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Climate Change Trends in Tafila Governorate (Central West Jordan) in the Period 1938- 2006

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Abstract

Climate change is an important environmental issue of progressive concern, especially where the change might worsen the already critical situations. In Jordan, the limited precipitation is almost the main supply of water for surface water bodies and groundwater recharge.

The aim of this study is to analyze the temporal and spatial pattern of precipitation in Tafila governorate, and to investigate the possible change trends in this climatological parameter. The study uses daily, monthly, and annually data from twelve meteorological stations available in the study area.

Results suggest a spatial pattern of changes in the precipitation distribution over the study period, which show some systematic decrease of annual rainfall especially in the high altitude stations. The slope of precipitation change trends ranges from -54 mm/20 years in Prince Hasan Nursery Station to 54mm/ 20 years in La'aban station. The sensitivity of the captured trends to change due to few possible successive futuristic measurements notable over or below the average is limited.

The study results show no temporal change in seasonality, where the rainy season still cover the same time space within the year during the studded time interval (1938-2006).

Keywords: Tafila Governorate, Precipitation, Trend Analysis. Climate Change

1. Introduction:

Due to its conspicuous importance, climate change has been an active area of research in the last decades. Civilization development, fauna, flora, and ecosystems, are vulnerable to variations in the quantity and quality of water. All of these, in turn, are sensitive to climate change (USGCRP 2009; USCCSP 2008). Such changes have been observed in precipitation, evaporation, surface temperature, and extreme events since the beginning of the 20th century. The global mean sea level has risen by 10 to 20 cm. There has been a 40% decline in Arctic Sea ice thickness in late summer to early autumn in the past 50-55 years (Gregory 1956). The frequency of severe floods in large river basins has increased during the 20th century. Also, synthesis of river-monitoring data reveals that the average annual discharge of freshwater from six of the largest Eurasian rivers to the Arctic Ocean has increased by 7% from 1936 to 1999 (Mall et al., 2006). These were a sample of changes, but it is a common thought that all regions of the world show an overall net negative impact of climate change on water resources and freshwater ecosystems (IPCC 2007).

Jordan is one of the poorest world countries in what concerning water resources. At present, the limited surface water resources and the decreasing precipitation are the main environmental issues facing the country. That explains the increasing concern in climate change studies (MOE 2013). Furthermore, the historical climate change effects are perceived or suspected in numerous historical observations (Shehadeh 1985; Mountfort 1965; Nelson 1973). For example, the murals in the Umayyad desert palaces shows ecosystems that receive more water than what is available nowadays (Alawneh et al., 2011; Mountfort 1965; Nelson 1965). The progressive reduction in Dead Sea area and the disappearing of some small rivers may be attributed at least partially to long term climate change (Alpert et al., 1997; Abu Gazleh et al., 2010; Al Eisawi 2005).

The National Climate Change Policy pays special attention to water resources because the real future of country is a function to the availability of this crucial resource (MOE 2013). The rapid and uncontrolled increasing in the population complicates Jordanian strategic plans, where a considerable share of the population growth is due to forced immigration from neighboring countries (Ramírez, et al., 2011; Sharadqah 2014)

Monitoring, analyzing and interpreting environmental indicators play a critical role in our understanding of climate change and its interactions.The state of certain environmental conditions over a given area and a specified period of time represents an indicator. Examples of climate change indicators include rainfall, temperature, and stream flow (EPA 2012).

This study attempts to evaluate the availability of data related to climate change in Tafila governorate, and aimed to investigate the possible climatological change trends, using simple methods. Among the major climate change indicators, the precipitation had been chosen to be addressed in the present study. That's because of the relative abundance of rainfall data in comparison with other parameters. Farthermore, the hydrology of arid and semiarid areas – which is the case in Tafila area- is particularly sensitive to small changes in precipitation (Kenneth Frederick 1997) .

2. STUDY AREA

Tafila governorate is located in the central west part of Jordan (fig. 1). The area ranges in elevation between –400 m below sea level in the southern part of dead sea to about 1500m en Al – Rashadiya (Fig 2). This region receives variable amount of precipitation, with an average annual amount of more than 250 mm on the mountains and less than 100 mm in the deserts (fig 3). The total area of Tafila governorate territories is 2254 km^2.

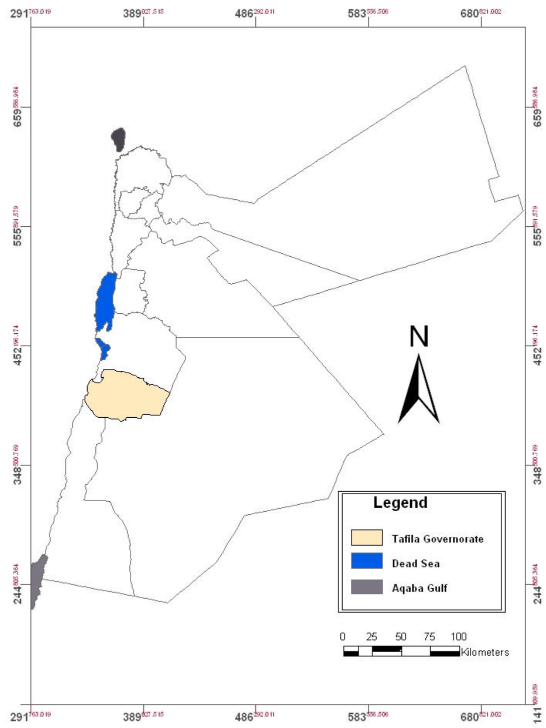

Fig. 1: Jordan map showing the location of the study area

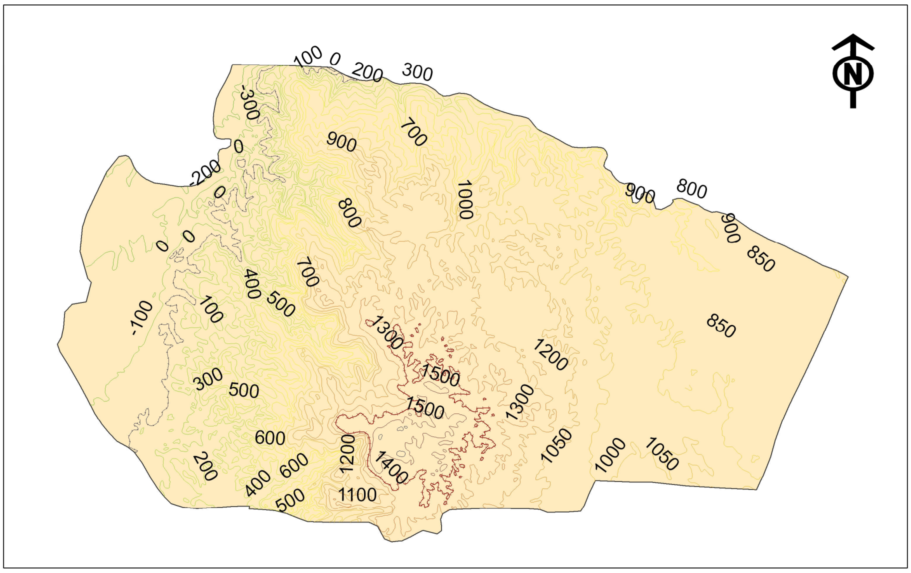

Fig. 2: Tafila Governorate elevation map

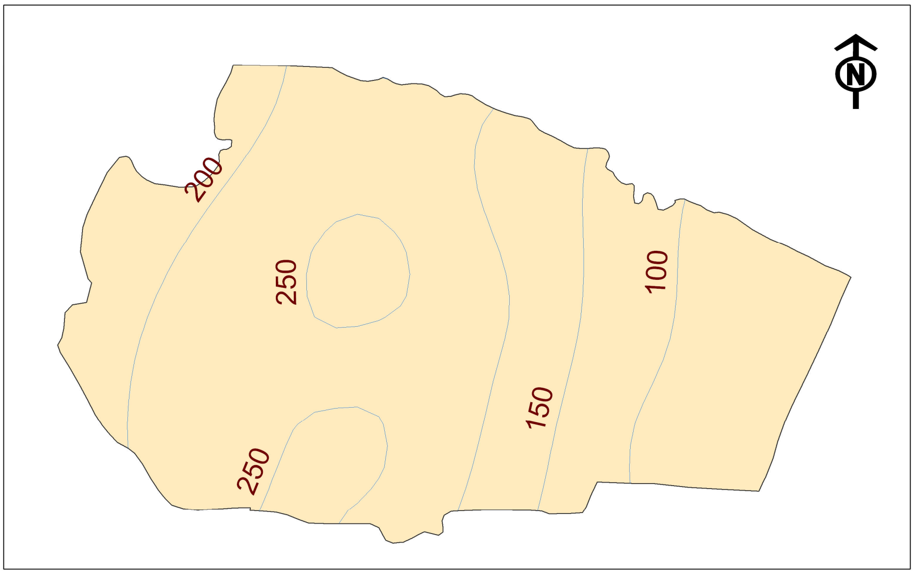

Fig. 3: Long- term annual precipitation average for Tafila Governorate

3. Data Description

The study area is covered by twelve meteorological stations based on the ministry of water and irrigation data base (Fig. 4). The row data represents the available daily rainfall data for these stations for the years 1937 to 2006. The length of data record and the density of data in each record are not homogenous for all stations. For example; Tafila station record covers all the period from October 1937 to December 2006, without gapes or excluded data. While the record of Qalat Al-Hasa station has only got data for the years 1938 and 1939 .

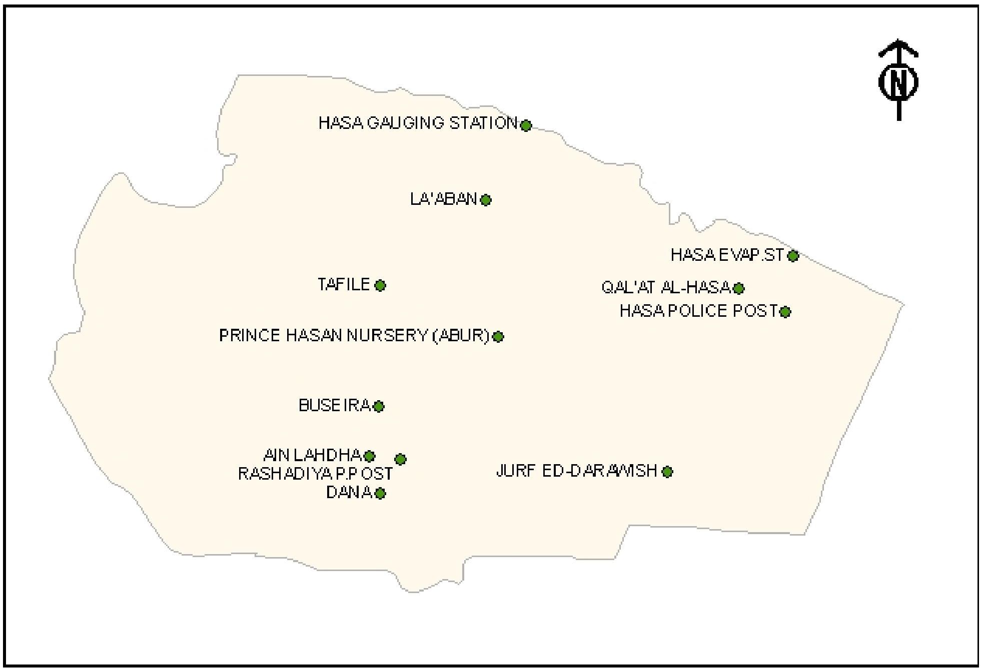

Fig. 4: Rainfall stations distribution in Tafila Governorate

4. Methods

A trend analysis of annual precipitation for each rainfall station of Tafila governorate for the 68 year period from 1937 to 2006 was carried out using standard linear regression. Also a trend analysis was carried out for the average of areal annual precipitated over the entire area of the governorate. This average areal precipitation, derived by calculates the area which each weather station represents using Thiessen's method. Then, areal average was estimated using the following formula:

$$P_{avg} = \sum_{j=1}^{n} w_j \, p_j$$

Where:

$$w_j = \frac{a_j}{A_T}$$

Pavg: average areal of annual precipitation in mm depth.

AT: Tafila governorate area (2254 km2)

pj: average annual precipitation for certain rainfall station (mm) depth.

aj : area that the station represents defined by Thiessen polygons and calculated using Arcgis tools (km2).

n: Station number (1 to 12)

To calculate the areal average of annual rainfall, the gaped data of yearly precipitation in any station was assumed to be the long term average for the same station. In both cases (Areal & point annual average), the regression coefficients are given in mm

A sample of data was tested for supposed temporal change in seasonality in Tafila region. A trend analysis was carried out for the first two months in the rainy season (October and November), and for the last two month of the rainy season (April and May).

To test the trend stability, a four consecutive precipitation values with 30% less or more than the long-term average in opposite direction of the trend signal were added at the end of actual record for each station, and then the trend was checked again.

5. Results and Discussion

Prior to applying the trend analysis, the data was examined to verify the relative consistency and homogeneity. For example, the figures 5 to 7 show high variability in the data for three different stations. The residual which is the result of subtraction of the long average from the annual precipitation data is frequently bigger than the average itself.

Figures 8-19 show the available annual precipitation record (algebraic summation for all precipitation events during the calendar year), trend line, and trend equation. The slope sign of an existing trend, which allows for the quantification of the amount or rate of change over time, is the most important criterion in the analysis. This means that the future projection of the precipitation could be extracted from the slope sign. So, wherever the slope was positive we estimate a positive climate change which means more rainfall. And exactly the reverse is deducted where the slope was negative.

The data show that the precipitation trend is predominantly negative. Just for three out of eleven[1] station the slope was positive. That means the rainfall in the majority of Tafila governorate rainfall stations, is a sign a decreasing annual values, mainly in the high areas which are characterized by higher rainfall, and an increasing annual precipitation, mostly in the desert areas (figures 16-19). Seven stations have got changes with more than 1mm/year even positive or negative. The highest decreasing trend slope is of the Prince Hasan Nursery station with 2.7mm/year (54mm/20years). Figures 2, 3 and 4 show that this station is located in intermediate zone between desert and high areas. Thus, a severe declination in rainfall may refers to progressive of desertification, however, to depict its extension and magnitude a specific and exhaustive study is required.

Although not very regular, the spatial pattern of rainfall distribution seems to be influenced by the governorate topography (see figures 3, 4, 7 to 18, and table 1). The average annual rainfall over the entire area of the governorate was derived by calculating the area which each weather station represents using Thiessen's method (Fig.19). The areal average curve of annual precipitation (fig.20) exhibits a decreasing trend of precipitation, which is already expected, where the predominant trend for the majority of rainfall stations is decreasing. The areal average trend coefficient is -0.43 mm/year. This means that the rainfall quantity over the study area decreases by 970000 m3/y. Such quantity seams small, however if the prediction extends two decades forward, the study area may will receive 19,000,000 m3/y less than what is being received nowadays. A declination in rainfall with this magnitude will have some implication in all local hydrological cycle components.

In Tafila region, the collective memory of people tells two impressions:

- There was more precipitation in the past.
- The rainfall season suffer of a temporal shift, where it started and ended earlier in the past.

The first impression seems to be reasonable as it is discussed above. Regarding the second one, the trend of precipitation for the first two months and last 2 months of the rainy season have been elaborated. Figure (20) shows that the rainy season starts in October and ends in May, where no recordable precipitation have been listed in any of the 12 stations from June to September. Despite the fact that October is the first month in the rainy season, the trend of precipitation have been made for October and November due to the scarcity of precipitations in October. The interpretation of the captured trend presumes a delay in the rainy season if the trend of precipitation in the first two months is decreasing with higher slope than the annual average precipitation trend. In the same way, the trend of precipitation for the last two months of the rainy season (April and May) have been elaborated. The end of rainy season will be considered delaying or extended forward if the trend of precipitation for the months April and May is an increasing trend or even a decreasing trend with less slopes than the average annual trend.

Results show no decreasing trends with higher slopes than the annual average in the first two months of the rainy season. Also no increasing trend, or decreasing with less slope than annual average trend in the last two months of the rainy season. All that suggests no notable shift in seasonality.

[1] The trend has not been presented for the twelfth station - Qalat al Hasa- due to its short record of data.

The high variability in precipitation data from year to year which can be observed through figures 5-18 could alter the coherency of the trend analysis and might provoke a doubt about the reliability of the captured trends and accuracy of the forecast. Coefficients of determination (R2 in table 1), responds clearly to the variability of data which the previous figures show, where it demonstrates weak fit between data and estimated trends. Therefore, it is necessary to test the sensitivity of these trends for future rainfall data in opposite direction. Figures 5 to 7 show that the highest number of consecutive years with precipitation values ≥ 30% all less or all more than the long term average is 4. Thus, this severe and short scenario has been adopted to test the trend sensitivity. So, 4 consecutive data with values 30% more or less than the long term average in opposite direction of actual trend sign have been added at the end of actual time series of each station. Then the trend tested again.

Results show that the trend sign wasn't changed for the average areal precipitation and for all stations except Jurf Ed Darawish station and Ain Lahdah station (see new trend equation field in table 1). This means that the signs of captured trends are almost stable and not expected to suffer changes during the close future. Furthermore, the trend change in Jurf Ed Darawish is expected due to its very small slope. While the trend changes for Ain Lahda station may be attributed to the short data record. Where the actual record just covers 17 years.

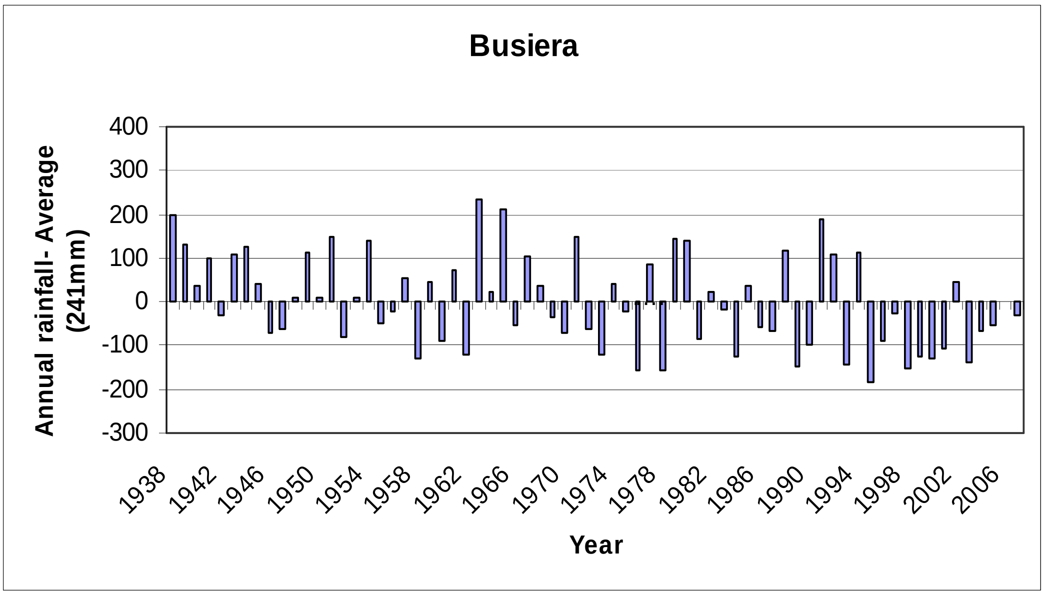

Fig. 5. Annual rainfall residuals for Busiera station

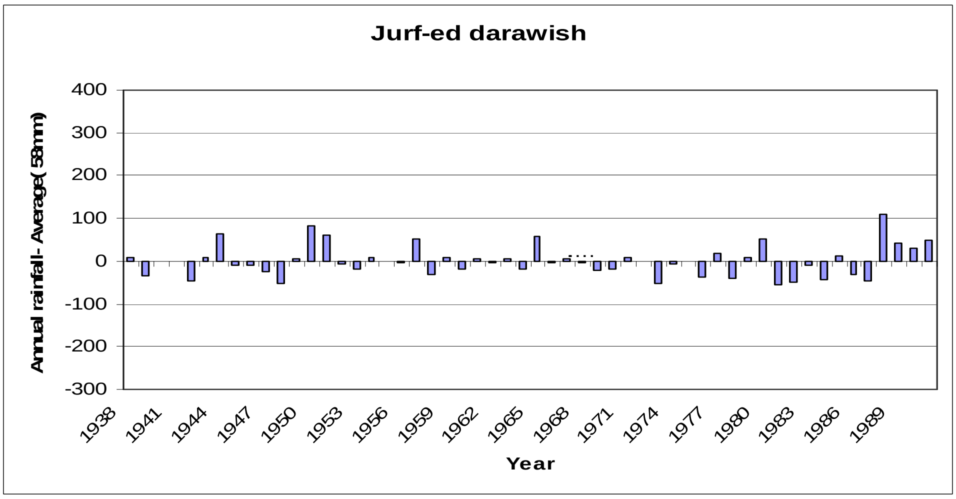

Fig.6. Annual rainfall residuals for Jurf- ed darawish station

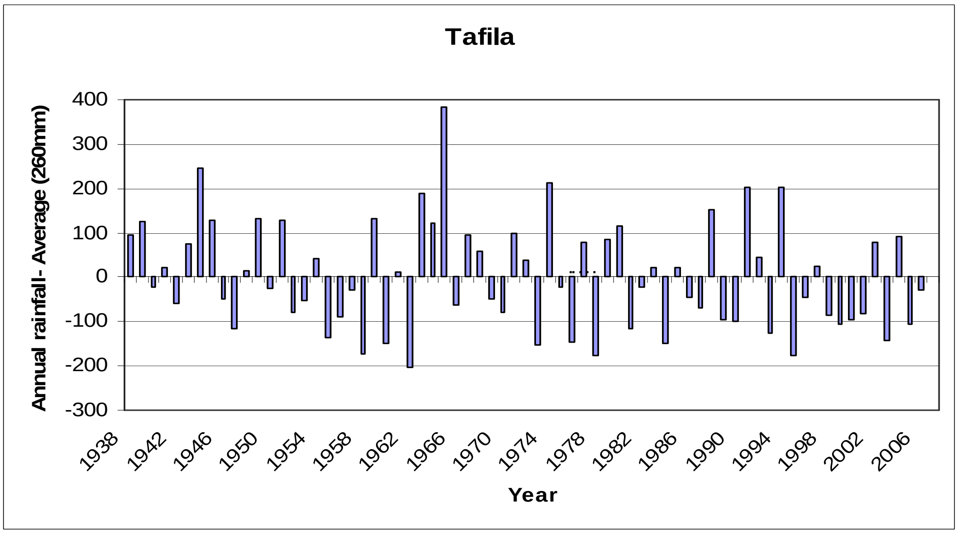

Fig. 7. Annual rainfall residuals for Tafila station

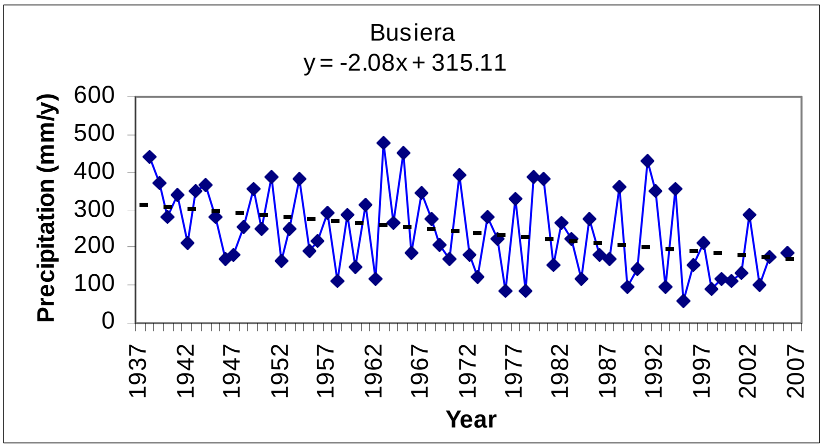

Fig. 8: temporal precipitation destribution for Busiera station (mm/year)

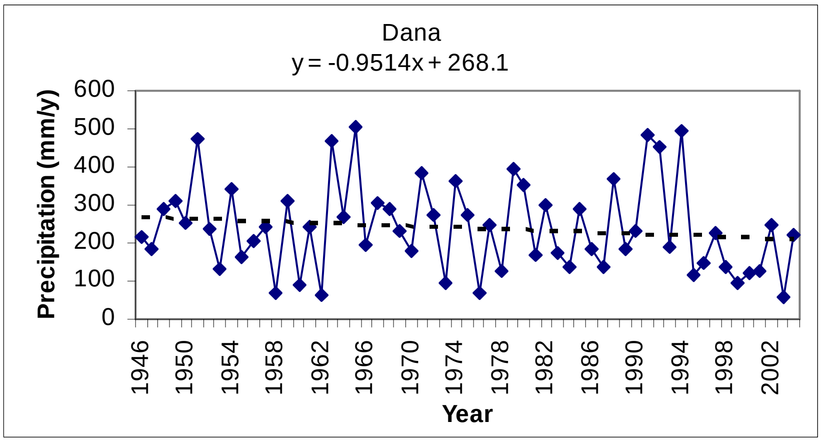

Fig. 9: temporal precipitation destribution for Dana station (mm/year)

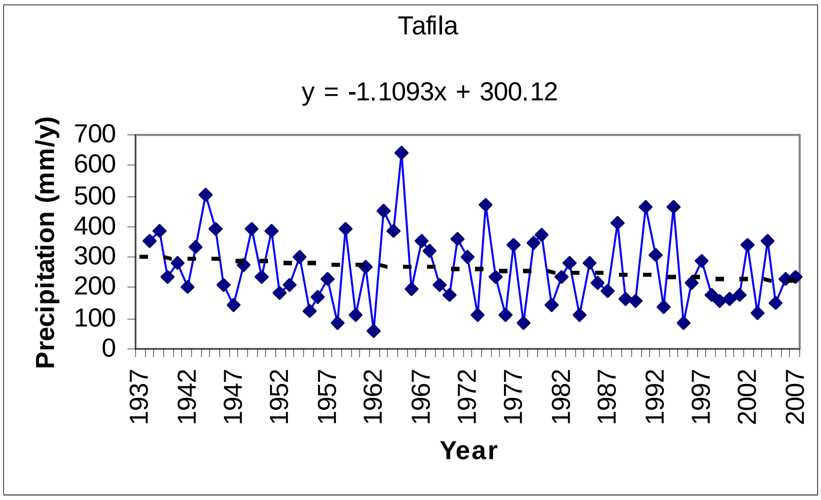

Fig. 10: temporal precipitation destribution for Tafila station (mm/year)

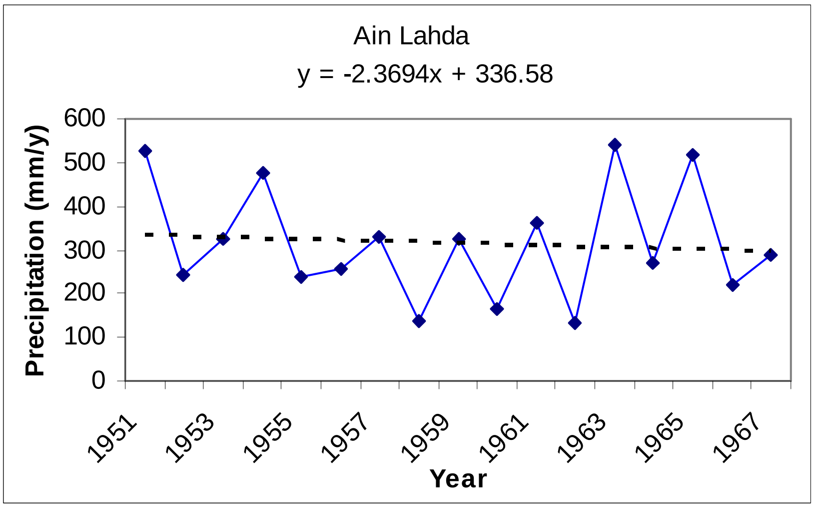

Fig. 11: temporal precipitation destribution for Ain Lahda station (mm/year)

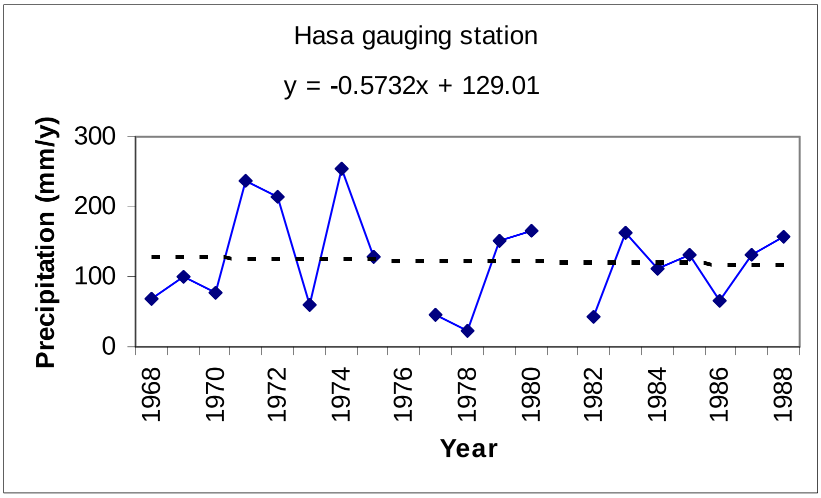

Fig 12: temporal precipitation destribution for Hasa Gaugin station (mm/year)

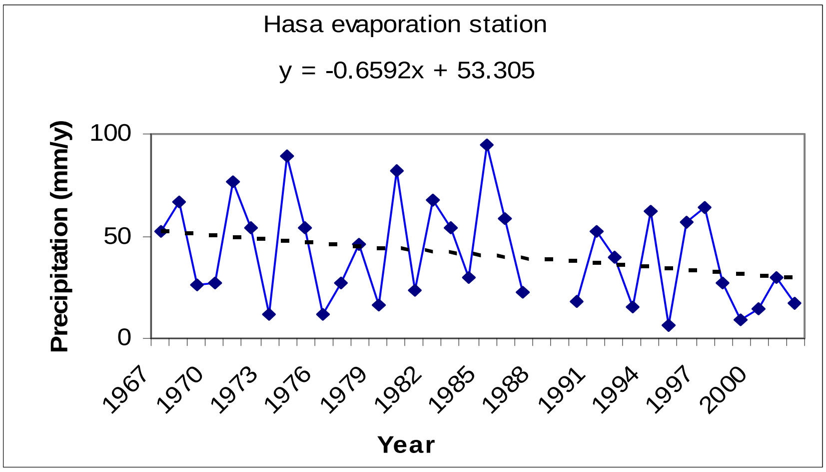

Fig 13: temporal precipitation destribution for Hasa evaporation station (mm/year)

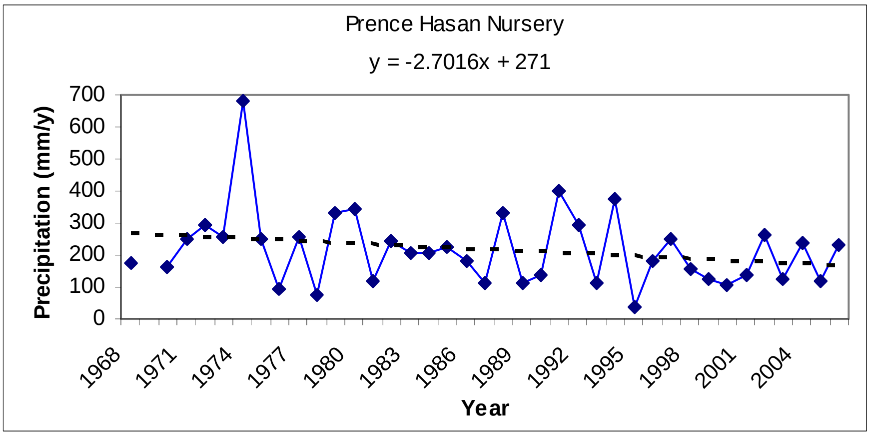

Fig 14: temporal precipitation destribution for Prens Hasan Nursery station (mm/year)

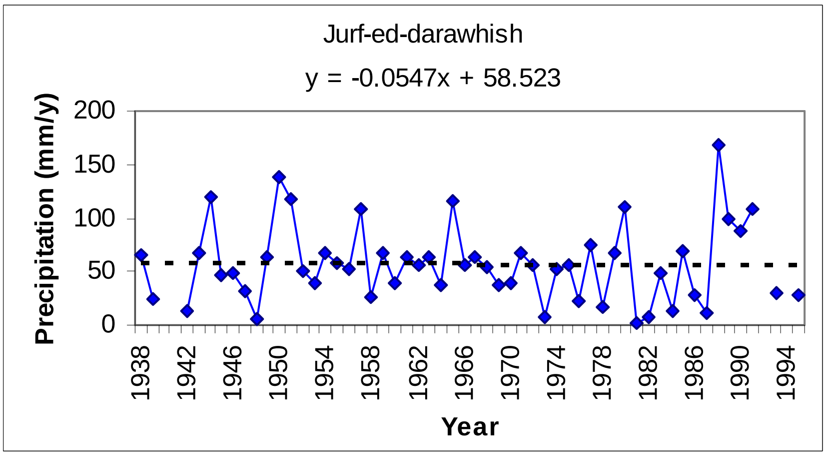

Fig. 15: temporal precipitation destribution for Jurf- ed-Darawish station (mm/year)

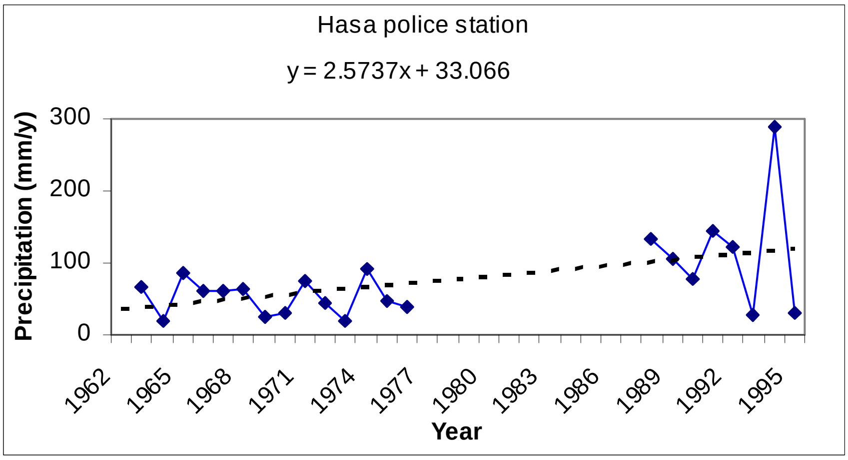

Fig. 16: temporal precipitation destribution for Hasa Police station (mm/year)

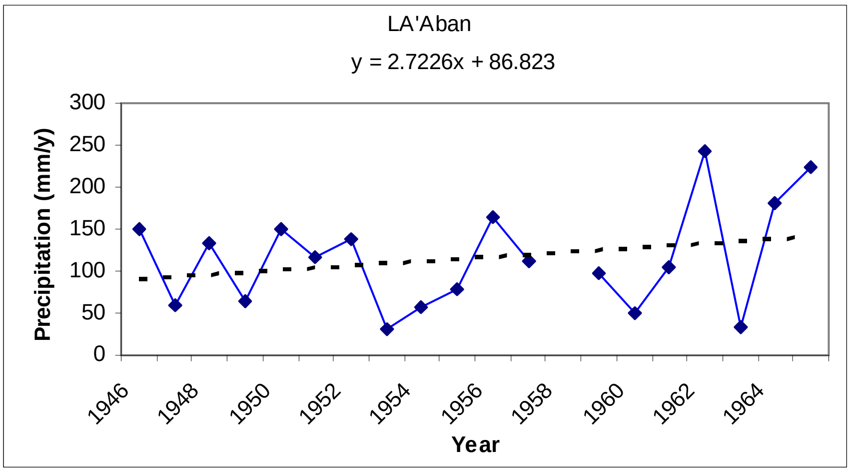

Fig. 17: temporal precipitation destribution for La' Aban station (mm/year)

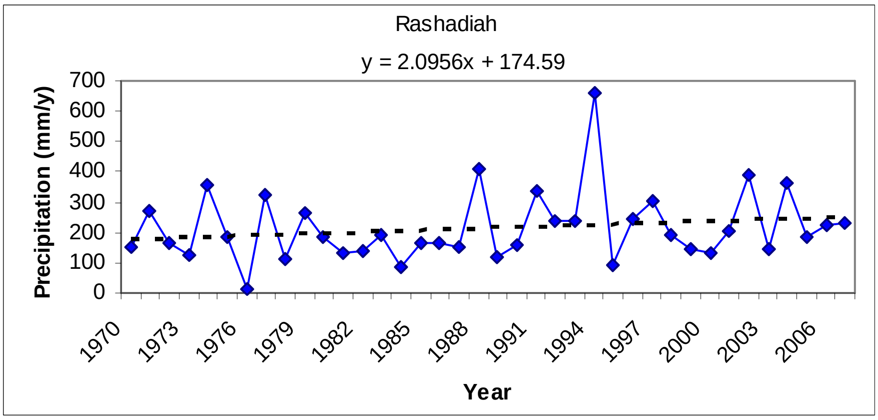

Fig. 18: temporal precipitation destribution for Rashadiah station (mm/year)

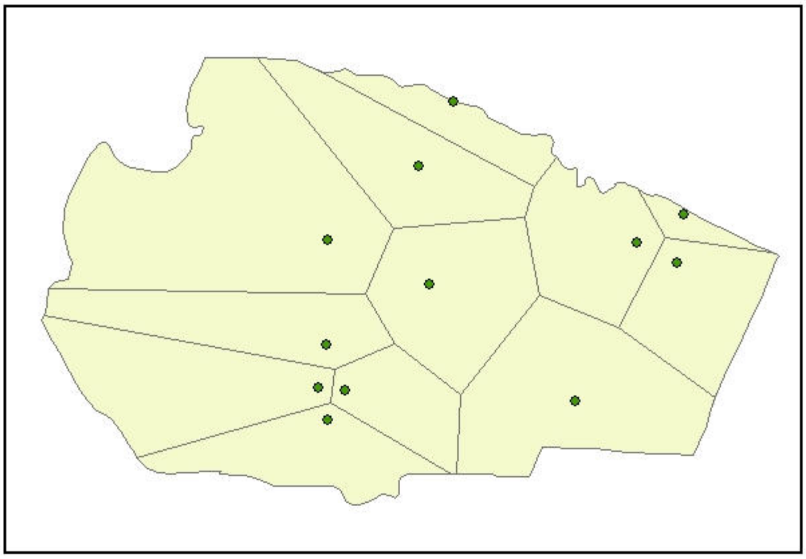

Fig. 19: Thiessen polygons for study area (each polygon represents the area of influence for one rainfall station)

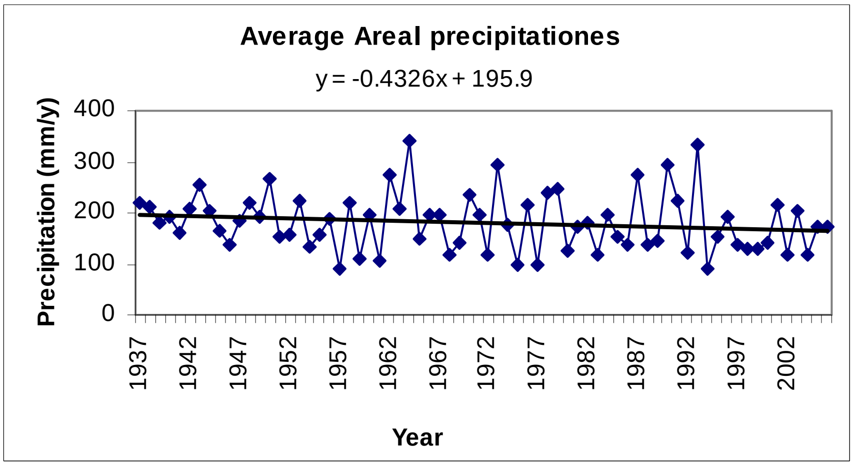

Fig. 20: Areal average rainfall for the study area (mm depth/y)

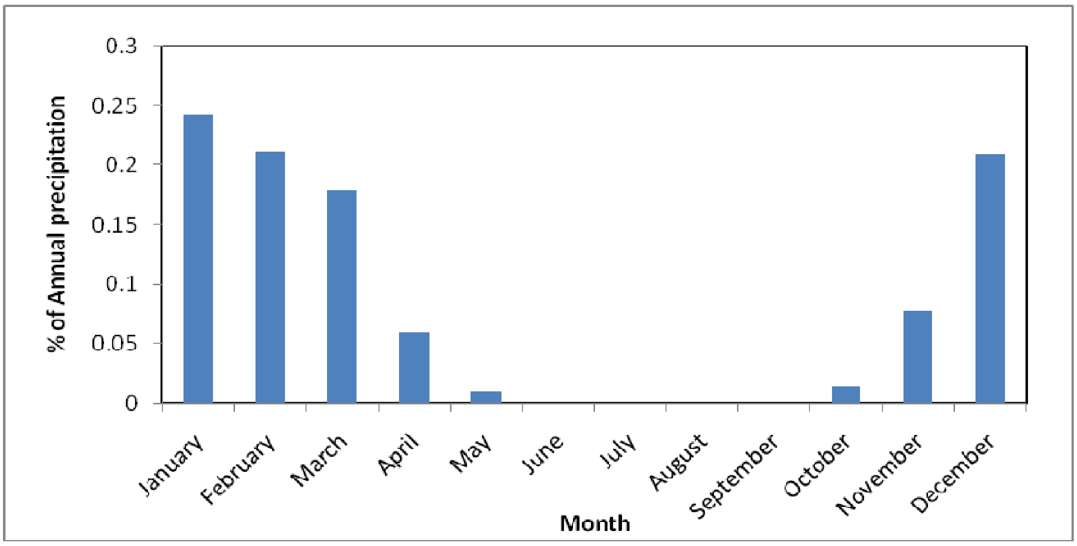

Fig. 21: Long term monthly distribution of rainfall in Tafila governorate.

Table 1: Selective attributes of Tafila governorate rainfall stations or their rainfall data

Station Name	Elevation	avg. Precipitation (mm/y)	R-squered	New trend equation
AIN LAHDHA	1420	325	0.014	y = 1.5245x + 307.41
BUSEIRA	1100	241	0.146	y = -1.4383x + 297.77
DANA	1230	240	0.019	y = -0.3743x + 256.1
HASA EVAP.ST	900	43	0.081	y = -0.316x + 48.72
HASA GAUGING STATION	380	113	0.003	y = -0.1162x + 129
HASA POLICE POST	825	72	0.238	y = 1.6711x + 49.48
JURF ED-DARAWISH	930	55	1.51E-05	y = -0.1554x + 60.329
LA'ABAN	700	109	0.073	y = 0.3502x + 104.85
PRINCE HASAN NURSERY (ABUR)	1220	220	0.029	y = -1.2097x + 247.56
QAL'AT AL-HASA	810	43	-	
RASHADIYA P.POST	1500	202	0.040	y = 1.3614x + 174.17
TAFILE	1000	260	0.035	y = -0.6194x + 287.3

6. Conclusions

The major conclusions of the actual study are:

- The spatial pattern of changes in the precipitation distribution over the study period shows some systematic decrease of annual rainfall especially in the high stations.
- The sensitivity of the captured trends to change due to few possible successive futuristic measurements notable over or below the average is limited.
- There is no evidence on temporal change in seasonality, where the rainy season still covers the same time space within the year during study time interval (1937-2006).
- The availability of rainfall data in the study area is acceptable to elaborate a climate change trends study.

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