily precipitation. The data were obtained through the Jordanian Ministry of water and Irrigation, and the data center of the National Oceanic and Atmospheric Administration (NOAA), which is considered the world's largest archive of climate data.

Table 1. Meteorological stations that are selected to investigate climate change in Northern Badia

Station ID	Station Name	Time Interval Start	End	North (JTM)	East (JTM)
F 0009	Azraq	06/1968	06/2011	525422.63	480628.28
AL0059	Um El-Jumal	06/1968	06/2011	575013.63	438260.31
AD0012	Ramtha	5/1976	12/2005	604961.08	405610.35
40265099999	Mafraq	12/1983	04/2012	583384.93	428124.59
40250099999	Rwaished	01/1963	04/2012	598394.42	611052.84
40260099999	Safawi	01/1964	04/2012	564623.05	508800.64
40095099999	Dara'a	09/1977	05/2011	609651.55	424372.22
40360099999	Guriat	02/1985	05/2012	474714.75	526910.06
40356099999	Turaif	03/1963	05/2012	508337.44	663586.08

4.2. Data Processing

Assessment of climate change at Northern Badia is performed based on climatic data obtained from nine stations: Mafraq, Safawi, Rwaished, Azraq, Um El-Jumal, Ramtha, Dara'a of Syria, and Turaif and Guriat of Saudi Arabia (Figures 2 and 3).

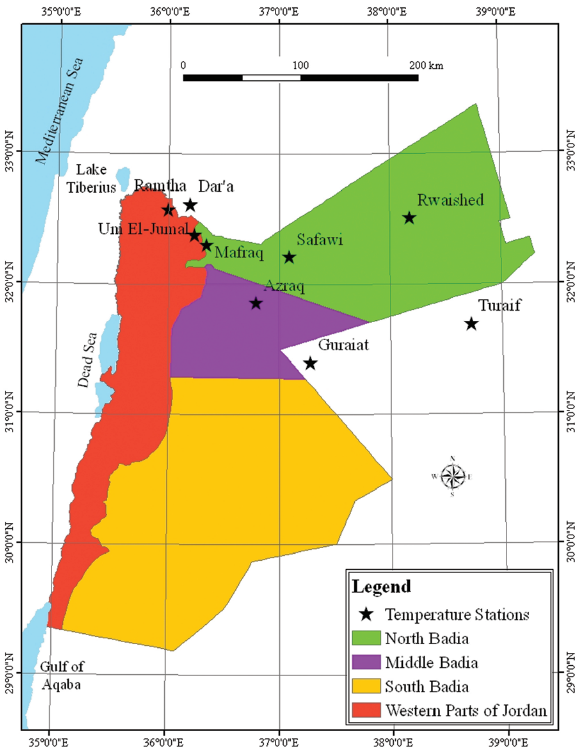

Figure 2. Monitoring stations that are selected to study temperature changes due to climate change.

A time-frame selected for the stations was in the range of 27-40 years of data covering the period 1972–2012. The data included daily rainfall and daily temperature. Processing of the data starts by calculating the monthly averages which are then plotted against historical records of atmospheric carbon dioxide in order to come up with plausible correlations and regression equations. In order to understand how air temperature and precipitation respond to the variation of atmospheric carbon dioxide, meteorological data are analyzed using IPM SPSS Version 19.0 (IBM Corp., 2010).

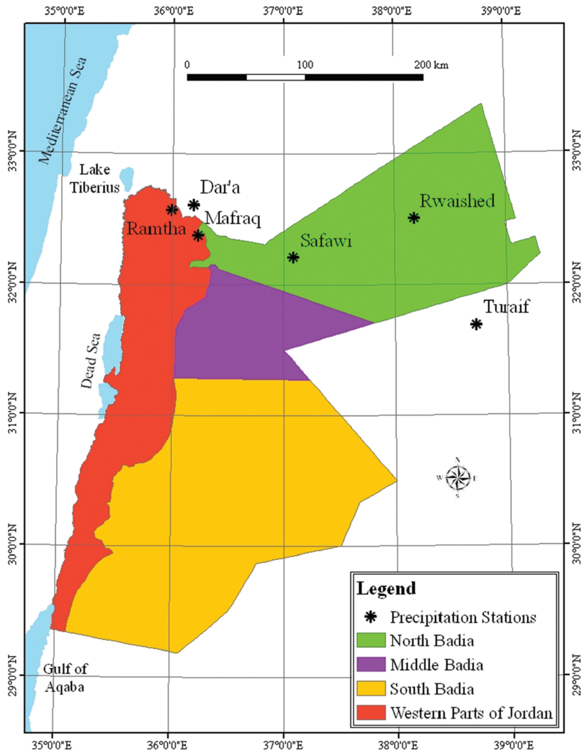

Figure 3. Monitoring stations that are selected to study precipitation variation due to climate change.

4.3. Air Temperature

The variations of air temperature at the study area are illustrated in Figures 4 through 12. It is evident that the air temperature is increasing at the nine stations. Figures 13- 21 illustrate the relationship between the mean concentration of atmospheric carbon dioxide and the mean annual air temperature at the nine stations. These Figures also show the projected air temperature at year 2050 based on the assumption that atmospheric carbon dioxide will continue to increase at its current incremental rate. It is evident that the increase in the abundance of atmospheric carbon dioxide leads to air temperature rise.

The correlation between the annual air temperature and the mean concentration of atmospheric carbon dioxide is utilized to forecast future air temperatures at North Jordanian Badia by deploying the linear regression approach which is available in the SPSS statistical package. Meteorological data for the years 1984-2010 were considered. The slope of the constructed regression line is used to predict future air temperatures. It is projected that average air temperature will increase by about 2-3°C at the nine stations by year 2050.

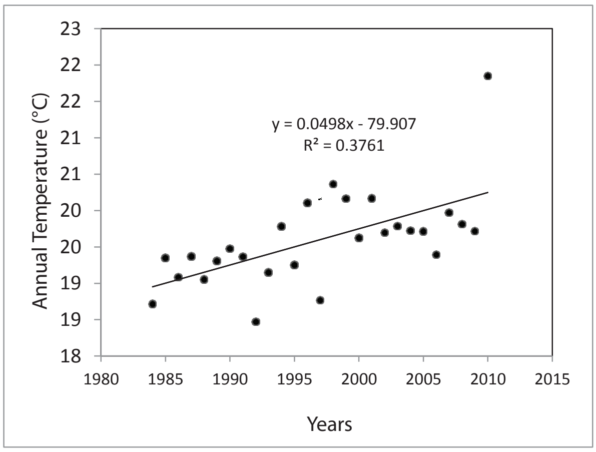

Figure 4. Average annual surface air temperature for Safawi station during the time period 1984-2010

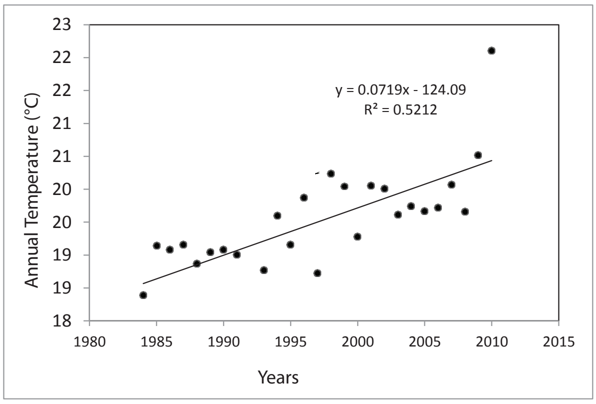

Figure 5. Average annual temperature for Rwaished station during the time period 1984-2010

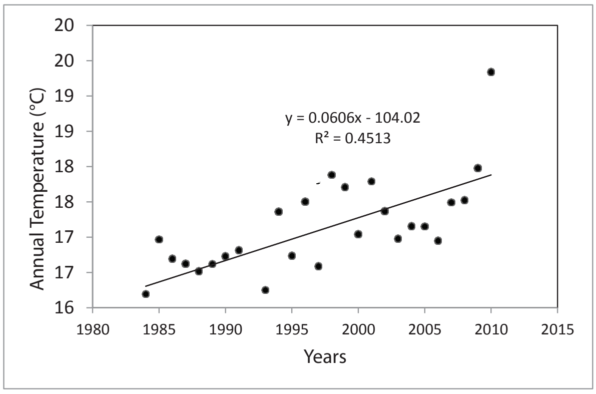

Figure 6. Average annual temperature for Mafraq station during the time period 1984-2010

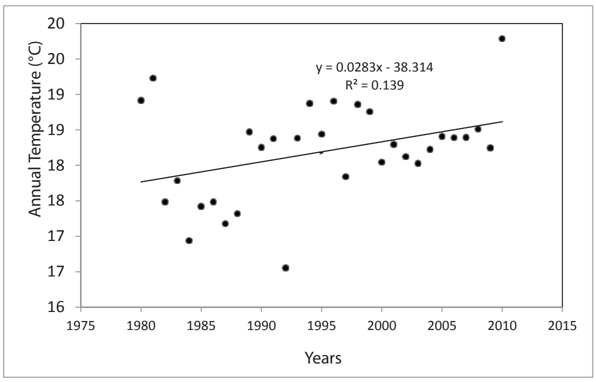

Figure 7. Average annual temperature for Um El-Jumal station during the time period 1980-2010

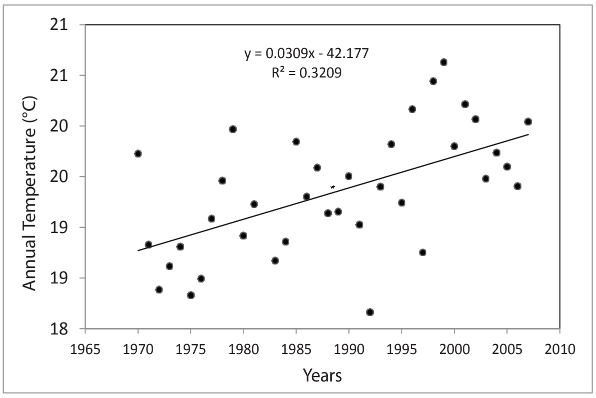

Figure 8. Average annual temperature for Azraq station during the time period 1970-2007

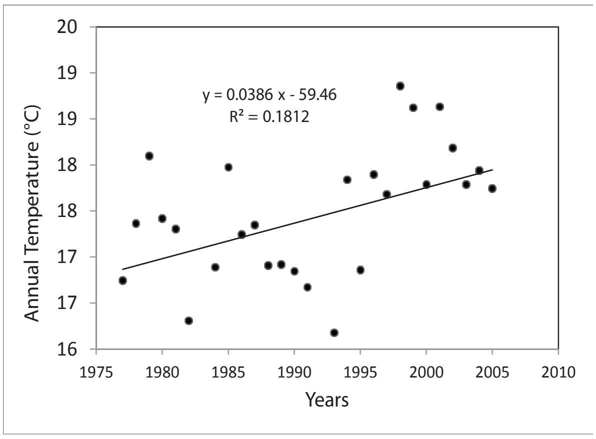

Figure 9. Average annual temperature for Ramtha station during the time period 1977-2005

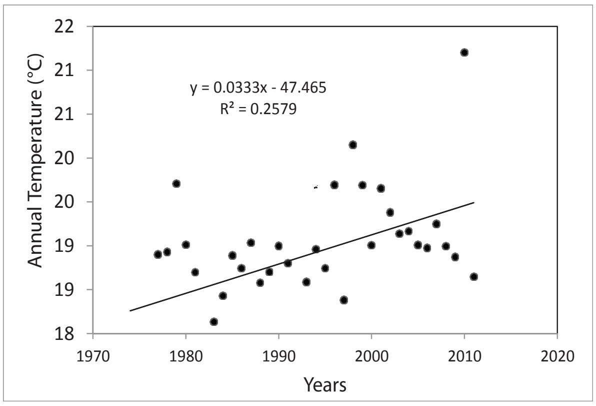

Figure 10. Average annual temperature for Turaif station during the time period 1974-2011

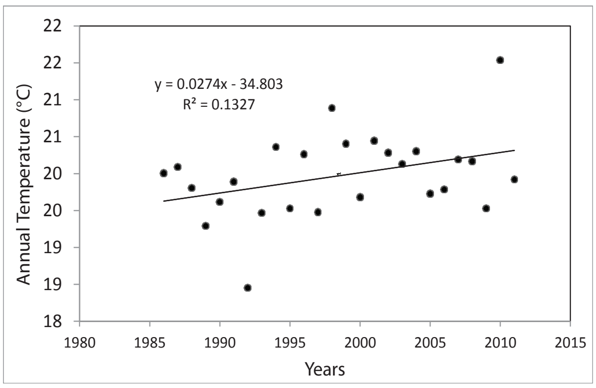

Figure 11. Average annual temperature for Guriat station during the time period 1986-2011

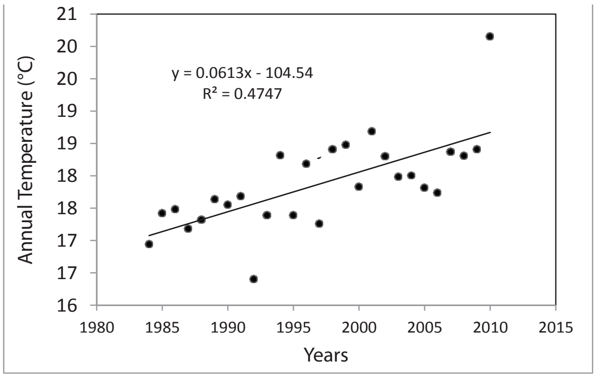

Figure 12. Average annual temperature for Dara'a station during the time period 1984-2010

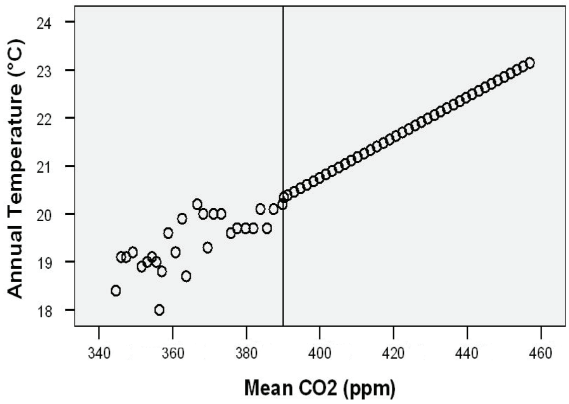

Figure 13. Projected air temperature at Rwaished in year 2050 based on presumed global CO_2 concentration

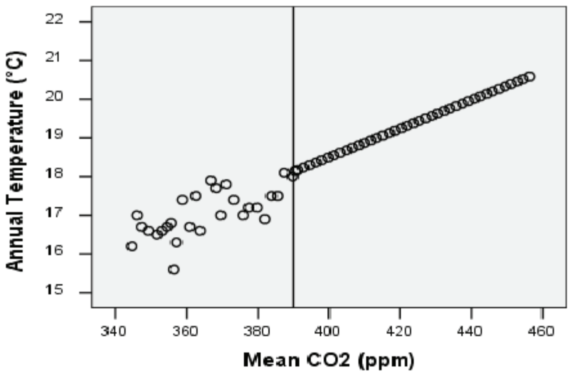

Figure 14. Projected air temperature at Mafraq in year 2050 based on presumed global CO_2 concentration

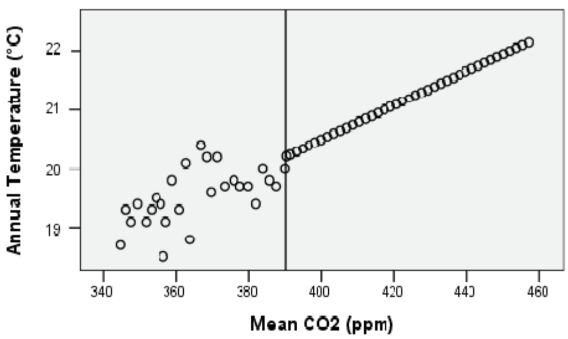

Figure 15. Projected air temperature at Safawi in year 2050 based on presumed global CO_2 concentration

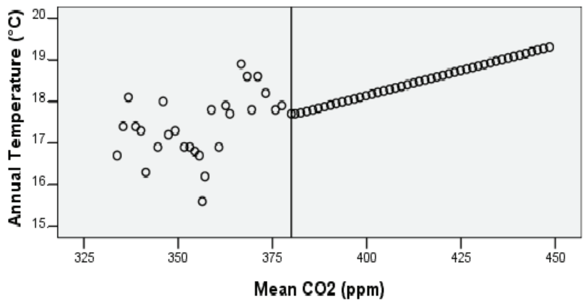

Figure 16. Projected air temperature at Ramtha in year 2050 based on presumed global CO_2 concentration

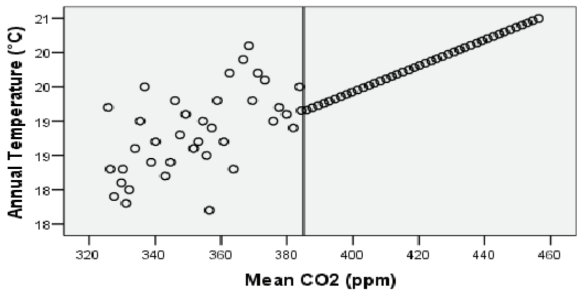

Figure 17. Projected air temperature at Azraq in year 2050 based on presumed global CO_2 concentration

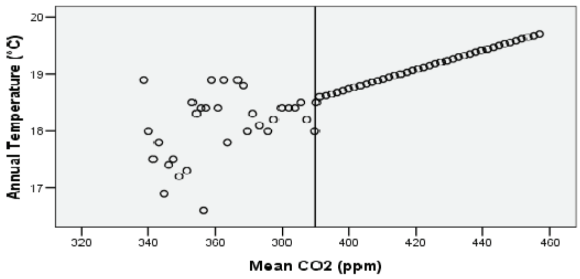

Figure 18. Projected air temperature at Um El-Jumal in year 2050 based on presumed global CO_2 concentration

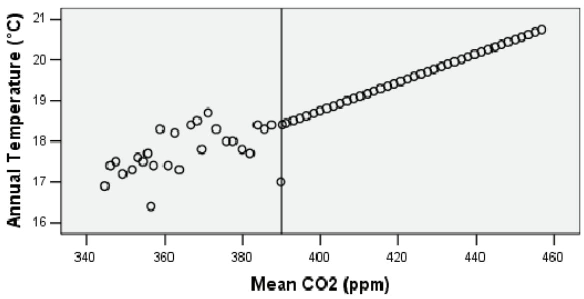

Figure 19. Projected air temperature at Dara'a in year 2050 based on presumed global CO_2 concentration

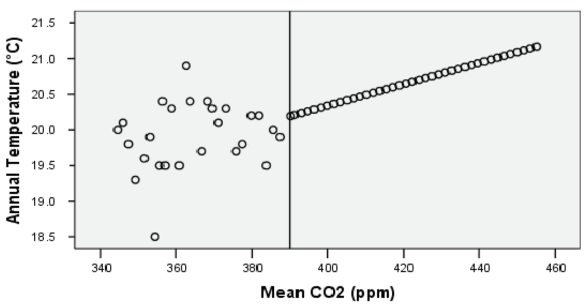

Figure 20. Projected air temperature at Guriat in year 2050 based on presumed global CO_2 concentration

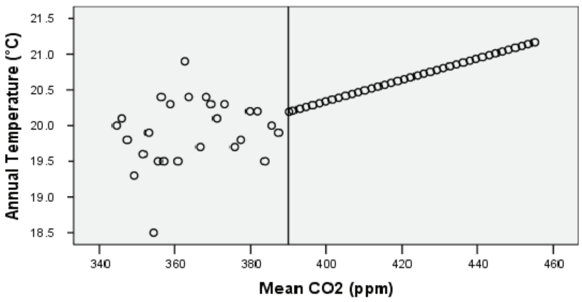

Figure 21. Projected air temperature at Turaif in year 2050 based on presumed global CO_2 concentration

4.4. Annual Precipitation

Figures 22-27 depict the variation of the annual precipitation at the nine stations. The charts reveal a decreasing trend in the annual precipitation at the North Jordanian Badia, but deriving sound conclusions or quantifying the annual decreasing rate is not feasible due to the high fluctuation in the precipitation data. Changes in precipitation due global warming may have severe implications on water resources in arid zones. Hydrological variability in a catchment area is influenced by the variations in precipitation over daily, seasonal, annual, and decadal time scales. Flood frequency is affected by the changes in the year-to-year variability in precipitation and by the changes in short-term rainfall properties (such as storm rainfall intensity). The frequency of low or drought flows is affected primarily by changes in the seasonal distribution of precipitation, year-to-year variability, and the occurrence of prolonged droughts.

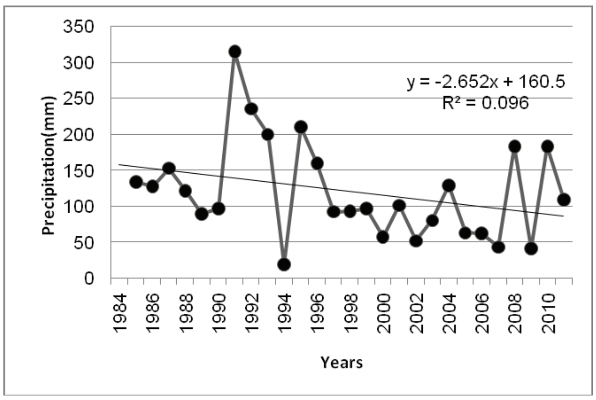

Figure 22. Annual precipitation for Safawi station (1985-2011) and the regression equation

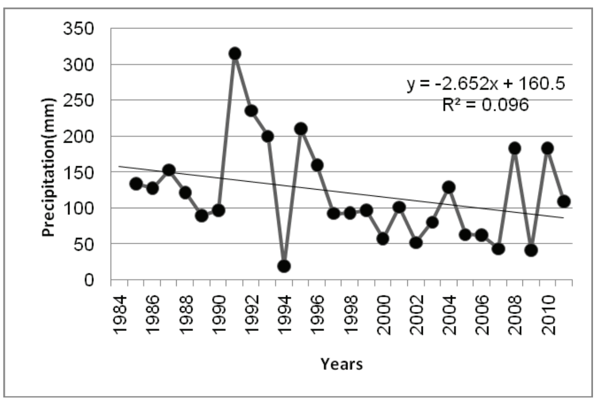

Figure 23. Annual precipitation for Rwaished station (1985-2011) and the regression equation

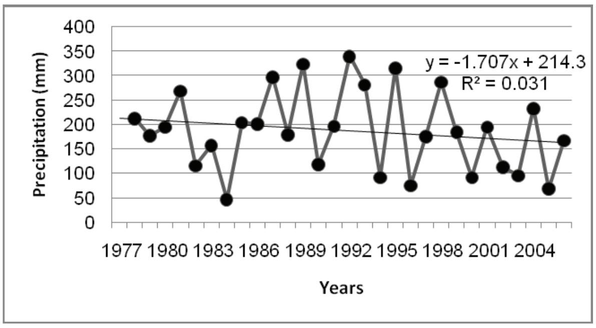

Figure 24. Annual precipitation for Ramtha station (1977-2005) and the regression equation

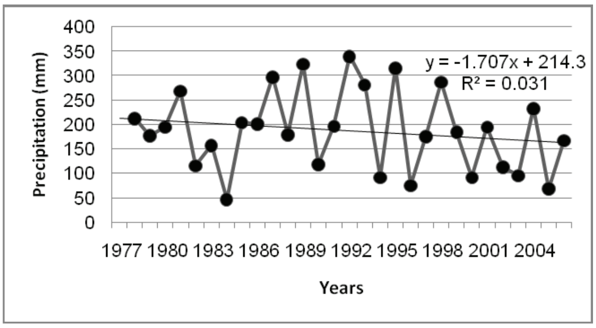

Figure 25. Annual precipitation for Mafraq station (1984-2011) and the regression equation

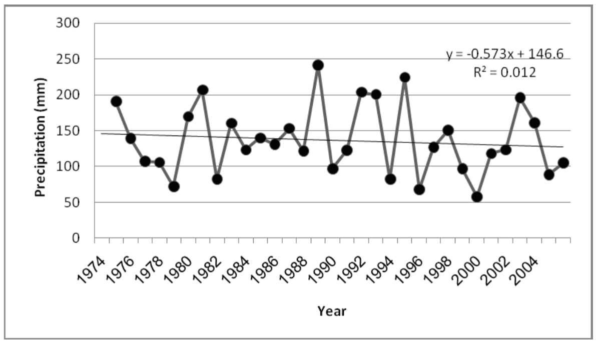

Figure 26. Annual precipitation for Turaif station (1975-2007) and the regression equation

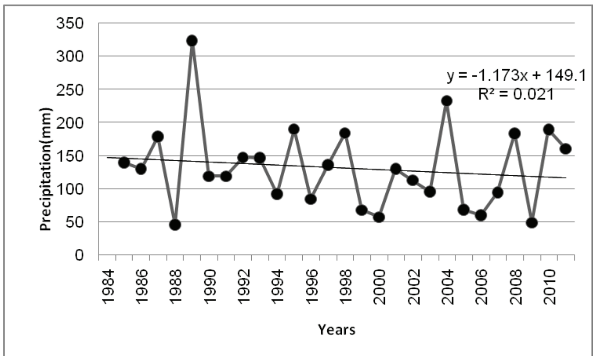

Figure 27. Annual precipitation for Dara'a station (1985-2011) and the regression equation

5. Summary and Conclusion

Northern Badia represents about 29 percent of Jordan's territory. It receives an annual rainfall of less than 200 mm and has general characteristics of seasonal contrasts in temperature with high variations in rainfall within and among years. Despite the low levels of rainfall in the northern Badia, the area constitutes an important source of grazing for livestock breeders. It is the source of livelihood for nomadic, semi-nomadic and settled communities that largely depend on raising livestock for a living. In addition to indigenous people, northern Badia hosts several Syrian refugee camps including Al-Zaa'tary.

The climate change will significantly affect the sustainability of water supplies in the Badia in the coming decades. The amount of water available and its quality will likely decrease, which will impact people's health and food supplies. These harsh conditions require local authorities and researchers to cope up with emerging crises associated with climate change. Thus, this study attempts to tackle this important issue by identifying changes in air temperature and precipitation, which are believed to be the two important indicators of climate change.

The air temperature and the annual precipitation for the nine stations in the northern Jordanian Badia and the neighboring countries were employed to detect the changes that are attributed to climate change. The Statistical Package for Social Sciences (SPSS) is deployed to come up with correlations that would project future values of air temperature and annual precipitation at the nine stations considered in the present study. Our findings revealed that while air temperature is increasing in the northern Jordanian Badia, annual precipitation is decreasing there. The pattern of the increase in the air temperature has been relatively uniform in the last 25 years. The annual precipitation data show a decreasing trend by up to 2.6 mm per year.

Acknowledgment

This study is part of the master thesis of the first author, Faculty of Natural Resources, Hashemite University, Jordan

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