Statistic and Probabilistic Variations with Precipitation Predictions of Jordan

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ABSTRACT

This thesis deals with the analysis of monthly rainfall data gathered from 66 meteorological stations for the hydrologic years from October 1960 to September 2017 that are distributed irregularly in the Kingdom of Jordan. The area with the help of Thessien polygon is divided into twelve main districts, and the representative number of stations were detected. In order to study and analyze the rainfall (precipitation) data, the used sample size is 57. Four data quality tests Normality, Consistency, Homogeneity, and Stationary/Unit root and also the trend analysis test were studied based on parametric and non-parametric tests. The proper probability distribution function was found for each region, among the main four distributions the Normal, the log-Normal, the Gumble, and the Gamma. In order to predict the further yearly precipitation data for each meteorological district, three diverse widely used time series models were used; the Moving average (MA), the Holt-Winters, and nine different combinations of ARIMA. For this reason, the data of hydrologic years 1960-61 up to 2015-16 were used as a training period and the hydrologic year 2015-16 measured precipitation data was used for testing the trained data set where the best representative model was designated among the models which has the closest forecasted 2016-17 value to the measured (actual) rainfall value. Also the best model for each region was selected to predict the 10 consecutive upcoming hydrologic years from 2017-18 to 2026-27. Even for each region the rainfall within the months (from October to May) were studies statistically and their wetness or dryness periods and their overall trends were determined.

Keywords: Rainfall, Time series models, Trends, Wet or dry spells.

ÖZ

Bu tez, hidrolojik yıl Ekim 1960 ile Eylül 2017 arasında Ürdün Kırallığında düzensiz bir şekilde dağılmış 66 meteoroloji istasyonundan toplanan yağış verilerinin analizinden oluşmaktadır. Bu alan Thessien polygon yöntemiyle oniki ana bölgeye bölünmüş ve her bölgeyi ifade edilen istasyonlarla belirlenmiştir. Yağış donelerini irdeleyip analiz yapabilmek için kullanılan örnek büyüklüğü 57'dir. Dört done kalite testi, Normality, Consistency, Homogeneity, ve Stationary/tek kök yanında trend analizi testi parametrik ve parametrik-olmayan testler yardımı ile çalışılmıştır. Her bölge için, önemli olasılık dağılımları olan Normal, log-Normal, Gumble, ve Gamma arasından en uygun olasılık dağılım fonksiyonu belirlenmiştir. Her bölgenin yıllık yağış miktarını ileriye dönük tahmin edebilmek için üç farklı çok yaygın zaman serisi modelleri olan Moving average (MA), Holt-Winters, ve dokuz farklı bileşenli ARIMA kullanılmıştır. Bu nedenle, hidrolojik yıllar 1960-61 ile 2015-16 arasındaki yağış doneleri, modeli tanıtma ve hidrolojik yıl 2015-16 ölçülmüş (gerçek) yağış donesinin üretilen değerleriyle karşılaştırılarak en yakın uyumu veren modeli belirleyip o bölge için seçilmiştir. Ayrıca seçilen bu model kullanılarak takip eden 10 yılın (hidrolojik yıl 2017-18 ile 2026-27) değerleri tahmin edilmiştir. Her bölge için ayrıca Ekim – Mayıs ayları ıstatıstiksel olarak çalışılmış ve ıslaklık veya kuruluk dönemleri ile genel eğilimleri belirlenmiştir.

Anahtar Kelimeler: Yağış, Zaman serisi modelleri, Eğilimler, Islaklık veya kuruluk dönemleri.

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LIST OF SYMBOLS AND ABBREVIATIONS

c_k	The autocovariance
C_s	Coefficient of skewness
Cv_x	Coefficient of variation
DMC	Double Mass Curve
d_x	Mean deviation
k	The lag of autocorrelation function
M_a	Slope of graph which data are adjusted
M_o	Slope of graph at time $P_{observed}$ was observed
MWI	Ministry of Water and Irrigation of Jordan
n	Number of years
SD	Standard deviation
s_x	Standard deviation
S_x	The variance of a sample
$\bar{X}$	The average of the precipitation data
X_i	The precipitation value of i year
X_t	The stationary process with mean zero
γ_k	Kurtosis value

Chapter 1

INTRODUCTION

1.1 Jordan

Jordan is located in south-west Asia and at the Middle East. It is at the southern part of the Levant and the northern part of the Arabian Peninsula. 11° 29’ - 22° 33’ North of Equator and 59° 34’ - 59° 39’ East of Greenwich (the world factbook, 2019). The main features of the area of the Hashemite Kingdom of Jordan are its longitudinal extension from north to south. The Jordan Valley extends from the western part to the north-south, followed by the eastern extension of mountain range in the same direction of the extension, and east of the Badia of Jordan.

Groove of Jordan

It is extended from the northwestern end of Jordan to the southwestern end of the Gulf of Aqaba and is divided into three sections:

1. The Jordan River valley is bordered by the Jordan River to the west and the highlands to the east. It is used for irrigation. The Jordan River's flood plain is known as Al-Zour. Also there is an area named Al-Katera which is a group of side valleys that accompanies with the Jordan River through the Jordan Valley area, a part of the mountainous highlands.
2. The Dead Sea is the lowest district in the world (420 meters below the sea level) (Klinger, 2000). There are many places for tourists on its northeastern edge.

3. The Wadi Arab is about 170 km in length, where it’s nearly arid and mainly considered as a desert.

The mountainous highlands in Jordan constitute a natural separation between the Jordan Valley and the Eastern Badia. It consists of a plateau. It is extended between the Yarmouk River at the north and the Jordanian-Saudi border at the south. The height average of this mountainous plateau is about 1,200 meters above the mean sea level and slowly descends eastward to the desert plateau, while the vast majority descends sharply towards the Jordan Valley in the west (Allison, et al., 2000).

Jordan is bordered on the north by Syria and the occupied Golan Heights, and from east by Iraq, bordered by Saudi Arabia from the south-east and south, while it has a border with Palestine from the West. Jordan has a short maritime border with Egypt and Saudi Arabia in the Gulf of Aqaba in the southwest. The border with Palestine is the closest international border away from the Jordanian capital of Amman, with a distance of 27 kilometers (Ministry of Water and Irrigation, 2019) where figure 1.1 shows the map of Jordan.

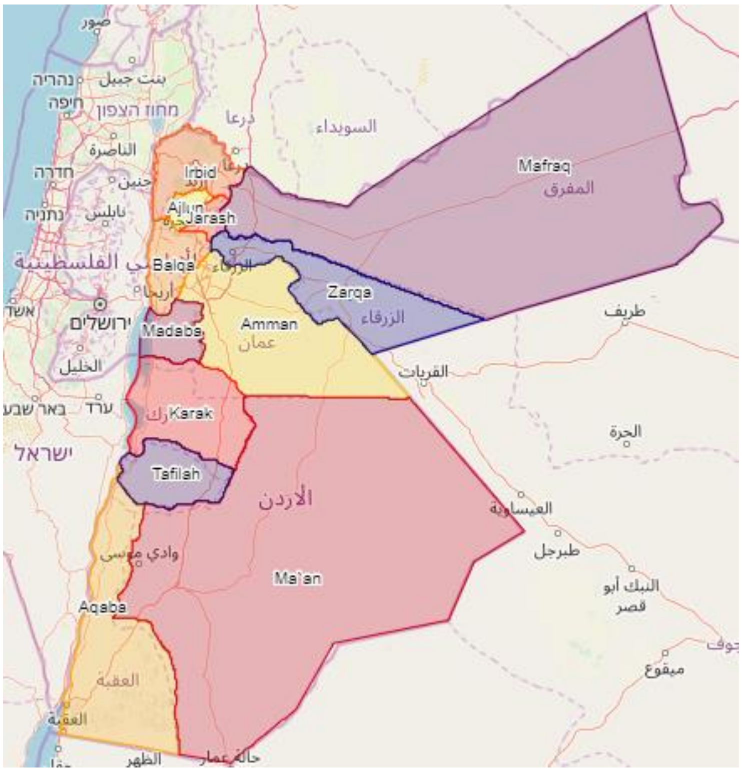

Figure 1: Jordan map showing the sub-districts (Ministry of Water and Irrigation, 2019)

1.2 Climate of Jordan

The current climate in the Hashemite Kingdom of Jordan is the Mediterranean climate. In general this climate is characterized by cool winters and hot summers (Smiatek et al., 2011). Jordan can be divided into four climatic zones:

- Mountain areas: cold winter and mild in summer,
- The Jordan Valley: warm winter and warm in summer,
- Aqaba: like the Jordan Valley, but less rain in winter, and
- Badia: cold winter and hot summer.

The Shara Mountains located in Shoubak district are considered as one of the coldest districts in the Kingdom. The annual average temperature is 12.6℃.

The rainy season usually begins in Jordan in mid-October and maybe delayed until mid-November in some years (Sada et al., 2015). The rainy season continues until end of May. The annual precipitation varies between the areas of the Kingdom, where the highest precipitation occurs in the western highlands and decreases to the east and south. The summer in Jordan is characterized by the same weather during the summer days where the weather is mild and some summer nights may be permeated with high humidity, which leads to the formation of light fog, and sometimes in the summer the temperature rises more than an average and the weather becomes dry, hot and annoying.

The autumn season in Jordan, is relatively short and represents a transitional period from summer to winter (Abumurad et al., 1997). This season is characterized by the occurrence of thunderstorms due to the instability of the atmosphere which may lead to floods and torrent sometimes.

The winter is characterized by cold weather and rainy. Jordan is affected by two types of weather conditions. The first type is the polar dry weather, which leads to a sharp decrease in temperature during the night, and may be extended to mountains and the desert and sometimes to the valley and cause damage to large crops. The second type is cold wet weather which is accompanied by the air depressions affecting the Kingdom (Abumurad and Al-Tamimi, 2005) and snow falls over the mountain highlands usually once to twice a year, and it may happen more than two times in some rare cases, while snow falls 3 to 4 times a year over the high mountain areas, and may be more than that in rare cases.

Finally, the spring in Jordan is characterized by being moderate; the weather in the Kingdom is hot, dry and dusty (Helfont and Helfont, 2012). Also thunderstorms occur in the spring due to instability, but in the spring thunderstorms sometimes merge with barren storms and devastating floods which occur in limited areas sometimes, and in the spring snow may fall over the mountain areas, whether high or normal, especially in March and early April.

Climate variability in Jordan is delicate to water resources, where the annual per capita water share is at one of the lowest levels in the world (Freiwan and Kadioğlu, 2008). Therefore, many research studies have been found to examine effective meteorological factors such as annual, seasonal and monthly precipitation and maximum time series.

The water year is a term commonly used in hydrology to describe a time period of 12 months for which precipitation totals are measured. However, Jordan water year consist of 8 months (October to May) and that’s due to the absence of rain in the remaining 4 months (June to September).

1.3 Population in Jordan

For centuries, the area of modern Jordan was densely populated, but the population grew rapidly from the second half of the 20th century (Department Of Statistics, 2015). About 10 million people live in Jordan, an increase of about 3 million on a geographical area of about 90 thousand square kilometers.

According to estimates of 2019 about 38% of the population is concentrated in Amman, and 62% live in the rest of the cities (Dupire, 2019), the countryside and the desert, raising the proportion of urbanization in the Kingdom. The population is expected to double by 2035, with 37.3 percent of the population under the age of 15, and 59.5 percent between 15 and 64 years of age, while 3.2% of the population aged 65 and over (Obeidat et al., 2019).

Among the others, the number of Syrian refugees is the largest in Jordan, registered is about 1.5 million, including 750,000 before the Syrian crisis that has ravaged Syria for four years and about 750,000 entered after the crisis (Forum, 2018). The number of Iraqis, is about half a million, since the US invasion of Iraq in 2003.

One of the biggest problems Jordan is experiencing due to the increase in the population is the scarcity of water. Jordan is considered one of the most water-scarce countries. It affects all aspects of life in the country, and the important sectors that affect the lives of citizens mainly and directly. Water is a major and important element for residential, agriculture, and industry. Many factors contribute to the annual per capita water shortage in Jordan, which is estimated to be less than 150 cubic meters (Haddadin, 2006). The most prominent of these is the increasing pressure on water as a result of the large population growth, not to mention the large expansion of the various economic activities that need large amounts of water.

1.4 Water in Jordan

Jordan is classified as arid and semi-arid, and is considered one of the four poorest countries in the world with an annual per capita water quota of less than 150 m^3 (Ministry of Water and Irrigation, 2019). Under the National Agenda and Water Strategy, the annual per capita quota is increased to 160 m^3. Jordan gets its water needs from sources that depend on replenishing its rain reserves, where precipitation has become volatile due to climate change. The Jordan River and the Yarmouk Basin are considered the most important sources of water in Jordan.

The Water Resources in Jordan

Water resources vary in the Hashemite Kingdom of Jordan, including conventional sources such as rain, surface water and groundwater, and non-conventional sources such as sewage treatment and desalination. These sources are detailed below (Haddadin, 2006).

Conventional water resources:

The most important sources are:

Rainwater: Rain is an important source of water in Jordan. Precipitation varies from one district to another. The amount of rain accumulated in the eastern part of the Kingdom is estimated at about 600 million cubic meters during the year. The Kingdom has a precipitation annual rate of about 10 mm, and in the direction of the highlands in the northwestern part of the Kingdom, the amount of rain rises to 500 mm/year. According to statistics, the total annual precipitation was about 7683 million cubic meters, and part of the rain falling on the surface water seeps into groundwater wells, while most of them are lost in the process of evaporation (Haddadin, 2006).

Surface Water: The surface water in Jordan includes the current valleys, springs and flood waters formed during the winter season. The surface water quantity in the early 1990s reached 677 million cubic meters per year. This amount has now risen to about 840 million/year, most of the surface water in Jordan is concentrated within the Yarmouk River, which holds about 495 million cubic meters of water. Two dams have been planned on this river, one near the entrance to the King Abdullah Canal and the other at the upper reaches of the river. The second source of surface water is the Zarqa River, which contains the King Talal Dam with a capacity of 90 million cubic meters. The water of this dam is used to irrigate agricultural crops on farms near the river. The Jordanian authorities have also established 5 dams in the Jordan Valley with a capacity of 104.8 million cubic meters, in addition to the construction of 14 dams in the high desert areas.

Groundwater: Among the various sources of water, groundwater is the main source of water in Jordan, where the Kingdom's area within the territorial limits and hydrological limits of the underground storage contains 12 renewable water basins. Due to the low precipitation and evaporation rates, characterized by an average flow, combined capacity of groundwater is approximately 277 million cubic meters of water. In the southern area of Jordan there is a group of non-renewable water basins that contain water that has accumulated in its depths since ancient geological periods, and has not leaked to other waters.

Non-conventional water resources:

Due to the lack of water resources in Jordan, there is a need to search for other sources that humans have a role in finding. Thus, non-traditional water resources, which are considered an additional source of water in Jordan, have emerged. These resources are treated wastewater for irrigation of agricultural crops, the amount of treated water is estimated to be about 70 million cubic meters per year and is expected to increase attention to sewage treatment to reach the amount of about 205 million cubic meters by 2020. Recently, the use of brackish groundwater desalination technology has begun, but the use of this technique is very costly (Haddadin, 2006).

1.5 Water Scarcity in Jordan

The rate of water poverty is not less than one per thousand cubic meters of water per year, here in Jordan per capita is only about 100 to 140 cubic meters per year. The population of Jordan is about 6 million people, growing at a rate of 2.2% annually, with a rapid growth rate. This is in addition to one million refugees and foreign workers living here in Jordan, which means that per capita water decreases annually. People here live on water rationing, meaning that every household gets water only twice a week. Domestic consumption of water consumes about 20% of the available water while 65% goes to agriculture (Hadadin et al., 2010). In Jordan, there are 10 dams and main reservoirs, which can accommodate 327 million cubic meters of water and are not always functioning in full capacity. The presence of hundreds of thousands of Syrian refugees in Jordan drains the scarce water resources in this country to the maximum. Jordan now statuses as the world's second water- poorest country, where water per capita is 88 per cent below the international water poverty line of 1,000 cubic meters annually, a situation which is being aggravated by a rapidly growing population. A large share of Jordan is considered arid and semi-arid, about 90% of its area has an annual precipitation totally less than 200 mm on average, most of it evaporates back to the atmosphere.

Table 1: Agro-climatological zones in Jordan (MWI, 2019)

Zone	Annual precipitation (mm/year)	Area (km^2)	Area as a percentage of the total area of Jordan
Semi-Humid	500-600	620	0.7%
Semi-arid	300-500	2,950	3.3%
Marginal	200-300	2,030	2.2%
Arid	100-200	20,050	22.3%
Desert	<100	64,350	71.5%
Total		90,000	100%

1.6 Study Area

Jordan is a country that is regarded as a water poor in spite of the great efforts that the institutions are making to compensate for the shortage of water and increasing the per capita water share. The projects that were set up to compensate for this shortage were directed by researchers to find out how to benefit from the rainwater, and find stations to collect water from the rain.

There are 125 metrological stations located within the 12 districts of Jordan. The breakdown of these stations are reorganized based on Thessien Polygon approach where it has been reduced to 66 stations as tabulated below.

Table 2: Representative meteorological stations for each district based on Thessien Polygon

District	Stations	Number of stations
Ajlun	AL0004, AL0005, AL0026 AB0004, AH0001, AH0002, AH0003	7
Amman	AN0002, AN0003, AL0017, AL0018, AL0022, AL0057	6
Aqaba	ED0001	1

District	Stations	Number of stations
Balqa	AM0001, AM0002, AL0010, AL0027, AL0028, AL0035, AL0045	7
Irbid	AB0002, AE0001, AE0003, AD0005, AD0008, AD0009, AD0010, AD0011, AD0012	9
Jarash	AL0002, AL0050	2
Karak	CD0007, CD0009, CD0010, CD0013, CD0029, CA0002, CA0004, CE0004	8
Ma'an	DG0001, DA0002, DA0003, DH0003, G0005, G0006, G0009	7
Madaba	CC0001, CC0002, CC0004, CD0005, CD0028	5
Mafraq	AD0013, AD0016, AD0017, F0001, AL0003, AL0048, AL0059	7
Tafilah	DB0001, DC0002	2
Zarqa	AL0012, AL0013, AL0015, AL0016, AL0066	5

The meteorological stations based on Thiessen polygon are shown in figure 2.

Figure 2: Precipitation meteorological station's distribution based on Thiessen polygon

In this study Thiessen polygon (Goovaerts, 2000) was applied to estimate the areal precipitation distribution for each considered storm. Perpendicular bisectors are constructed to the lines joining each district's center with those immediately surrounding it. These bisectors form a series of polygons, each polygon containing one district.

1.7 Objectives

1- Thiessen polygon was applied to estimate the areal precipitation for each area in Jordan.

2- Providing a prediction function that will give a guess value for the precipitations amounts for the future months and years.

3- Long year monthly variations where wet/dry spells are studied for the whole 12 districts to observe the recent situation.

Chapter 2

STATISTICAL TERMINOLOGIES, AND PROCEDURES

2.1 Introduction

The main propose of statistics is to bring facts, which can describe a specific phenomena. Statistics is used in almost all fields of science life. In hydrology, for example, a statistician may keep records of the amount of precipitations a country gets in a season. Many previous studies have used statistical terminologies in hydrology science to describe many critical cases; predicting watershed flood, critical precipitation changes in hydrology and temporal precipitation disaggregation (Müller and Haberlandt, 2018; Knighton and Walter, 2016; Latifoğlu et al., 2015).

2.2 Word index

Statistics: Statistics is the science of conducting studies to collect data, analysis and draw conclusion from the original data.

Data: All the information that can be collected related to the study and used to make decisions.

Population: the complete collection of all elements to be studied; the collection is complete in the sense that it includes all subjects to be studied.

Sample: Sub collection of members selected from a population with a particular scope is called a sample.

Sample size: It shows the whole number in a sample, when the data considers less or equal to 30 or less, sample can be assumed to form the sample (Seyhan, 1994).

2.3 Hydrologic Variables

In general, hydrologic cycle composed of precipitation, runoff, infiltration and evaporation. Many variables can be used in order to describe each phenomenon. These variables are divided into main two types, continuous and discrete.

Continuous variable: All values that can be measured along a continuous scale are called continuous variables. For example, the annual amount of precipitation and the discharge of runoff.

Discrete variable: All variables that can be counted are called discrete variables. Discrete variables usually have gaps between the values. For example, the number of rainy days in a month, the number of floods phenomenon occurring in a specific period of time.

Grouped data: All the data that collected after the classification stage is called grouped data.

Hydrologic Time Series: A set of observations can be measured over the variation of time according to some aspects of phenomenon is called time series. For example; the flow rate of the river, precipitation amount over a watershed area.

2.4 Statistical Descriptions

2.4.1 Average or Mean

A single value can be used as a representative value for the group of data and which represents the center value for others, is called the average. The central tendency can be defined by the average value.

2.4.2 Analytical Means

This method concern on the date that can be collected the field and observations of the sample without any missed or ignored values.

2.4.3 Non-Analytical Means

By non-analytical means method, the central tendency value can be determined by using the specific selected data.

2.4.4 Mean Deviation

Mean deviation is a descriptive statistics, called absolute deviation. It can be observed from mean or median. Dispersion for a set of observations can be defined by knowing mean deviation value. Mean deviation's equation is:

$$d_x = \frac{1}{n}\sum_{i=1}^{n}\left|x_i - \overline{x}\right| \tag{2.1}$$

2.4.5 Variance

Variance's equation is very closed to mean deviation's equation, but in this statistics value, central value should be taken as a starting point for a measure of spread values. The variance of a sample is defined as

$$S_x^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \overline{x})^2 \tag{2.2}$$

2.4.6 Standard Deviation

In order to remove the differences between two dimensions of variance, main root should be taken over the variance value. The standard deviation is calculated as:

$$S_x = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{2.3}$$

2.4.7 Coefficient of Variance

The coefficient of variation can be expressed the variability of the observations regard to the mean of the main sample. Formula of the coefficient of variation is:

$$Cv_x = \frac{S_x}{\bar{x}} \tag{2.4}$$

2.4.8 Asymmetry or Skewness

Skewness is the degree of asymmetry and it is related to the distribution. Skewness can be zero if the distribution is proportioned. When the skewness's value is positive the distribution will have long tail at right side. On the other hand, when it is negative the distribution will have a long tail at the left side. Implying the coefficient of skewness is calculated by:

$$C_s = \frac{n\sum_{i=1}^{n}(X_i - \bar{X})^3}{(n-1)(n-2)s^3} \tag{2.5}$$

Note: skewness has limit can be defined as,

$$|C_s| \leq \sqrt{n-2}$$

There are two types of Skewness: Positive and Negative as shown in figure 3.

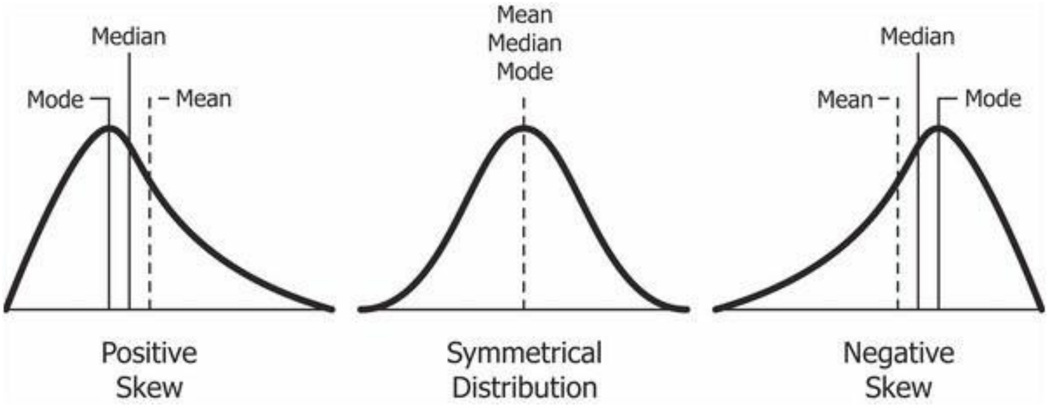

Figure 3: Positive, symmetrical and negative skewness distributions

Positive Skewness means when the tail on the right side of the distribution is longer or fatter. The mean and median will be greater than the mode.

Negative Skewness is when the tail of the left side of the distribution is longer or fatter than the tail on the right side. The mean and median will be less than the mode.

2.4.9 Peakedness or Kurtosis

Kurtosis value can describe the degree of flatness or the degree of peakedness of the orginal sample, kurtosis can be expressed bythe following equation,

$$\gamma_k = \frac{\sum_{i=1}^{n} (X_i - \overline{X})^4}{(n-1) * SD^4} \tag{2.6}$$

2.4.10 Autocovariance Function

The degree of linear autodependence (self-dependence) of any time series can be described by the coffeicient of autocovaiance function. The autocovariance be defined by the correlated pairs x_t and x_{t+k} as,

$$c_k = \frac{1}{n} \sum_{t=1}^{n-k} (x_t - \overline{x}), \qquad [0 \le k < n] \tag{2.7}$$

2.4.11 Autocorrelation Factor

Measuring the linear dependence can be done by dividing the $C_{k\neq0}$ over $C_{k=0}$. The result will be dimensionless coefficient. This factor is aiming to identify the non-randomness of the data and to express the appropriate time series model in case of no random data.

Autocorrelation coefficient can be expressed as:

$$r_k = \frac{c_{k\neq0}}{c_{k=0}} = \frac{\sum_{t=1}^{n-k}(x_t - \bar{x})(x_{t+k} - \bar{x})}{\sum_{t=1}^{n}(x_t - \bar{x})^2} \tag{2.8}$$

2.4.12 ANOVA (t-test, F-test)

In order to test the homogeneity, correlation and comparison of any data, ANOVA test should be used. ANOVA test depend on two tests T and F test. T-test and F-test values should be checked by specific tables. The values should be between the acceptable ranges. T-test depends on the means and F-test is related to the standard deviations of the sample. T-test and F-test formulas are giving below.

(t) test;

$$t = \frac{(\bar{x} - \bar{y})}{\sqrt{\frac{s_x^2}{n} + \frac{s_y^2}{m}}} \tag{2.9}$$

(F) test;

$$F = \frac{s_x^2}{s_y^2} \tag{2.10}$$

2.4.13 Parametric – Nonparametric Tests

Parametric test is based on several statistics values like; mean, stander deviation, skewness and the (*t*-test, F test) of the ANOVA, etc. A nonparametric test is a test that can be used without a parametric assumption, for example; Mann-Kendall test, Sen's Median slope, etc. Distribution free test is another name for the nonparametric test. Both of these tests can be used in order to detecting and measuring the trends of the sample.

2.4.14 Cumulative Density Function (CDF)

Cumulative density function can be used in order to describe the probability. When random variables' values are equal or less the specific value of x.

$$F(x) = \Pr[X \leq x] = \alpha \qquad (2.11)$$

In hydrology science different CDF formula can be used, in this study the formulas listed below were used.

Table 3: CDF formulas

Distribution	Equations	Comments
Normal	$x = \bar{x} + zs_x$	z can be found by using the Normal & Log-normal distributions' table in the appendix
Log Normal	$y = Log(x)$, $y = \bar{y} + zs_y$	using the normal distribution table z is found
Smallest Extreme - Value (Gumble)	$q = (1-p) = e^{-e^{-y}}$	$y = a(x - x_0)$, $a = \frac{\sigma_n}{s_x}$, $x_0 = \bar{x} - y_n \frac{s_x}{\sigma_n}$ y_n, σ_n values can gathered from Gumble and Log-Gumble table from appendix
Pearson Type III (Gamma)	$x = \bar{x} + Ks_x$	According to Pearson Type III table defined in appendix, K can be found

2.4.15 Confidence Interval ($\alpha_{\%}$)

A frequency curved is created from sample data. It is the best expression of the population curve. It can be used in order to expect the new data that would occur over the next period or any short time. It depends on different frequency record. The collected data for many times can give array of frequency; these arrays can estimate the upcoming records.

2.4.16 Degree of Freedom (df)

It is defined as a number can describe the population factors subtracted from the number of independent observations, which are observed from the mean and the standard deviation values.

2.4.17 Double Mass Curve (DMC)

Double mass curve is a major concept in statistics data analysis. In this curve the cumulative values of one variable should be drawn against the accumulation of another quantity during the same time of period. When the accumulation of two stations' data is plotted for a certain district, static error can be found if the data line has a deviation or a gap. On the other hand, if, there is no gap or change of curve, it can be claimed that, the two sets of compared data are consistent. Correction of the data can be done by multiplying a constant ratio based on slopes of curve, correction equations is described below.

$$P_{adjusted} = \frac{M_a}{M_0} P_{observed} \qquad (2.12)$$

2.5 Procedure and Sample Calculations

2.5.1 Test of Normality

Usually it's assumed that the time series is normally distributed. However, testing that this assumption is correct is often disregarded. There are two methods for testing the normality; graphical and statistical methods. In this study, the Anderson-Darling (A-D) was used to inspect the normality of the precipitation data (Kanji, 2006). The Anderson-Darling test is used to examine if a series comes from a population with a normal distribution.

Anderson-Darling test

The value of A-D calculated is compared with the corresponding critical value (alpha) of the theoretical distribution. The hypothesis that the distribution is normal is rejected if the value of A-D is greater than the critical value (Goswami et al., 2006). The A-D test was applied to the data from each district. Because this test for each district is done by Minitab 16 software, the theory is not explained here. If the P value that is given by software will be equal or greater than 5%, then it is concluded that, the time series is normally distributed. In this thesis Anderson Darling test is selected for testing normality in Minitab.

2.5.2 Test of Homogeneity

In order to achieve the homogeneity and corrections between two groups of data, t-test and Fisher's F test can be used. Each test has specific procedures described below.

Procedure for *t*-test

First, two variables should be founded;

- Mean of the two groups of set $\bar{x}$ and $\bar{y}$.
- Stander deviation of s_x and s_y sets.

Then, t-test formula can be used as described below,

$$t = \frac{(\bar{x} - \bar{y})}{\sqrt{\frac{s_x^2}{n} + \frac{s_y^2}{m}}} \tag{2.13}$$

Both confidence interval and freedom degree values should be fixed regarding to table of t-distribution and find the value of t critical. Then, the difference between the two values of t should be compared, when t critical is higher, test can be accepted.

Procedure for F-test

F-test depends on comparing between the standard deviations values. First, the standard deviations of two groups of set should be obtained, and then the smallest value of deviation should be over the large value of deviation as described in equation below.

$$F = \frac{s_x^2}{s_y^2} \tag{2.14}$$

The allowable F value should be obtained from the appropriate table. Comparison between calculated F and allowable F, if the calculated F is smaller than allowable F, a correlation between two sets is existed. If not, there is no correlation between two sets.

2.5.3 Test of Consistency

The main purpose of consistency test is to find if the data lies on the gathered data or not. In order to examine the consistency of data DMC method should be applied. Double mass curve procedures are described below,

- Gathered desired parameter for each district should be known.
- Accumulation of the total average of the data over the nearest districts should be found.
- Relationship between the cumulative precipitation data for one station and the mean of remaining stations precipitation data for a specific district should be drawn on graph by x and y axis respectively.

2.5.4 Probability Density Functions and Cumulative Density Functions

Probability function helps the researchers to know the state of distributed data and to choose the best model which can fit the data collections. In order to know the probability functions, different checking functions can be used such as; checking the hypothesis and Tests of Goodness of Fit. To find the suitable function for the data, following procedures can be followed:

- Sorting the data discerningly based on the type of probability function like normal or log normal style, a suitable equation and table index should be used to find the probabilities of the observed data.
- Compare between the new gathered data and observed set of data, and the best function will be selected. In order to gather a new set of data, plotting positions method can be used.
- Finally, checking function like regression analysis ‘r’ and Chi-Square (χ^2) can be used regarding to the observed probabilities and generated data collections.

2.5.5 Moving Average (MA)

Moving average (MA) can be defined as a parametric technique for smoothing data and filtering. This method is used because some of original data could be fluctuated, so moving average is used to reduce that fluctuation and the trend line more clearly. This fluctuation may happen because of increasing or decreasing in values after normal behavior which is observed earlier. Moving average could be used in temperature and precipitation values, because a lot of fluctuations can be faced in temperature and precipitation lines. Moving average equation is described below which can be used with the odd numbers.

$$Y_i = (2k+1)^{-1} \sum_{j=-k}^{k} X_{i+j} \qquad (2.15)$$

2.5.6 Mann Kendall Tests and Sen's Median Slope

The slope of (Mann and Sen) tests are used because some of slope data is not meaningful, in order to know the behavior of trend lines. Median values should be examined by using the slope of MA method as described in equation below.

$$\tau = \sum_{i=2}^{n} \sum_{j=1}^{i-1} \text{sign}(\mathrm{X}_{\mathrm{i}} - X_j) \qquad (2.16)$$

2.5.7 Dry and Wet Spells

For management planning, it is essentially to know the intensity of rain for each year. Wetness and dryness of years can be checked by several methods like; severity index and drought index. The method that is used in this study is depended on comparing between the precipitations values of each year with the mean value of whole years. If the precipitation is greater than the mean it will be named as wet year and if it is less than mean, it will be considered as dry year.

2.5.8 Analysis of monthly precipitation data and its trends built on the Hydrological years from 1960-61 to 2016-17

A statistical measures was done for each month from October until May, a verity of parameters was computed such as mean, standard error, median, standard deviation, sample variance, kurtosis, skewness, range, minimum and maximum precipitation values and the total amount of precipitation in the 57 years in that month.

2.5.9 Correlations

Correlation coefficient is used to compare between two values or more. A lot of methods can be used to obtain the correlation coefficient. Simple linear correlation method is considered as the easiest one. It is same as simple regression analysis.

Correlation coefficient can be used for different relationship such as; temperature versus evaporation, temperature versus precipitation and precipitation versus temperature.

Chapter 3

TIME SERIES

3.1 Introduction

Time series can be defined as a collection of data points that are measured in a constant time interval. Time series is used in statistical methods in order to analysis the time over the collected data and to extract meaningful statistical results.

Time series can be used in; forecasting process, quality control, utility studies, etc.
In term of time series, many programs have been used in order to analysis time series data and to evaluate long term trends. Note that, time series forecasting has been used to investigate the future value of the data set based on previously collected data set.

By using time series technique two goals can be achieved the first one is to understand the natural state of the collected data or observations and the second one is expecting and forecasting the values of the future data. In order to achieve these goals, specific time series for the data set should be described for understanding and predicting the pattern of data set.

Different types of time series have been used in previous studies, each type can be used to achieve a specific purpose. Some of time series methods are described below with their purposes.

- Exploratory analysis: this method is considered as obvious way to explain the regular time series by using chart line.
- Curve fitting: this method is concluded by drawing best curve fitting or for data set on the chart to predict main function of the future values.
- Function approximation: when the time series is very closed to any target data.
- Statistical models: this method can give a prediction of the future data.

In order to use curve fitting method, different models can be used to get the best fit of observed data. Three of these models are described below.

- Moving Average model,
- Holt-Winters multiplicative Smoothing model, and
- Box-Jenkins ARIMA models.

In most recent analysis, time series is consisted of a systematic pattern and random error which makes identification of data difficult. In order to describe any time series, the possible time series components are;

- Trend (Tt) — long term movements in the mean,
- Seasonal effects (It) — cyclical fluctuations related to the calendar,
- Cycles (Ct) — other cyclical fluctuations (such as a climate cycles),
- Residuals (Et) — other random or systematic fluctuations.

Trend describes time series of the data set without any overlaying or repeating in time data. On the other hand, Seasonality has the same behavior of trend line but the time can be repeated in systematic intervals (periodically) over the time. Figure 2 shows time series of precipitation data set over the time period for Amman based on hydrologic year (October-September).

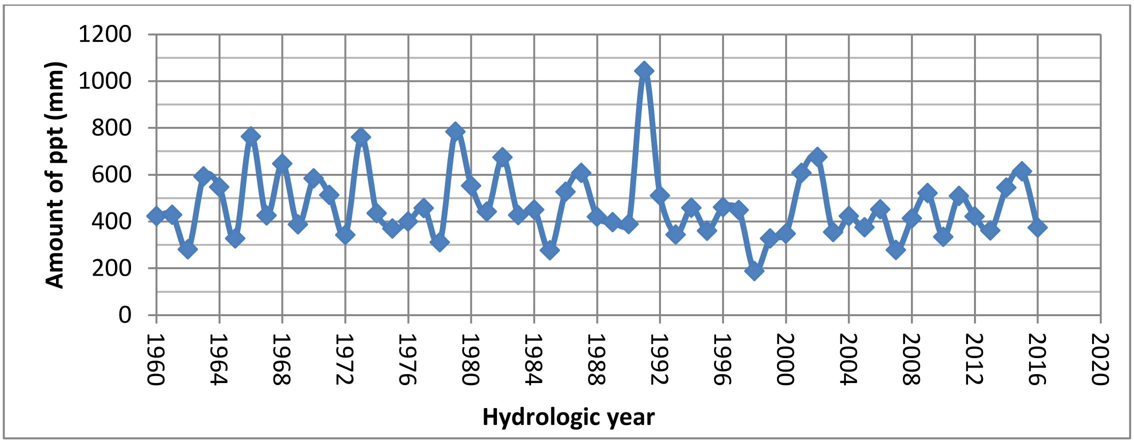

Figure 4: Amman district precipitation data set from 1960-61 to 2016-17

3.2 Climate Variability and Changes

In order to understand the issue that related to climate changes, it is important to know the term of climate change, as opposed to climate variability. Generally, “climate change” is concerned about describing a long-term underlying shift in the climate, while the “climate variability” is including the natural variation in general climate that can be showed even in any underlying long-term changes.

3.3 The Importance of Climate Change Analysis

Detecting trends of data set in any time series of hydrological variables is essential in scientific and practical purposes. The system of any water resources has been worked and designed based on the assumption of statistical hydrology. If the value of assumption is improper then the existing procedures should be revised. Without doing a revision for the systems over or under designed process, over cost will be resulted (Scholze et al., 2006).

3.4 The Scope of Hydrological Change Studies

A change can happen abruptly (step change) or progressively (trend) or may take different forms. Changes can be found in mean values, in variability (variance, extremes, persistence) or can be found in annual time series (changing seasonality). Sudden changes could be described as a result of an unexpected alteration within the watershed (reservoir construction, installing water diversions).

There are different amount of hydrological data sets that can be used for the analysis. These data sets can be gathered at a range of temporal period; hourly, daily, monthly, annually, or in irregularly ways.

Studies of hydrological changes can be considered complicated by factors such as missing values, measurement errors, and lack of homogeneity because of changes in instruments and observation techniques (Andreasson et al., 2004).

3.5 Approaches for Testing the Change

In literature, there are many different methods that can be used to describe the trends series in hydrological approaches. In discovering which method should be chosen is important provided that of which test procedures are available and which procedures are most helpful are detected. In classical statistics parametric testing procedures are very useful. In parametric testing, it is important to suppose an underlying distribution for the variable data and to make assumptions that data collected are independent of other. For many hydrological time series, these assumptions cannot be appropriate. Few hydrological series have a normal distribution. Secondly, there is dependence in hydrological time series, particularly if the time period interval is short. If parametric techniques can be used, it may be important to transform data so that its distribution is around normal and concerned analysis to yearly time series, for which independence assumptions can be accepted, rather than having the more detailed monthly, daily or hourly time series.

In non-parametric and distribution-free approaches, little assumptions about the data need to be done. In this approach, it is not important to suppose any distribution type. However, many of these ways still depend on assumptions of independence data. More developed approaches should be useable for daily or hourly time series. A helpful class of non-parametric tests is permutation tests. They are depended on changes of the order of data points, calculating statistics, and comparing these with the collected test statistics.

3.6 Trend Analysis

Generally, in most trend line methods there is no specific technique in order to describe the trend‘s components even if the trend has constant behavior in decreasing or increasing values. Step and monotonic are two kind of trends which can be analyzed statically. Both monotonic and step have gradual changes in decreasing or increasing values without any reversal of direction, and they may have cyclic behavior like seasonal variation. Most of monotonic data can be adequately predicted by a linear function, if there is an obvious monotonous non-linear component. If the time series data has considerable error so the first step in the process of trend identification has to be smoothing. In moving average smoothing technique, each element of the series is replaced by either the simple or weighted average of ‘n’ surrounding elements, where ‘n’ is the width of the smoothing (Partal and Kahya, 2006).

3.7 Seasonality Analysis

Seasonality is called seasonal dependency. It's a common factor of the time series configuration. It can be described as correlational of the ''k'' order between each part ''I'' for the time series. ''k'' can be called the lag. In case of error is not that much large, seasonality is clearly described for the time series as a pattern which can be repeated every ''k'' parts. Seasonal arrangements of the series are checked by using correlograms (Maussion et al., 2014).

3.8 Methods for Smoothing Time Series

Smoothing time series can be used in order to show the patterns and trends of series in obvious way. Usually Smoothing time series neglects the irregular roughness data to see better sign. Time series methods are basically depended on smoothing techniques that filters out the effect of the random variation values. Simple averaging technique can be helpful in smoothing methods (Schkade and Clark, 1974).

In this study, the moving average (MA) smoothing technique is selected. It filters out the fluctuations and batches the trends. It plays in series as indicator which describes the middling value of the investigated data over its specific time. MA's equation is described below:

$$Y_i = (2k+1)^{-1} \sum_{j=-k}^{k} X_{i+j} \tag{3.1}$$

k is the MA year. The trend is gathered for a restricted limit of (2k+1) (Kottegoda, 1980).

3.9 Stationary Time Series

In any statistical study, stationary time series has to be applied before creating any time series model because it is considered as one of the most important properties in the series model (Baabak and Jian, 2010).

Using stationary for a specific series can result by satisfying two clauses:

- Constant Mean must be involved in stationary time series.
- Variance of time series supposed to be not changed over the time series.

Augmented Dickey – Fuller Unit Root (ADF) Test

(ADF) Stationary test is used for the time series of a specific sample in unit root. It can be used for the larger and complex set of series.

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \delta_1 \Delta_{y_{t-1}} + \cdots + \delta_{p-1} \Delta_{y_{t-p-1}} + \varepsilon_t \qquad (3.2)$$

where;

α can be considered as constant,

β coefficient located on the trend of the time,

p is the lag order in process.

In this study Autoregressive order one (AR1) is used, as shown in equation below:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \varepsilon_t \qquad (3.3)$$

where;

$H_0: p \geq \alpha$ the data can be consider as a stationary

$H_0: p < \alpha$ the data can be considered as a non-stationary

3.10 Forecasting Models

Forecasting model is a stage concerned about estimation procedures. This stage works on how to estimate the upcoming outcome values of an arbitrary progression. Five forecasting models have been used in this study are described below.

3.10.1 Moving Average (MA) Model

Once a time series arrangement cannot show the trends' values or seasonal features in hydrology problems, using moving average can be used by ignoring the random deviation. As described in equation below, this system contains a simple average observation over the most recent periods time (Tanaka, 1990).

$$\hat{y}_{t+1} = \frac{y_t + y_{t-1} + y_{t-2} + \cdots + y_{t-M+1}}{M} \qquad (3.4)$$

3.10.2 Holt-Winter Multiplicative method

There are two approaches, the additive and the multiplicative. In this study the multiplicative Holt-Winter method is applied. This technique is consisted of forecasting calculation and three smoothing calculations, the first calculation is to the level l_t, the second calculation belongs to trend b_t, and the third is related to seasonal component described by finding S_t, related to smoothing parameter values which are α, β and γ. In many cases the multiplicative method is preferred and it be done by using Minitab software. It's equation is shown below (Rob and George, 2013).

$$\widehat{y_t} = (l_t + hb_t)S_{t-m+h} \qquad (3.5)$$

3.10.3 ARIMA model

A hydrological time series (y_t, t= 1, 2, 3,…, n) could be either stationary or nonstationary. Given that there are basically no strictly deterministic hydrological processes in nature, the analysis of hydrological data by means of nonstationary time series is of position, among which ARIMA model is one of the available choices. In order to study the monthly time series from the precipitation stations, an ARIMA modeling approach is used in this study (Wang et al., 2014). A seasonal ARIMA model denoted as ARIMA (p,d,q) that is a combination of previous values and previous residuals. A stationary time series has the property that its statistical characteristics such as the mean and the autocorrelation structure are almost fixed over time. When the experiential time series presents a trend and heteroscedasticity, differencing and power transformation are often applied to the data to remove the trend and stabilize variance before an ARIMA model can be fitted (Yürekli et al., 2005).

Identification of the order of ARIMA model

The next step is to establish the order terms of its ARIMA model, the order of differencing, d for nonstationary time series, the order of auto-regression, p, the order of moving average, q, and the seasonal terms if the data series show seasonality. In ARIMA model, nine dissimilar ARIMA orders (p,d,q) were used in Minitab as following: (1,0,1), (2,0,2), (1,0,2), (2,0,1), (1,2,1), (2,2,2), (1,2,2), (2,2,1) and (2,1,1).

The Portmanteau test (Ljung–Box test)

The Ljung- Box Q or $Q(r)$ measurement can be specialized to form individuality instead of visual review of the sample autocorrelations. A test of this hypothesis can be completed for the model capability by selecting a level of significance and then comparing the value of calculated X^2 with the X^2 table critical value, the present model is adequate on the basis of available data. The $Q(r)$ statistic is calculated by the following equation (Yürekli et al., 2005).

$$Q(r) = n(n+2)\sum_{k=1}^{m}(n-k)^{-1}r_k(a)^2 \quad (3.6)$$

The Runs Test

The runs test can be used to decide if a data set is from a random process. A run is defined as a series of growing values or a series of reducing values. The number of growing (or reducing) values is the size of the run. In a random data set, the probability that the (i + 1)*th* value is greater or lesser than the *ith* value follows a binomial distribution, which forms the basis of the runs test (Yürekli et al., 2005). The statistical hypothesis were obtained through Minitab, if the p-value were greater than the significant level (0.05), Runs test for this model will be accepted.

Chapter 4

CALCULATIONS AND RESULTS

4.1 Introduction

In this thesis the precipitation (rainfall) data for the 12 districts were studied, where each district is represented by a certain number of stations as mentioned earlier, based on the Thessien Polygon Theory. Average representative data sets were computed based on the selected stations in each district.

In this part of the thesis, the gathered monthly precipitation data sets from the hydrologic years 1960-61 to 2016-17 (57 years' data set) were alienated into three parts; the first one deals with the quality tests and the simple statistical measurements, the second part, it is mainly concentrated on the solicitation of the time of series data, where prediction models were applied on the data, and a prediction of 10 years precipitation data for each area was established based on the best representative model for each district. The third part is presenting the study of each month's in each district separately, where a descriptive statistical parameters were computed for each month, and the data was plotted centered on 10 years MA due to the reason that almost all the months had too many nil values which causes a difficulty in finding the pattern of the trend.

The probability distribution prototypes

- Normal Distribution,

- Log-Normal Distribution,
- Extreme – Value (Gumble), and
- Pearson Type III (Gamma).

The models of time series prediction are:

- Moving Average Model,
- Holt-Winters Multiplicative Model, and
- ARIMA Model with 9 different combinations.

4.2 Meteorological District: Ajlun

Table 4: Monthly precipitation data with the statistical measures of Ajlun district for hydrological years started in 1960-61 until 2016-17 in (mm)

Year \month	October	November	December	January	February	March	April	May	Total (mm)
1960-61	0	81	37	134	121	17	27	13	430
1961-62	3	12	239	88	78	8	29	8	464
1962-63	11	9	66	54	108	50	26	40	364
1963-64	33	31	129	81	150	93	7	8	532
1964-65	0	103	71	176	67	45	55	0	516
1965-66	52	25	65	40	70	102	7	2	362
1966-67	31	17	209	143	60	165	6	22	654
1967-68	23	62	54	129	36	19	22	3	348
1968-69	17	26	149	158	36	134	18	0	539
1969-70	21	38	30	132	41	168	27	0	457
1970-71	6	16	68	126	107	66	160	0	547
1971-72	0	47	141	58	97	71	32	8	454
1972-73	4	32	20	89	18	76	1	6	247
1973-74	5	95	39	252	104	40	36	0	569
1974-75	0	32	63	39	169	69	7	0	379
1975-76	2	39	85	70	121	101	36	11	465
1976-77	12	74	18	89	38	91	65	0	388
1977-78	31	5	124	63	23	75	12	0	332
1978-79	25	15	73	53	22	48	5	0	239

Year \month	October	November	December	January	February	March	April	May	Total (mm)
1979-80	52	106	200	81	95	110	17	0	660
1980-81	5	13	190	94	71	38	27	0	438
1981-82	0	60	18	67	123	64	6	8	346
1982-83	6	64	47	145	136	114	20	5	536
1983-84	9	41	16	121	40	120	29	0	376
1984-85	27	24	37	34	212	30	21	1	387
1985-86	12	19	39	80	121	19	15	30	337
1986-87	29	199	66	87	37	67	3	0	488
1987-88	29	9	125	115	180	87	12	0	557
1988-89	7	33	156	52	36	80	2	0	364
1989-90	11	70	65	119	57	76	26	0	424
1990-91	6	18	8	136	66	107	19	5	364
1991-92	7	86	312	158	301	32	4	7	908
1992-93	0	51	205	83	61	36	22	22	481
1993-94	8	22	16	121	63	93	8	2	333
1994-95	21	183	124	17	67	31	15	0	458
1995-96	6	44	26	124	17	150	14	0	382
1996-97	30	21	55	102	204	102	13	12	538
1997-98	19	47	117	133	56	159	11	6	548
1998-99	4	6	18	89	55	34	17	0	222
1999-00	2	2	22	284	77	57	1	0	446
2000-01	32	12	145	63	73	12	2	19	357
2001-02	11	28	102	161	50	106	49	5	513
2002-03	6	32	202	52	233	181	16	0	722
2003-04	18	25	91	160	75	22	6	0	397
2004-05	20	95	35	115	154	35	13	12	479
2005-06	9	44	88	97	117	14	66	0	435
2006-07	56	16	60	84	114	103	29	8	468
2007-08	2	49	29	101	79	6	0	8	274
2008-09	17	9	81	16	168	121	11	0	422
2009-10	25	72	92	68	126	24	0	4	410
2010-11	3	0	63	88	95	78	36	23	388
2011-12	0	69	36	124	105	108	3	0	443
2012-13	11	62	83	245	34	6	34	10	484
2013-14	0	6	139	0	2	89	0	30	267
2014-15	13	31	57	24	109	43	26	0	303
2015-16	8	41	32	115	47	101	37	5	386
2016-17	12	24	68	71	64	43	16	0	298

Year \month	October	November	December	January	February	March	April	May	Total (mm)
Average	14.2	43.7	86.7	102	90.97	72.6	21.5	6	437.3
Standard Error	1.82	5.21	8.69	7.34	7.80	5.97	3.21	1.19	16.16
Median	10.8	32.30	66.2	89.48	74.67	71.23	16.07	1.50	429.8
Standard Deviation	13.7	39.31	65.63	55.42	58.88	45.04	24.25	8.98	122
Sample Variance	188	1545	4308	3072	3467	2028	587.8	80.62	14885
Kurtosis	1.46	5.40	1.49	2.02	2.05	-0.43	18.62	3.79	3.08
Skewness	1.30	2.03	1.27	1.03	1.26	0.48	3.62	1.97	1.15
Range	55.7	199.1	303.9	284.2	298.7	175.3	159.9	39.86	686.5
Minimum	0.00	0.00	8.23	0.00	2.38	6.08	0.00	0.00	221.7
Maximum	55.7	199.1	312.1	284.2	301	181.3	159.9	39.86	908.2

4.2.1 Normality Test for Ajlun District

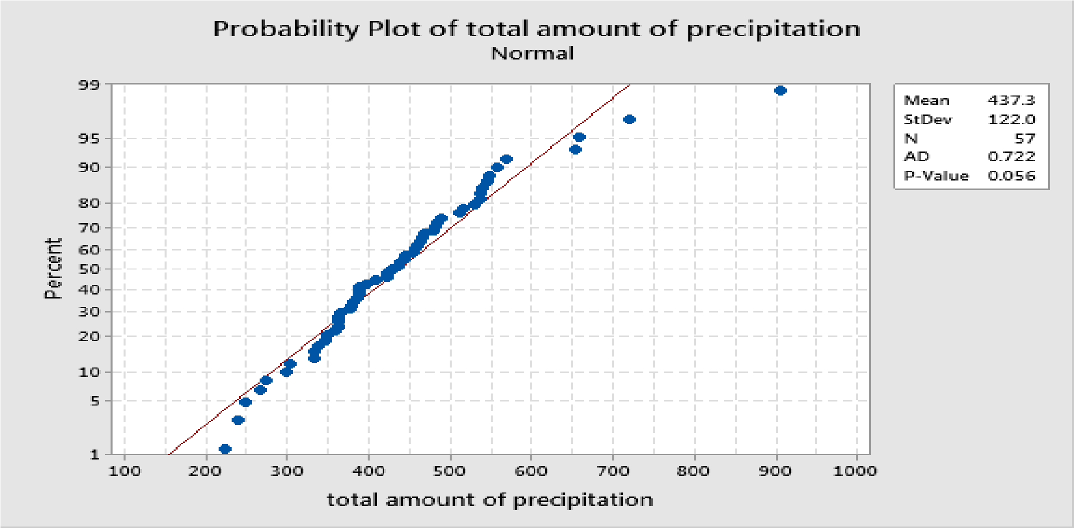

Figure 5: Ajlun District's Normality Test Details

Test interpretation:

H_0: The variable from which the sample was extracted follows a Normal distribution, and H_a: The variable from which the sample was extracted does not follow a Normal distribution.

As the computed p-value is higher than the significance level alpha=0.05, one should accept the null Hypothesis H_0.

Result: p-value = 0.056>0.05. Therefore, Ajlun yearly Precipitation data does follow the Normal distribution.

4.2.2 Checking Homogeneity by Examining the Relationship of Ajlun District's Yearly Precipitation Records with the other 11 Districts Yearly Precipitation Records

Table 5: Homogeneity results of Ajlun district with the other 11 districts through t-test and F-test

Ajlun		**Amman**	**Balqa**	**Irbid**	**Jarash**	**Karak**	**Madaba**
Mean	**437**	467.9	412.2	379.1	279.6	300.8	257.9
SD	**122**	150.1	128.5	109.5	89.1	98.1	86.3
t-test		1.194<1.67	1.071<1.67	2.68>1.67	7.878>1.67	6.584>1.67	9.066>1.67
examining t test		✓	✓	x	x	x	x
F (P-value)		0.124>0.05	0.7>0.05	0.419>0.05	0.02<0.05	0.105>0.05	0.011<0.05
examining F test		✓	✓	✓	x	✓	x

Ajlun		**Mafraq**	**Tafilah**	**Zarqa**	**Maan**	**Aqaba**
Mean	**467.9**	176.2	244.7	142.6	175.2	27.9
SD	**150.1**	55.3	114.9	48.5	80.3	21.6
t (Ajlun)		14.719>1.67	8.677>1.1.67	16.948>1.67	13.545>1.67	24.948>1.67
examining t test		x	x	x	x	x
F (Ajlun)		<0.0001	0.654>0.05	<0.0001	0.002<0.05	<0.0001
examining F test		x	✓	x	x	x

Result: Built on *t*-test and F-test Ajlun district yearly precipitation data is linked with Amman and Balqa districts precipitation data.

4.2.3 Consistency test of Ajlun district's stations yearly precipitation data with the average of nearby 6 representative stations yearly precipitation data by DMC test

Ajlun district having 7 representative stations (AL0005, AL0004, AB0004, AH0001, AH0002, AH0003 and AL0026). The cumulative yearly Precipitation data for each station was plotted with the other 6 remaining yearly average cumulative Precipitation (ppt) data as shown in the following figures.

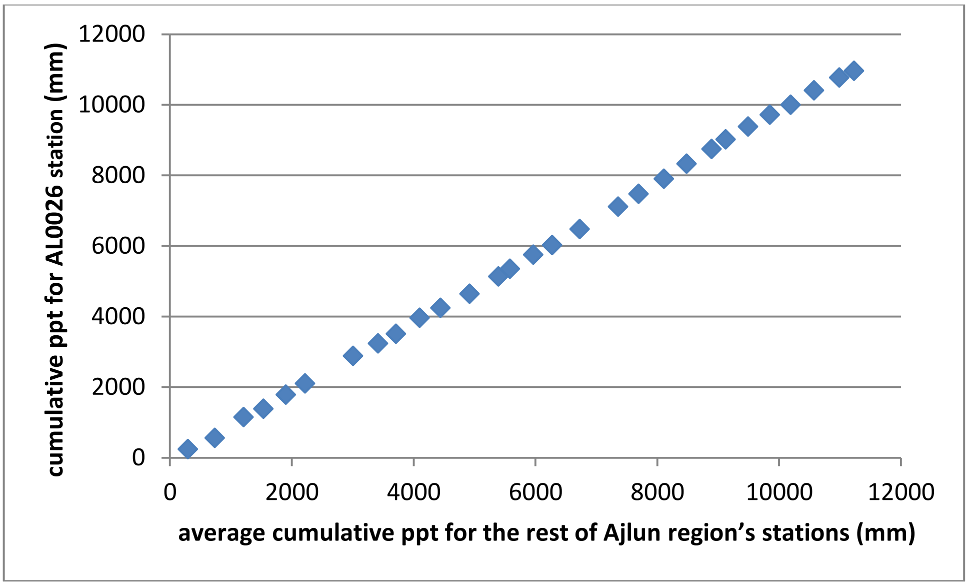

Figure 6: AL0026 station DMC for yearly precipitation data with remaining neighboring 6 representative stations in Ajlun's district

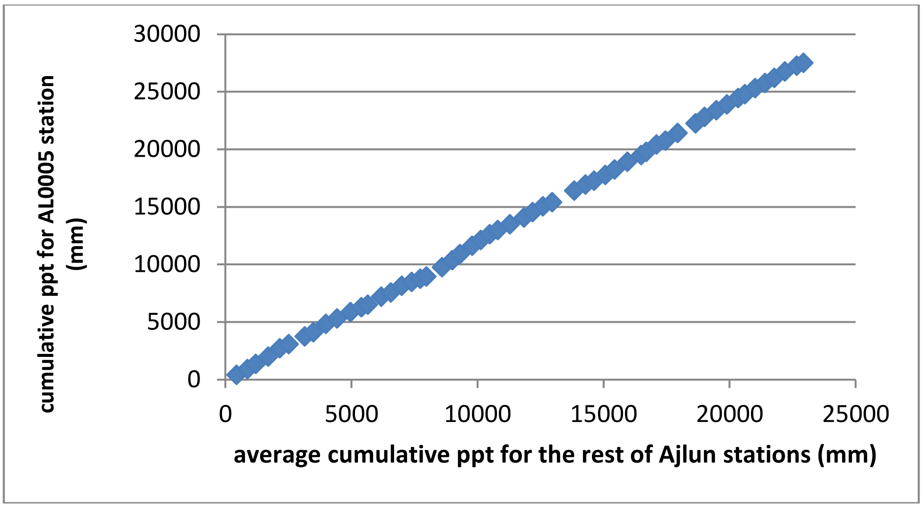

Figure 7: AL0005 station DMC for yearly precipitation data with remaining neighboring 6 representative stations in Ajlun's district

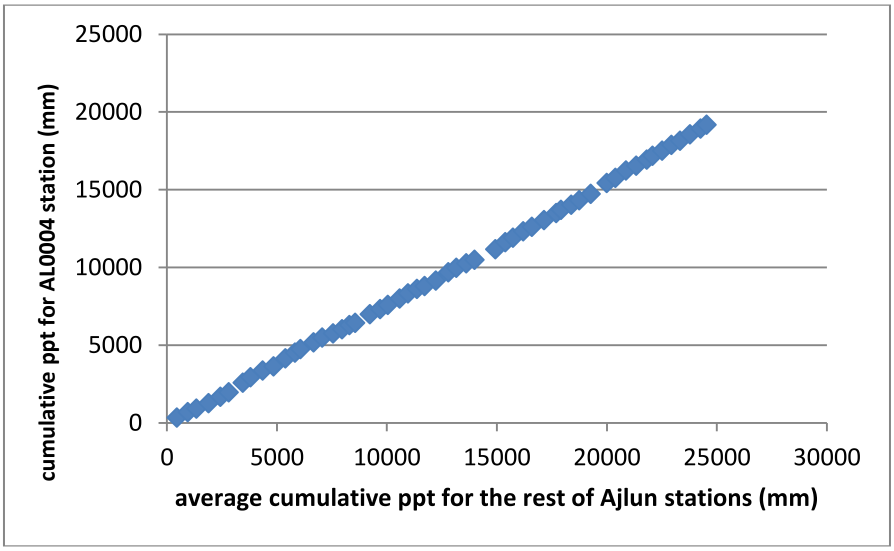

Figure 8: AL0004 station DMC for yearly precipitation data with remaining neighboring 6 representative stations in Ajlun's district

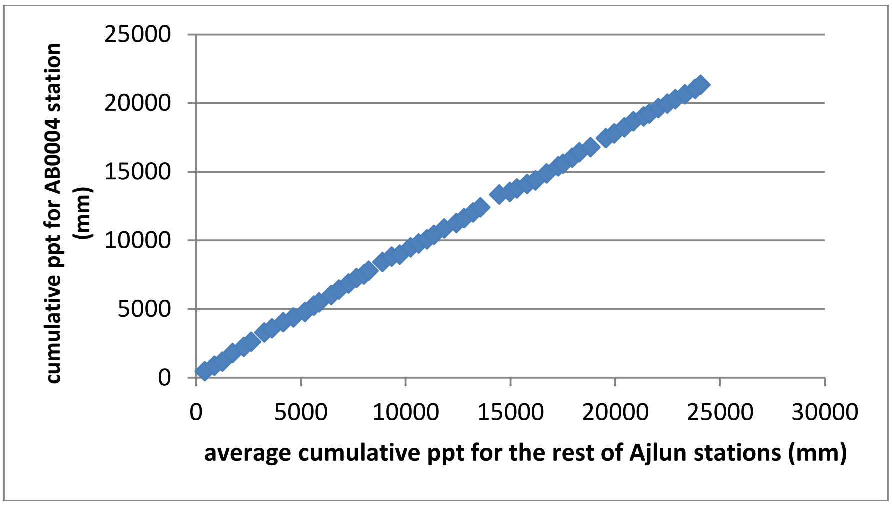

Figure 9: AB0004 station DMC for yearly precipitation data with remaining neighboring 6 representative stations in Ajlun’s district

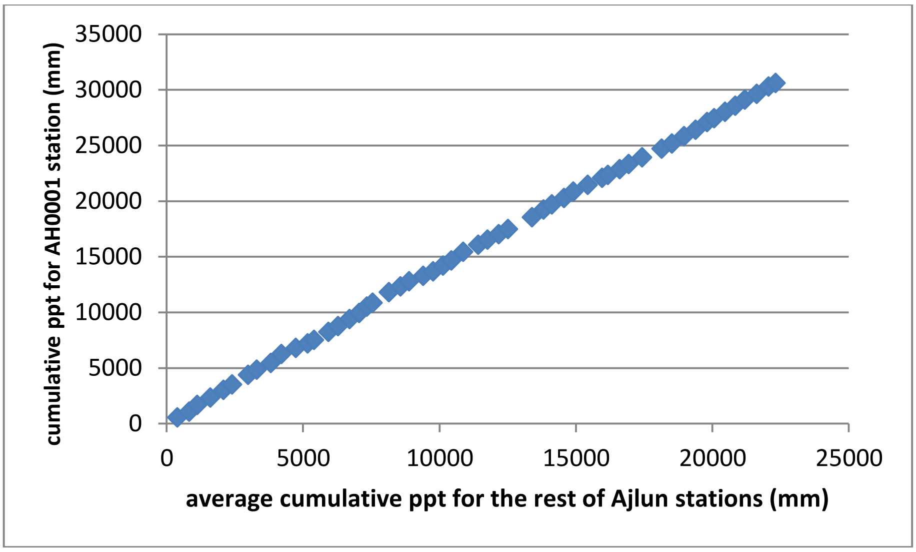

Figure 10: AH0001 station DMC for yearly precipitation data with remaining neighboring 6 representative stations in Ajlun’s district

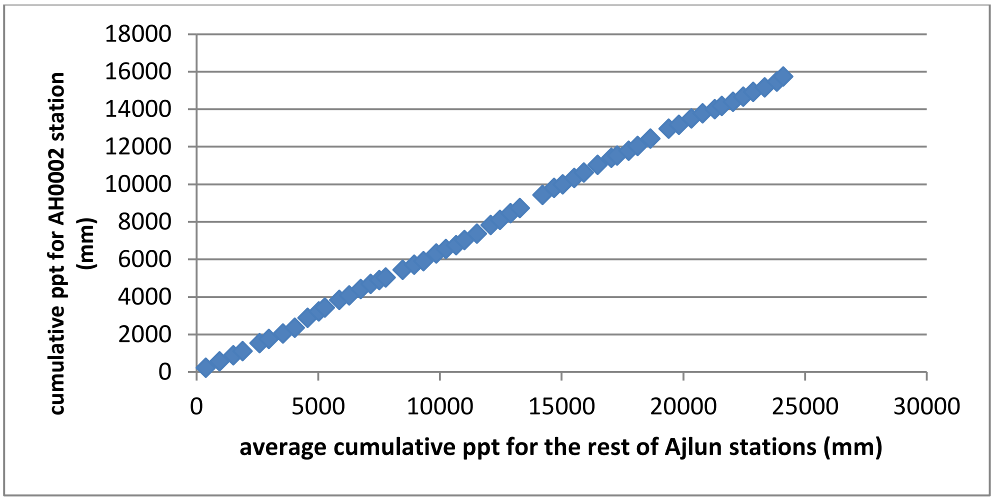

Figure 11: AH0002 station DMC for yearly precipitation data with remaining neighboring 6 representative stations in Ajlun's district

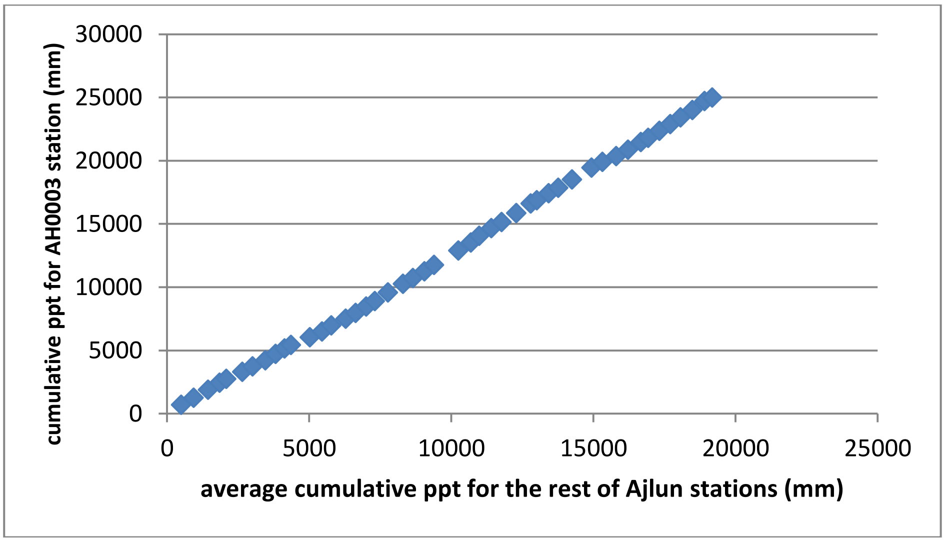

Figure 12: AH0003 station DMC for yearly precipitation data with remaining neighboring 6 representative stations in Ajlun's district

Result: The yearly precipitation data of Ajlun district is considered as consistent data, since all the double mass curves roughly representing straight line trend with no significant deviation.

4.2.4 Trend of Ajlun District's Precipitation Data

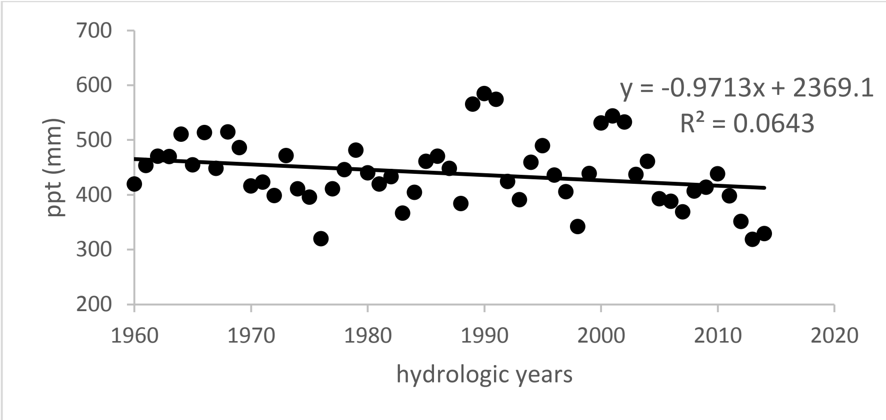

Figure 13: 3 years MA of Ajlun district's yearly precipitation data

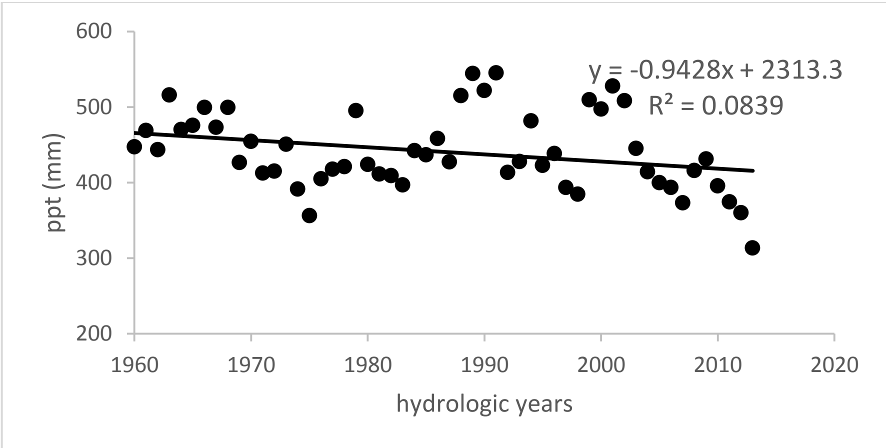

Figure 14: 4 years MA of Ajlun district's yearly precipitation data

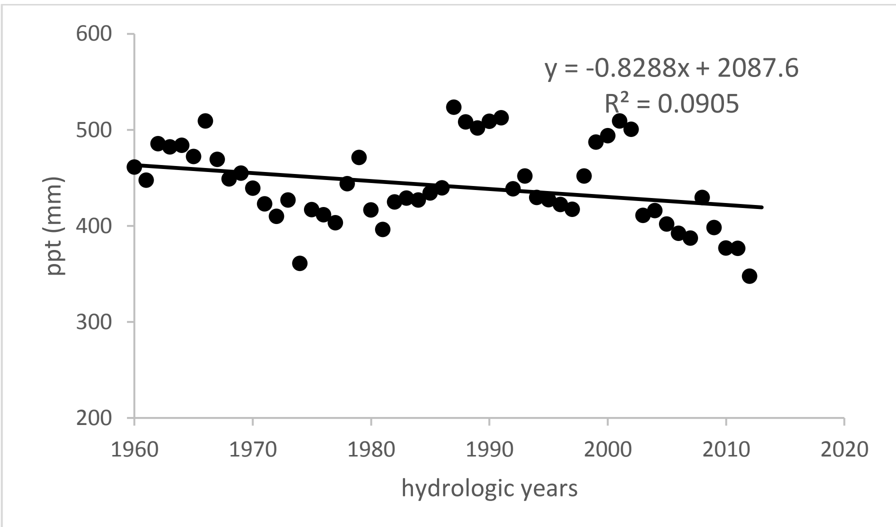

Figure 15: 5 years MA of Ajlun district's yearly precipitation data

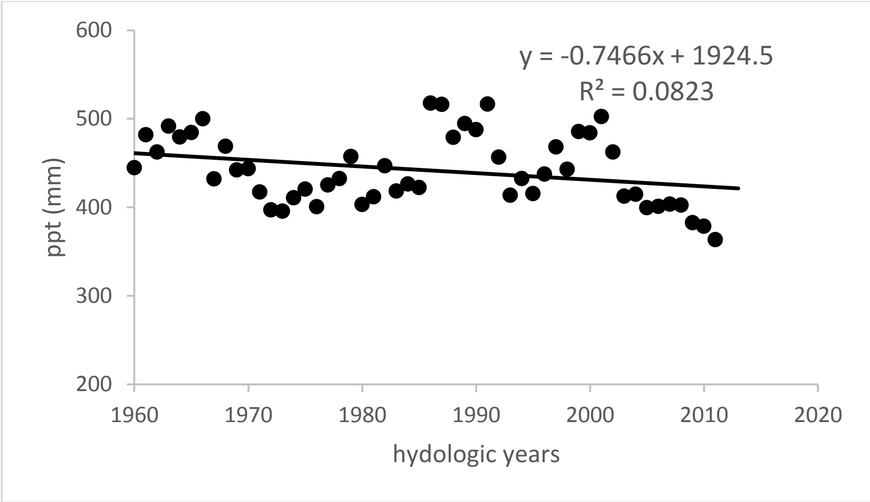

Figure 16: 6 years MA of Ajlun district's yearly precipitation data

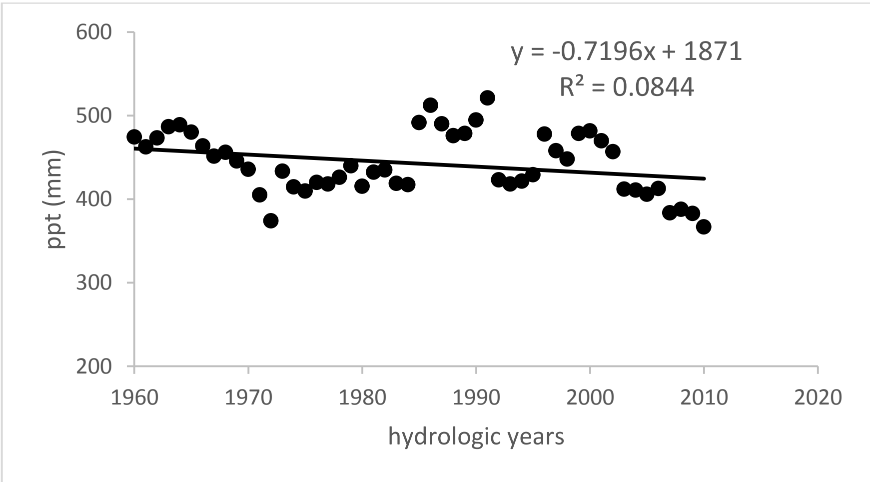

Figure 17: 7 years MA of Ajlun district's yearly precipitation data

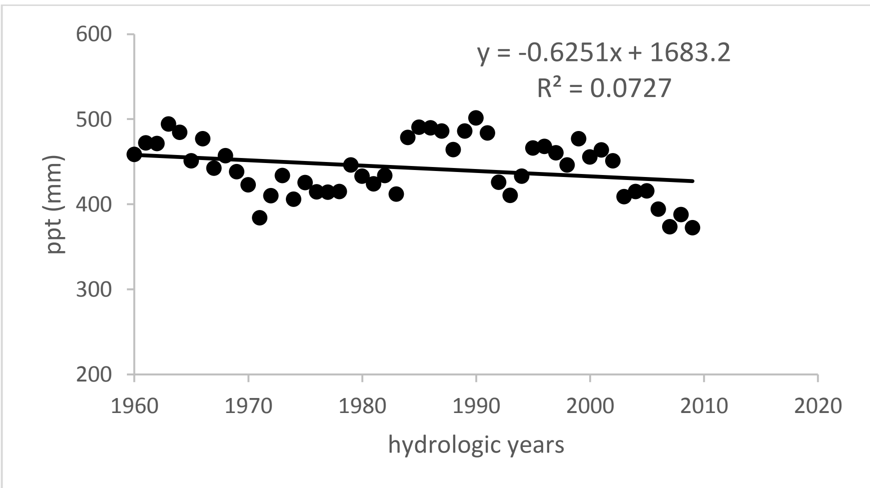

Figure 18: 8 years MA of Ajlun district's yearly precipitation data

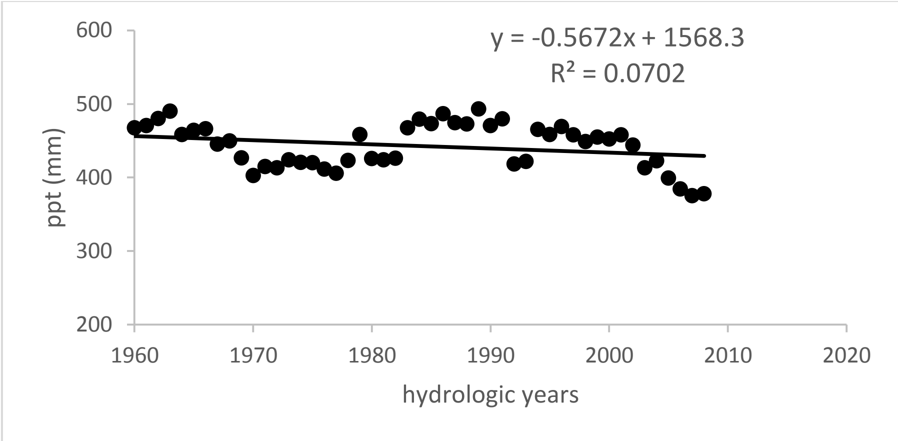

Figure 19: 9 years MA of Ajlun district's yearly precipitation data

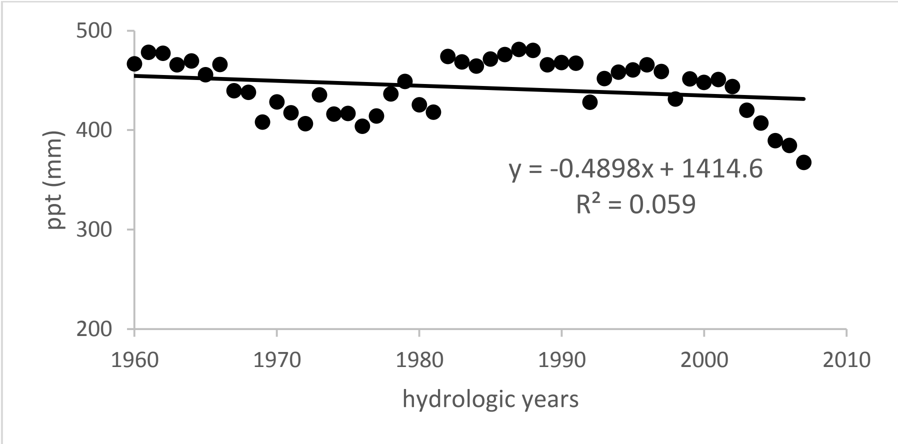

Figure 20: 10 years MA of Ajlun district's yearly precipitation data

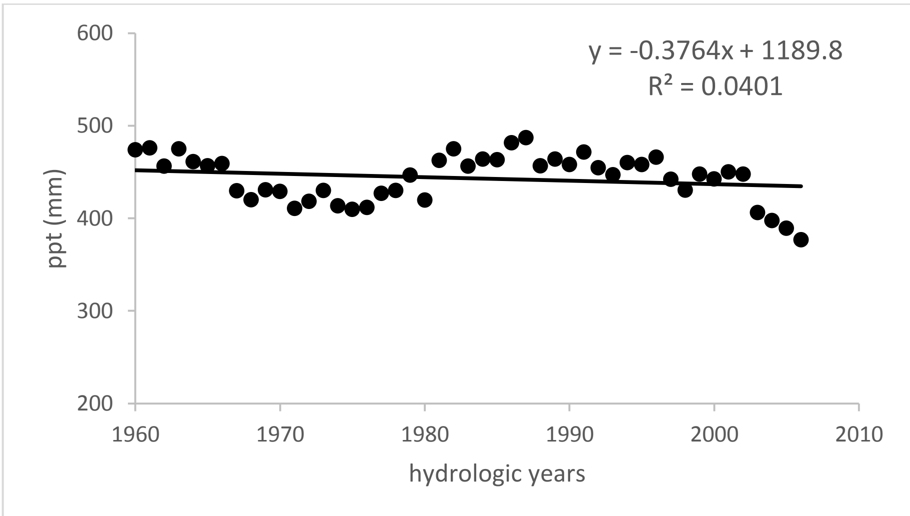

Figure 21: 11 years MA of Ajlun district's yearly precipitation data

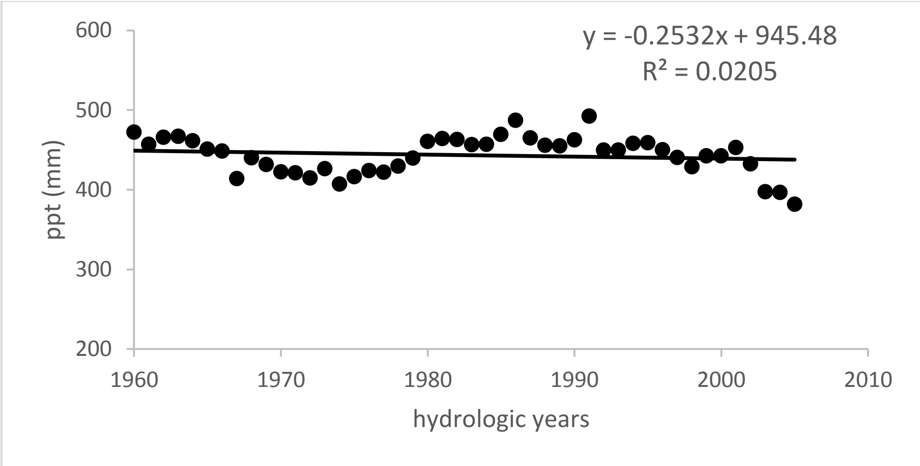

Figure 22: 12 years MA of Ajlun district's yearly precipitation data

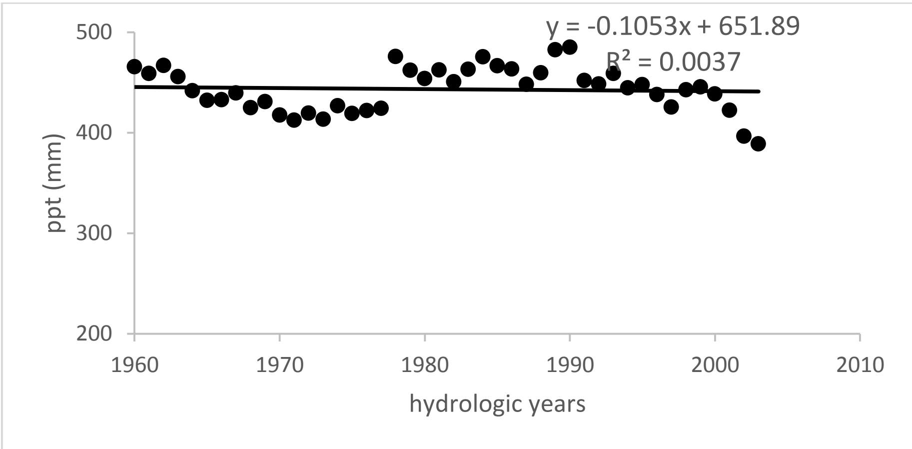

Figure 23: 13 years MA of Ajlun district's yearly precipitation data

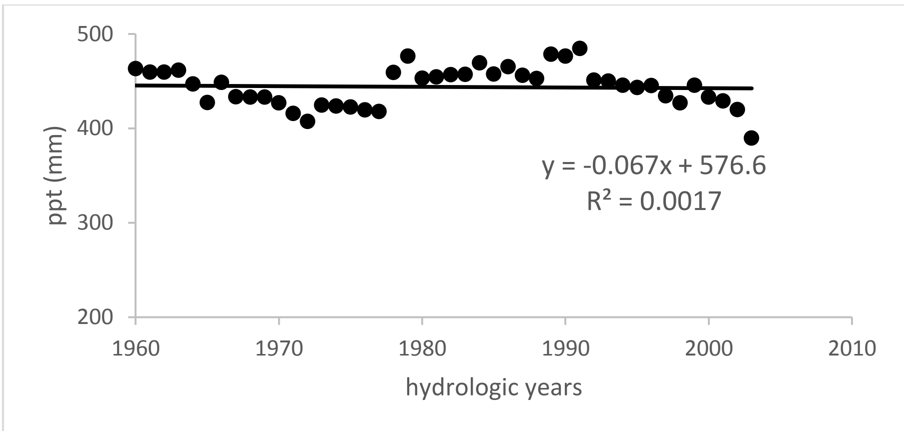

Figure 24: 14 years MA of Ajlun district's yearly precipitation data

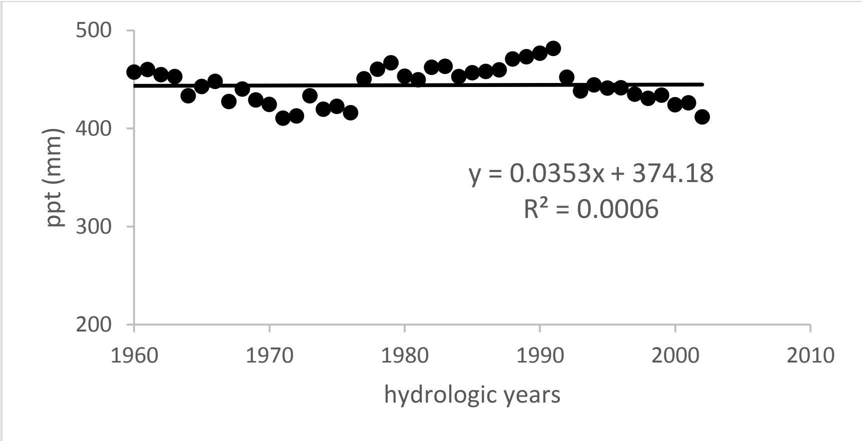

Figure 25: 15 years MA of Ajlun district's yearly precipitation data

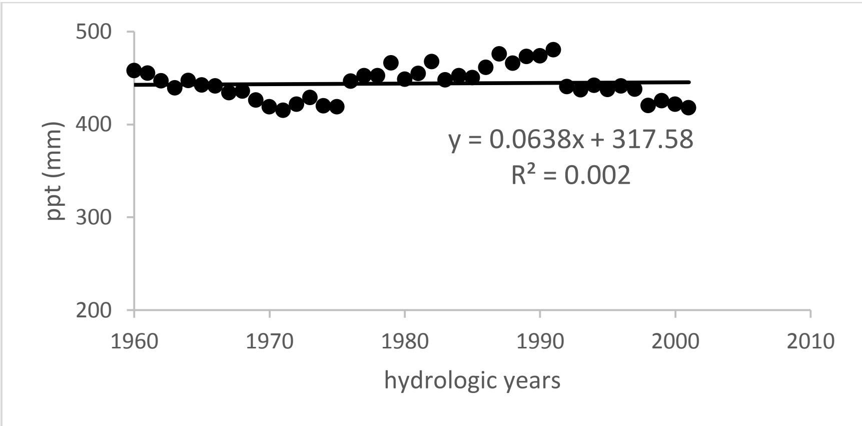

Figure 26: 16 years MA of Ajlun district's yearly precipitation data

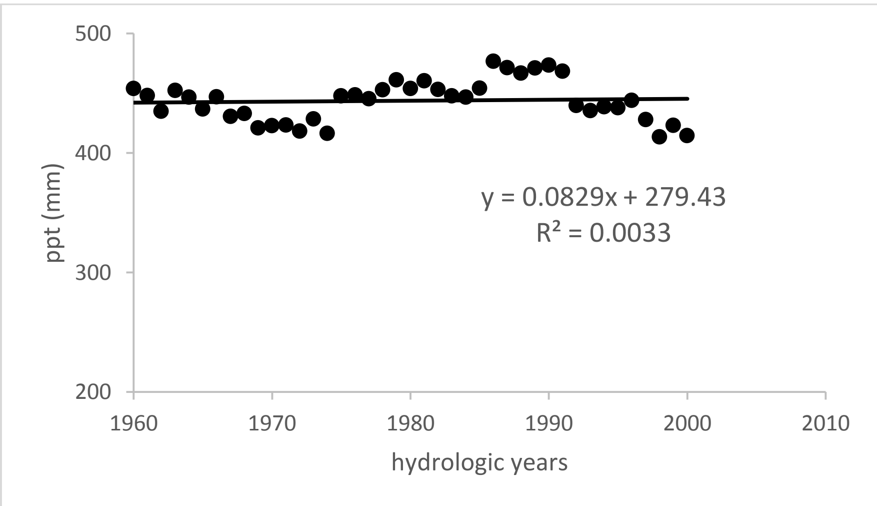

Figure 27: 17 years MA of Ajlun district's yearly precipitation data

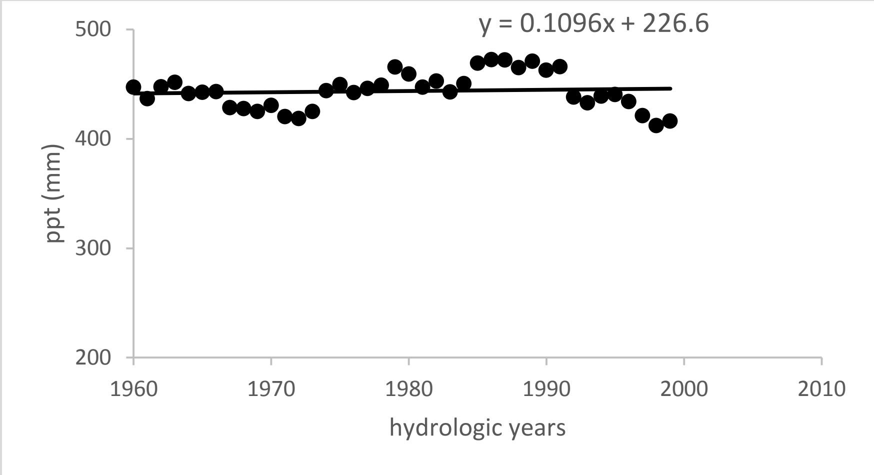

Figure 28: 18 years MA of Ajlun district's yearly precipitation data

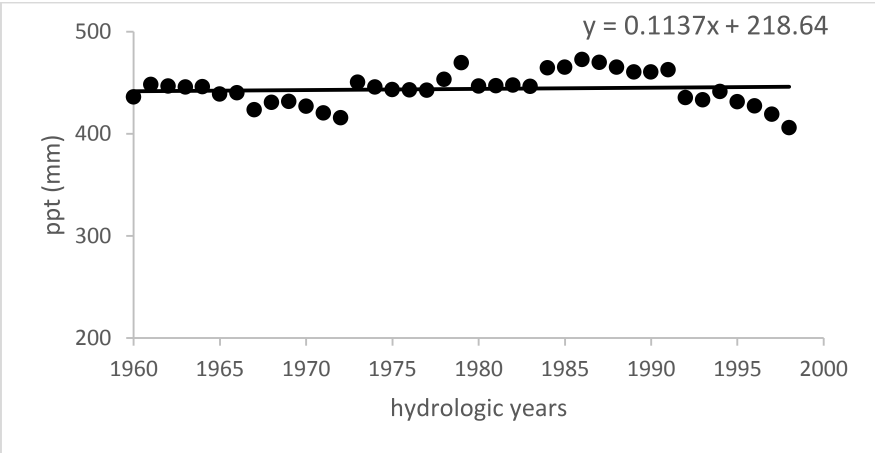

Figure 29: 19 years MA of Ajlun district's yearly precipitation data

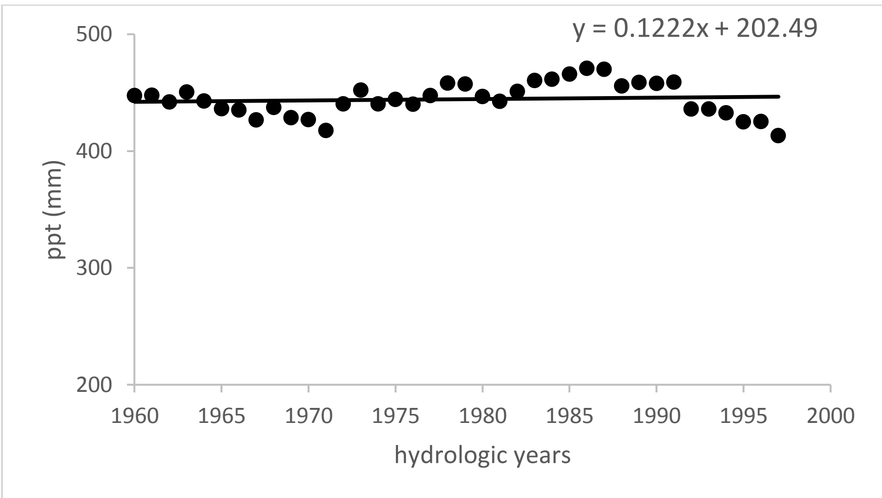

Figure 30: 20 years MA of Ajlun district's yearly precipitation data

Result: For Ajlun district the best representative appropriate trend was 3-years MA, having the highest absolute incline value with a decreasing trend (i.e. -0.97 mm per year), where the negative sign implies that the precipitation data has a decreasing trend.

4.2.5 Mann-Kendall and Sen's Median Slope Tests of Ajlun district's Precipitation data

Table 6: Mann-Kendall test's parameters for Ajlun district's Precipitation data

Mann-Kendall trend test:

Kendall's tau	-0.115
S	-184.000
Var(S)	21102.667
p-value (Two-tailed)	0.208
Alpha	0.05
Sen's slope:	-1.179
Confidence interval:	(-1.682 , -0.826)

Note that:

- Test interpretation for Mann-Kendall trend test:

H_0: There is no trend in the series

H_a: There is a trend in the series

As the computed p-value is greater than the significance level alpha=0.05, one cannot reject the null hypothesis H_0.

- Test interpretation for Sen's Slope trend test:

If the Sen's slope lies within the confidence interval accept the hypothesis.

Result: the p-value of Mann-Kendall trend test is 0.208 so the computed p-value is higher than the significance level alpha=0.05, and Sen's slope -1.179 within the confidence interval (-1.682, -0.826), hence, no trend was founded in Ajlun district's yearly precipitation data.

4.2.6 Stationary Test of Ajlun district yearly Precipitation data set

Table 7: Augmented Dickey-Fuller test (ADF Stationary) for Ajlun district's Precipitation data

Tau (Observed value)	-4.101
Tau (Critical value)	-0.734
p-value (one-tailed)	0.010
alpha	0.05

Augmented Dickey–Fuller test interpretation:

H_0: There is a unit root for the series.

H_a: There is no unit root for the series. The series is stationary.

Results: p-value = 0.01<0.05, as the computed p-value is lower than the significance level alpha=0.05, one should reject the null hypothesis H_0, and accept the alternative hypothesis H_a which means Ajlun district's yearly Precipitation data is stationary.

4.2.7 Summary of Ajlun District's Quality Tests

Table 8: Results of quality Tests of Ajlun district's precipitation data

Test	Tests' results
Normality	Statistical hypothesis = 0.056 > 0.05. Thus, Ajlun's precipitation data was represented as normally distribution.
Homogeneity	Based on t and F tests, Ajlun district's precipitation data is homogeneous with Amman and Balqa districts precipitation data sets.
Consistency	Precipitation data of Ajlun district is considered to be consistent, based on DMC carried out among 7 representative stations.

Trend	Trend was not existed in Ajlun district’s precipitation data based on Mann Kendall and Sen’s slope trend tests.
Stationary	Ajlun district’s precipitation data was considered stationary by Augmented Dickey-Fuller test.

4.2.8 Ajlun District’s Probability Distributions

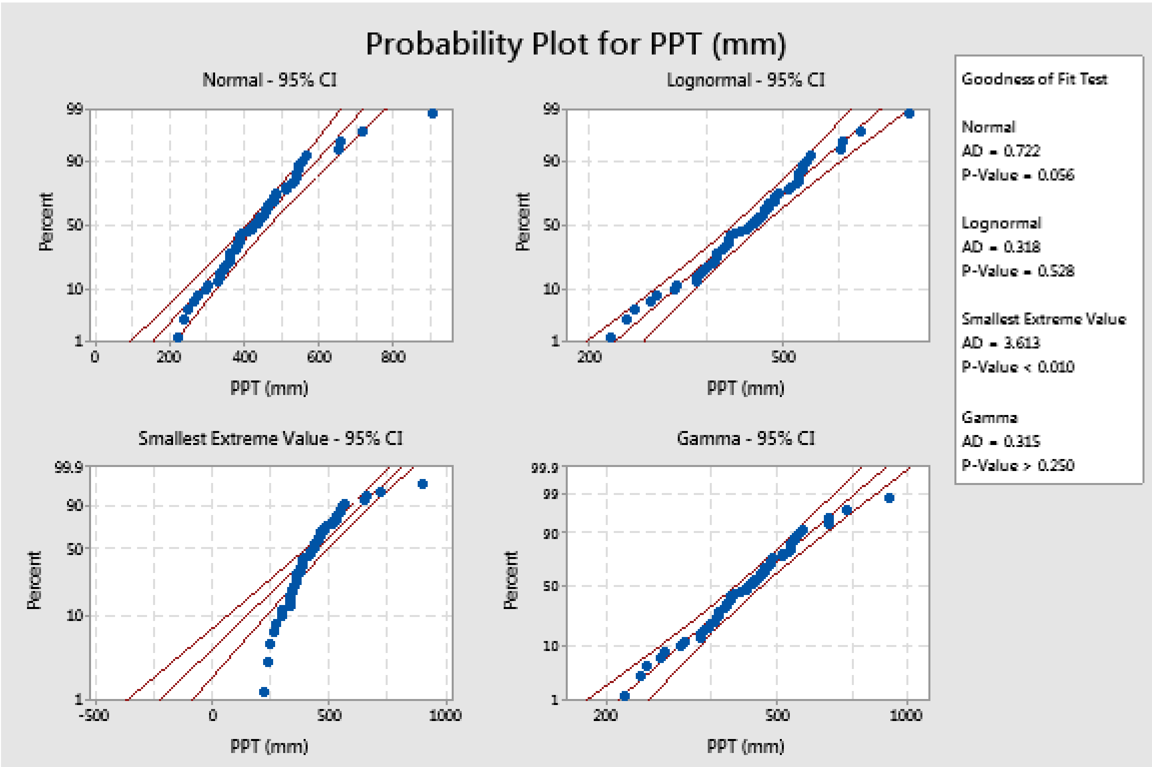

Figure 31: Ajlun District’s Probability Distributions

Table 9: Functions of the Probability distribution of Ajlun district’s yearly precipitation data

Name	Distribution Parameters	P-value
Normal	$x = 437 + 120.9\, Z$	0.056
Log Normal	$y = logx = 2.6 + 0.12\, Z$	0.528

Extreme -Value (Gumble)	$q = (1 - p) = exp(-exp(-0.01(x - 380)$	<0.01
Pearson III	$x = \bar{x} + Ks_x$	0.25

Result: In the above table, the main four probability distribution's functions with their p-values for Ajlun district's yearly precipitation data are generated. The greatest p-value was for the Log-Normal distribution, hence considered to be the best fit model representing Ajlun district.

4.2.9 Analysis of Ajlun District's Precipitation Data

Moving average (3-years) (MA (3))

Table 10: 3 years MA Model of Ajlun district's precipitation data

Hydrological Year	Precipitation(mm)		Hydrological Year	Precipitation(mm)	
	Measured	Trained		Measured	Trained
1960-61	430		**1988-89**	364	461
1961-62	464		**1989-90**	424	470
1962-63	364		**1990-91**	364	448
1963-64	532	419	**1991-92**	908	384
1964-65	516	453	**1992-93**	481	565
1965-66	362	470	**1993-94**	333	584
1966-67	654	470	**1994-95**	458	574
1967-68	348	511	**1995-96**	382	424
1968-69	539	455	**1996-97**	538	391
1969-70	457	514	**1997-98**	548	459
1970-71	547	448	**1998-99**	222	489
1971-72	454	515	**1999-00**	446	436
1972-73	247	486	**2000-01**	357	405
1973-74	569	416	**2001-02**	513	342
1974-75	379	423	**2002-03**	722	439
1975-76	465	398	**2003-04**	397	531
1976-77	388	471	**2004-05**	479	544
1977-78	332	411	**2005-06**	435	533
1978-79	239	395	**2006-07**	468	437
1979-80	660	320	**2007-08**	274	461

Hydrological Year	Precipitation(mm)		Hydrological Year	Precipitation(mm)	
	Measured	Trained		Measured	Trained
1980-81	438	411	**2008-09**	422	392
1981-82	346	446	**2009-10**	410	388
1982-83	536	481	**2010-11**	388	368
1983-84	376	440	**2011-12**	443	407
1984-85	387	419	**2012-13**	484	414
1985-86	337	433	**2013-14**	267	438
1986-87	488	366	**2014-15**	303	398
1987-88	557	404	**2015-16**	386	351

Table 11: Ajlun District's forecasted precipitation value for hydrologic year 2016-17 based on 3 years MA

Hydrological Year	Precipitation (mm)	
	Measured	Forecasted
2016-17	298	319

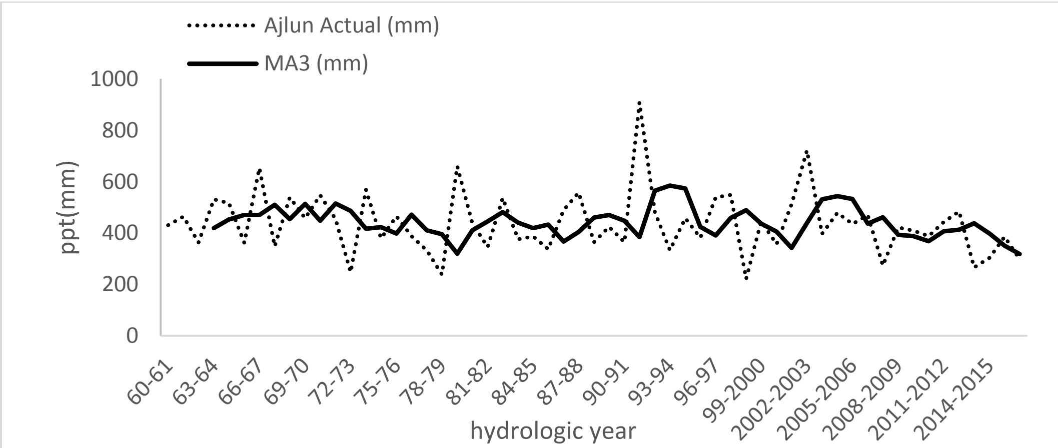

Figure 32: Ajlun's 3-years MA Model of precipitation data and the actual precipitation data

Holts-Winter Multiplicative Model

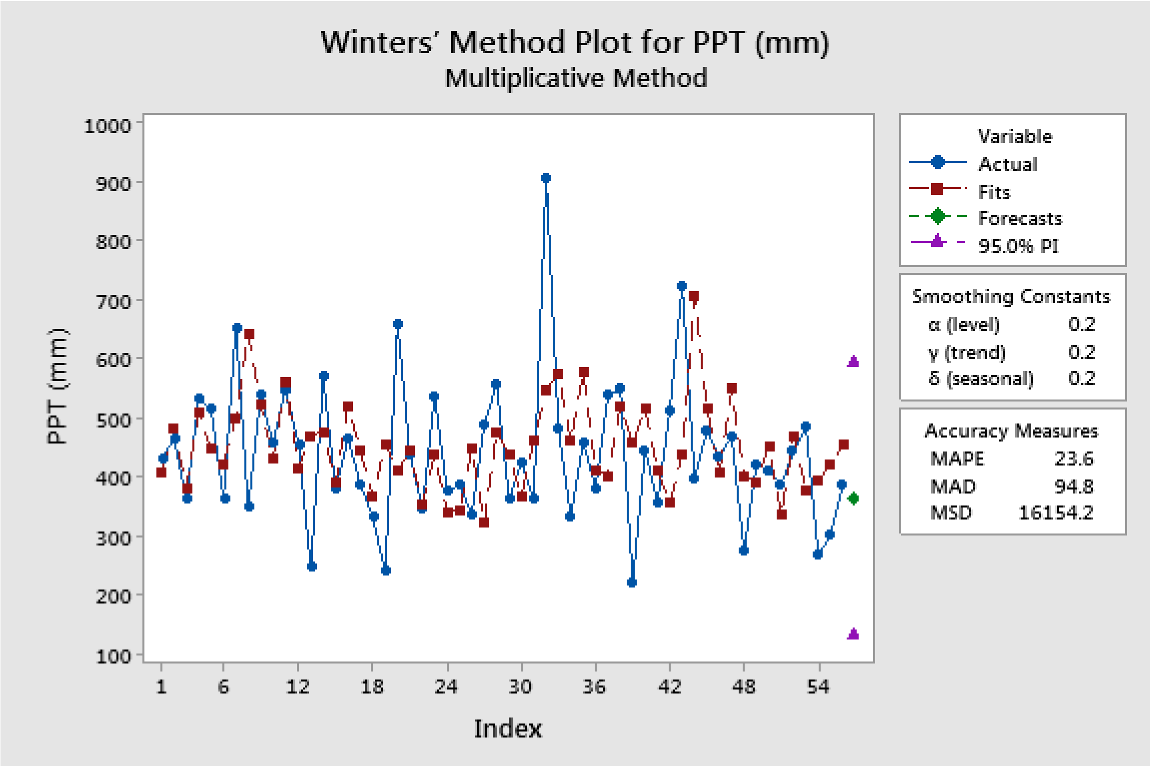

Figure 33: Ajlun district's forecasted precipitation value for hydrologic year 2016-17 based on Holt-Winter Multiplicative Model

Table 12: Ajlun district's forecasted precipitation value for hydrologic year 2016-17 based on Holt-Winter Multiplicative Model

Hydrological Year	Precipitation (mm)	
	Measured	Forecasted
2016-17	298	364

ARIMA

9 models with different sets of (p, q, d) parameters was applied on Ajlun district's Precipitation data, where 6 models were acceptable that gave a greater p-value than alpha level (0.05) for both Ljung-Box and Runs test. These 9 models are:

1. ARIMA (1,0,1)

```
Runs test
```

K = 439.778

The # of observed runs = 25
The # of expected runs = 28.96
29 observations overhead K, and 27 runs were lower than K
P-value = 0.284 (OK)

Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

Lag	12	24	36	48
Chi-Square	4.41	14.08	21.20	26.56
DF	9	21	33	45
P-Value	0.882	0.866	0.944	0.987

(OK)

2. ARIMA (2,0,2)

Runs test

K = 439.652

The # of observed runs = 31
The # of expected runs = 28.42
32 observations overhead K, and 24 runs were lower than K
P-value = 0.479 (OK)

Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

Lag	12	24	36	48
Chi-Square	3.55	12.68	19.28	24.51
DF	7	19	31	43
P-Value	0.829	0.854	0.950	0.990

(Ok)

3. ARIMA (1,0,2)

Runs test

K = 439.682

The # of observed runs = 35
The # of expected runs = 28.43
32 observations overhead K, and 24 runs were lower than K
P-value = 0.07 (OK)

Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

Lag	12	24	36	48
Chi-Square	4.25	12.97	18.95	23.76
DF	8	20	32	44
P-Value	0.833	0.879	0.967	0.995

(OK)

4. ARIMA (2,0,1)

Runs test

K = 439.742

The # of observed runs = 37
The # of expected runs = 28.43
32 observations overhead K, and 24 runs were lower than K
P-value = 0.018(Reject)

Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

Lag	12	24	36	48
Chi-Square	5.08	13.72	19.52	23.45
DF	8	20	32	44
P-Value	0.749	0.844	0.959	0.995

(OK)

5. ARIMA (1,2,1)

Runs test

K = 451.515

The # of observed runs = 22
The # of expected runs = 27.67
24 observations overhead K, and 30runs were lower than K
P-value = 0.115(OK)

Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

Lag	12	24	36	48
Chi-Square	16.24	27.10	36.76	41.89
DF	9	21	33	45
P-Value	0.062	0.168	0.299	0.604

(OK)

6. ARIMA (2,2,2)

Runs test

K = 428.627

The # of observed runs = 21
The # of expected runs = 27.85
25 observations overhead K, and 29 runs were lower than K
P-value = 0.058(OK)

Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

Lag	12	24	36	48
Chi-Square	20.56	29.87	37.20	39.60
DF	7	19	31	43
P-Value	0.004	0.053	0.205	0.620

(OK)

7. ARIMA (1,2,2)

Runs test

K = 424.221

The # of observed runs = 34
The # of expected runs = 27.96
26 observations overhead K, and 28 runs were lower than K
P-value = 0.097(OK)

Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

Lag	12	24	36	48
Chi-Square	21.84	38.92	53.47	59.47
DF	8	20	32	44
P-Value	0.005	0.007	0.010	0.060

(reject)

8. ARIMA (2,2,1)

```
Runs test

K = 434.462

The # of observed runs = 22
The # of expected runs = 28.00
27 observations overhead K, and 27 runs were lower than K
P-value = 0.099(OK)

Modified Box-Pierce (Ljung-Box) Chi-Square Statistic
Lag          12    24    36    48
Chi-Square   13.98 24.44 33.73 37.43
DF           8     20    32    44      (OK)
P-Value      0.082 0.224 0.384 0.748
```

9. ARIMA (2,1,1)

```
Runs test

K = 440.028

The # of observed runs = 6
The # of expected runs = 28.27
30 observations overhead K, and 25 runs were lower than K
P-value = 0.000(REJECT)

Modified Box-Pierce (Ljung-Box) Chi-Square Statistic

Lag             12    24    36    48
Chi-Square    7.58 17.09 24.52 27.09
DF               8    20    32    44
P-Value      0.475 0.647 0.825 0.979   (OK)
```

Table 13: ARIMA model's results of Ajlun district with the forecasted value for 2016-17 hydrologic year

District	Model of ARIMA	ARIMA forms								
		(1,0,1)	(2,0,2)	(1,0,2)	(2,0,1)	(1,2,1)	(2,2,2)	(1,2,2)	(2,2,1)	(2,1,1)
Ajlun	Ljung-Box	✓	✓	✓	✓	✓	✓	x	✓	✓
	Runs test	✓	✓	✓	x	✓	✓	✓	✓	x
Forecasted value for 2016-17		478	473	461	-	342	276	-	315	-

Result: concerning ARIMA test as it is shown in the above table, the actual value is 298 mm and the most close value is (2,2,1) model's with forecasted value of 315 mm.

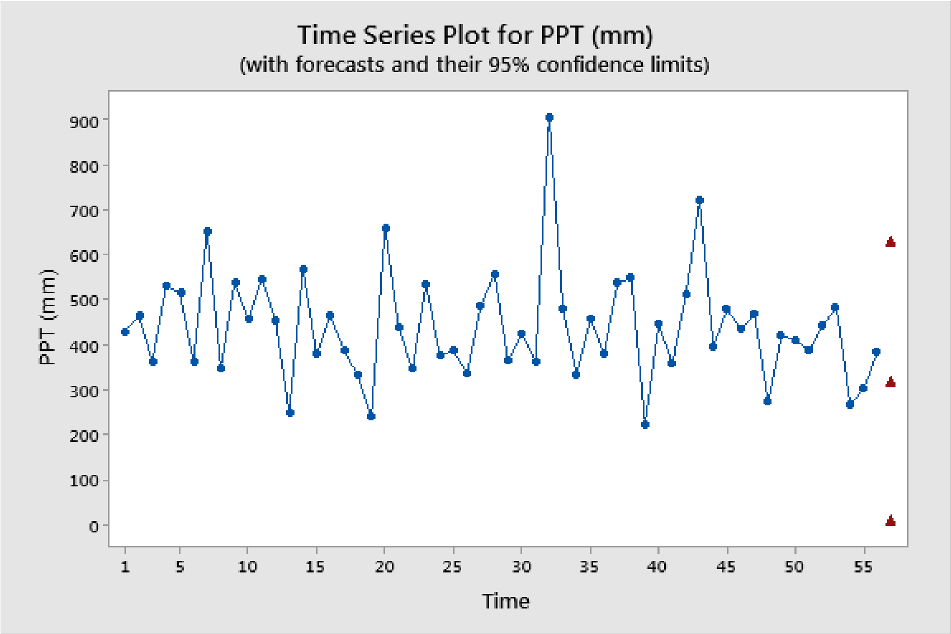

Figure 34: Ajlun district's forecasted precipitation data for 2016-17 built on ARIMA (2,2,1) model

4.2.10 Forecasted Ajlun District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The closest model to the actual Ajlun precipitation data was ARIMA model (2, 2, 1) which will be used to compute the predicted precipitation yearly data for the approaching 10 water years.

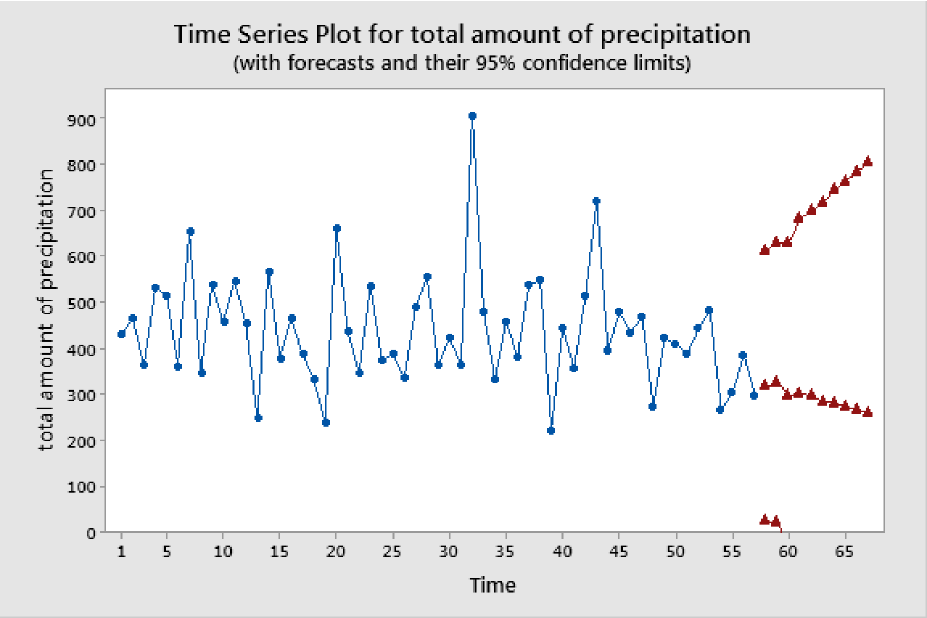

Figure 35: Ajlun forecasted 10 years Precipitation data set built on ARIMA (2, 2, 1) model

Table 14: Forecasted yearly Precipitation data for Ajlun district built on ARIMA (2, 2, 1) model

Hydrologic Year	Forecasted Yearly Precipitation (mm)
2017-18	318
2018-19	327
2019-20	298
2020-21	303
2021-22	297
2022-23	285
2023-24	282
2024-25	274
2025-26	265
2026-27	259

4.2.11 Checking Wetness and Dryness for Ajlun district

Table 15: Arithmetical representation of dry and wet spells for Ajlun district Precipitation data

Hydrologic year	Precipitation in(mm)	Wet\ Dry	Hydrologic Year	Precipitation (mm)	Wet\ Dry	Hydrologic Year	Precipitation (mm)	Wet\ Dry
Ajlun average = 437 mm			**Ajlun average = 437 mm**			**Ajlun average = 437 mm**		
1960-61	430	dry	**1979-80**	660	wet	**1998-99**	222	dry
1961-62	464	wet	**1980-81**	438	wet	**1999-00**	446	wet
1962-63	364	dry	**1981-82**	346	dry	**2000-01**	357	dry
1963-64	532	wet	**1982-83**	536	wet	**2001-02**	513	wet
1964-65	516	wet	**1983-84**	376	dry	**2002-03**	722	wet
1965-66	362	dry	**1984-85**	387	dry	**2003-04**	397	dry
1966-67	654	wet	**1985-86**	337	dry	**2004-05**	479	wet
1967-68	348	dry	**1986-87**	488	wet	**2005-06**	435	dry
1968-69	539	wet	**1987-88**	557	wet	**2006-07**	468	wet
1969-70	457	wet	**1988-89**	364	dry	**2007-08**	274	dry
1970-71	547	wet	**1989-90**	424	dry	**2008-09**	422	dry
1971-72	454	wet	**1990-91**	364	dry	**2009-10**	410	dry
1972-73	247	dry	**1991-92**	908	wet	**2010-11**	388	dry
1973-74	569	wet	**1992-93**	481	wet	**2011-12**	443	wet
1974-75	379	dry	**1993-94**	333	dry	**2012-13**	484	wet
1975-76	465	wet	**1994-95**	458	wet	**2013-14**	267	dry
1976-77	388	dry	**1995-96**	382	dry	**2014-15**	303	dry
1977-78	332	dry	**1996-97**	538	wet	**2015-16**	386	dry
1978-79	239	dry	**1997-98**	548	wet	**2016-17**	298	dry

Result: Ajlun district was represented as a dry district during the study period, since the number of dry spells = 30 (53%) are higher than the number of wet spells = 27 (47%).

4.2.12 Analysis of monthly Precipitation data of Ajlun district and its trends built on the Hydrological years from 1960-61 to 2016-17

October

The figure below surmises 5 different trends based on 10-years moving average, a declining slope for the primary 8 years, then followed with an increasing trend for the next 10 years, a decreasing 13 years after, an increasing 10 years period and in the end a dry 7 years was in the period. For the monthly spells, the month of October considered as a dry month within the study period with a 36 dry months (63%) out of 57.

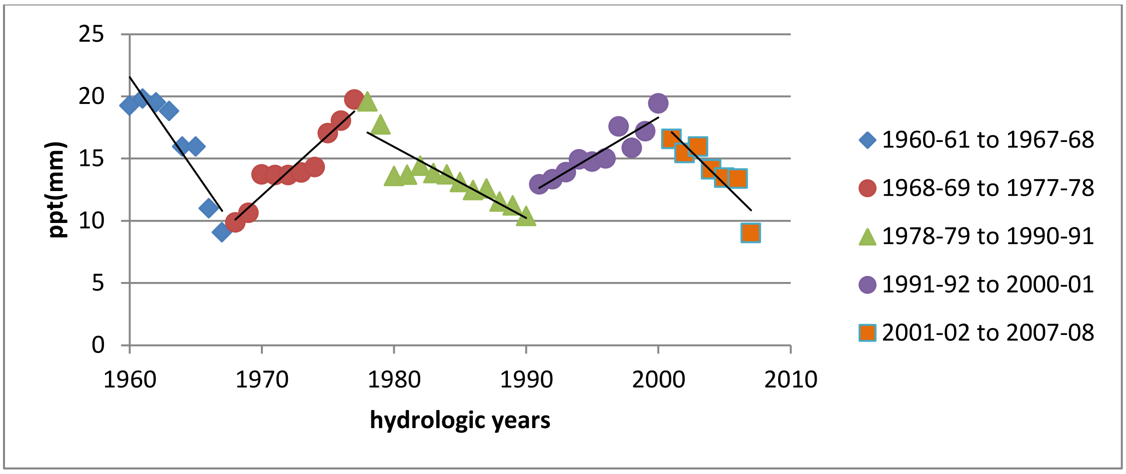

Figure 36: Ajlun district's 10 years MA monthly precipitation data set for the month of October for the water years 1960-61 to 2016-17

November

The figure summarizes 3 different trends based on 10-year moving average, an increasing slope for the initial 27 years, followed with a declining trend for the next 9 years then a slight increase for the last 12 years. For the monthly spells, the month of November considered as a dry month within the study period with a 35 dry months (61%) out of 57.

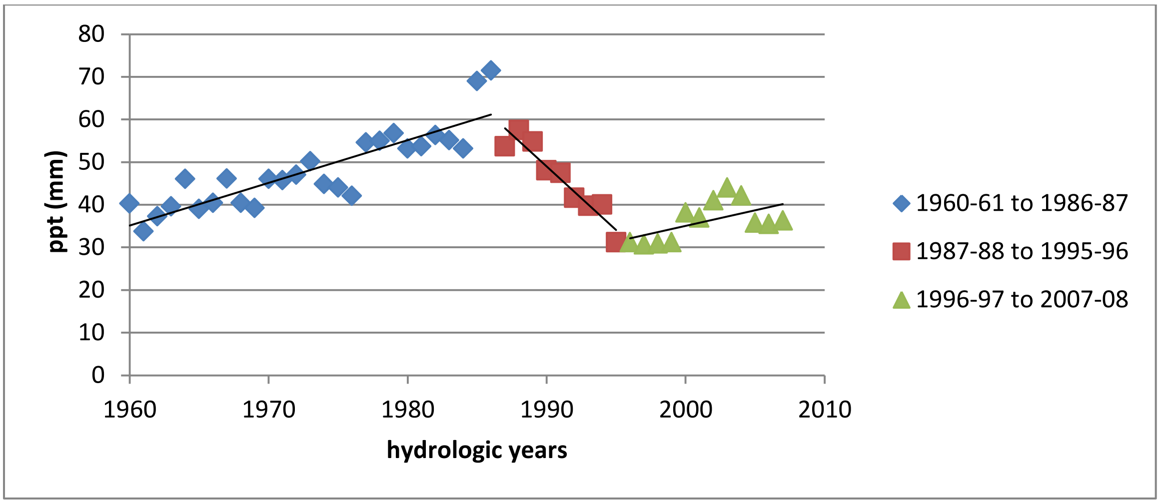

Figure 37: Ajlun district's 10 years MA monthly precipitation data set for the month of November for the water years 1960-61 to 2016-17

December

The figure surmises 2 different trends built on 10-year MA, a declining slope for the initial 10 years, and then followed by a slight declining slope for the next 38 years. For the monthly spells, the month of December considered as a dry month within the study period with a 36 dry months (63%) out of 57.

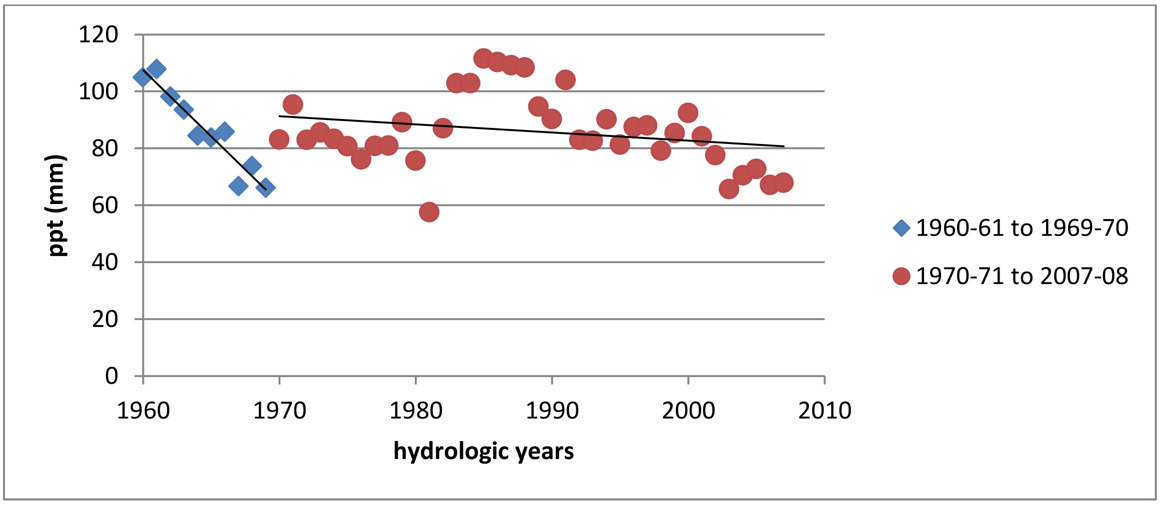

Figure 38: Ajlun district's 10 years MA monthly precipitation data set for the month of December for the water years 1960-61 to 2016-17

January

The figure inferences 3 different trends built on 10-year MA, a declining trend for the initial 14 years, an increasing slope for the next 22 years, then a declining trend for the last 12 years. For the monthly spells, the month of January considered as a dry month within the study period with a 32 dry month (56%) out of 57.

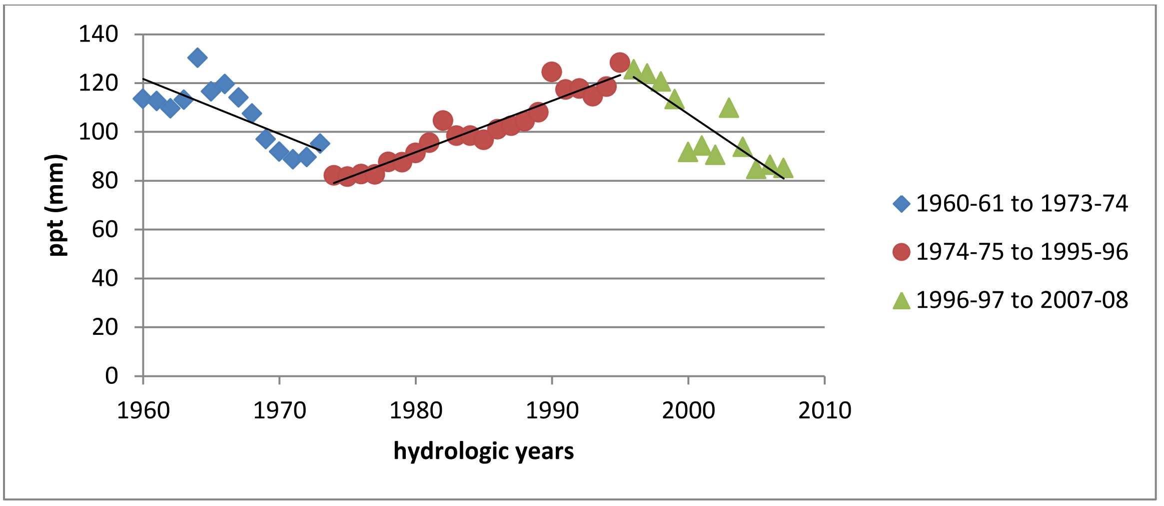

Figure 39: Ajlun district's 10 years MA monthly precipitation data set for the month of January for the water years 1960-61 to 2016-17

February

The figure inferences 3 different trends built on 10-year MA, an increasing slope for the initial 23 years, and a declining trend for the next 13 years, and then a declining trend for the last 12 years with different slope. For the monthly spells, the month of February considered as a dry month within the study period with a 32 dry month (56%) out of 57.

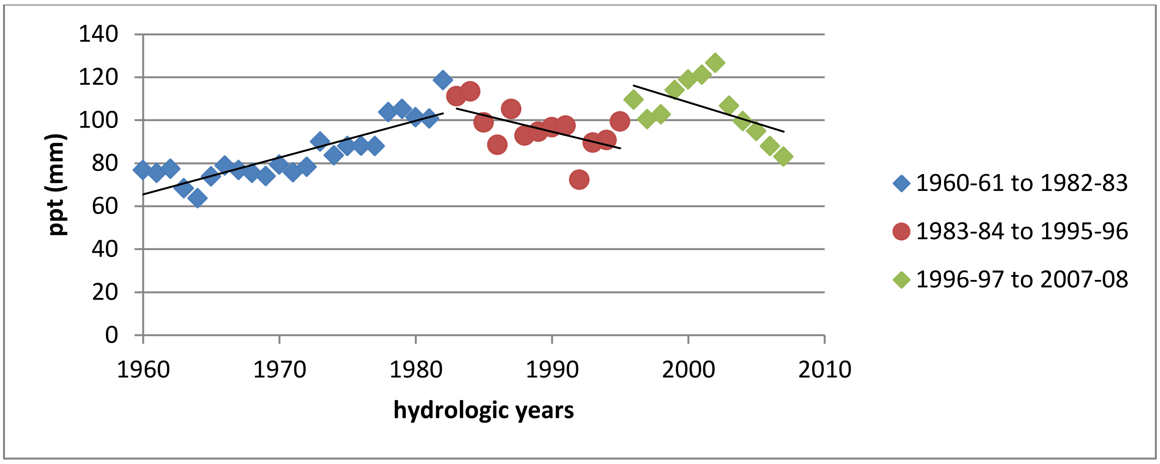

Figure 40: Ajlun district's 10 years MA monthly precipitation data set for the month of February for the water years 1960-61 to 2016-17

March

The figure inferences 2 dissimilar declined slopes built on 10-year MA, a declining slope for the initial 26 years, and then a declining slope for the next 22 years with different gradient. For the monthly spells, the month of March barely considered as a dry month within the study period with a 29 dry month (51%) out of 57.

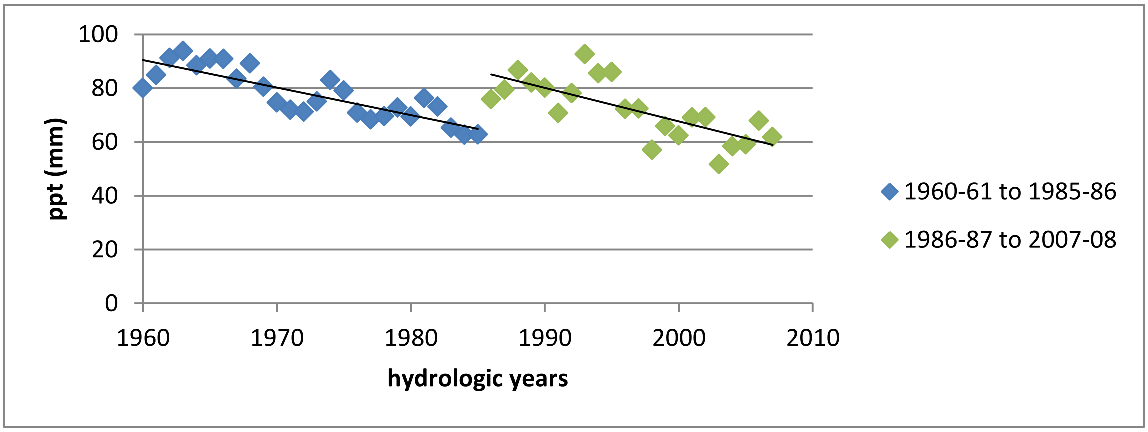

Figure 41: Ajlun district's 10 years MA monthly precipitation data set for the month of March for the water years 1960-61 to 2016-17

April

The figure inferences 2 trends built on 10-year MA, a declining slope for the initial 30 years, and then an increasing slope for the next 18 year. For the monthly spells, the month of April considered as a dry month within the study period with a 35 dry month (61%) out of 57.

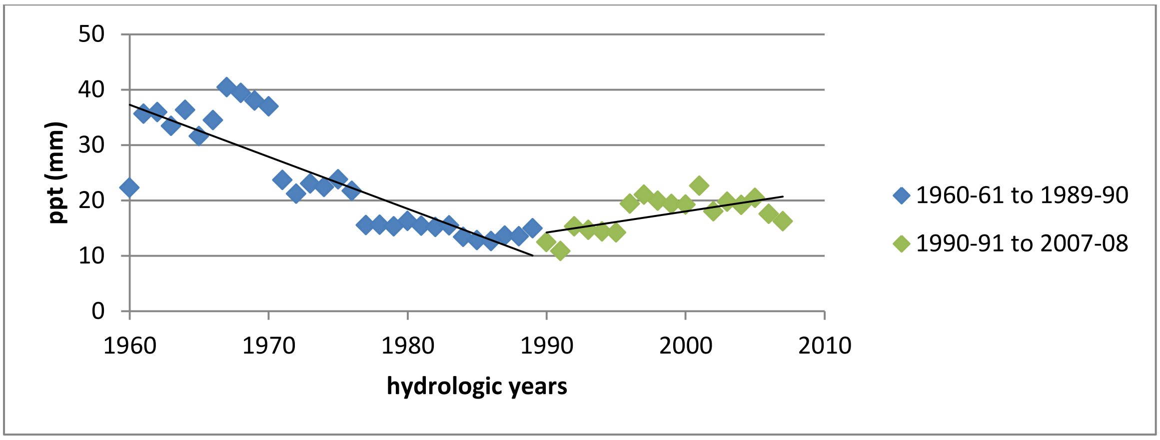

Figure 42: Ajlun district’s 10 years MA monthly precipitation data set for the month of April for the water years 1960-61 to 2016-17

May

The figure shows the trend for May built on 10-year MA, a slightly increasing slope for the whole study period. For the monthly spells, the month of May considered as a dry month within the study period with a 38 dry month (67%) out of 57.

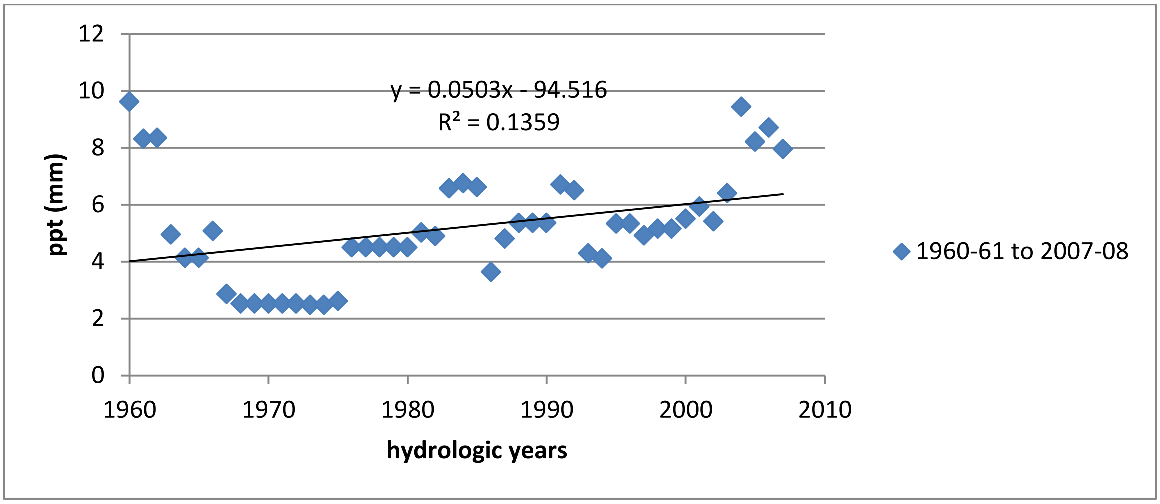

Figure 43: Ajlun district's 10 years MA monthly precipitation data set for the month of May for the water years 1960-61 to 2016-17

4.3 Meteorological District: Mafraq

Table 16: Monthly precipitation data with the statistical measures of Mafraq district for hydrological years from 1960-61 to 2016-17 in (mm)

Year\month	October	November	December	January	February	March	April	May	TOTAL
1960-61	0	35	22	59	58	30	12	3	218
1961-62	7	9	78	41	37	5	9	0	186
1962-63	3	0	16	10	65	15	18	2	130
1963-64	14	10	59	47	69	54	10	8	270
1964-65	0	32	55	83	16	15	33	0	234
1965-66	19	10	21	30	17	66	2	0	166
1966-67	15	20	105	65	33	69	0	23	330
1967-68	21	31	26	64	23	14	13	11	203
1968-69	5	11	49	67	17	80	14	2	246
1969-70	19	14	5	30	23	55	10	0	155
1970-71	0	8	45	41	34	29	85	0	242
1971-72	0	16	74	23	52	36	24	2	226
1972-73	1	20	1	41	11	35	6	3	119
1973-74	2	38	14	132	62	19	11	0	277
1974-75	0	14	18	10	91	31	12	0	176
1975-76	7	10	31	35	42	43	7	6	180
1976-77	5	11	18	37	15	23	20	0	129
1977-78	11	2	46	20	11	29	7	0	125

Year\month	October	November	December	January	February	March	April	May	TOTAL
1978-79	7	4	29	28	24	16	5	0	112
1979-80	14	68	75	49	49	50	11	0	316
1980-81	3	3	85	16	37	16	5	0	165
1981-82	0	16	5	32	36	19	14	10	131
1982-83	10	27	10	51	66	42	1	11	219
1983-84	2	16	5	37	16	54	3	0	132
1984-85	14	19	22	17	82	27	3	4	188
1985-86	3	3	27	14	44	4	11	8	114
1986-87	8	92	19	34	16	34	0	0	202
1987-88	15	7	48	66	80	46	11	1	274
1988-89	4	10	77	24	11	16	0	0	142
1989-90	3	15	22	45	29	24	11	0	149
1990-91	4	7	6	53	26	40	5	2	142
1991-92	5	15	87	47	91	9	0	1	254
1992-93	0	18	43	37	16	10	0	8	131
1993-94	1	5	4	46	21	33	2	0	112
1994-95	8	84	41	15	33	11	3	0	194
1995-96	0	11	11	40	3	48	3	0	115
1996-97	6	19	17	51	49	29	2	4	177
1997-98	13	15	37	61	15	65	5	0	211
1998-99	0	3	6	24	24	3	3	0	63
1999-00	0	0	5	91	12	17	0	0	125
2000-01	13	0	48	27	30	8	9	3	138
2001-02	1	17	31	74	17	31	12	1	184
2002-03	2	23	65	23	82	43	4	0	241
2003-04	0	10	48	29	36	4	3	19	150
2004-05	2	31	13	33	47	10	6	4	146
2005-06	2	11	20	24	34	9	21	0	120
2006-07	11	2	19	25	39	27	2	4	131
2007-08	1	23	15	47	44	2	0	0	131
2008-09	7	4	15	8	89	21	1	0	146
2009-10	7	25	45	41	64	5	0	0	187
2010-11	0	0	25	30	64	9	7	5	140
2011-12	0	21	10	58	56	30	3	0	177
2012-13	5	23	20	129	6	1	6	6	196
2013-14	9	13	68	20	3	42	0	14	168
2014-15	4	9	22	24	52	8	7	0	126
2015-16	0	31	46	69	32	15	3	7	202
2016-17	0	11	23	55	38	28	3	22	180
Average	5.4	17.5	33.3	42.6	38.4	27.2	8.4	3.4	176.2

Year\month	October	November	December	January	February	March	April	May	TOTAL
Standard Error	0.77	2.381	3.34	3.35	3.16	2.52	1.64	0.73	7.33
Median	3.72	13.67	23	37.23	33.91	26.8	4.95	0	168.3
Standard Deviation	5.78	17.98	25.18	25.31	23.89	19	12.4	5.53	55.3
Sample Variance	33.3	323.1	633.8	640.7	570.7	362	153	30.55	3059
Kurtosis	0.11	7.8	0.110	3.51	-0.43	0.02	26.8	4.433	0.32
Skewness	1	2.56	0.937	1.57	0.643	0.75	4.57	2.126	0.76
Range	21	91.76	103.4	123	88.68	79.1	85.2	23.16	266.3
Minimum	0	0	1.28	8.44	2.77	1.1	0	0	63.3
Maximum	21.0	91.76	104.7	132	91.4	80.2	85.2	23.16	329.6

4.3.1 Trend of Mafraq District's Precipitation Data

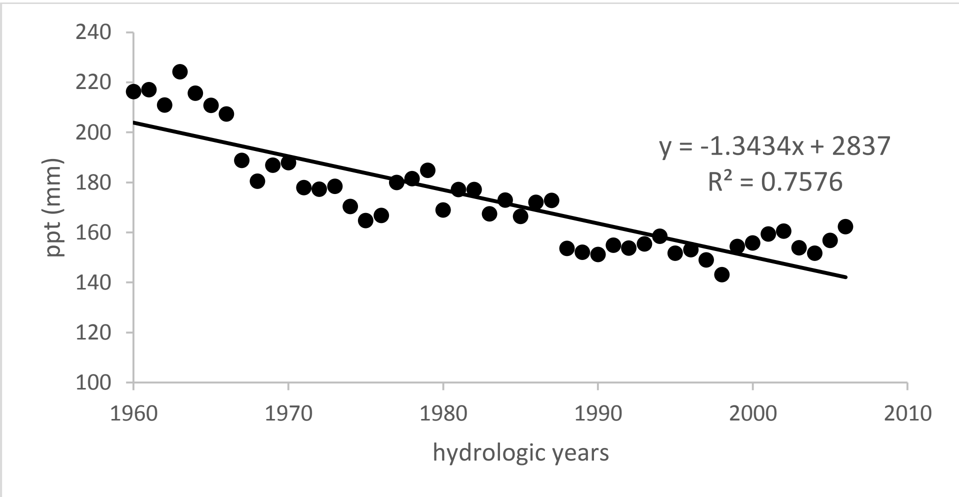

Figure 44: 11-years MA of Mafraq district's yearly precipitation data

Result: For Mafraq district the best representative appropriate trend was 11-years MA, having the highest absolute incline value with a decreasing trend (i.e. -1.34 mm per year), where the negative sign indicates that the precipitation data has a decreasing trend.

4.3.2 Summary of Mafraq District's Quality Tests

Table 17: Results of quality tests of Mafraq district's precipitation data

Test	Tests' results
Normality	Statistical hypothesis=0.0008. Thus, Mafraq's precipitation data was not represented as normally distribution data.
Homogeneity	Based on t and F tests, Mafraq district's precipitation data is not homogeneous with any other district in the kingdom.
Consistency	Precipitation data of Mafraq district is considered to be consistent, based on DMC carried out among 7 representative stations.
Trend	Trend was not existed in Mafraq district's precipitation data based on Mann Kendall and Sen's slope trend tests.
Stationary	Mafraq district's precipitation data is considered stationary by Augmented Dickey-Fuller test.

4.3.3 Forecasted Mafraq District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The best model was winters model which will be used to compute the predicted Precipitation data for the upcoming 10 years. The actual value for the 2016-17 in mafraq was 180 mm and the forecasted value for this model was 169 mm.

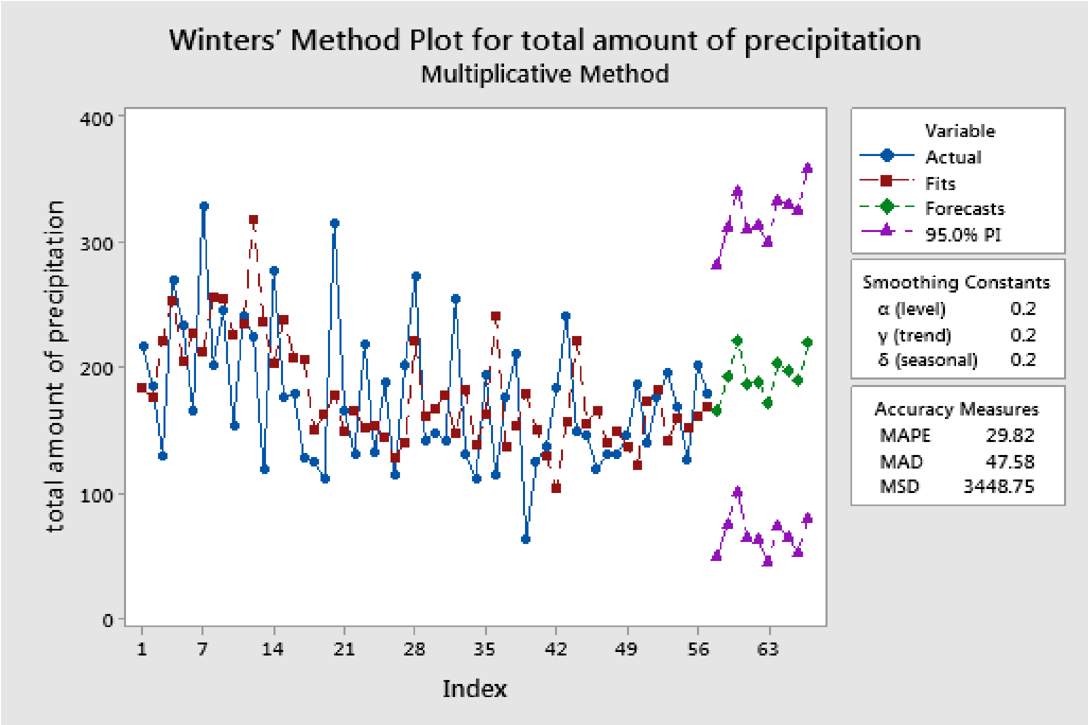

Figure 45: Mafraq forecasted 10 years precipitation data set built on winter's model

Table 18: Forecasted yearly precipitation data for Mafraq district built on winters model

Hydrologic Year	Forecasted Yearly Precipitation (mm)
2017-18	166
2018-19	194
2019-20	222
2020-21	188
2021-22	189
2022-23	172
2023-24	204
2024-25	198
2025-26	189
2026-27	220

4.3.4 Analysis of monthly Precipitation data of Mafraq district and its trends built on the Hydrological years from 1960-61 to 2016-17

October

The figure implicates the trend for October built on 10-year MA, a slightly declining slope for the whole study period. For the monthly spells, the month of October considered as a dry month within the study period with a 35 dry month (61%) out of 57.

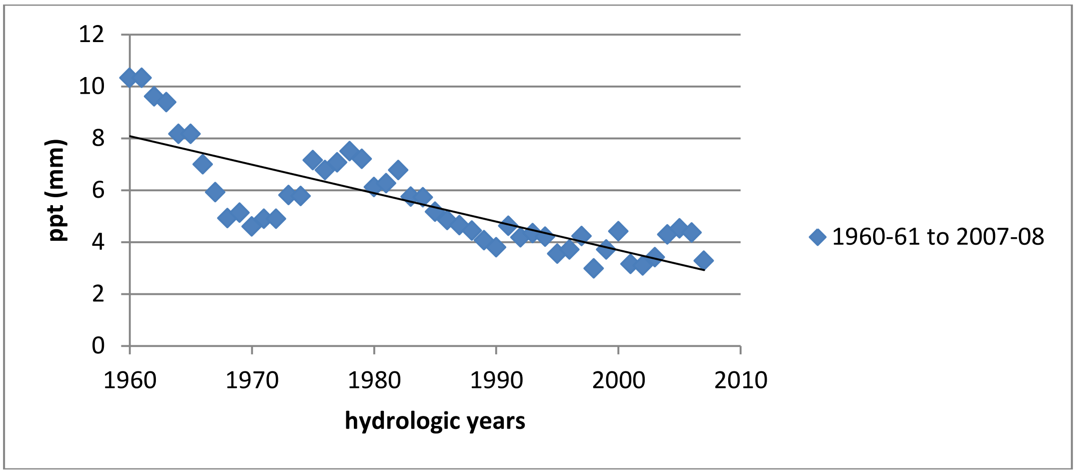

Figure 46: Mafraq district's 10 years MA monthly precipitation data set for the month of October for the water years 1960-61 to 2016-17

November

The figure implicates the trend for November built on 10-year MA, a slightly declining slope for the whole study period. For the monthly spells, the month of November considered as a dry month within the study period with a 37 dry month (65%) out of 57.

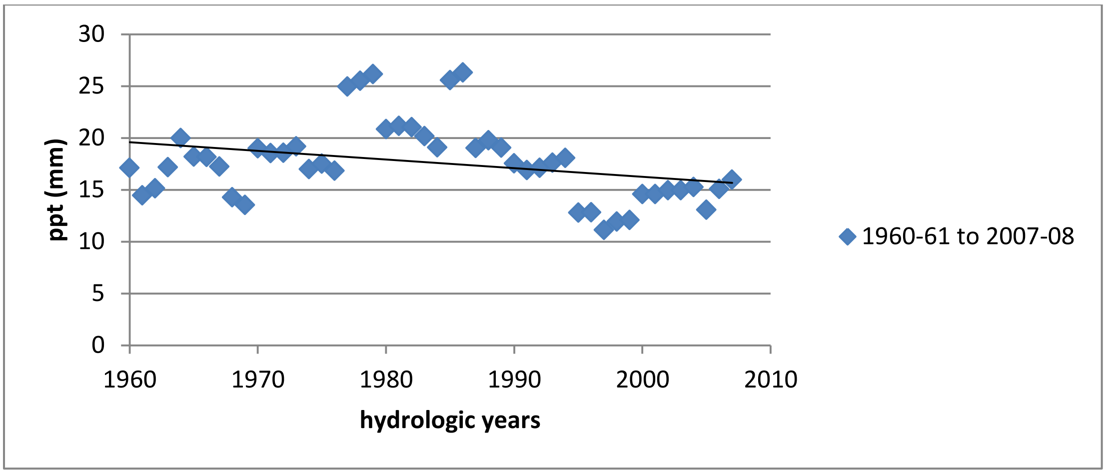

Figure 47: Mafraq district's 10 years MA monthly precipitation data set for the month of November for the water years 1960-61 to 2016-17

December

The figure surmises 2 different trends built on 10-year MA, a sharper declining slope for the initial 10 years then followed by a slight declining slope for the next 38 years. For the monthly spells, the month of December considered as a dry month within the study period with a 35 dry months (61%) out of 57.

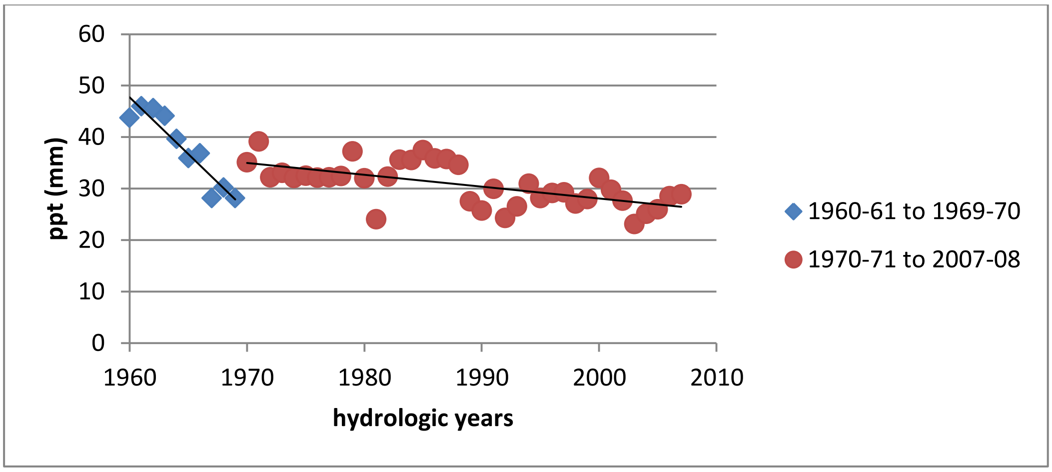

Figure 48: Mafraq district's 10 years MA monthly precipitation data set for the month of December for the water years 1960-61 to 2016-17

January

The figure infers 4 different trends built on 10-year MA, a declining slope for the initial 14 years, followed by an increasing slope for the next 22 years, a declining 6 years after and in the end an increasing 6 years period. For the monthly spells, the month of January considered as a dry month within the study period with a 34 dry months (60%) out of 57.

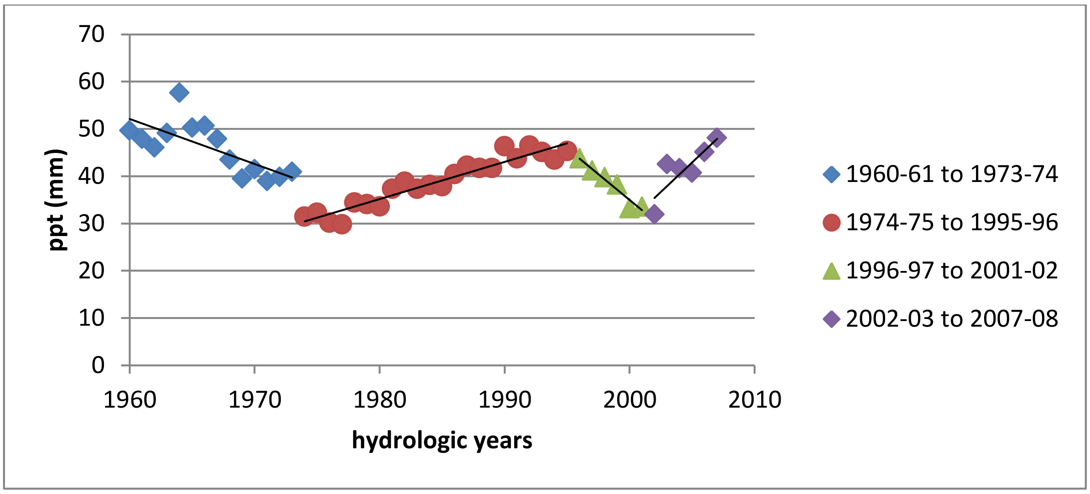

Figure 49: Mafraq district's 10 years MA monthly precipitation data set for the month of January for the water years 1960-61 to 2016-17

February

The figure inferences 3 different trends built on 10-year MA, an increasing slope for the initial 23 years, a declining trend for the next 10 years, and then upward slope for the last 15 years. For the monthly spells, the month of February considered as a dry month within the study period with a 34 dry month (60%) out of 57.

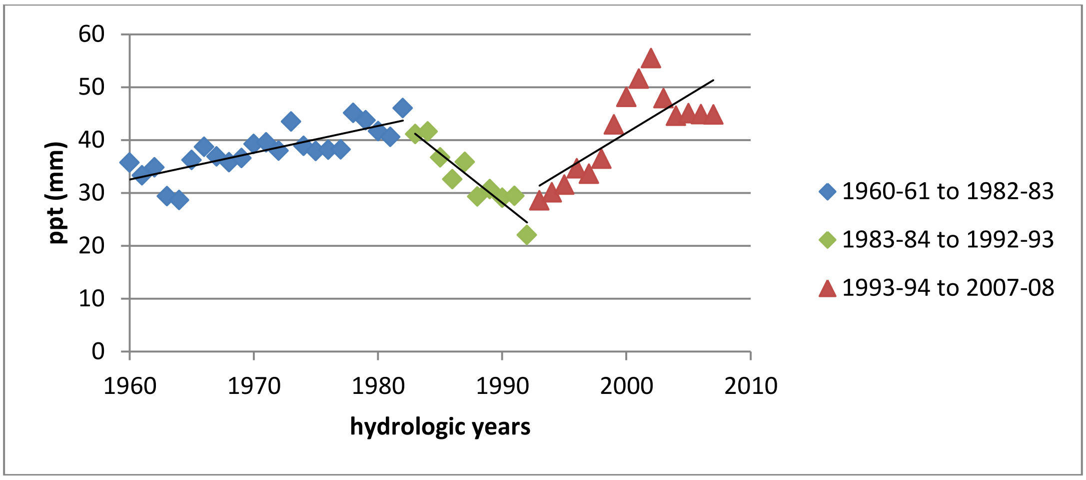

Figure 50: Mafraq district's 10 years MA monthly precipitation data set for the month of February for the water years 1960-61 to 2016-17

March

The figure inferences 3 dissimilar declined trends built on 10-year MA. For the monthly spells, the month of March barely considered as a dry month within the study period with a 29 dry month (51%) out of 57.

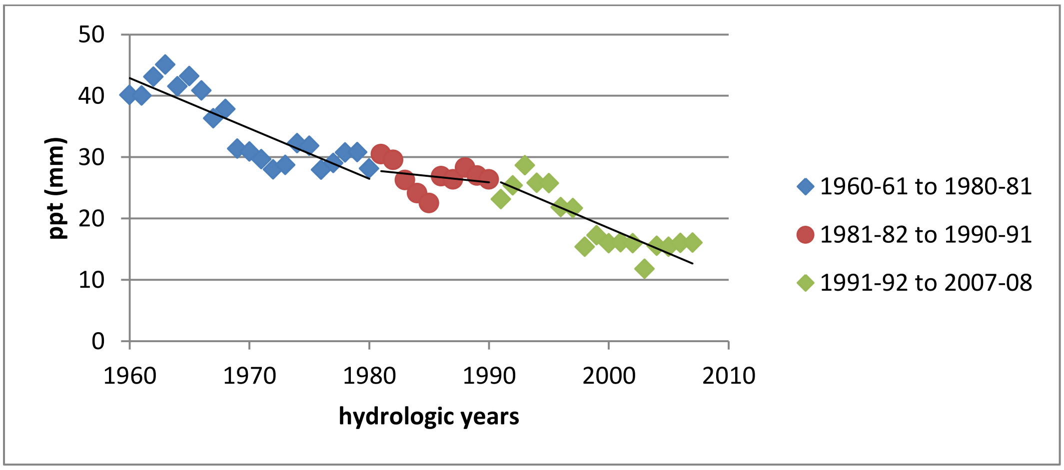

Figure 51: Mafraq district's 10 years MA monthly precipitation data set for the month of March for the water years 1960-61 to 2016-17

April

The figure inferences 2 trends built on 10-year MA, a declining slope for the initial 21 years, then slightly increasing slope for the next 27 year. For the monthly spells, the month of April considered as a dry month within the study period with a 36 dry month (63%) out of 57.

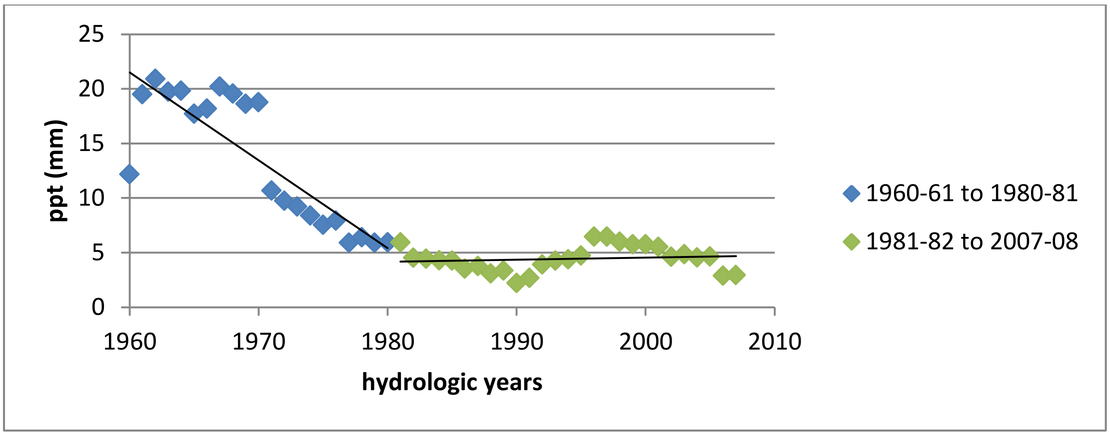

Figure 52: Mafraq district's 10 years MA monthly precipitation data set for the month of April for the water years 1960-61 to 2016-17

May

The figure implicates the trend for May built on 10-year MA, a mild decreasing slope for the whole study period. For the monthly spells, the month of May considered as a dry month within the study period with a 38 dry month (67%) out of 57.

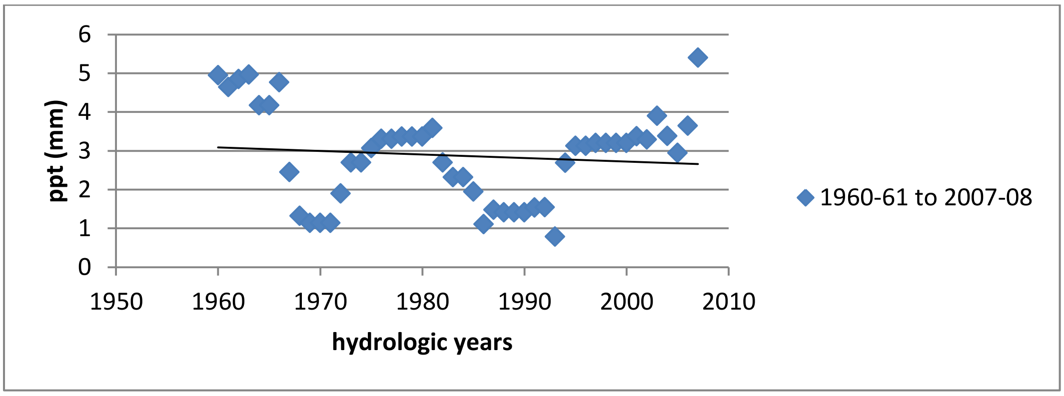

Figure 53: Mafraq district's 10 years MA monthly precipitation data set for the month of May for the water years 1960-61 to 2016-17

4.4 Meteorological District: Madaba

Table 19: Monthly precipitation data with the statistical measures of Madaba district for hydrological years started in 1960-61 until 2016-17 in (mm)

Year\month	October	November	December	January	February	March	April	May	TOTAL
1960-61	0	37	20	86	94	17	28	2	282
1961-62	5	14	111	41	103	1	8	0	282
1962-63	5	0	6	2	59	21	7	24	123
1963-64	8	13	183	64	56	54	2	2	381
1964-65	0	41	45	153	24	28	72	0	362
1965-66	22	12	17	25	37	94	0	0	207
1966-67	24	5	90	103	30	139	0	0	391
1967-68	2	56	38	100	39	14	6	6	261
1968-69	14	41	65	82	22	147	23	0	394
1969-70	9	8	13	63	13	67	13	0	187
1970-71	2	10	60	32	12	52	162	0	330
1971-72	0	30	149	27	53	60	17	6	342
1972-73	3	22	8	83	17	24	6	0	163
1973-74	6	20	18	230	56	16	36	0	381
1974-75	0	27	36	9	106	34	3	0	216
1975-76	0	20	18	12	41	45	7	4	147
1976-77	2	13	6	57	19	22	62	0	181
1977-78	0	9	70	29	22	57	8	0	196
1978-79	2	0	40	56	16	37	0	0	151
1979-80	14	79	144	58	57	57	15	0	423
1980-81	3	2	168	42	43	20	3	0	281
1981-82	0	18	15	58	21	28	2	17	159
1982-83	0	19	11	67	92	47	4	0	238
1983-84	0	13	3	34	20	56	0	0	126
1984-85	30	15	14	26	161	45	5	2	297
1985-86	5	0	36	16	61	8	2	14	144
1986-87	11	100	39	54	15	32	1	0	252
1987-88	11	3	87	69	121	67	8	0	365
1988-89	4	16	79	55	45	50	0	0	250
1989-90	4	7	18	79	49	32	40	0	230
1990-91	2	5	3	64	58	89	4	0	225
1991-92	5	25	169	79	215	28	0	7	527
1992-93	0	47	50	34	76	26	0	8	241

Year\month	October	November	December	January	February	March	April	May	TOTAL
1993-94	18	18	20	71	56	15	8	0	206
1994-95	11	132	91	4	31	10	11	0	291
1995-96	0	11	11	57	22	81	0	0	183
1996-97	8	7	16	54	90	42	5	0	222
1997-98	16	2	75	72	39	48	2	3	257
1998-99	5	11	3	40	59	13	7	0	138
1999-00	0	4	2	80	21	37	0	0	143
2000-01	9	0	88	40	36	8	5	11	198
2001-02	1	33	50	137	34	31	35	0	321
2002-03	5	15	84	40	83	51	18	0	295
2003-04	4	4	45	66	38	14	2	1	174
2004-05	2	121	25	72	56	35	1	0	313
2005-06	2	20	59	28	50	4	79	0	244
2006-07	9	7	67	96	65	55	18	2	319
2007-08	2	12	13	85	65	0	0	0	177
2008-09	13	9	9	6	167	65	0	0	269
2009-10	8	15	43	82	170	1	0	0	319
2010-11	0	0	31	65	55	11	16	2	181
2011-12	0	31	20	128	119	92	0	0	390
2012-13	2	11	36	170	23	1	14	4	261
2013-14	0	9	170	0	6	101	0	26	312
2014-15	1	35	17	76	110	6	16	0	260
2015-16	34	5	14	123	44	25	31	1	276
2016-17	3	0	92	68	36	18	0	0	217
Average	6	21.7	51	64	58	40	14	2.5	257.9
Standard Error	1.01	3.65	6.40	5.66	5.82	4.26	3.51	0.74	11.42
Median	3.23	13.07	36.46	63.0	48.98	32.4	5.36	0.00	251.7
Standard Deviation	7.6	27.56	48.36	42.7	43.97	32.2	26.46	5.61	282.4
Sample Variance	58	759.6	2338	1824	1934	1035	700	31.4	86.25
Kurtosis	3.77	7.02	0.97	3.39	2.66	2.15	17.71	8.59	7440
Skewness	1.91	2.57	1.31	1.37	1.60	1.34	3.78	2.93	0.31
Range	33.8	131.9	181.4	229.5	208.6	147	162	25.8	0.63
Minimum	0	0	1.63	0.20	6.32	0	0	0	403.5

Year\month	October	November	December	January	February	March	April	May	TOTAL
Maximum	33.8	131.9	183	229.7	214.9	147	162	25.8	123.2

4.4.1 Trend of Madaba District's Precipitation Data

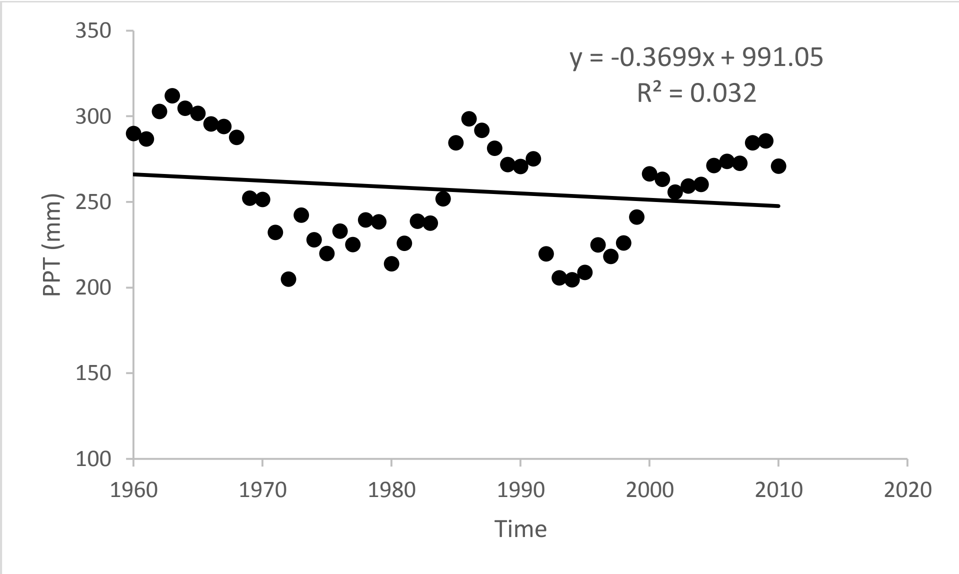

Figure 54: 7-years MA of Madaba district's yearly precipitation data

Result: For Madaba district the best representative appropriate trend was 7-years MA, having the highest absolute incline value with a decreasing trend (i.e. -0.3699 mm per year), where the negative sign signify that the precipitation data are decreasing by 0.3699 mm per year.

4.4.2 Summary of Madaba District's Quality Tests

Table 20: Results of quality Tests of Madba district's precipitation data

Test	Tests' result
Normality	Statistical hypothesis = 0.335>0.05. Thus, Madaba's precipitation data was represented as normally distribution.
Homogeneity	Based on t and F tests, Madaba district's precipitation data is homogeneous with Jarash district's precipitation data sets.
Consistency	Precipitation data of Madaba district was considered to be consistent, based on DMC carried out among 5 representative stations.
Trend	Trend was not existed in Madaba district's precipitation data based on Mann Kendall and Sen's slope trend tests.
Stationary	Madaba district's precipitation data is not stationary and has a unit root based on Augmented Dickey-Fuller test.

4.4.3 Forecasted Madaba District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The best model was ARIMA (1, 0, 1) which will be used to compute the predicted precipitation data for the upcoming 10 years. The actual value for the 2016-17 in Madaba was 217 mm and the forecasted value for this model was 256 mm.

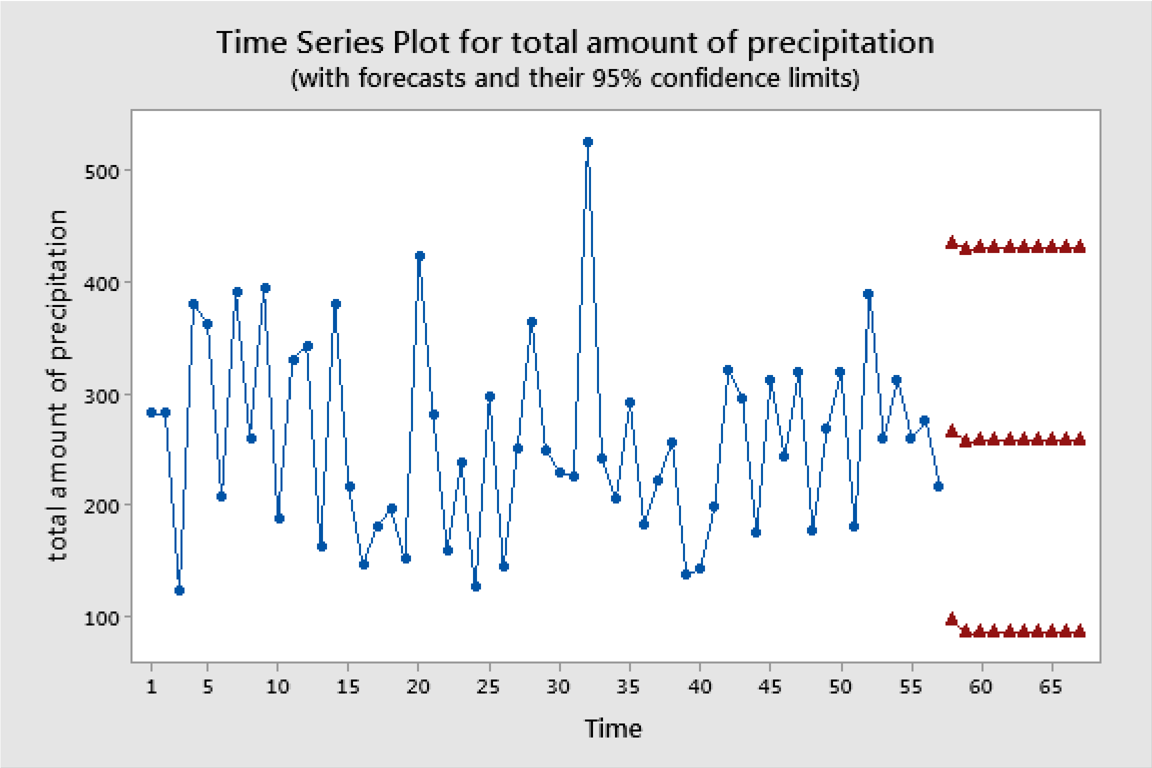

Figure 55: Madaba forecasted 10 years Precipitation data set built on ARIMA (1, 0, 1) model

Table 21: Forecasted yearly precipitation data for Madaba district built on ARIMA (1, 0, 1) model

Hydrologic Year	**Forecasted Yearly Precipitation (mm)**
2017-18	265
2018-19	257
2019-20	258
2020-21	258
2021-22	258
2022-23	258
2023-24	258
2024-25	258
2025-26	258
2026-27	258

4.4.4 Analysis of monthly Precipitation data of Madaba district and its trends built on the Hydrological years from 1960-61 to 2016-17

October

The figure implicates the trend for October built on 10-year MA, a slightly declining slope for the whole study period. For the monthly spells, the month of October considered as a dry month within the study period with a 39 dry month (68%) out of 57.

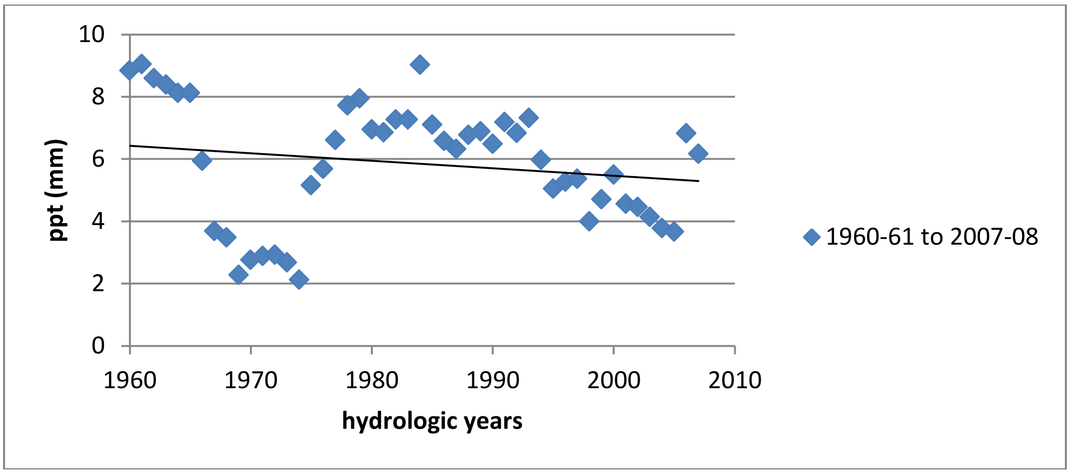

Figure 56 : Madaba district's 10 years MA monthly precipitation data set for the month of October for the water years 1960-61 to 2016-17

November

The figure implicates the trend for November built on 10-year MA, a slightly declining slope for the whole study period. For the monthly spells, the month of November considered as a dry month within the study period with a 42 dry month (74%) out of 57.

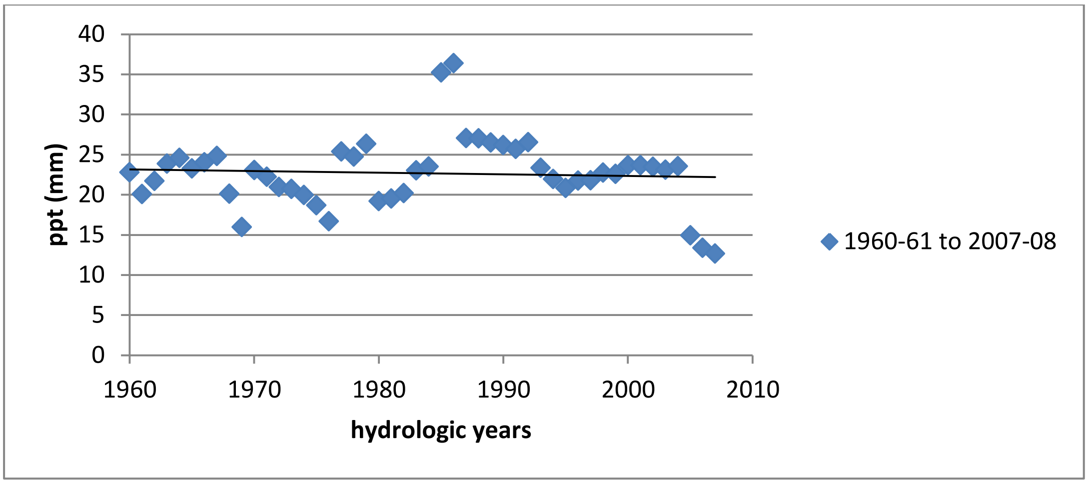

Figure 57: Madaba district's 10 years MA monthly precipitation data set for the month of November for the water years 1960-61 to 2016-17

December

The figure implies the trend for December built on 10-year MA, a declining slope for the whole study period. For the monthly spells, the month of December considered as a dry month within the study period with a 37 dry month (65%) out of 57.

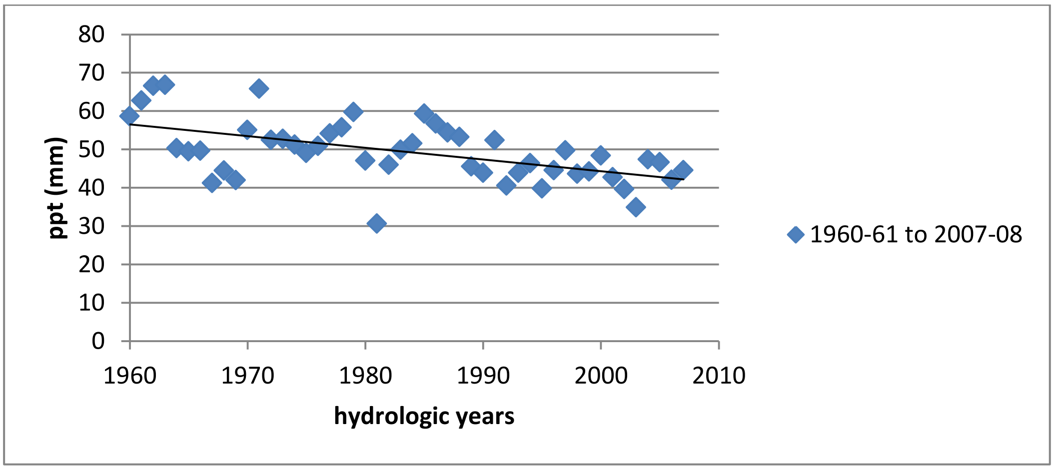

Figure 58: Madaba district's 10 years MA monthly precipitation data set for the month of December for the water years 1960-61 to 2016-17

January

The figure implies 2 trends built on 10-year MA, a declining slope for the initial 14 years, then increasing slope for the next 34 year. For the monthly spells, the month of January considered as a dry month within the study period with a 31 dry month (54%) out of 57.

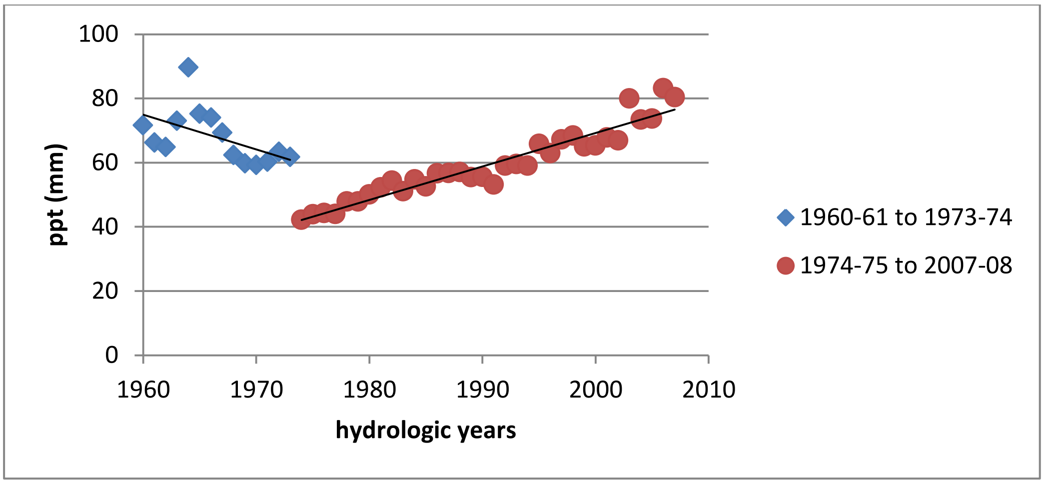

Figure 59: Madaba district's 10 years MA monthly precipitation data set for the month of January for the water years 1960-61 to 2016-17

February

The figure implies 4 different trends built on 10-year MA, an increasing slope for the initial 23 years, a declining trend for the next 10 years, and then upward slope for the 10 years in the end a greater increasing slope for the latest 5 years. For the monthly spells, the month of February considered as a dry month within the study period with a 38 dry month (67%) out of 57.

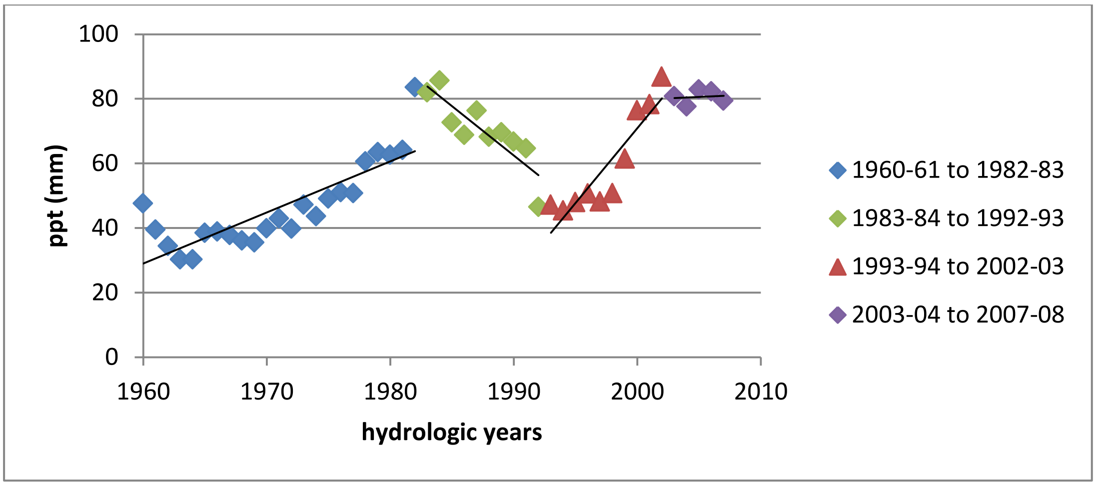

Figure 60: Madaba district's 10 years MA monthly precipitation data set for the month of February for the water years 1960-61 to 2016-17

March

The figure implies 2 dissimilar declined trends built on 10-year MA. For the monthly spells, the month of March considered as a dry month within the study period with a 33 dry month (58%) out of 57.

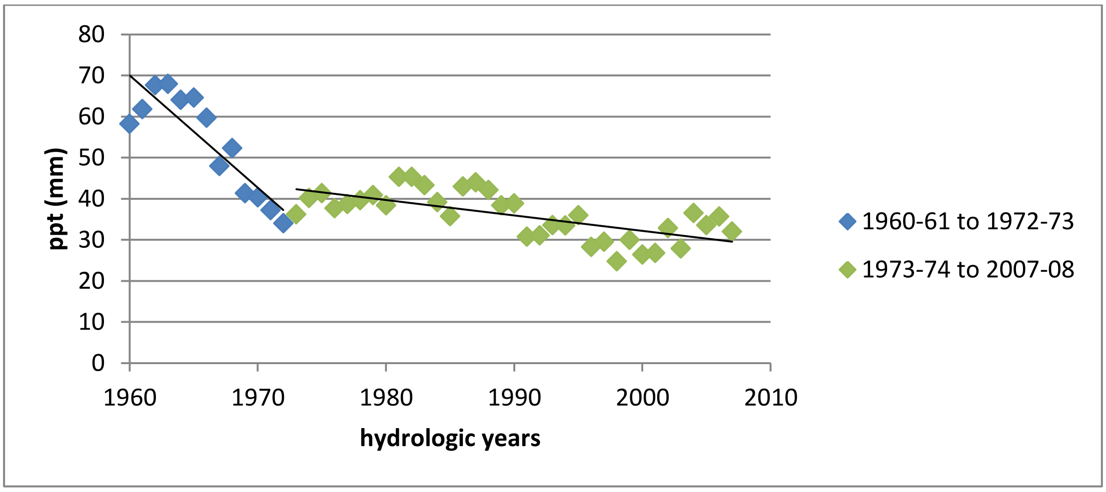

Figure 61: Madaba district's 10 years MA monthly precipitation data set for the month of March for the water years 1960-61 to 2016-17

April

The figure implies 2 trends built on 10-year MA, a declining slope for the initial 32 years, then slightly increasing slope for the next 16 year. For the monthly spells, the month of April considered as a dry month within the study period with a 41 dry month (72%) out of 57.

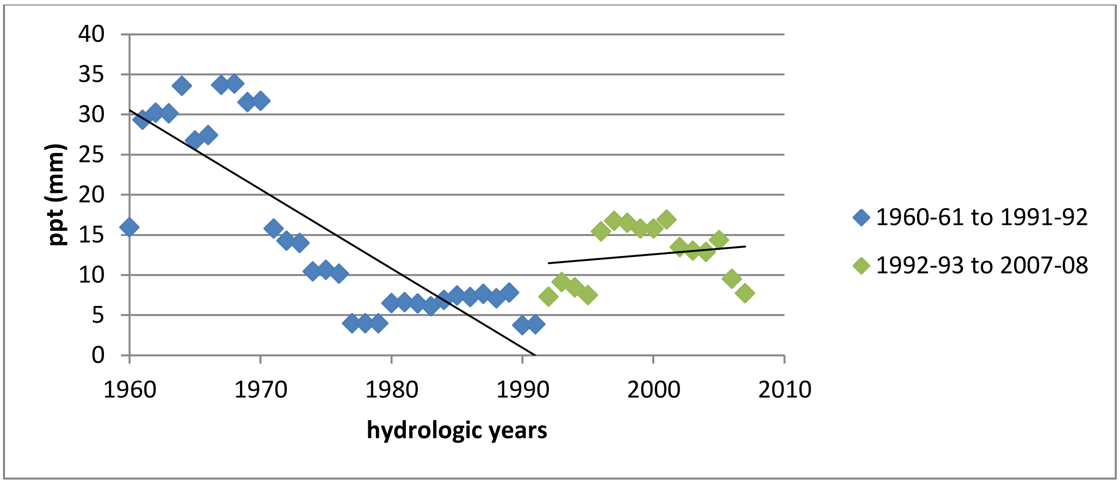

Figure 62: Madaba district's 10 years MA monthly precipitation data set for the month of April for the water years 1960-61 to 2016-17

May

The figure implies the trend for May built on 10-year MA, a mild declining slope for the whole study period. For the monthly spells, the month of May month considered as a dry within the study period with a 45 dry month (79%) out of 57.

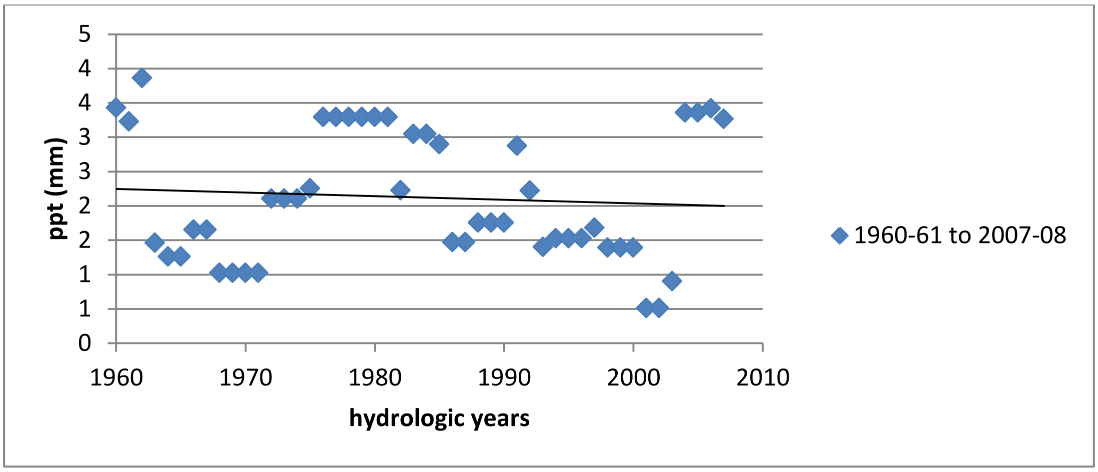

Figure 63: Madaba district's 10 years MA monthly precipitation data set for the month of May for the water years 1960-61 to 2016-17

4.5 Meteorological District: Zarqa

Table 22: Monthly precipitation data with the statistical measures of Zarqa district for hydrological years from 1960-61 to 2016-17 in (mm)

Year\month	October	November	December	January	February	March	April	May	TOTAL
1960-61	1	23	16	60	43	6	6	4	158
1961-62	1	8	90	26	51	1	2	0	178
1962-63	2	0	20	3	52	14	4	8	102
1963-64	11	7	57	41	36	29	4	0	185
1964-65	0	15	24	67	14	11	18	0	150
1965-66	4	6	25	15	11	78	0	0	138
1966-67	24	17	69	50	15	75	0	3	255
1967-68	26	24	17	60	14	13	9	5	167
1968-69	2	20	26	56	10	63	5	6	187
1969-70	11	6	4	31	11	30	4	4	102
1970-71	1	15	16	25	12	18	63	0	150
1971-72	0	16	49	13	35	31	14	1	158
1972-73	6	30	1	40	12	13	2	0	104
1973-74	3	27	12	154	44	7	13	0	261
1974-75	0	17	13	12	70	19	5	0	136
1975-76	0	19	13	9	31	46	6	8	132
1976-77	3	5	0	24	14	26	18	0	90
1977-78	12	4	32	12	8	29	4	0	101

Year\month	October	November	December	January	February	March	April	May	TOTAL
1978-79	2	0	22	11	9	13	1	0	58
1979-80	19	66	53	50	47	62	8	0	305
1980-81	0	4	113	18	20	9	2	0	165
1981-82	0	10	1	39	34	23	12	14	133
1982-83	14	19	12	58	60	33	1	2	198
1983-84	0	0	0	31	9	58	4	0	101
1984-85	9	13	31	13	80	33	3	2	184
1985-86	5	3	26	10	35	3	5	7	94
1986-87	19	60	11	23	12	32	0	0	158
1987-88	27	4	38	35	65	35	9	0	213
1988-89	4	6	78	28	12	15	0	0	144
1989-90	0	12	16	29	24	24	12	0	116
1990-91	9	5	1	52	24	19	6	0	115
1991-92	3	13	83	39	85	10	1	1	236
1992-93	0	23	26	19	18	8	8	7	109
1993-94	9	9	7	49	11	18	0	0	102
1994-95	4	68	57	1	16	6	1	0	155
1995-96	0	5	13	44	9	28	3	0	100
1996-97	6	26	19	50	26	20	3	3	153
1997-98	12	11	34	38	16	25	1	0	138
1998-99	0	0	4	13	29	6	2	0	54
1999-00	0	1	2	55	12	18	0	0	89
2000-01	10	2	36	23	16	4	7	6	103
2001-02	4	16	34	48	17	23	11	1	153
2002-03	2	15	49	35	66	28	4	0	199
2003-04	1	8	55	22	37	1	1	0	124
2004-05	1	39	14	29	37	11	4	4	139
2005-06	0	6	21	15	32	2	25	0	101
2006-07	4	2	23	35	29	20	5	4	122
2007-08	1	14	12	38	34	2	0	0	101
2008-09	8	0	12	5	60	20	0	0	105
2009-10	5	17	30	34	57	12	0	0	155
2010-11	2	0	12	30	37	5	4	6	96
2011-12	0	18	11	38	46	34	0	0	147
2012-13	0	8	16	92	11	5	7	3	143
2013-14	0	15	27	1	2	44	0	19	108
2014-15	0	12	16	60	15	16	13	0	132
2015-16	2	9	15	72	51	19	17	0	185

Year\month	October	November	December	January	February	March	April	May	TOTAL
2016-17	3	11	7	40	56	18	3	0	138
Average	5.1	14.1	26.7	35.4	30.5	22.3	6.2	2	142.5
Standard Error	0.9	2.0	3.2	3.3	2.7	2.37	1.24	0.5	6.43
Median	2.1	10.9	18.6	33.5	26.2	18.56	4.00	0.0	137.8
Standard Deviation	6.8	14.8	24.2	25.2	20.6	17.90	9.39	3.7	48.52
Sample Variance	46.6	218.6	586.1	636.9	424.7	320.42	88.17	13.5	2354
Kurtosis	2.7	5.6	2.5	7.8	-0.2	1.98	23.3	7.6	1.68
Skewness	1.8	2.2	1.6	2.0	0.8	1.42	4.21	2.5	1.06
Range	27.1	68.4	112.6	153.6	83.5	77.25	62.7	18.5	250.7
Minimum	0.0	0.0	0.0	0.8	1.8	0.60	0.00	0.0	53.97
Maximum	27.1	68.4	112.6	154.4	85.3	77.85	62.7	18.5	304.63

4.5.1 Trend of Zarqa District's Precipitation Data

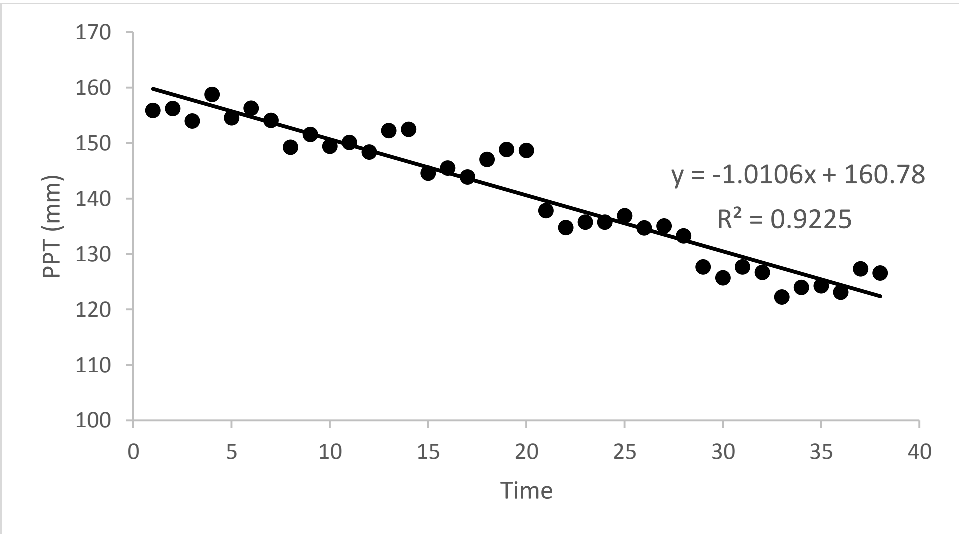

Figure 64: 20-years MA of Zarqa district's yearly precipitation data

Result: For Zarqa district the best representative appropriate trend was 20-years MA, having the highest absolute incline value with a decreasing trend (i.e. -1.01), where the negative sign signify that the precipitation data are decreasing by 1.01 mm per year.

4.5.2 Summary of Zarqa District's Quality Tests

Table 23: Results of quality Tests of Zarqa district's precipitation data

Test	Tests' results
Normality	Statistical hypothesis is <0.0005. Thus, Zarqa's precipitation data was not represented as normally distribution.
Homogeneity	Based on t and F tests, Zarqa district's precipitation data is not homogeneous with any other district in the kingdom.
Consistency	Precipitation data of Zarqa district was considered to be consistent, based on DMC carried out among 5 representative stations.
Trend	Trend was not existed in Zarqa district's precipitation data based on Mann Kendall and Sen's slope trend tests.
Stationary	Zarqa district's precipitation data was considered stationary by Augmented Dickey-Fuller test.

4.5.3 Forecasted Zarqa District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The best model was ARIMA (2, 0, 1) which will be used to compute the predicted Precipitation data for the upcoming 10 years. The actual value for the 2016-17 in Zarqa was 138 mm and the forecasted value for this model was 138 mm.

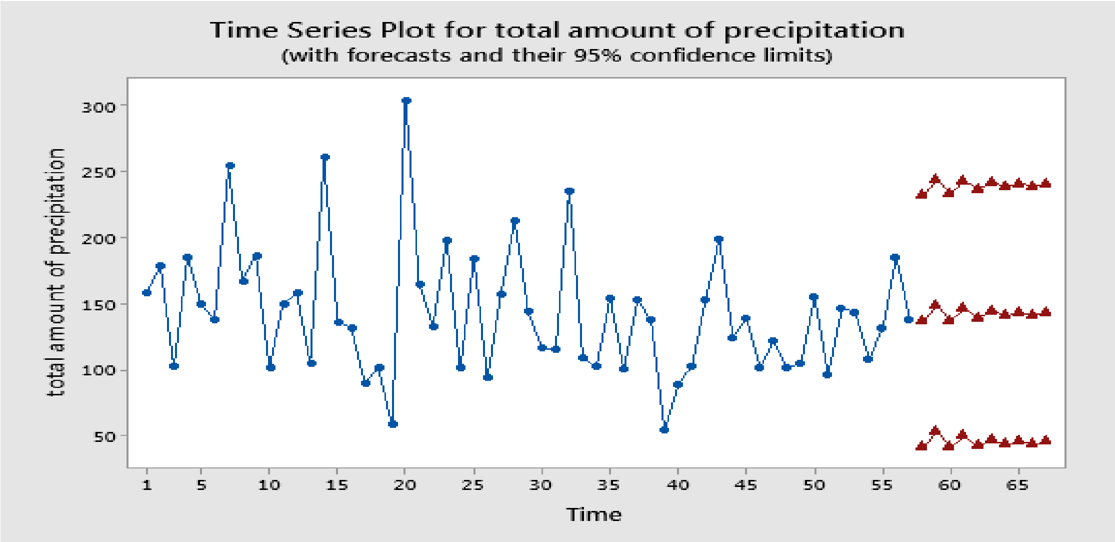

Figure 65: Zarqa forecasted 10 years precipitation data set built on ARIMA (2, 0, 1) model

Table 24: Forecasted yearly Precipitation data for Zarqa district built on ARIMA (2, 0, 1) model

Hydrologic year	**Forecasted yearly precipitation (mm)**
2017-18	137
2018-19	149
2019-20	137
2020-21	146
2021-22	139
2022-23	145
2023-24	141
2024-25	144
2025-26	142
2026-27	143

4.5.4 Analysis of monthly Precipitation data of Zarqa district and its trends built on the Hydrological years from 1960-61 to 2016-17

October

The figure implies the trend for October built on 10-year MA, a slightly declining slope for the whole study period. For the monthly spells, the month of October considered as a dry month within the study period with a 39 dry month (68%) out of 57.

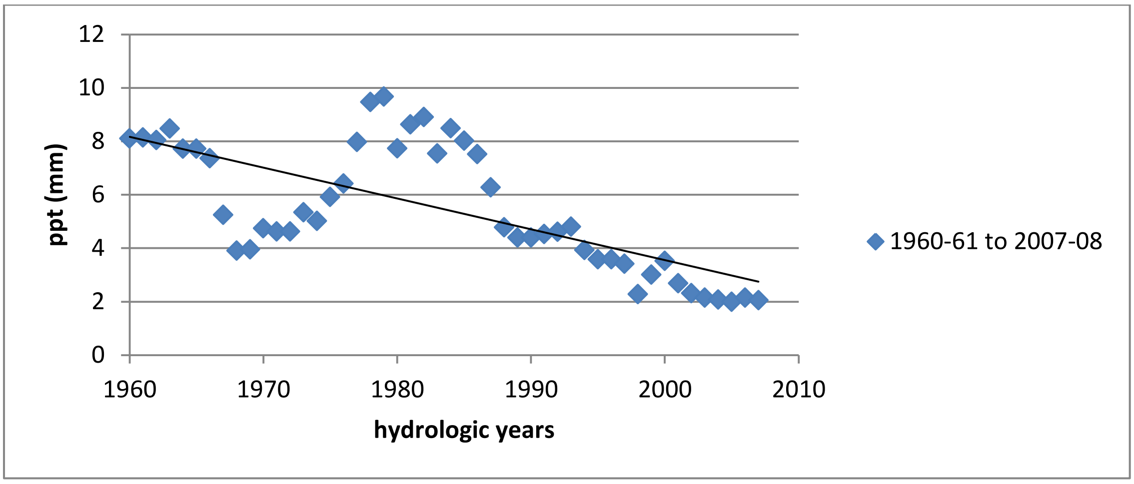

Figure 66: Zarqa district's 10 years MA monthly precipitation data set for the month of October for the water years 1960-61 to 2016-17

November

The figure implies the trend for November built on 10-year MA, a declining slope for the whole study period. For the monthly spells, the month of November considered as a dry month within the study period with a 34 dry month (60%) out of 57.

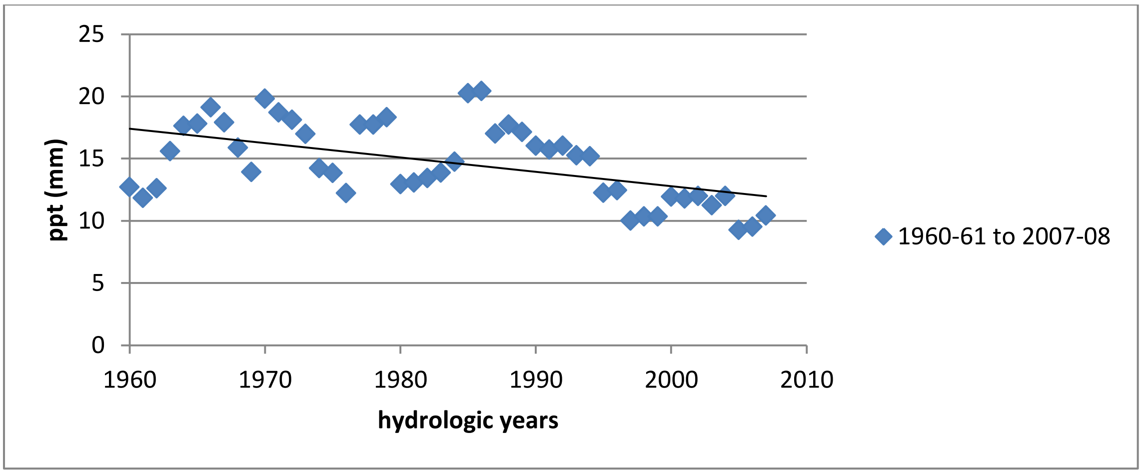

Figure 67: Zarqa district's 10 years MA monthly precipitation data set for the month of November for the water years 1960-61 to 2016-17

December

The figure implies 3 different trends built on 10-year MA, a declining slope for the initial 10 years, an increasing slope for the following 19 years, and then downward slope for the last 19 years. For the monthly spells, the month of December considered as a dry month within the study period with a 38 dry month (67%) out of 57.

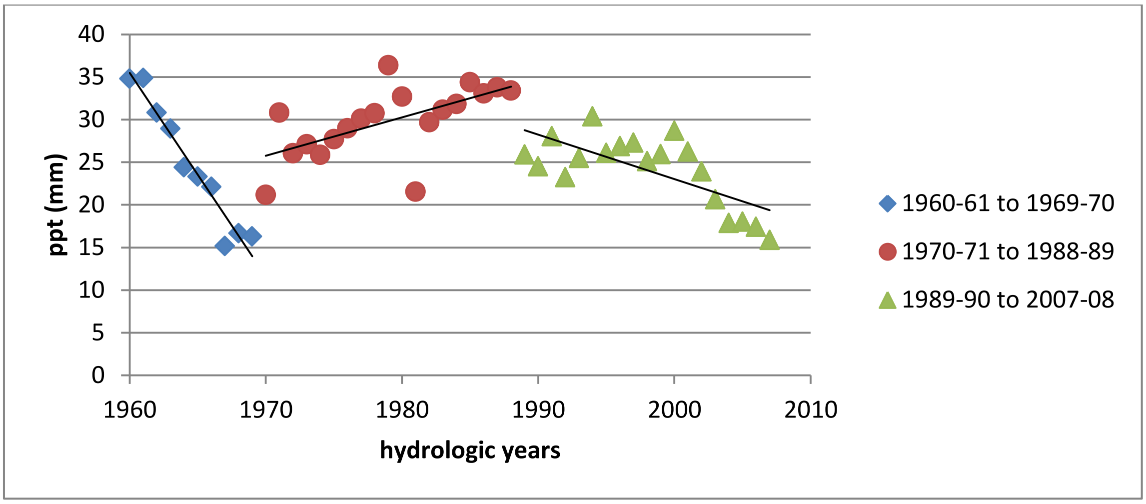

Figure 68: Zarqa district's 10 years MA monthly precipitation data set for the month of December for the water years 1960-61 to 2016-17

January

The figure implies 4 different trends built on 10-year MA, a declining slope for the initial 14 years, an increasing slope for the following 22 years, then a downward slope for 6 years and in the end an increasing slope for the last 6 years. For the monthly spells, the month of January considered as a dry month within the study period with a 31 dry month (54%) out of 57.

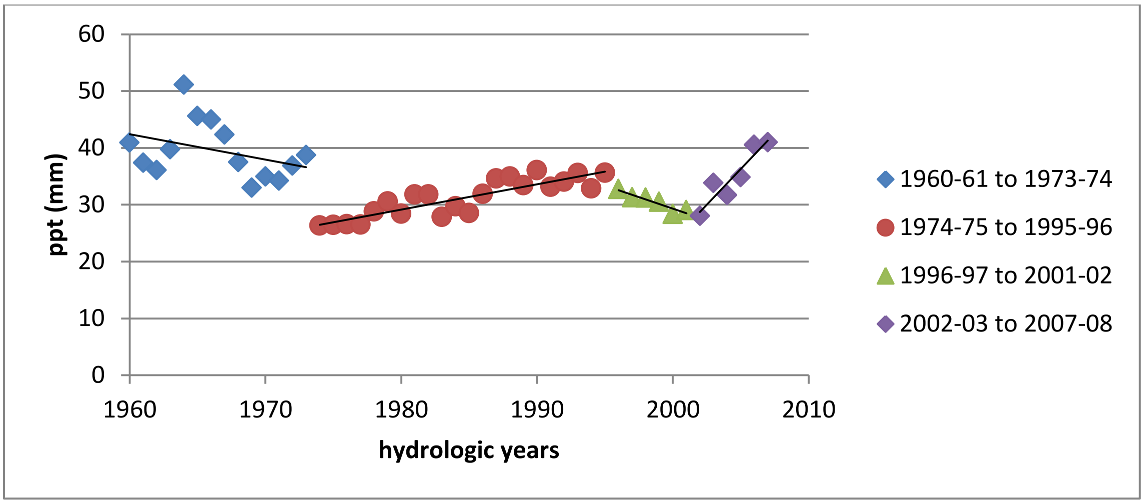

Figure 69: Zarqa district's 10 years MA monthly precipitation data set for the month of January for the water years 1960-61 to 2016-17

February

The figure implies 3 different trends built on 10-year MA, an increasing slope for the initial 23 years, a declining slope for the following 10 years, and then an upward slope for the 15 years. For the monthly spells, the month of February considered as a dry month within the study period with a 41 dry month (72%) out of 57.

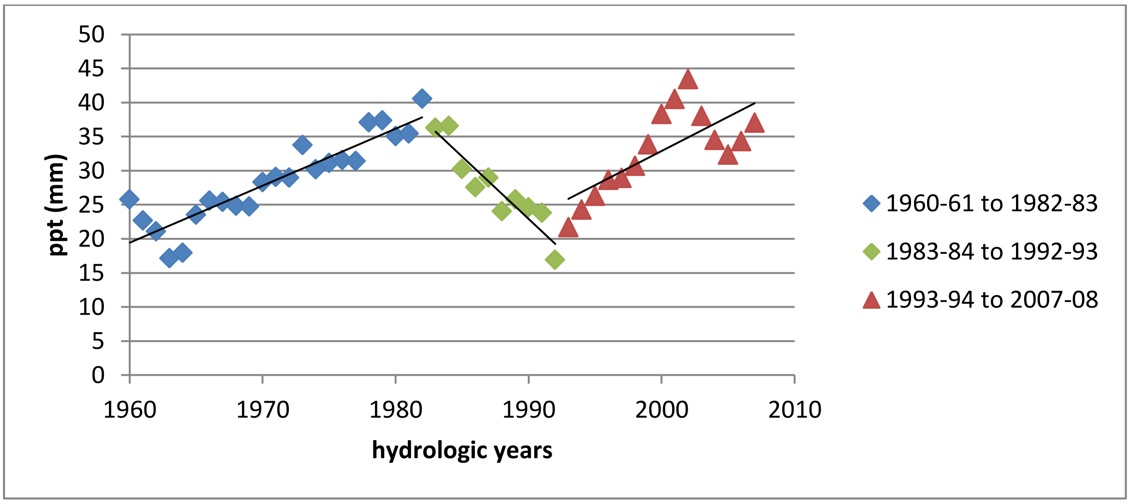

Figure 70: Zarqa district's 10 years MA monthly precipitation data set for the month of February for the water years 1960-61 to 2016-17

March

The figure implies 2 dissimilar declined trends in the beginning built on 10-year MA. Followed by an increasing trend for the last 17 years. For the monthly spells, the month of March considered as a dry month within the study period with a 34 dry month (60%) out of 57.

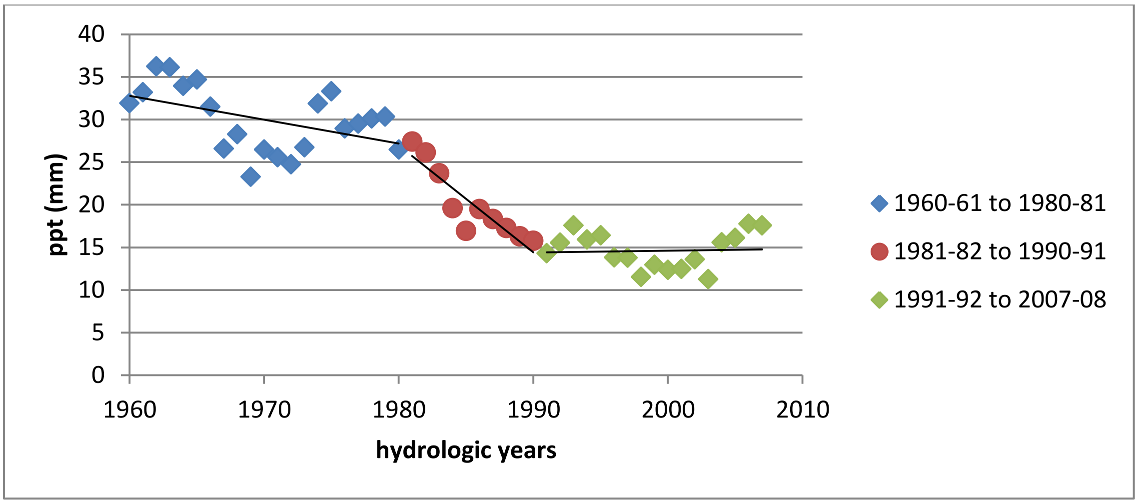

Figure 71: Zarqa district's 10 years MA monthly precipitation data set for the month of March for the water years 1960-61 to 2016-17

April

The figure implies 2 trends built on 10-year MA, a declining slope for the initial 21 years, then slightly increasing slope for the last 27 year. For the monthly spells, the month of April considered as a dry month within the study period with a 40 dry month (70%) out of 57.

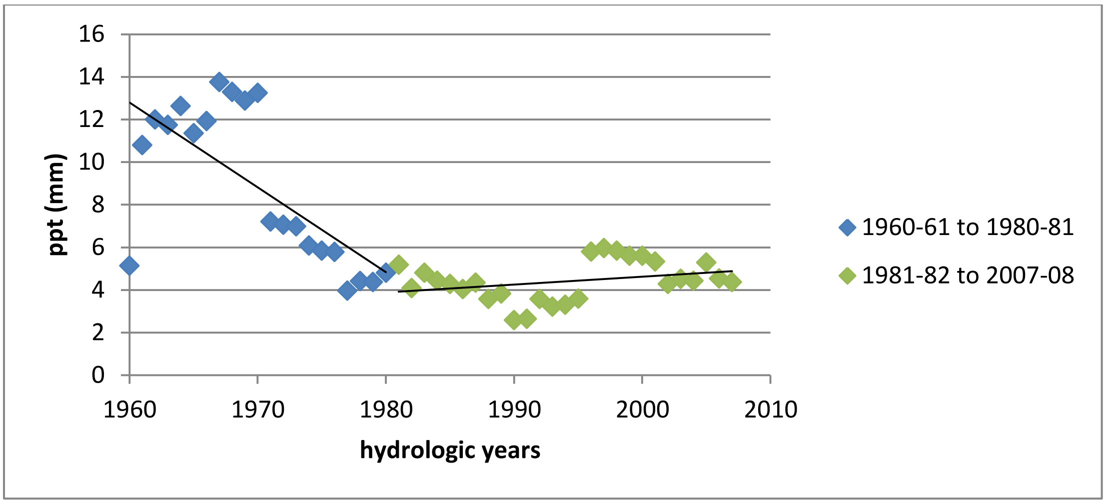

Figure 72: Zarqa district's 10 years MA monthly precipitation data set for the month of April for the water years 1960-61 to 2016-17

May

The figure implies the trend for May built on 10-year MA, a mild declining slope for the whole study period. For the monthly spells, the month of May considered as a dry month within the study period with a 39 dry month (68%) out of 57.

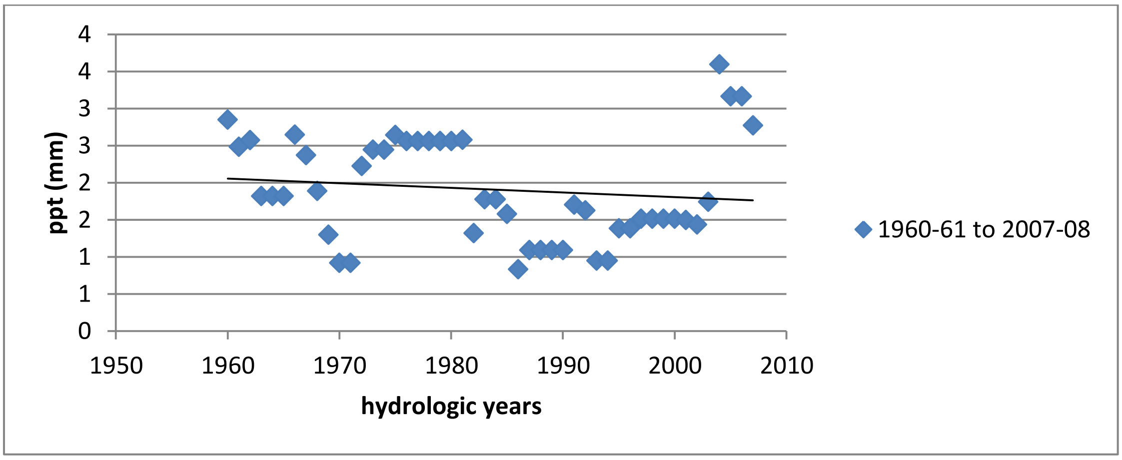

Figure 73: Zarqa district's 10 years MA monthly precipitation data set for the month of May for the water years 1960-61 to 2016-1

4.6 Meteorological District: Tafilah

Table 25: Monthly precipitation data with the statistical measures of Tafilah district for hydrological years started in 1960-61 until 2016-17 in (mm)

Year\month	October	November	December	January	February	March	April	May	TOTAL
1960-61	0	25	22	59	100	12	10	6	234
1961-62	3	11	71	18	14	0	21	0	136
1962-63	0	0	4	1	51	12	14	2	84
1963-64	1	5	364	98	88	43	19	0	617
1964-65	0	34	102	488	7	82	38	0	751
1965-66	16	6	7	32	64	43	0	0	167
1966-67	12	12	34	72	62	124	3	25	343
1967-68	7	44	18	91	49	25	43	6	282
1968-69	17	28	59	51	5	103	32	0	295
1969-70	0	16	0	38	0	55	9	0	118
1970-71	0	10	61	36	14	12	127	0	259
1971-72	0	1	123	5	28	163	8	2	329
1972-73	0	14	14	86	0	5	0	0	119
1973-74	0	29	13	186	74	20	24	0	345
1974-75	0	16	106	26	154	21	2	0	326
1975-76	0	0	20	14	29	48	7	0	117
1976-77	3	8	4	80	20	5	116	0	235
1977-78	0	14	98	23	10	25	5	0	174
1978-79	0	0	35	61	51	41	0	4	193
1979-80	2	56	89	37	65	44	12	0	304
1980-81	2	1	122	13	60	38	12	0	248
1981-82	0	15	0	38	32	20	1	8	114
1982-83	0	46	47	110	58	61	3	0	325
1983-84	0	0	6	13	8	48	0	0	75
1984-85	24	0	6	4	75	22	19	0	150
1985-86	0	9	97	15	37	2	44	10	214
1986-87	0	59	21	4	27	60	0	0	170
1987-88	3	0	80	119	67	120	0	0	390
1988-89	2	0	103	49	47	37	0	0	237
1989-90	8	0	3	25	15	34	77	0	162
1990-91	7	0	0	104	25	210	0	0	345
1991-92	19	3	67	58	59	10	1	0	216
1992-93	0	34	138	33	85	16	0	0	306
1993-94	0	9	43	136	72	51	7	0	317
1994-95	20	225	52	0	71	2	5	0	375

Year\month	October	November	December	January	February	March	April	May	TOTAL
1995-96	0	7	6	98	15	96	0	0	222
1996-97	0	9	13	110	56	34	11	0	233
1997-98	16	0	67	100	49	31	0	0	263
1998-99	0	0	4	25	112	15	3	0	159
1999-00	0	0	3	57	15	31	0	0	105
2000-01	5	0	45	57	49	0	3	19	177
2001-02	0	37	28	133	63	32	21	0	313
2002-03	3	17	95	37	3	46	15	0	216
2003-04	0	0	33	174	47	15	0	0	270
2004-05	5	74	42	88	41	23	3	0	275
2005-06	0	4	11	17	99	0	53	0	183
2006-07	0	0	59	107	72	40	5	10	293
2007-08	0	1	22	91	69	0	0	0	183
2008-09	39	0	0	2	85	39	0	0	165
2009-10	0	13	35	62	134	19	0	0	262
2010-11	11	0	9	25	122	4	24	0	195
2011-12	0	13	21	82	50	36	0	0	202
2012-13	3	14	1	99	62	76	17	2	273
2013-14	0	11	83	12	22	95	0	65	288
2014-15	16	33	10	39	38	10	25	0	171
2015-16	23	9	43	50	62	45	0	0	233
2016-17	33	0	68	27	42	8	21	0	198
Average	5	17	48	65	51	40	15	3	244.7
Standard Error	1.18	4.3	7.6	9.6	4.53	5.5	3.4	1.3	15.22
Median	0.00	8.6	33.6	50.4	50	31.8	5.1	0.0	233.3
Standard Deviation	8.89	32.8	57.2	72.2	34.1	41.2	25.7	9.6	114.9
Sample Variance	79.1	1077	3276	5208	1167	1697	658.1	91.8	13199
Kurtosis	3.93	29.5	15.8	20.8	0.60	5.1	9.55	32.9	7.059
Skewness	2.04	4.9	3.2	3.8	0.71	2.0	2.94	5.4	2.022
Range	39	226	364	488.4	154	209.9	126.5	65.0	676.1
Minimum	0	0	0	0	0	0	0	0	75
Maximum	39	226	363.7	488.4	154	209.9	126.5	65.0	751.1

4.6.1 Trend of Tafilah District's Precipitation Data

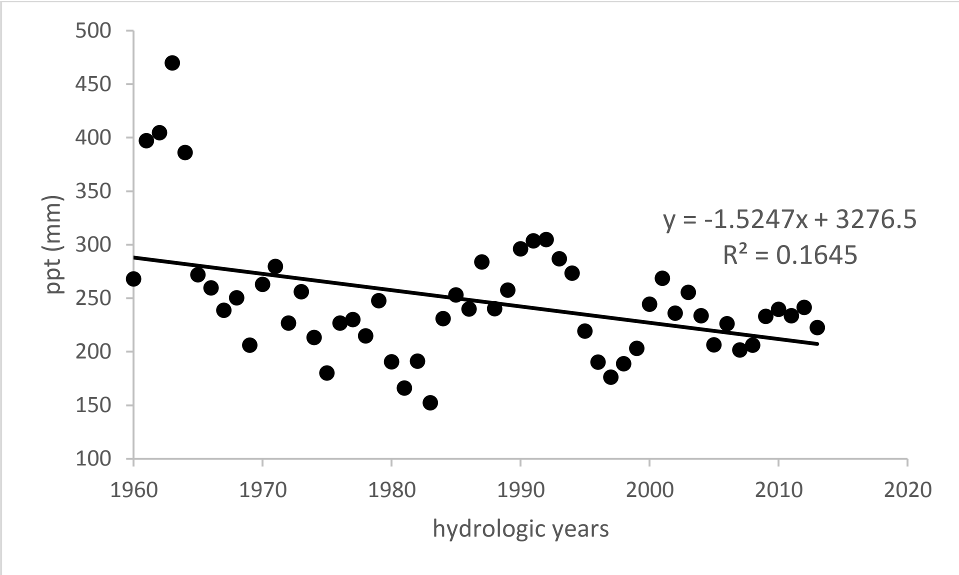

Figure 74: 4-years MA of Tafilah district's yearly precipitation data

<u>Result</u>: For Tafilah district the best representative appropriate trend was 4-years MA, having the highest absolute incline value with a decreasing trend (i.e. -1.52 mm per year).

4.6.2 Summary of Tafilah District's Quality Tests

Table 26: Results of quality Tests of Tafilah Precipitation data

Test	Tests' results
Normality	Statistical hypothesis is<0.0005. Thus, Tafilah's precipitation data was not represented as normally distribution.
Homogeneity	Built on t and F tests, Tafilah district's precipitation data is not homogeneous with any other district in the kingdom.
Consistency	Precipitation data of Tafilah district was considered to be consistent, built on DMC carried out among 2 representative stations.

Trend	Trend was not existed in Tafilah district's precipitation data based on Mann Kendall and Sen's slope trend tests.
Stationary	Tafilah district's precipitation data was considered stationary by Augmented Dickey-Fuller test.

4.6.3 Forecasted Tafilah District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The best model was ARIMA (1, 2, 1) which will be used to compute the predicted Precipitation data for the upcoming 10 years. The actual value for the 2016-17 in Tafilah was 198 mm and the forecasted value for this model was 199 mm.

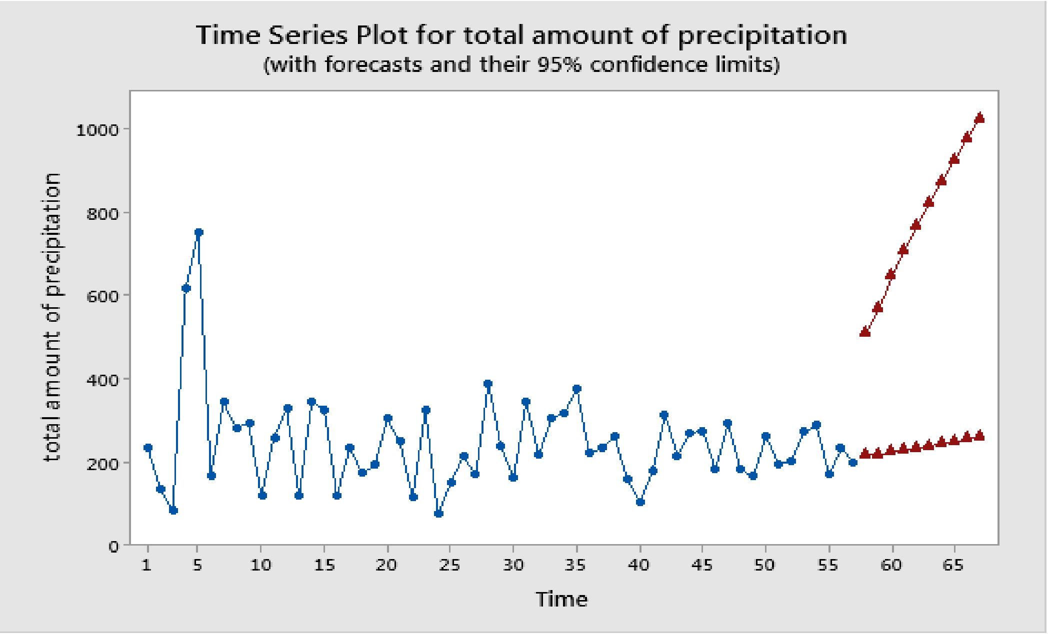

Figure 75: Tafilah forecasted 10 years precipitation data set built on ARIMA (1, 2, 1) model

Table 27: Forecasted yearly Precipitation data for Tafilah district built on ARIMA (1, 2, 1) model

Hydrologic Year	Forecasted Yearly Precipitation (mm)
2017-18	218
2018-19	217
2019-20	224
2020-21	229
2021-22	234
2022-23	239
2023-24	245
2024-25	250
2025-26	256
2026-27	261

4.6.4 Analysis of monthly Precipitation data of Tafilah district and its trends built on the Hydrological years from 1960-61 to 2016-17

October

The figure implies the trend for October built on 10-year MA, a slightly increasing the slope of the whole study period. For the monthly spells, the month of October considered as a dry month within the study period with a 39 dry month (68%) out of 57.

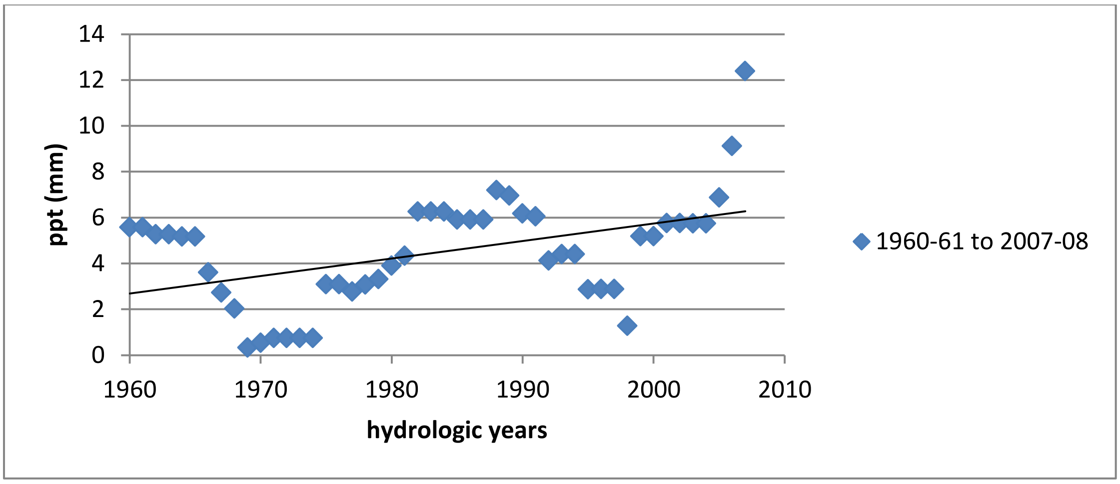

Figure 76: Tafilah district's 10 years MA monthly precipitation data set for the month of October for the water years 1960-61 to 2016-17

November

The figure implies the trend for November built on 10-year MA, a not significantly declining slope for the whole study period. For the monthly spells, the month of November considered as a dry month within the study period with a 43 dry month (75%) out of 57.

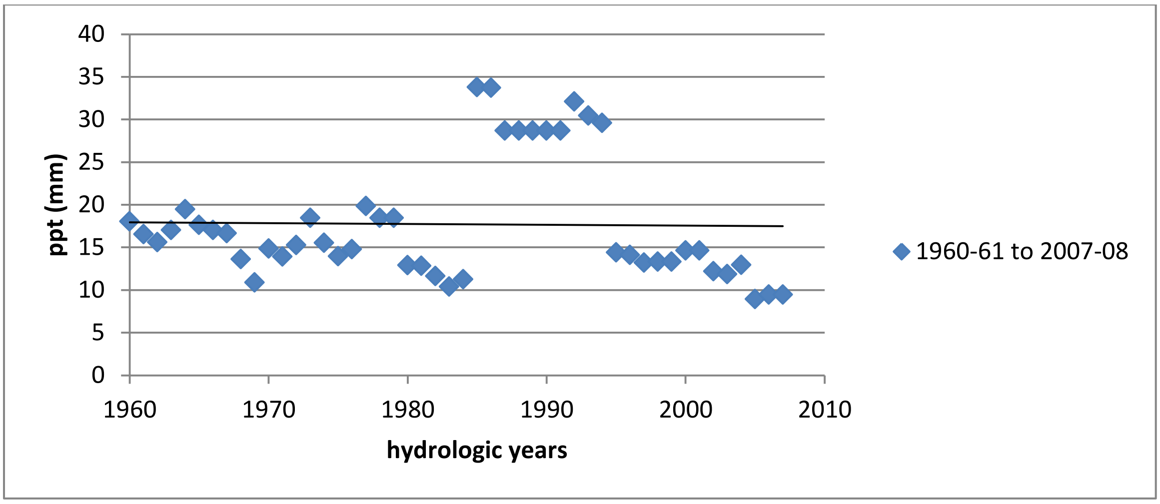

Figure 77: Tafilah district's 10 years MA monthly precipitation data set for the month of November for the water years 1960-61 to 2016-17

December

The figure implies 2 dissimilar declined slopes built on 10-year MA. For the monthly spells, the month of December considered as a dry month within the study period with a 36 dry month (63%) out of 57.

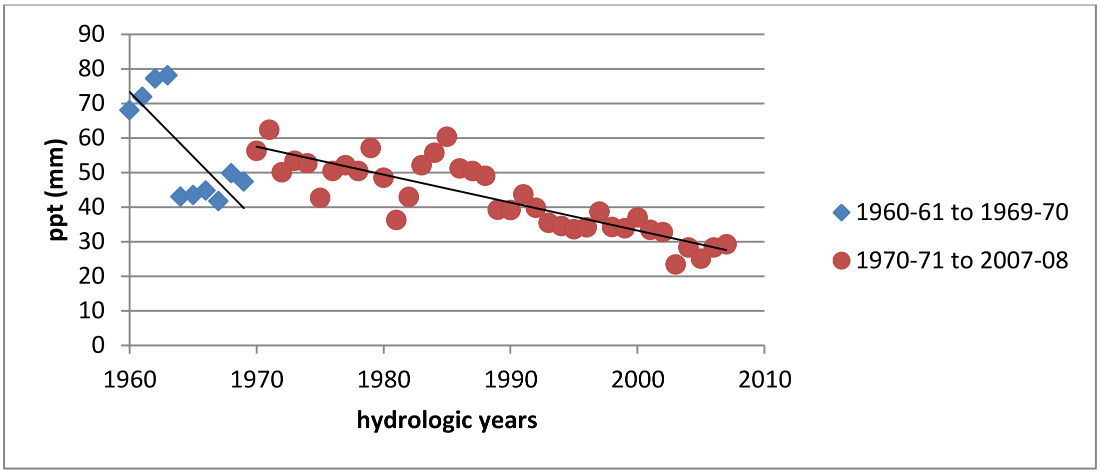

Figure 78: Tafilah district's 10 years MA monthly precipitation data set for the month of December for the water years 1960-61 to 2016-17

January

The figure implies 3 different slopes built on 10-year MA, a declining slope for the first 14 years, followed by an increasing slope for the next 22 years, then a downward slope for 12 years in the end. For the monthly spells, the month of January considered as a dry month within the study period with a 36 dry month (63%) out of 57.

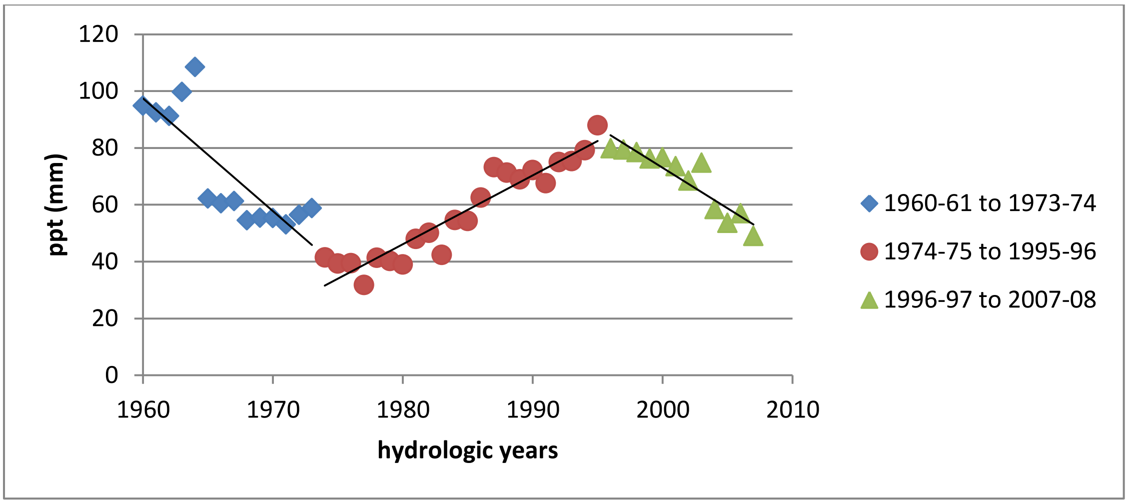

Figure 79: Tafilah district's 10 years MA monthly precipitation data set for the month of January for the water years 1960-61 to 2016-17

February

The figure implies 2 dissimilar increasing slopes built on 10-year MA. For the monthly spells, the month of December considered as a dry month within the study period with a 30 dry month (53%) out of 57.

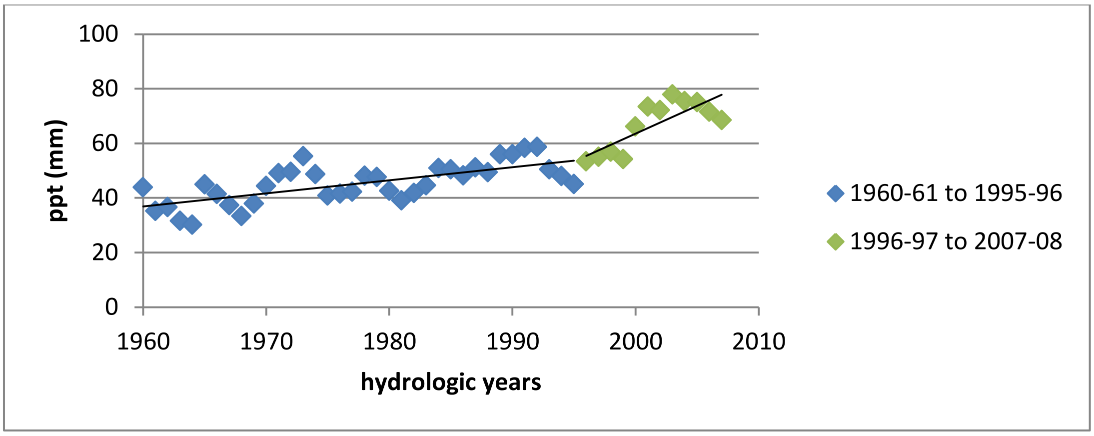

Figure 80: Tafilah district’s 10 years MA monthly precipitation data set for the month of February for the water years 1960-61 to 2016-17

March

The figure implies 2 dissimilar declined slopes built on 10-year MA. Then an increasing slope for the last 17 years. For the monthly spells, the month of March considered as a dry month within the study period with a 34 dry month (60%) out of 57.

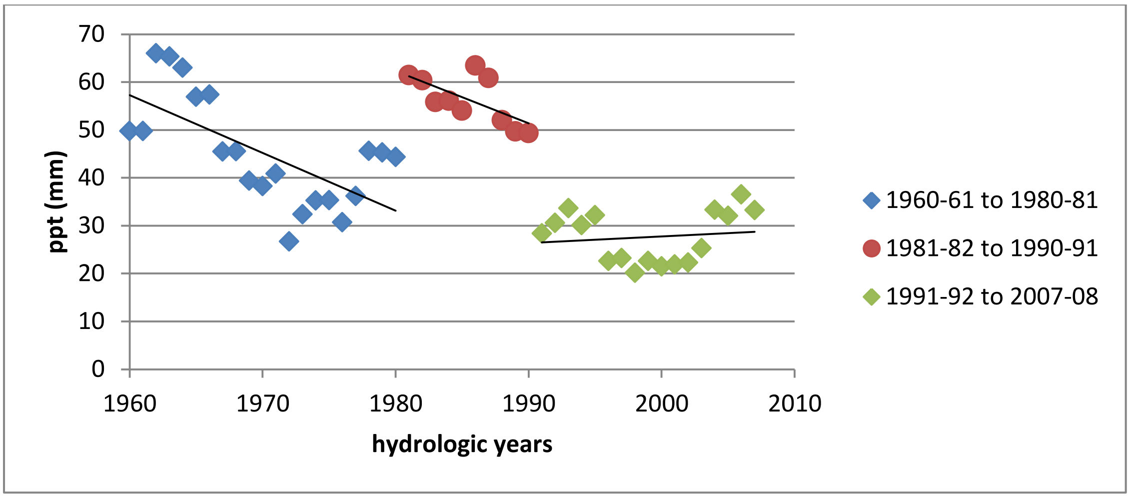

Figure 81: Tafilah district's 10 years MA monthly precipitation data set for the month of March for the water years 1960-61 to 2016-17

April

The figure implies 2 trends built on 10-year MA, a declining slope for the initial 30 years, and then an increasing slope for the next 18 year. For the monthly spells, the month of April considered as a dry month within the study period with a 40 dry month (70%) out of 57.

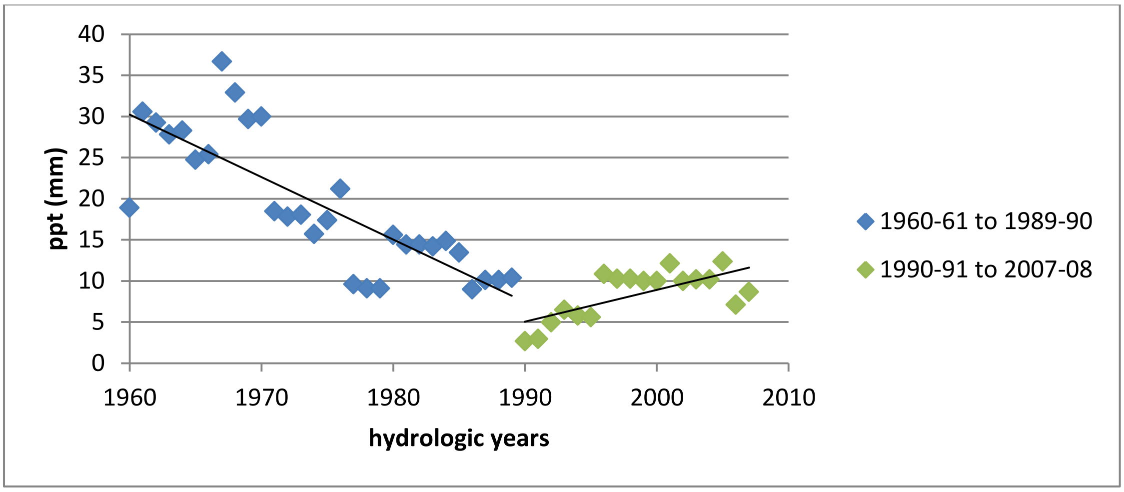

Figure 82: Tafilah district's 10 years MA monthly precipitation data set for the month of April for the water years 1960-61 to 2016-17

May

The figure implies the trend for May built on 10-year MA, a mild increasing slope for the whole study period. For the monthly spells, the month of May considered as a dry month within the study period with a 48 dry month (84%) out of 57.

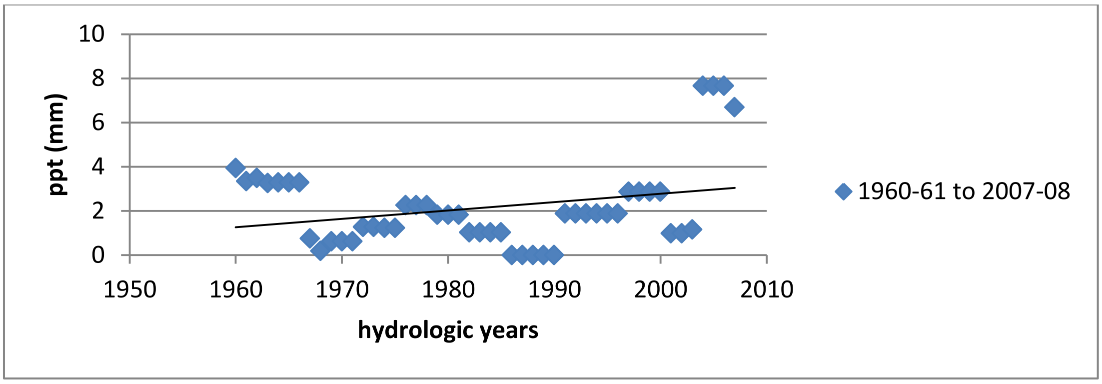

Figure 83: Tafilah district's 10 years MA monthly precipitation data set for the month of May for the water years 1960-61 to 2016-17

4.7 Meteorological District: Ma'an

Table 28: Monthly precipitation data with the statistical measures of Ma'an district for hydrological years started in 1960-61 until 2016-17 in (mm)

Year\month	October	November	December	January	February	March	April	May	TOTAL
1960-61	0	16	22	53	75	8	18	9	200
1961-62	9	14	73	61	8	0	18	0	182
1962-63	0	0	7	0	47	13	27	0	93
1963-64	0	4	223	75	67	13	10	0	392
1964-65	0	15	62	256	4	46	21	0	405
1965-66	11	3	4	27	62	51	0	3	161
1966-67	9	22	23	38	44	72	2	31	240
1967-68	7	33	10	54	34	20	14	7	178
1968-69	10	38	23	46	3	99	39	2	261
1969-70	6	5	0	27	2	57	9	0	106
1970-71	0	6	38	33	14	4	105	0	201

Year\month	October	November	December	January	February	March	April	May	TOTAL
1971-72	0	6	128	7	37	91	20	1	290
1972-73	7	25	9	17	1	1	1	0	63
1973-74	0	9	12	143	69	21	11	0	266
1974-75	0	11	55	14	110	19	3	0	212
1975-76	0	1	35	6	13	46	1	4	106
1976-77	3	3	3	41	12	11	72	0	146
1977-78	1	21	73	26	16	32	0	0	169
1978-79	0	3	34	55	58	26	0	8	185
1979-80	3	52	106	13	84	15	3	0	277
1980-81	7	21	78	17	17	44	9	6	198
1981-82	0	8	8	41	55	32	8	8	160
1982-83	0	57	32	44	51	61	16	0	262
1983-84	4	3	4	22	6	30	61	0	129
1984-85	8	2	29	8	62	32	24	6	170
1985-86	6	3	91	8	38	6	36	6	194
1986-87	0	40	13	5	34	67	0	0	159
1987-88	1	0	36	67	79	106	1	0	292
1988-89	2	0	65	71	50	38	0	0	226
1989-90	0	4	9	17	9	42	68	0	149
1990-91	6	0	15	78	26	175	0	0	299
1991-92	4	9	38	71	110	17	19	0	268
1992-93	0	17	61	25	34	4	0	0	141
1993-94	9	1	34	83	34	43	2	0	206
1994-95	25	86	48	72	60	7	24	0	322
1995-96	0	10	1	69	10	53	3	0	147
1996-97	0	17	32	80	28	17	8	0	182
1997-98	14	2	34	80	37	32	3	0	203
1998-99	1	0	5	26	63	13	1	0	108
1999-00	3	4	19	34	4	17	0	0	82
2000-01	7	5	21	29	16	7	25	19	129
2001-02	20	11	20	64	53	7	13	0	186
2002-03	7	7	60	18	1	17	6	0	115
2003-04	0	0	26	96	18	4	0	0	144
2004-05	7	25	15	43	12	13	14	2	131
2005-06	2	2	10	18	56	0	34	0	122
2006-07	0	0	50	31	41	20	13	15	170
2007-08	0	0	22	57	34	0	0	0	113
2008-09	14	0	1	4	16	21	0	1	57

Year\month	October	November	December	January	February	March	April	May	TOTAL
2009-10	0	5	30	31	54	15	0	2	136
2010-11	0	0	6	9	27	4	19	0	65
2011-12	0	8	6	31	30	21	0	0	96
2012-13	0	15	4	91	55	2	1	4	173
2013-14	5	7	63	10	9	43	0	28	166
2014-15	2	2	7	18	30	4	3	0	65
2015-16	15	1	0	0	1	29	4	0	50
2016-17	19	0	3	10	9	1	0	0	42
Average	4.5	11.6	34	43	36	30	13.8	2.9	175.2
Standard Error	0.76	2.17	5.07	5.46	3.58	4.22	2.74	0.85	10.6
Median	2.35	5.33	22.76	30.79	33.66	19.76	5.81	0.00	169
Standard Deviation	5.74	16.4	38.26	41.25	27.05	31.84	20.68	6.41	80.33
Sample Variance	33	268	1464	1702	731.6	1014	427.6	41.09	6452
Kurtosis	2.41	7.79	10.03	11.79	0.21	7.12	7.36	10.19	0.61
Skewness	1.59	2.56	2.63	2.73	0.76	2.27	2.52	3.11	0.74
Range	24.6	86.1	223	255.6	109	174.8	105	31	362.5
Minimum	0	0	0.20	0	1	0	0	0	42
Maximum	24.6	86.1	223	255.6	110	174.8	105	31	404.5

4.7.1 Trend of Ma'an District's Precipitation Data

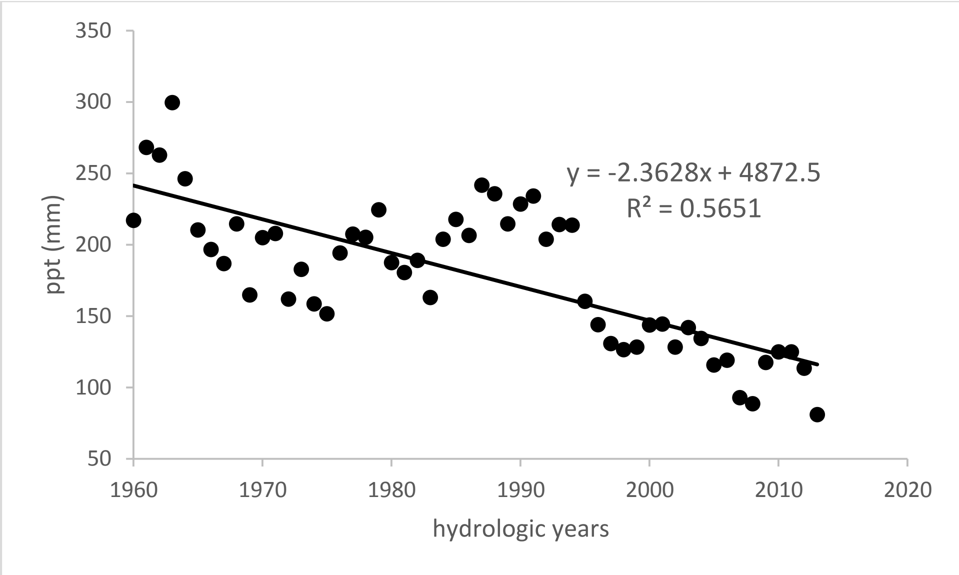

Figure 84: 4-years MA of Ma'an district's yearly precipitation data

Result: For Ma'an district the best representative appropriate trend was 4-years MA, having the highest absolute incline value with a decreasing trend (i.e. -2.363), where the negative sign signify that the precipitation data are decreasing by 2.363 mm per year.

4.7.2 Summary of Ma'an District's Quality Tests

Table 29: Results of quality Tests of ma'an district's precipitation data

Test	Tests' results
Normality	Statistical hypothesis = 0.102>0.05. Thus, Ma'an's precipitation data was represented as normally distribution.
Homogeneity	Based on t and F tests, Ma'an district's precipitation data is not homogeneous with any other district in the kingdom.
Consistency	Precipitation data of Ma'an district was considered to be consistent, based on DMC carried out among 7 representative stations.

Trend	Trend exists in Ma'an district's precipitation data based on Mann Kendall and Sen's slope trend tests.
Stationary	Ma'an precipitation data is not stationary and has a unit root built on Augmented Dickey-Fuller test.

4.7.3 Forecasted Ma'an District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The best model was winter model which will be used to compute the predicted Precipitation data for the upcoming 10 years. The actual value for the 2016-17 in Ma'an was 42 mm and the forecasted value for this model was 67 mm.

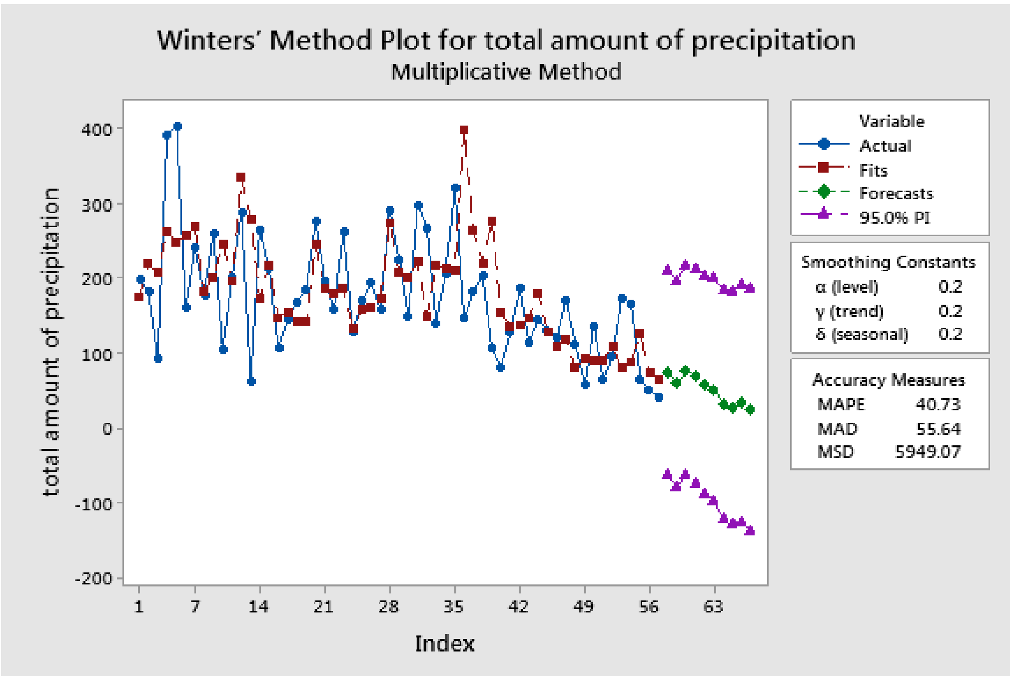

Figure 85: Ma'an forecasted 10 years precipitation data set built on winter's model

Table 30: Forecasted yearly Precipitation data for Ma'an district built on winter's model

Hydrologic Year	Forecasted Yearly Precipitation (mm)
2017-18	75
2018-19	59
2019-20	77
2020-21	69
2021-22	58
2022-23	51
2023-24	32
2024-25	28
2025-26	34
2026-27	24

4.7.4 Analysis of monthly Precipitation data of Ma'an district and its trends built on the Hydrological years from 1960-61 to 2016-17

October

The figure implies the trend for October built on 10-year MA, a slightly increasing slope for the whole study period. For the monthly spells, the month of October considered as a dry month within the study period with a 35 dry month (61%) out of 57.

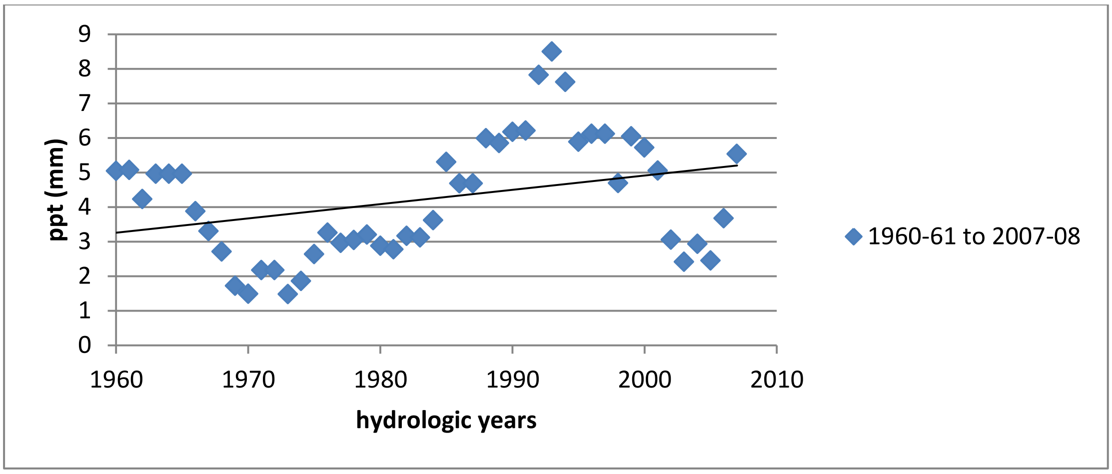

Figure 86: Ma'an district's 10 years MA monthly precipitation data set for the month of October for the water years 1960-61 to 2016-17

November

The figure implies the trend for November built on 10-year MA, a declining slope for the whole study period. For the monthly spells, the month of November considered as a dry month within the study period with a 40 dry month (70%) out of 57.

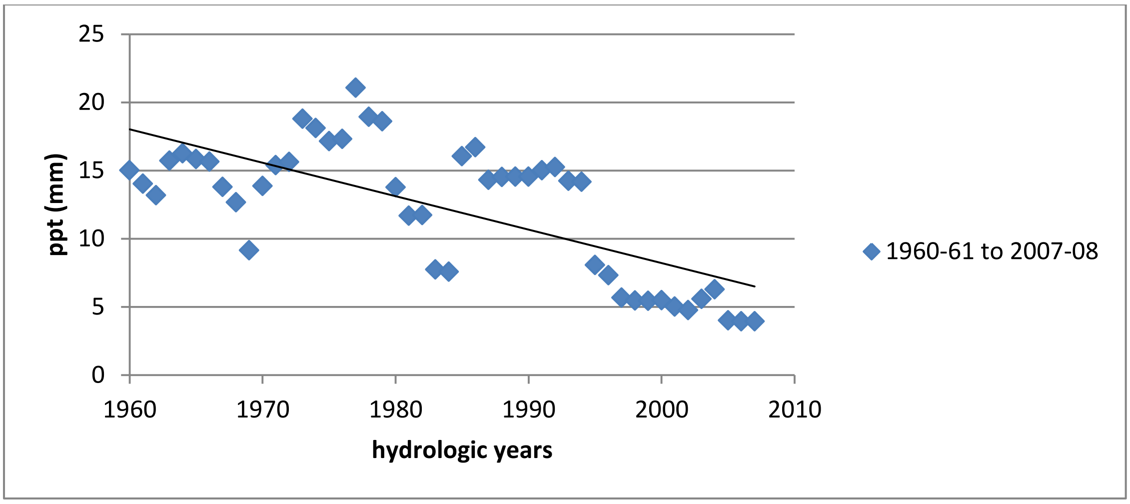

Figure 87: Ma'an district's 10 years MA monthly precipitation data set for the month of November for the water years 1960-61 to 2016-17

December

The figure implies the trend for December built on 10-year MA, a declining slope for the whole study period. For the monthly spells, the month of December considered as a dry month within the study period with a 38 dry month (67%) out of 57.

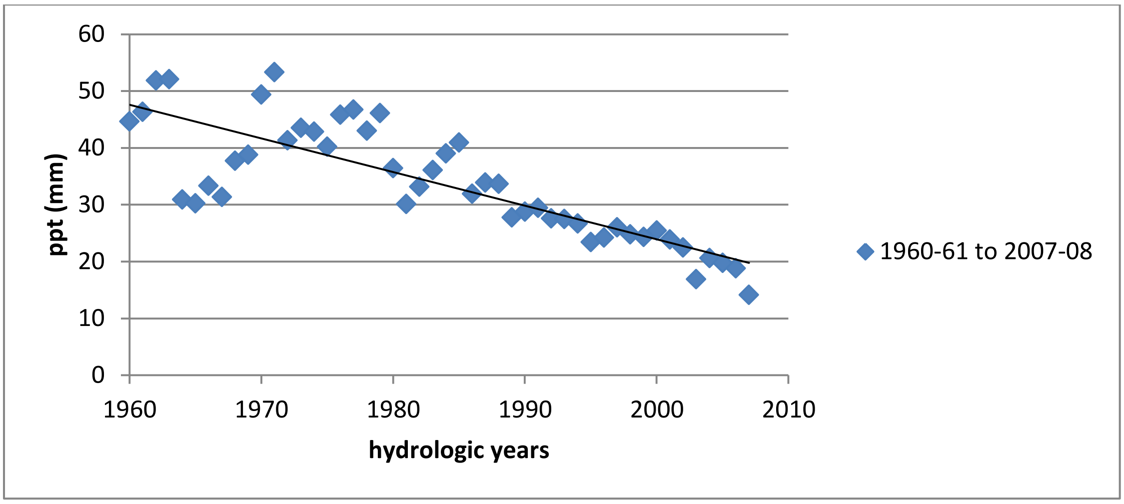

Figure 88: Ma'an district's 10 years MA monthly precipitation data set for the month of December for the water years 1960-61 to 2016-17

January

The figure implies 3 different trends built on 10-year MA, a declining slope for the initial 17 years, an increasing slope for the next 12 years, and then a downward slope for 19 years in the end. For the monthly spells, the month of January considered as a dry month within the study period with a 34 dry month (60%) out of 57.

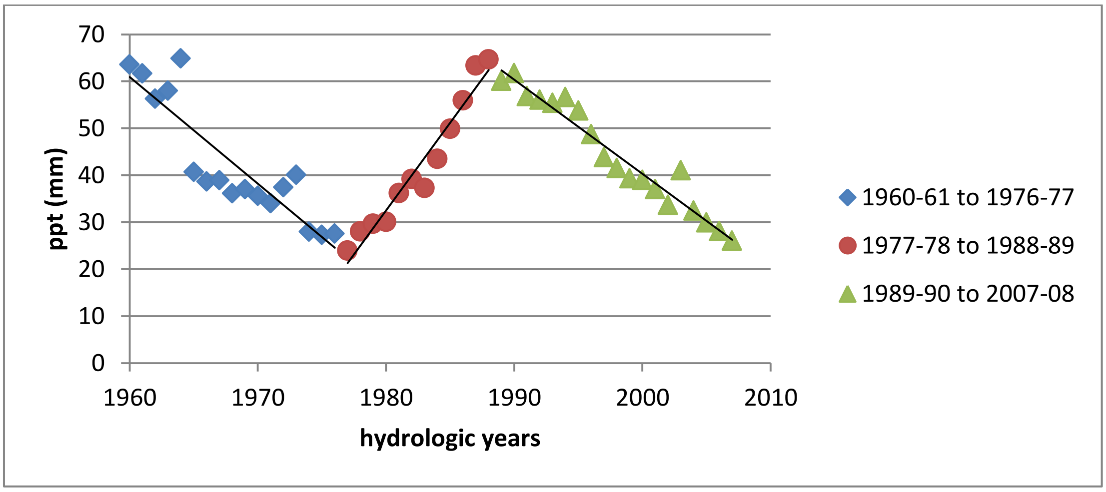

Figure 89: Ma'an district's 10 years MA monthly precipitation data set for the month of January for the water years 1960-61 to 2016-17

February

The figure implies 4 different trends built on 10-year MA, an increasing slope for the initial 23 years, then a declining slope for the next 10 years, an increasing trend for the next 10 years and a downward slope for 4 years in the end. For the monthly spells, the month of February considered as a dry month within the study period with a 32 dry month (56%) out of 57.

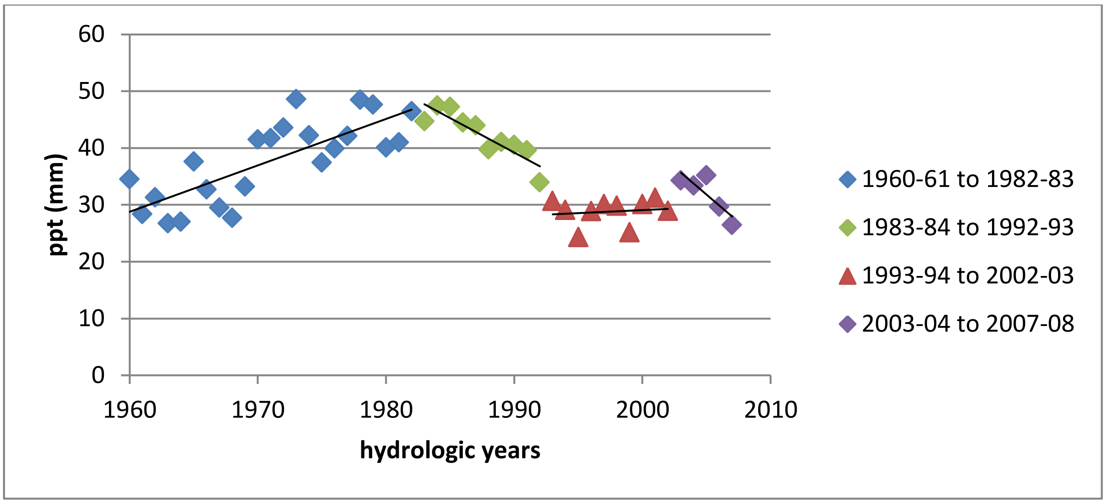

Figure 90: Ma'an district's 10 years MA monthly precipitation data set for the month of February for the water years 1960-61 to 2016-17

March

The figure implies 3 different trends built on 10-year MA, a declining slope for the initial 13 years, an increasing slope for the next 11 years, and then a downward slope for 24 years in the end. For the monthly spells, the month of January considered as a dry month within the study period with a 36 dry month (63%) out of 57.

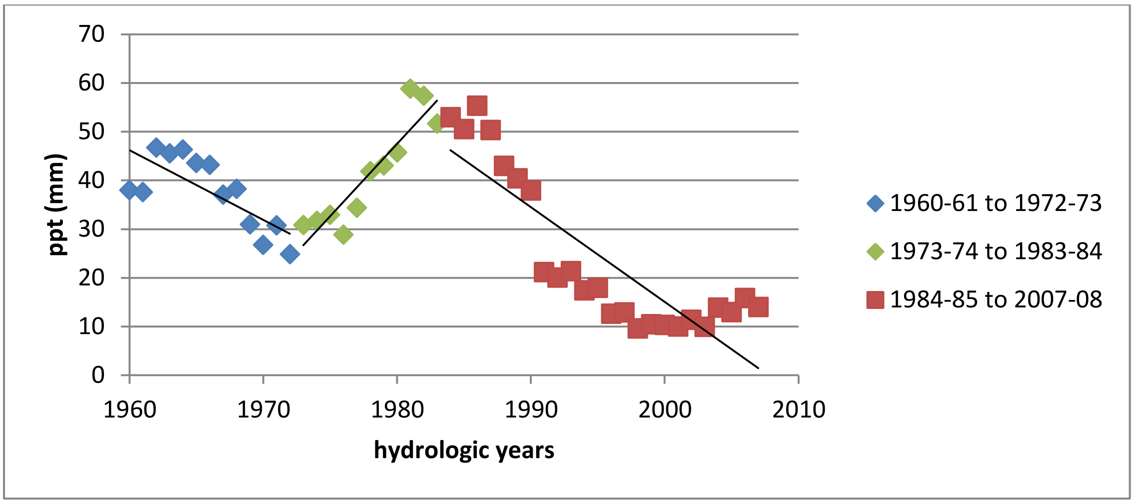

Figure 91: Ma'an district's 10 years MA monthly precipitation data set for March month for the water years 1960-61 to 2016-17

April

The figure implies the trend for April built on 10-year MA, a declining slope for the whole study period. For the monthly spells, the month of April considered as a dry month within the study period with a 37 dry month (65%) out of 57.

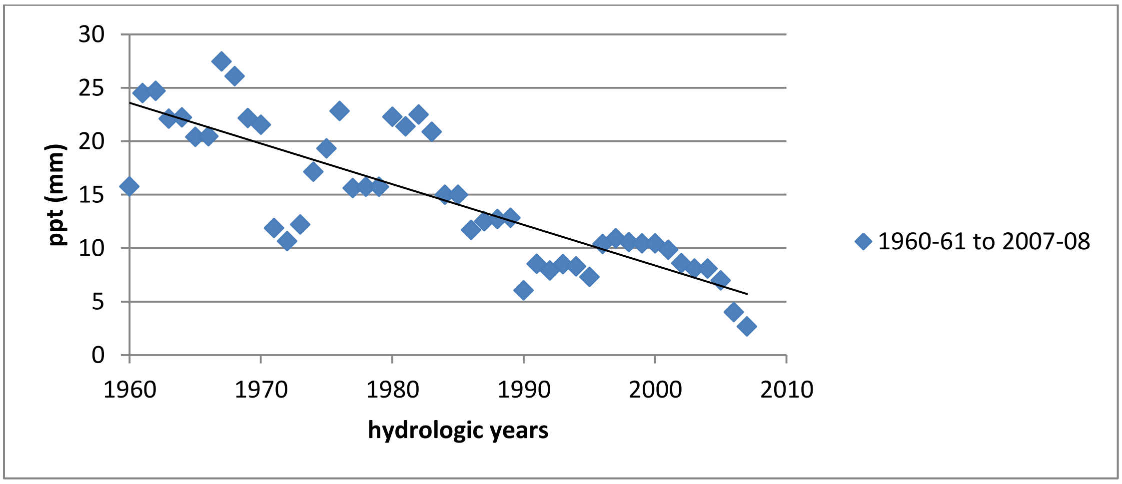

Figure 92: Ma'an district's 10 years MA monthly precipitation data set for the month of April for the water years 1960-61 to 2016-17

May

The figure implies the trend for May built on 10-year MA, a mild declining slope for the whole study period. For the monthly spells, the month of May considered as a dry month within the study period with a 43 dry month (75%) out of 57.

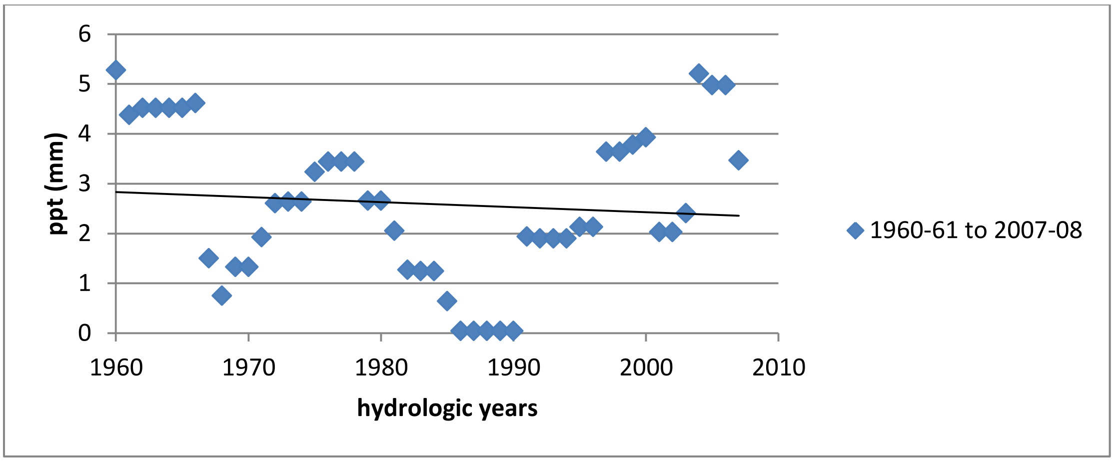

Figure 93: Ma'an district's 10 years MA monthly precipitation data set for May month for the water years 1960-61 to 2016-17

4.8 Meteorological District: Karak

Table 31: Monthly precipitation data with the statistical measures of Karak district for hydrological years started in 1960-61 until 2016-17 in (mm)

Year\month	October	November	December	January	February	March	April	May	TOTAL
1960-61	0	21	17	97	130	16	11	4	296
1961-62	4	23	101	36	40	0	18	0	221
1962-63	0	0	6	5	85	14	9	3	123
1963-64	7	18	262	65	83	36	12	0	483
1964-65	0	48	65	390	16	66	39	0	624
1965-66	72	22	27	25	48	76	0	0	270
1966-67	19	14	90	76	53	107	3	12	374
1967-68	4	63	30	122	49	11	27	5	312
1968-69	20	39	65	50	3	112	23	0	312
1969-70	5	24	14	55	11	100	13	0	221

Year\month	October	November	December	January	February	March	April	May	TOTAL
1970-71	0	15	48	35	15	18	213	0	344
1971-72	0	24	217	24	65	107	15	7	458
1972-73	2	36	19	92	4	13	2	0	168
1973-74	1	26	21	264	83	25	30	0	449
1974-75	0	20	77	23	160	32	1	0	313
1975-76	0	23	38	16	43	48	13	0	181
1976-77	4	12	9	89	19	13	75	0	220
1977-78	1	16	92	52	22	56	5	0	244
1978-79	0	0	46	96	28	60	12	9	251
1979-80	5	71	150	87	95	64	10	0	483
1980-81	4	1	152	16	56	59	14	0	301
1981-82	0	40	51	50	74	42	8	6	272
1982-83	0	70	48	141	101	57	5	1	422
1983-84	1	5	6	49	14	82	0	0	155
1984-85	19	13	26	3	172	41	36	3	314
1985-86	2	5	71	28	48	6	24	8	192
1986-87	2	90	33	17	40	80	0	0	262
1987-88	10	1	94	114	137	84	10	0	449
1988-89	2	1	91	72	92	74	0	0	331
1989-90	0	5	19	78	45	39	81	0	267
1990-91	3	3	7	127	43	262	1	1	447
1991-92	10	24	123	112	153	26	1	5	454
1992-93	0	57	89	40	64	18	0	18	287
1993-94	4	39	29	121	64	34	11	0	303
1994-95	16	115	109	12	71	5	4	0	332
1995-96	0	12	13	64	19	84	2	0	195
1996-97	7	6	23	89	84	48	5	0	262
1997-98	11	3	62	82	63	47	20	0	287
1998-99	13	7	1	40	76	13	21	0	173
1999-00	6	3	2	67	20	47	23	0	168
2000-01	11	1	85	73	57	11	18	40	296
2001-02	1	32	45	133	42	45	20	7	324
2002-03	8	14	145	44	33	61	16	0	321
2003-04	0	6	49	100	54	18	5	1	233
2004-05	25	109	67	85	63	28	0	0	377
2005-06	1	17	24	20	99	2	96	0	259
2006-07	8	12	51	77	86	59	14	3	310
2007-08	0	3	8	89	58	29	6	2	194
2008-09	26	3	5	32	102	52	0	0	221

Year\month	October	November	December	January	February	March	April	May	TOTAL
2009-10	3	11	32	71	191	13	0	0	321
2010-11	0	0	17	66	95	8	26	5	218
2011-12	0	18	16	90	100	56	43	0	322
2012-13	1	25	18	163	30	20	11	5	274
2013-14	0	4	139	28	6	127	10	33	348
2014-15	7	44	20	93	103	6	60	0	333
2015-16	22	14	7	157	69	52	50	1	371
2016-17	18	31	97	72	109	13	1	0	341
Average	6.8	23.8	57.3	77.5	66.4	47.7	20.6	3.1	303.2
Standard Error	1.50	3.5	7.2	8.3	5.7	5.6	4.4	0.97	12.9
Median	2.85	16.2	44.9	71.8	62.9	42.5	11.2	0	301.3
Standard Deviation	11.3	26.2	54.3	62.8	43.2	42.6	33.2	7.35	97.4
Sample Variance	128	685.7	2944	3950	1865	1816	1103	54.06	9481
Kurtosis	19.2	3.5	3.2	10.9	0.6	10.3	20.2	15.17	0.989
Skewness	3.78	1.9	1.6	2.7	0.8	2.5	4.0	3.73	0.761
Range	72	114.8	260	386.5	187.8	262	212.9	39.79	500
Minimum	0	0	2	3.4	3.0	0	0	0	123
Maximum	72	114.8	262	389.9	190.8	262	212.9	39.79	623

4.8.1 Trend of Karak District's Precipitation Data

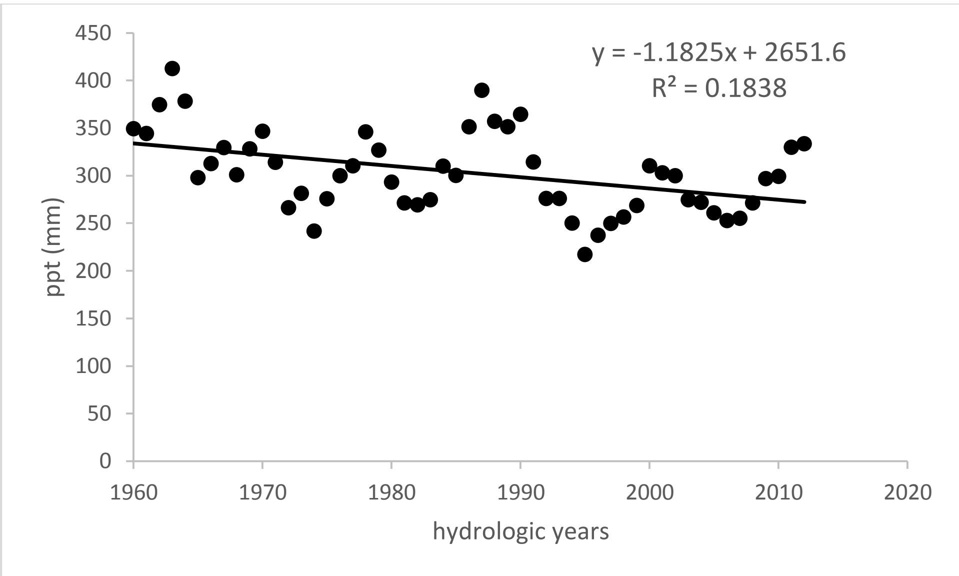

Figure 94: 5-years MA of Karak district's yearly precipitation data

Result: For Karak district the best representative appropriate trend was 3-years MA, having the highest absolute incline value with a decreasing trend (i.e. -1.18 mm per year).

4.8.2 Summary of Karak District's Quality Tests

Table 32: Results of quality Tests of Karak district's precipitation data

Test	Tests' results
Normality	Statistical hypothesis = 0.759 > 0.05. Thus, Karak's precipitation data was represented as normally distribution.
Homogeneity	Based on t and F tests, Karak district's precipitation data is homogeneous with Jarash district's precipitation data sets.
Consistency	Precipitation data of Karak district was considered to be consistent, based on DMC carried out among 8 representative stations.
Trend	Trend was not existed in Karak district's precipitation data based on Mann Kendall and Sen's slope trend tests.
Stationary	Karak district's precipitation data was considered stationary by Augmented Dickey-Fuller test.

4.8.3 Forecasted Karak District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The best model was winter model which will be used to compute the predicted Precipitation data for the upcoming 10 years. The actual value for the 2016-17 in Karak was 341 mm and the forecasted value for this model was 338 mm.

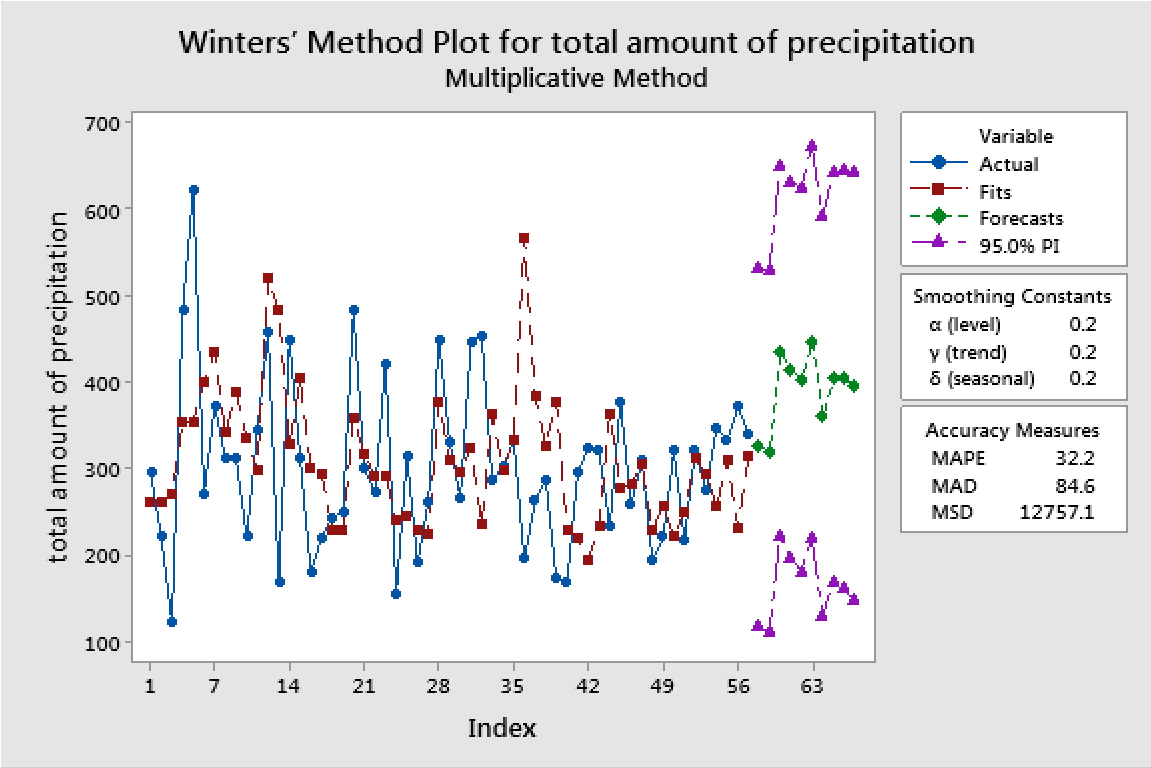

Figure 95: Karak forecasted 10 years precipitation data set built on winter's model

Table 33: Forecasted yearly Precipitation data for Karak district built on winter's model

Hydrologic Year	**Forecasted Yearly Precipitation (mm)**
2017-18	325
2018-19	320
2019-20	436
2020-21	414
2021-22	403
2022-23	447
2023-24	360
2024-25	406
2025-26	404
2026-27	395

4.8.4 Analysis of monthly Precipitation data of Karak district and its trends built on the Hydrological years from 1960-61 to 2016-17

October

The figure implies the trend for October built on 10-year MA, a slightly increasing slope for the whole study period. For the monthly spells, the month of October considered as a dry month within the study period with a 39 dry month (68%) out of 57.

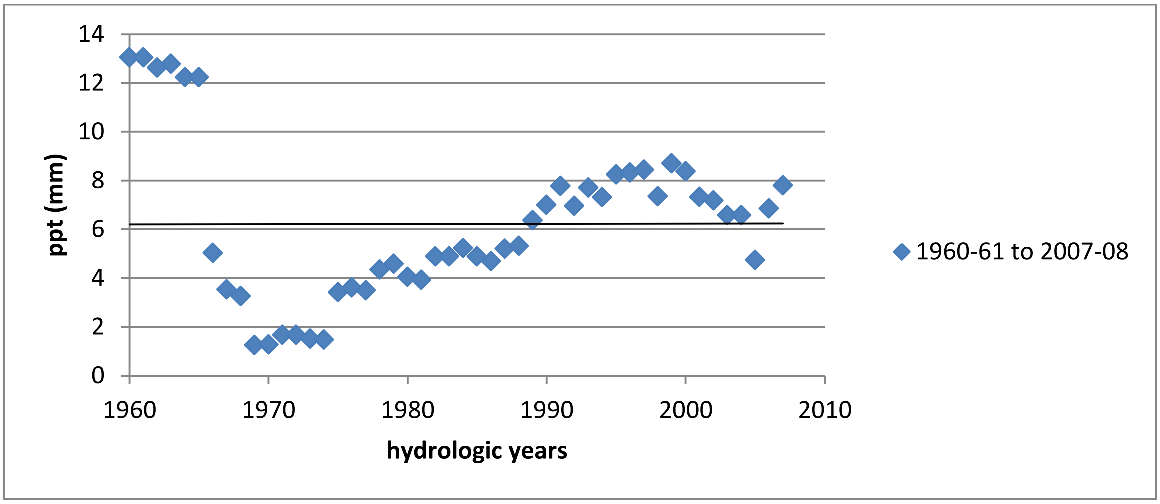

Figure 96: Karak district's 10 years MA monthly precipitation data set for the month of October for the water years 1960-61 to 2016-17

November

The figure implies the trend for November built on 10-year MA, a declining slope for the whole study period. For the monthly spells, the month of November considered as a dry month within the study period with a 38 dry month (67%) out of 57.

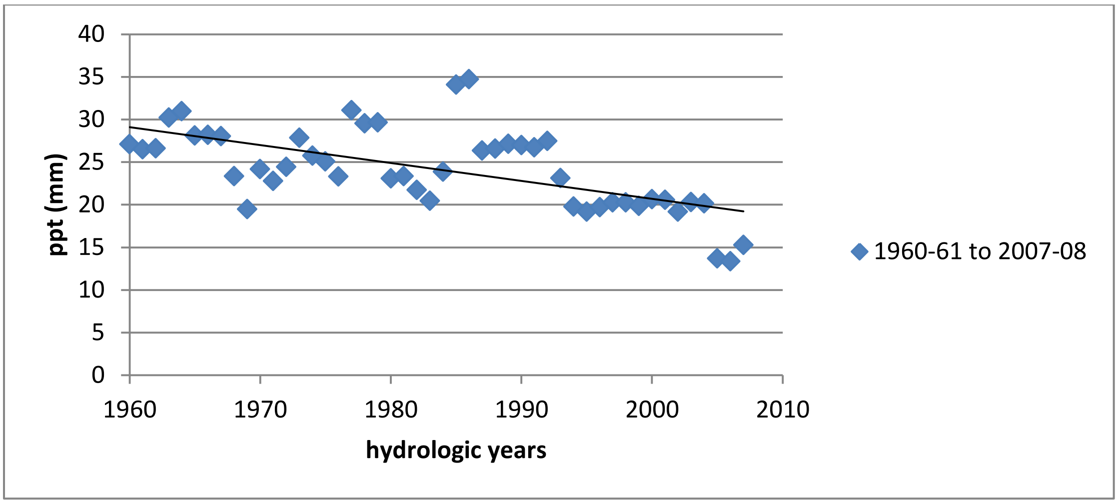

Figure 97: Karak district's 10 years MA monthly precipitation data set for the month of November for the water years 1960-61 to 2016-17

December

The figure implies the trend for December built on 10-year MA, a declining 2 dissimilar slopes for the whole study period. For the monthly spells, the month of December considered as a dry month within the study period with a 35 dry month (61%) out of 57.

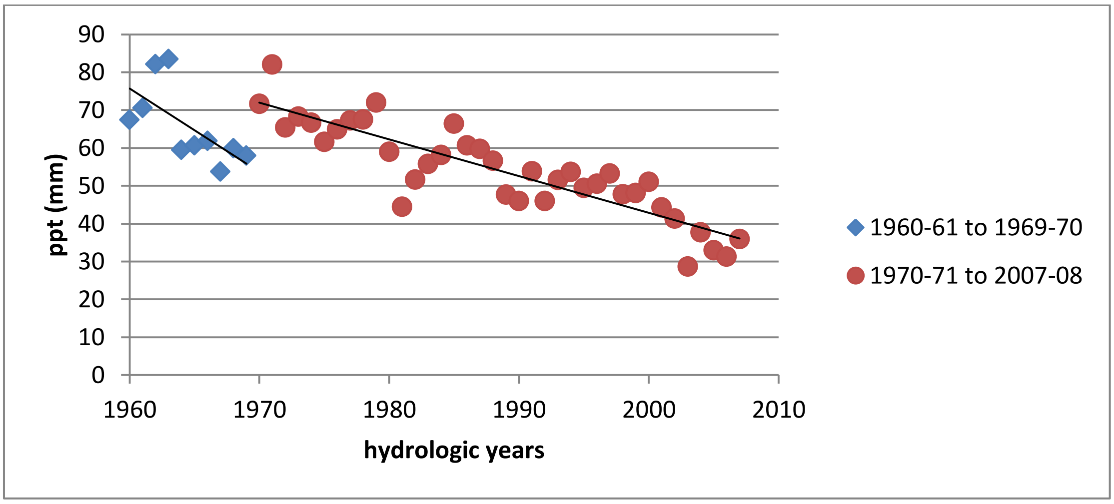

Figure 98: Karak district's 10 years MA monthly precipitation data set for the month of December for the water years 1960-61 to 2016-17

January

The figure implies 2 different trends built on 10-year MA, a declining slope for the initial 14 years, and an increasing slope for the next 34 years. For the monthly spells, the month of January considered as a dry month within the study period with a 33 dry month (58%) out of 57.

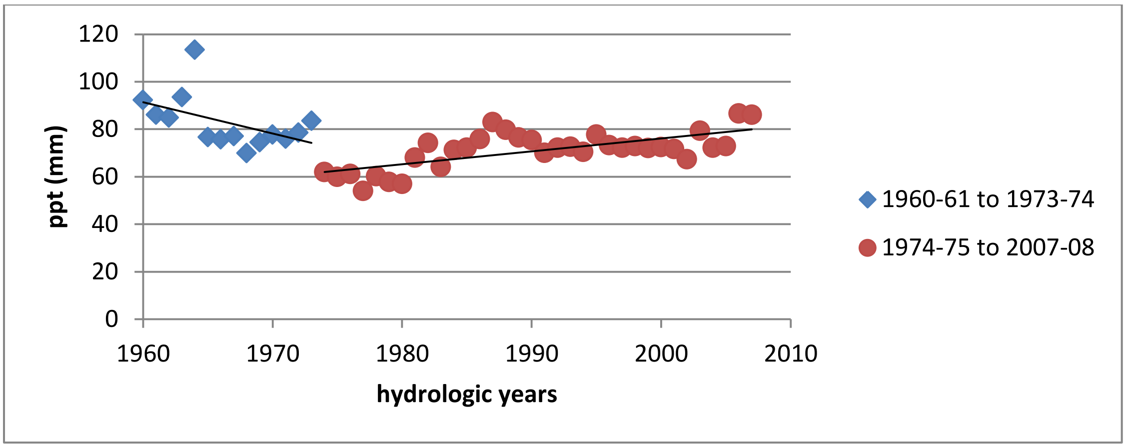

Figure 99: Karak district's 10 years MA monthly precipitation data set for the month of January for the water years 1960-61 to 2016-17

February

The figure implies 3 different trends built on 10-year MA, an increasing slope for the initial 22 years, a declining slope for the next 13 years, then an upward slope for 12 years in the end. For the monthly spells, the month of February considered as a dry month within the study period with a 33 dry month (58%) out of 57.

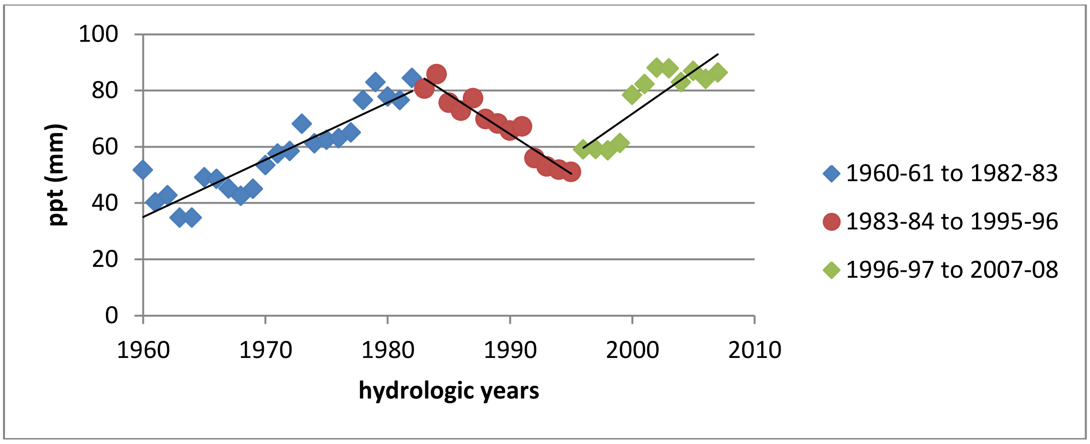

Figure 100: Karak district's 10 years MA monthly precipitation data set for the month of February for the water years 1960-61 to 2016-17

March

The figure implies 3 different trends built on 10-year MA, a declining slope for the initial 21 years, another dissimilar decline trend for the next 10 years, and then an upward slope for 17 years in the end. For the monthly spells, the month of January considered as a dry month within the study period with a 32 dry month (56%) out of 57.

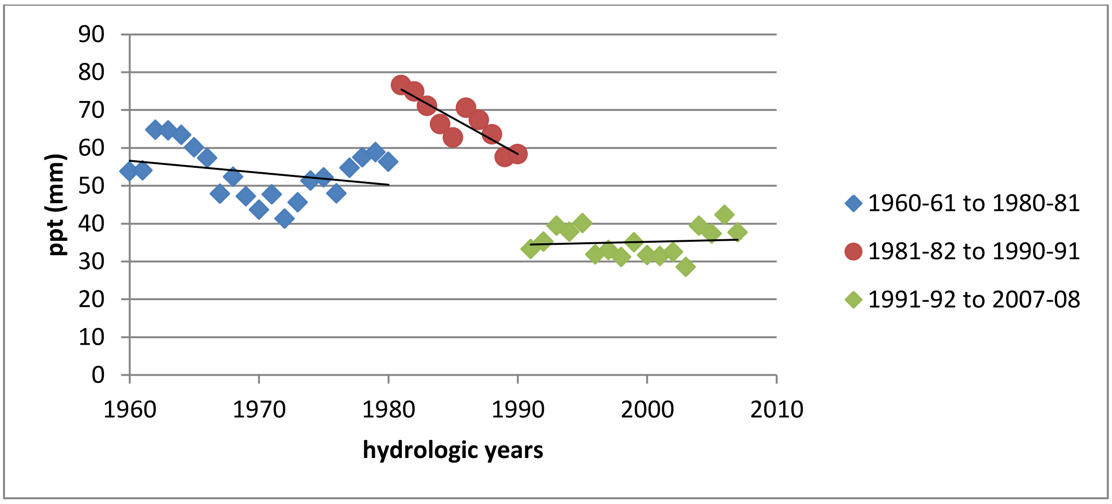

Figure 101: Karak district's 10 years MA monthly precipitation data set for the month of March for the water years 1960-61 to 2016-17

April

The figure implies the trend for April built on 10-year MA, a declining slope for the initial 30 years, then an increasing 18 years in the end. For the monthly spells, the month of April considered as a dry month within the study period with a 41 dry month (72%) out of 57.

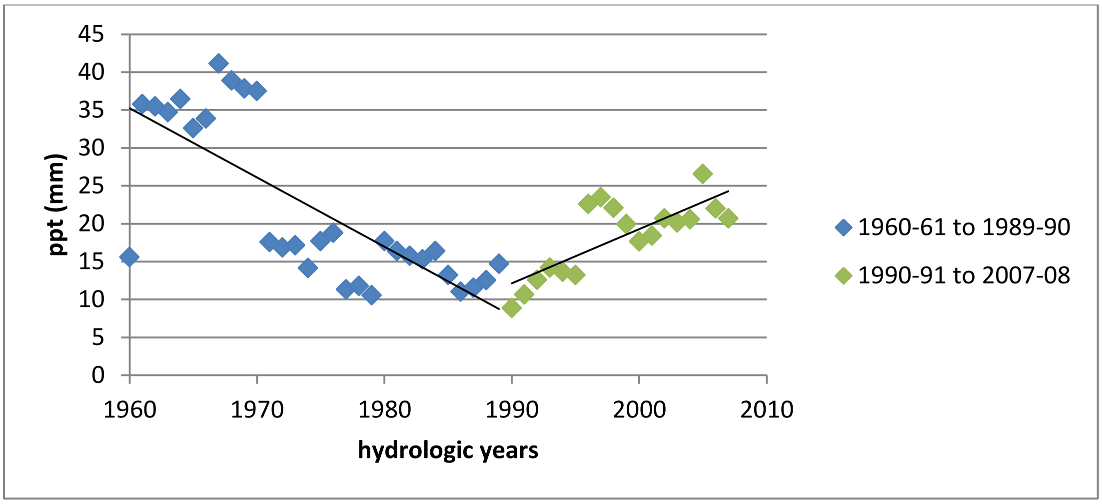

Figure 102: Karak district's 10 years MA monthly precipitation data set for the month of April for the water years 1960-61 to 2016-17

May

The figure implies the trend for May built on 10-year MA, a mild increasing slope for the whole study period. For the monthly spells, the month of May considered as a dry month within the study period with a 41 dry month (72%) out of 57.

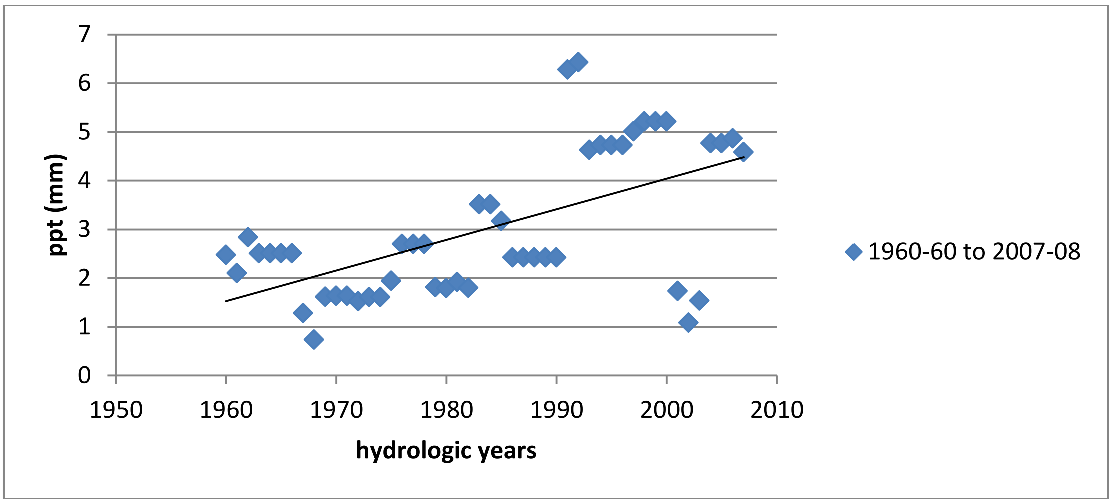

Figure 103: Karak district's 10 years MA monthly precipitation data set for the month of May for the water years 1960-61 to 2016-17

4.9 Meteorological District: Jarash

Table 34: Monthly precipitation data with the statistical measures of Jarash district for hydrological years started in 1960-61 until 2016-17 in (mm)

Year\month	October	November	December	January	February	March	April	May	TOTAL
1960-61	0	42	18	76	62	12	12	2	224
1961-62	4	1	72	58	47	0	16	0	199
1962-63	0	0	19	15	90	22	33	2	179
1963-64	20	16	58	60	99	58	9	0	321
1964-65	0	40	69	128	20	29	19	0	305
1965-66	8	6	28	34	36	72	0	0	183
1966-67	36	23	112	85	22	129	0	48	455
1967-68	7	28	35	70	28	12	8	0	187
1968-69	1	11	89	99	10	103	8	0	320
1969-70	10	12	16	52	25	76	16	0	205
1970-71	0	7	42	31	30	28	119	0	257
1971-72	0	28	81	24	58	26	17	0	235
1972-73	0	16	0	44	36	41	6	0	142
1973-74	0	52	19	163	51	27	25	0	336
1974-75	0	20	19	17	131	24	10	0	219
1975-76	0	6	38	20	67	89	12	0	232
1976-77	7	45	1	60	21	48	45	0	227
1977-78	19	9	73	20	39	59	9	0	227
1978-79	15	0	61	39	30	50	5	0	201

Year\month	October	November	December	January	February	March	April	May	TOTAL
1979-80	28	101	109	64	74	54	9	0	438
1980-81	8	3	151	51	39	15	9	0	276
1981-82	0	30	8	41	79	33	7	6	204
1982-83	10	40	14	71	94	82	2	0	311
1983-84	0	9	26	85	45	122	9	0	295
1984-85	16	8	36	19	156	15	3	2	257
1985-86	6	6	18	28	56	6	7	21	148
1986-87	13	124	34	115	27	30	0	0	342
1987-88	25	4	87	52	120	35	6	0	328
1988-89	4	12	160	39	21	32	0	0	269
1989-90	0	38	38	71	31	46	14	0	237
1990-91	2	14	0	65	46	53	10	0	190
1991-92	1	32	130	101	143	17	0	4	428
1992-93	0	9	72	47	23	13	0	6	170
1993-94	6	11	9	72	27	56	0	0	182
1994-95	9	120	71	7	56	23	6	0	292
1995-96	2	26	26	66	7	81	5	0	211
1996-97	13	7	25	77	96	53	2	4	277
1997-98	9	20	53	104	29	85	5	0	304
1998-99	0	0	8	44	50	14	5	0	120
1999-00	0	0	12	166	36	31	0	0	244
2000-01	17	6	112	66	48	6	3	4	260
2001-02	3	23	85	133	30	75	34	2	385
2002-03	4	19	204	41	203	100	6	0	577
2003-04	8	21	97	116	64	11	10	0	327
2004-05	8	81	28	100	153	21	6	9	405
2005-06	4	34	81	86	112	15	52	0	382
2006-07	33	9	50	62	103	81	14	5	356
2007-08	1	48	26	41	140	3	0	0	258
2008-09	6	7	51	12	186	33	3	0	297
2009-10	18	45	76	58	119	26	0	3	345
2010-11	0	0	50	75	102	25	17	6	274
2011-12	0	47	16	94	116	108	1	0	382
2012-13	0	35	74	245	40	3	17	5	419
2013-14	5	2	135	0	4	40	0	14	200
2014-15	9	27	38	22	98	35	18	0	247
2015-16	6	38	32	110	46	91	35	3	361
2016-17	10	21	61	67	74	39	16	0	288
average	7	25	55	67	66	44	12	3	279
Standard Error	1.15	3.60	5.84	5.84	6.21	4.28	2.41	0.95	11.8

Year\month	October	November	December	January	February	March	April	May	TOTAL
Median	5.00	19.30	41.60	61.95	50	33.3	7.90	0.00	269
Standard Deviation	8.65	27.19	44.11	44.07	46.9	32.3	18.2	7.16	89.1
Sample Variance	74.8	739	1945	1942	2195	1046	331	51.24	7946
Kurtosis	2.35	4.9	1.39	3.86	0.43	-0.08	20.9	30.18	0.96
Skewness	1.58	2.1	1.18	1.49	1.02	0.85	4.01	5.11	0.8
Range	36	124	204	245	199	129	119	48	457
Minimum	0	0	0	0	4	0	0	0	120
Maximum	36	124	204	245	203	129	119	48	577

4.9.1 Trend of Jarash District's Precipitation Data

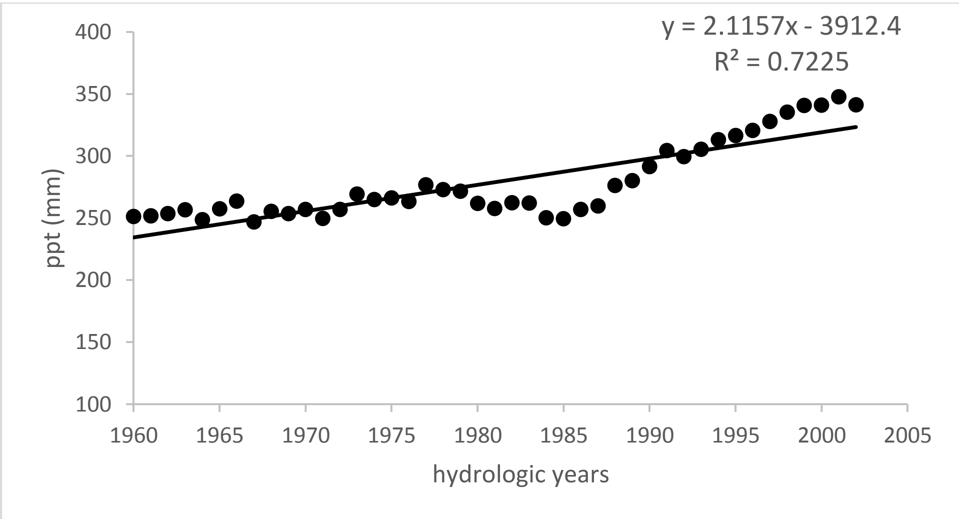

Figure 104: 15-years MA of Jarash district's yearly precipitation data

Result: For Jarash district the best representative appropriate trend was 15-years MA, having the highest absolute incline value with an increasing trend (i.e. 2.116 mm per year), where the Positive sign signify that the precipitation data are increasing by 2.116 mm per year.

4.9.2 Summary of Jarash District's Quality Tests

Table 35: Results of quality Tests of Jarash district's precipitation data

Test	Tests' results
Normality	Statistical hypothesis = 0.211 Thus, Jarash's precipitation data was represented as normally distribution.
Homogeneity	Based on t and F tests, Jarash district's precipitation data is homogeneous with Karak and Madaba districts' precipitation data sets.
Consistency	Precipitation data of Jarash district was considered to be consistent, based on DMC carried out among 2 representative stations.
Trend	Trend exists in Jarash district's precipitation data based on Mann Kendall and Sen's slope trend tests.
Stationary	Jarash precipitation data is not stationary and has a unit root built on Augmented Dickey-Fuller test.

4.9.3 Forecasted Jarash District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The best model was winter model which will be used to compute the predicted Precipitation data for the upcoming 10 years. The actual value for the 2016-17 in Jarash was 288 mm and the forecasted value for this model was 284 mm.

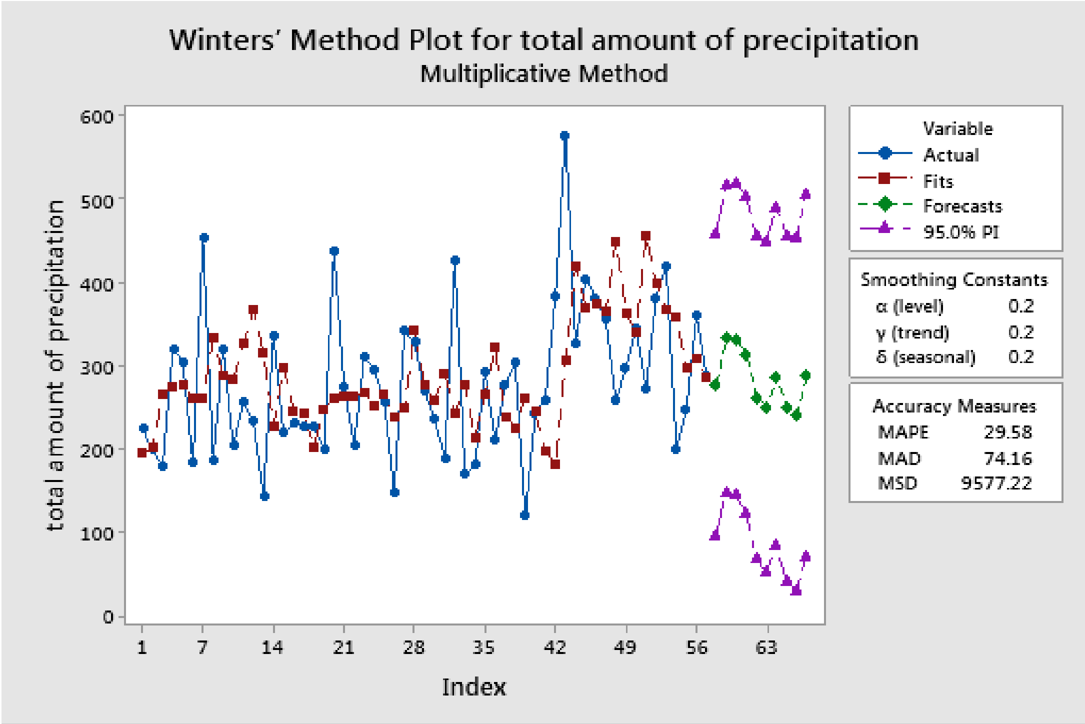

Figure 105: Jarash forecasted 10 years precipitation data set built on winter's model

Table 36: Forecasted yearly Precipitation data for Jarash district built on winter's model

Hydrologic Year	Forecasted Yearly Precipitation (mm)
2017-18	278
2018-19	333
2019-20	332
2020-21	314
2021-22	262
2022-23	251
2023-24	287
2024-25	250
2025-26	242
2026-27	289

4.9.4 Analysis of monthly Precipitation data of Jarash district and its trends built on the Hydrological years from 1960-61 to 2016-17

October

The figure implies the trend for October built on 10-year MA, a slightly declining slope for the whole study period. For the monthly spells, the month of October considered as a dry month within the study period with a 35 dry month (61%) out of 57.

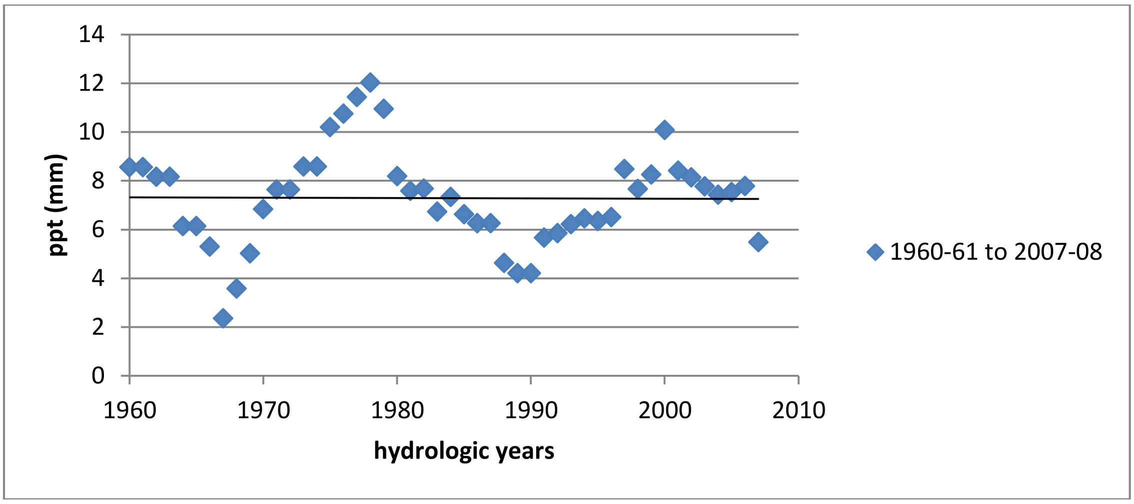

Figure 106: Jarash district's 10 years MA monthly precipitation data set for the month of October for the water years 1960-61 to 2016-17

November

The figure implies 3 different trends built on 10-year MA, an increasing slope for the initial 26 years, then a declining slope for the next 9 years, then an upward slope for 13 years in the end. For the monthly spells, the month of November considered as a dry month within the study period with a 35 dry month (61%) out of 57.

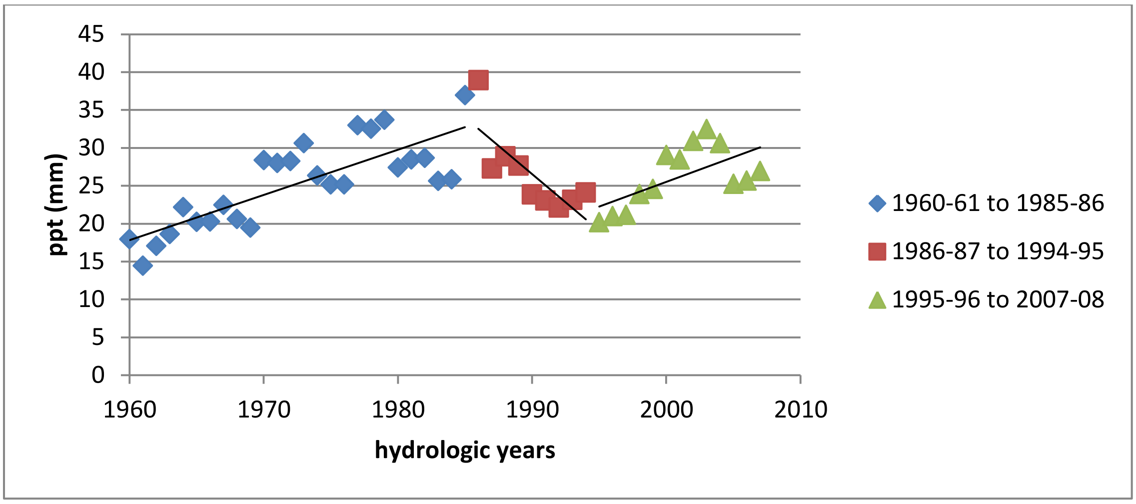

Figure 107: Jarash district's 10 years MA monthly precipitation data set for the month of November for the water years 1960-61 to 2016-17

December

The figure implies the trend for December built on 10-year MA, a declining slope for the initial 10 years, then an increasing slope for the next 19 years, an aggregate slope for the next 12 years, at last declining 7 years slope. For the monthly spells, the month of December considered as a dry month within the study period with a 33 dry month (58%) out of 57.

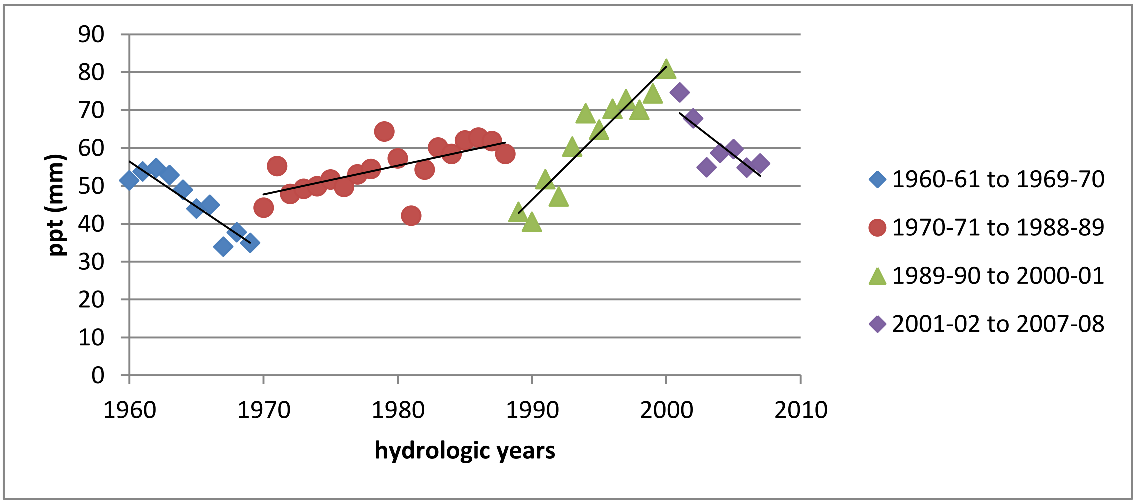

Figure 108: Jarash district's 10 years MA monthly precipitation data set for the month of December for the water years 1960-61 to 2016-17

January

The figure implies 3 different trends built on 10-year MA, a declining slope for the initial 14 years, an increasing slope for the next 23 years, and then a declining slope for the last 11 years. For the monthly spells, the month of January considered as a dry month within the study period with a 33 dry month (58%) out of 57.

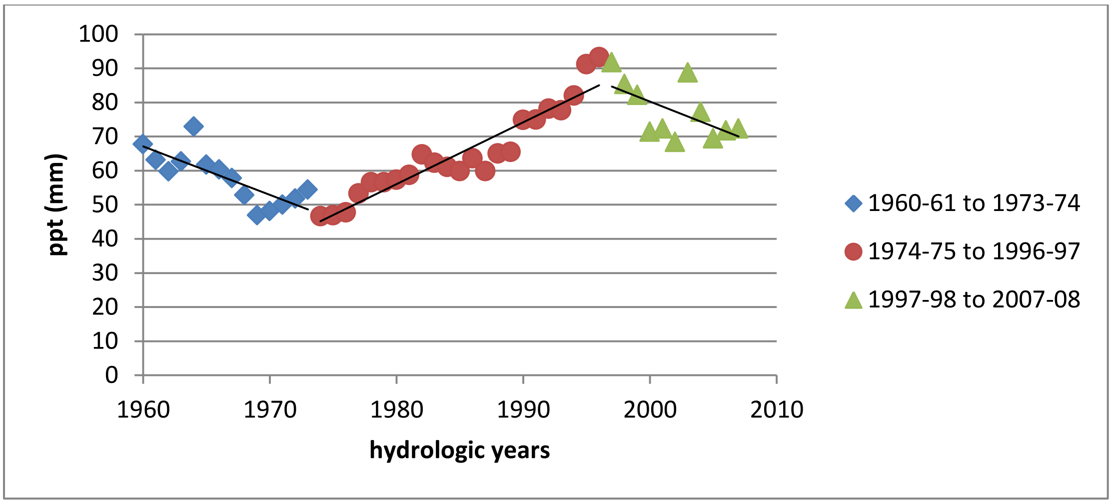

Figure 109: Jarash district's 10 years MA monthly precipitation data set for the month of January for the water years 1960-61 to 2016-17

February

The figure implies 4 different trends built on 10-year MA, an increasing slope for the initial 23 years, then a declining slope for the next 10 years, then an upward slope for 10 years, in the end a declining 5 years trend. For the monthly spells, the month of February considered as a dry month within the study period with a 35 dry month (61%) out of 57.

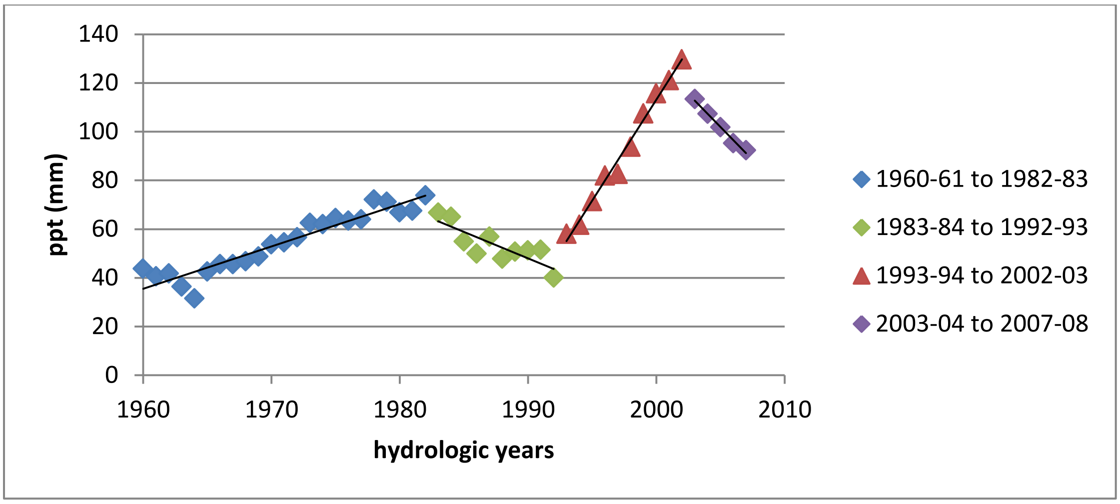

Figure 110: Jarash district's 10 years MA monthly precipitation data set for the month of February for the water years 1960-61 to 2016-17

March

The figure implies the trend for March built on 10-year MA, a declining slope for whole study area. For the monthly spells, the month of March considered as a dry month within the study period with a 34 dry month (60%) out of 57.

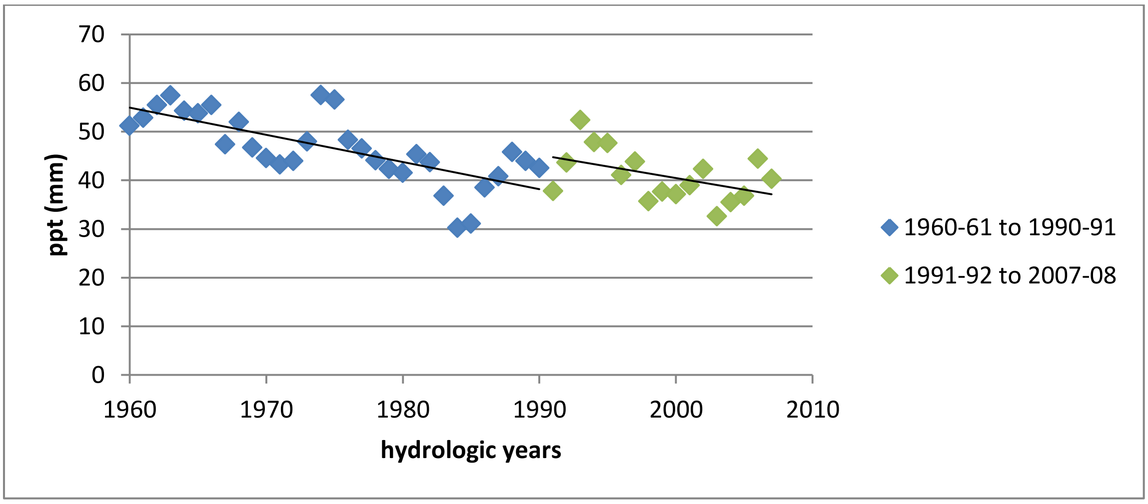

Figure 111: Jarash district's 10 years MA monthly precipitation data set for the month of March for the water years 1960-61 to 2016-17

April

The figure implies the trend for April built on 10-year MA, a declining slope for the initial 32 years, then an increasing 16 years in the end. For the monthly spells, the month of April considered as a dry month within the study period with a 40 dry month (70%) out of 57.

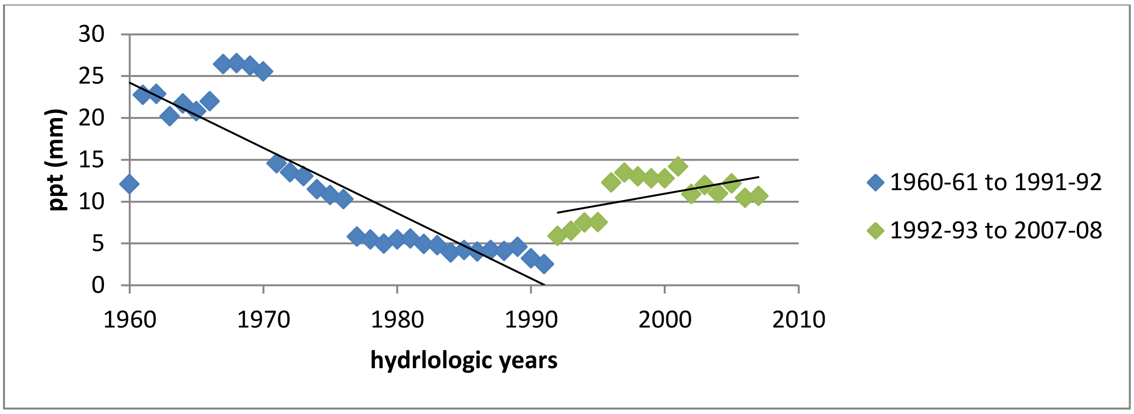

Figure 112: Jarash district's 10 years MA monthly precipitation data set for the month of April for the water years 1960-61 to 2016-17

May

The figure implies the trend for May built on 10-year MA, a mild declining slope for the whole study period. For the monthly spells, the month of May considered as a dry month within the study period with a 43 dry month (75%) out of 57.

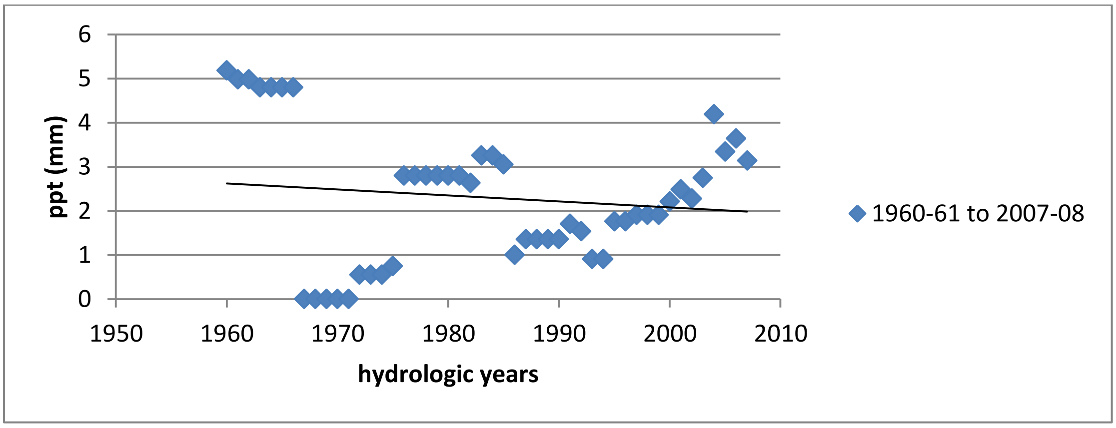

Figure 113: Jarash district's 10 years MA monthly precipitation data set for the month of May for the water years 1960-61 to 2016-17

4.10 Meteorological District: Irbid

Table 37: Monthly precipitation data with the statistical measures of Irbid district for hydrological years started in 1960-61 until 2016-17 in (mm)

Year\month	October	November	December	January	February	March	April	May	TOTAL
1960-61	0	73	51	73	105	29	30	6	366
1961-62	4	32	236	80	76	3	13	7	450
1962-63	7	1	59	50	92	54	24	24	310
1963-64	31	33	98	76	127	85	5	12	467
1964-65	0	94	55	133	54	38	38	3	415
1965-66	54	11	53	44	56	99	3	0	321
1966-67	23	18	166	131	69	149	3	13	573
1967-68	12	58	62	180	37	19	21	9	398
1968-69	11	27	134	133	32	112	18	2	470
1969-70	26	33	22	122	34	121	24	0	383
1970-71	5	10	63	67	121	43	151	0	460
1971-72	0	26	123	68	96	46	30	2	391
1972-73	3	18	18	101	23	67	3	6	240
1973-74	8	69	46	216	84	41	38	0	502
1974-75	0	22	45	33	124	63	8	0	295
1975-76	0	36	75	49	92	63	26	4	346
1976-77	16	59	25	75	24	67	61	0	327
1977-78	16	2	108	46	37	78	11	0	298
1978-79	22	11	49	42	22	55	9	0	209
1979-80	29	88	182	104	83	116	20	1	623
1980-81	12	8	120	101	63	45	22	0	370
1981-82	0	43	18	45	88	60	7	14	274
1982-83	5	49	34	108	154	79	17	5	449
1983-84	2	39	13	78	35	106	51	0	324
1984-85	20	39	45	25	197	19	12	0	357
1985-86	11	16	29	75	95	19	19	25	288
1986-87	19	169	84	73	37	89	1	0	472
1987-88	13	7	109	109	123	93	17	0	470
1988-89	6	36	95	31	34	49	0	0	249
1989-90	8	40	45	130	56	83	26	0	387
1990-91	5	22	28	137	46	91	25	5	360
1991-92	1	65	189	160	276	27	4	7	729
1992-93	0	41	164	56	47	24	2	24	358

Year\month	October	November	December	January	February	March	April	May	TOTAL
1993-94	10	22	15	102	63	74	4	0	291
1994-95	8	138	100	18	56	28	16	0	364
1995-96	8	53	24	102	18	106	8	0	320
1996-97	23	18	38	73	170	71	13	4	411
1997-98	15	28	96	111	50	146	16	4	468
1998-99	3	0	23	59	46	27	12	0	171
1999-00	0	4	21	183	54	36	0	0	298
2000-01	22	2	70	53	59	11	1	12	230
2001-02	9	41	77	120	38	90	52	3	428
2002-03	8	27	188	38	265	170	19	0	714
2003-04	11	17	75	108	89	23	2	1	326
2004-05	31	113	23	82	152	15	7	10	433
2005-06	4	39	68	71	95	9	61	0	349
2006-07	49	13	23	56	102	55	17	5	321
2007-08	0	55	24	64	88	10	0	7	248
2008-09	10	13	49	11	165	80	17	0	344
2009-10	20	66	95	88	74	8	0	2	353
2010-11	24	0	83	60	95	68	55	16	401
2011-12	2	61	41	119	120	101	0	0	444
2012-13	8	55	90	230	24	4	41	4	455
2013-14	12	4	150	1	3	67	0	33	271
2014-15	11	23	17	105	65	75	6	0	302
2015-16	5	62	135	122	56	28	16	0	424
2016-17	12	22	51	100	29	88	12	0	314
Average	12	38	74	88	81	62	20	5	379
Standard Error	1.52	4.46	6.99	6.30	7.39	5.18	3.16	0.98	14.5
Median	8.75	31.62	59.11	77.60	65.00	62.83	15.76	1.43	359.6
Standard Deviation	11.47	33.64	52.74	47.54	55.83	39.11	23.83	7.39	109.5
Sample Variance	131.5	1132	2781	2260	3117	1529	567.9	54.6	11981
Kurtosis	3.39	4.01	0.68	0.96	3.19	-0.05	15.71	4.23	2.11
Skewness	1.63	1.74	1.10	0.81	1.60	0.56	3.31	2.08	1.1
Range	53.83	169	222.9	229	272.5	166	150.5	33	558
Minimum	0	0	12.57	1	3.5	3.5	0	0	171
Maximum	53.83	169	235.5	230	276	169.5	150.5	33	729

4.10.1 Trend of Irbid District's Precipitation Data

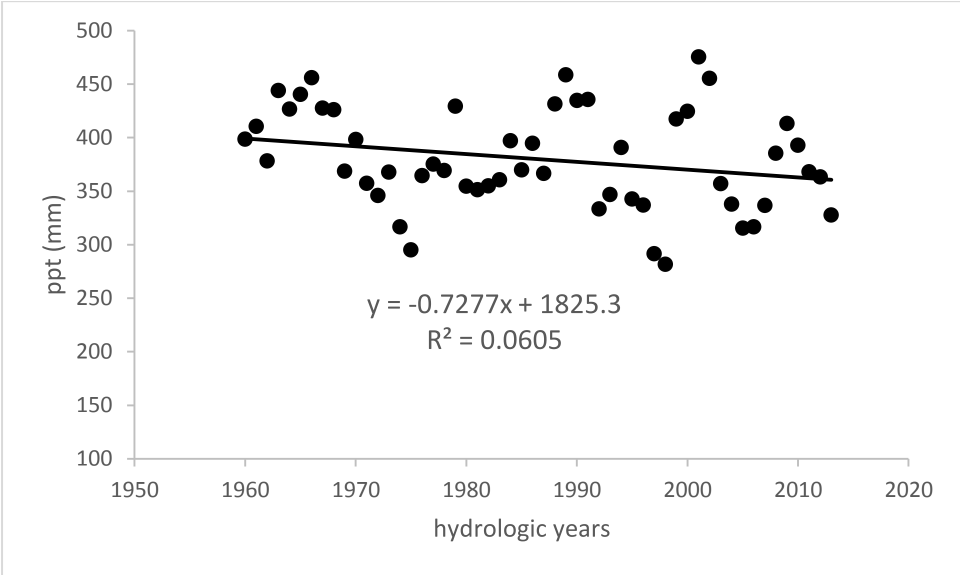

Figure 114: 4-years MA of Irbid district's yearly precipitation data

Result: For Irbid district the best representative appropriate trend was 4-years MA, having the highest absolute incline value with a decreasing trend (i.e. -0.728), where the negative sign implies that the precipitation data has a decreasing trend.

4.10.2 Summary of Irbid District's Quality Tests

Table 38: Results of quality Tests of Irbid district's precipitation data

Test	Tests' results
Normality	Statistical hypothesis= 0.014<0.05. Thus, Irbid's precipitation data was not represented as normally distribution.
Homogeneity	Based on t and F tests, Irbid district's precipitation data is homogeneous with Balqa district precipitation data sets.
Consistency	Precipitation data of Irbid district was considered to be consistent, based on DMC carried out among 9 representative stations.

Trend	Trend was not existed in Irbid district's precipitation data based on Mann Kendall and Sen's slope trend tests.
Stationary	Irbid district's precipitation data was considered stationary by Augmented Dickey-Fuller test.

4.10.3 Forecasted Irbid District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The best model was ARIMA (2, 2, 2) which will be used to compute the predicted Precipitation data for the upcoming 10 years. The actual value for the 2016-17 in Irbid was 314 mm and the forecasted value for this model was 309 mm.

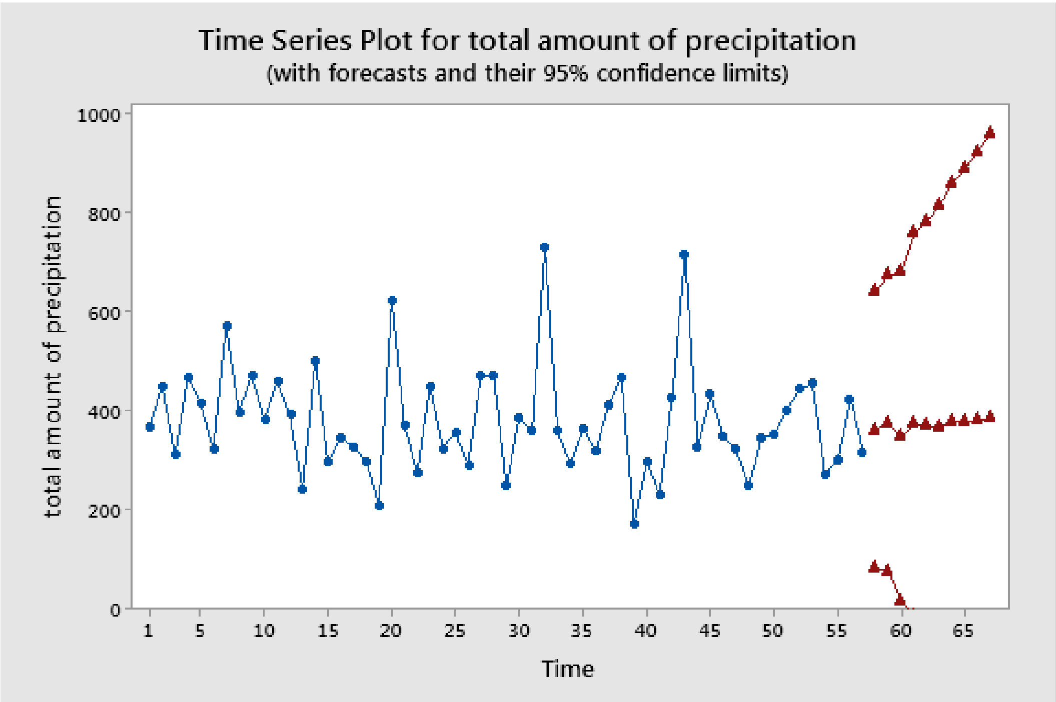

Figure 115: Irbid forecasted 10 years Precipitation data set built on ARIMA (2, 2, 2) model

Table 39: Forecasted yearly Precipitation data for Irbid district built on ARIMA (2, 2, 2) model

Hydrologic Year	Forecasted Yearly Precipitation (mm)
2017-18	361
2018-19	374
2019-20	348
2020-21	372
2021-22	369
2022-23	368
2023-24	377
2024-25	377
2025-26	380
2026-27	385

4.10.4 Analysis of monthly Precipitation data of Irbid district and its trends built on the Hydrological years from 1960-61 to 2016-17

October

The figure implies the trend for October built on 10-year MA, a slightly increasing slope for the whole study period. For the monthly spells, the month of October considered as a dry month within the study period with a 37 dry month (65%) out of 57.

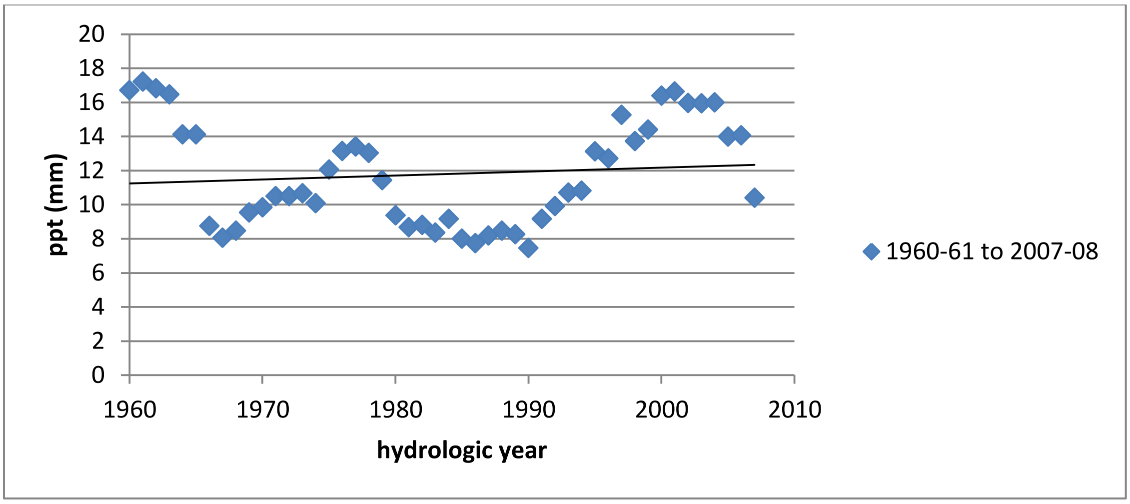

Figure 116: Irbid district's 10 years MA monthly precipitation data set for the month of October for the water years 1960-61 to 2016-17

November

The figure implies 3 different trends built on 10-year MA, an increasing slope for the initial 26 years, then a declining slope for the next 9 years, then an upward slope for 13 years in the end. For the monthly spells, the month of November considered as a dry month within the study period with a 33 dry month (58%) out of 57.

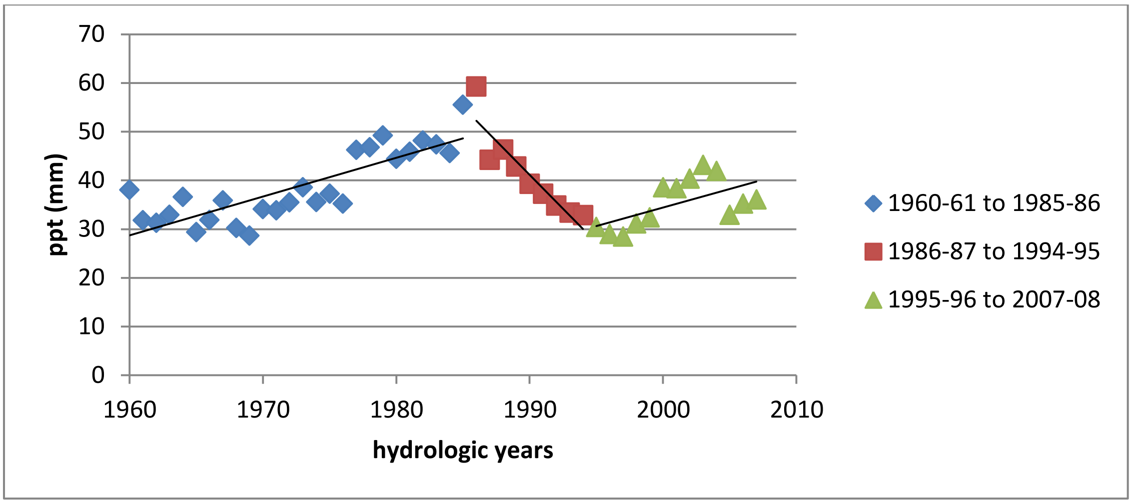

Figure 117: Irbid district's 10 years MA monthly precipitation data set for the month of November for the water years 1960-61 to 2016-17

December

The figure implies the trend for December built on 10-year MA, a declining slope for the initial 10 years, then an increasing slope for the next 19 years, a declining slope for the next 19 years. For the monthly spells, the month of December considered as a dry month within the study period with a 33 dry month (58%) out of 57.

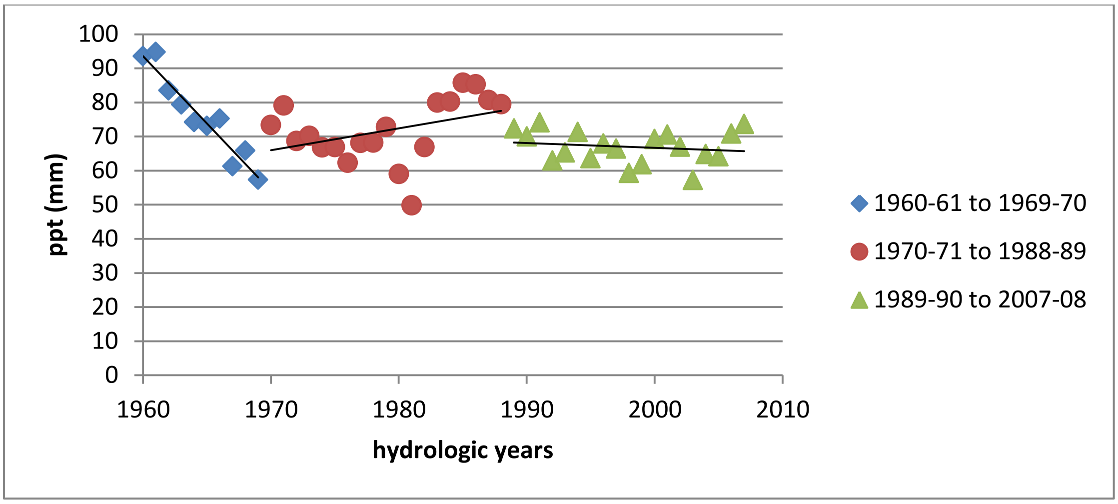

Figure 118: Irbid district's 10 years MA monthly precipitation data set for the month of December for the water years 1960-61 to 2016-17

January

The figure implies the trend for January built on 10-year MA, a declining slope for the initial 14 years, then an increasing slope for the next 17 years, a declining slope for the next 11 years, at last declining 6 years trend. For the monthly spells, the month of January considered as a dry month within the study period with a 32 dry month (56%) out of 57.

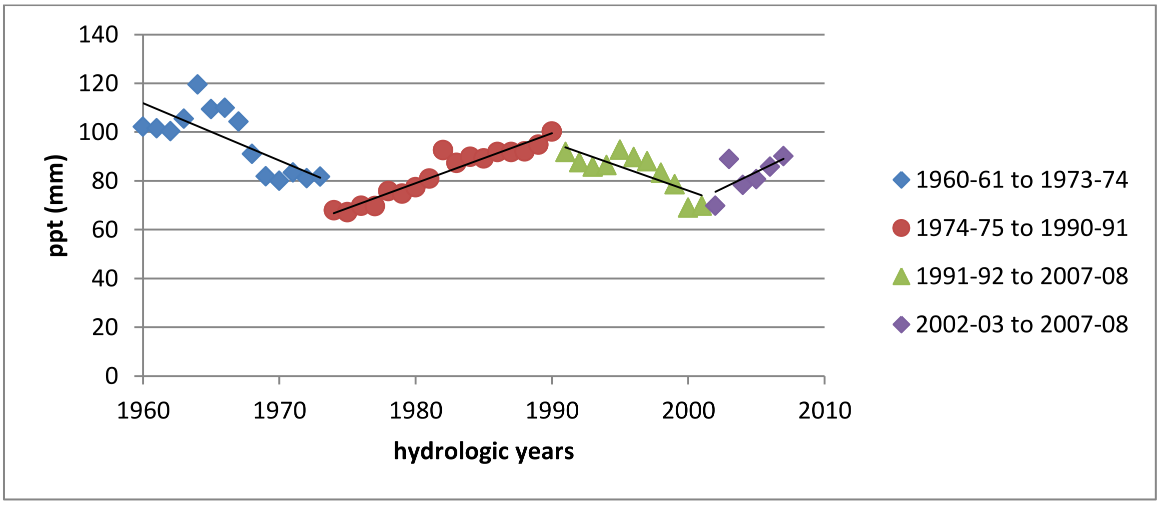

Figure 119: Irbid district's 10 years MA monthly precipitation data set for the month of January for the water years 1960-61 to 2016-17

February

The figure implies 4 different trends built on 10-year MA, an increasing slope for the initial 23 years, then a declining slope for the next 10 years, then an upward slope for 10 years, in the end a declining 5 years trend. For the monthly spells, the month of February considered as a dry month within the study period with a 32 dry month (56%) out of 57.

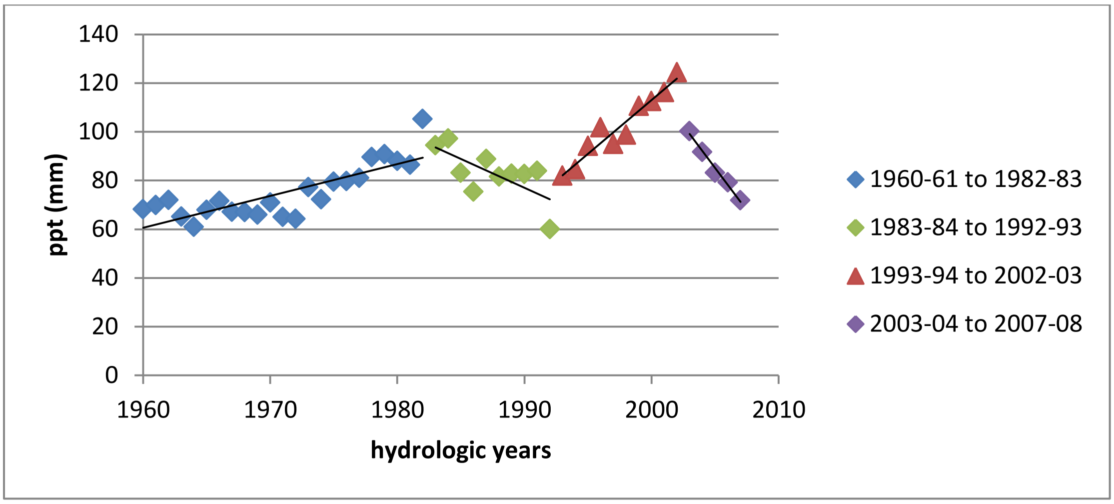

Figure 120: Irbid district's 10 years MA monthly precipitation data set for the month of February for the water years 1960-61 to 2016-17

March

The figure implies the trend for March built on 10-year MA, a declining slope for whole study area with two different declining slopes. For the monthly spells, the month of March barely considered as a wet month within the study period with a 29 wet month (51%) out of 57.

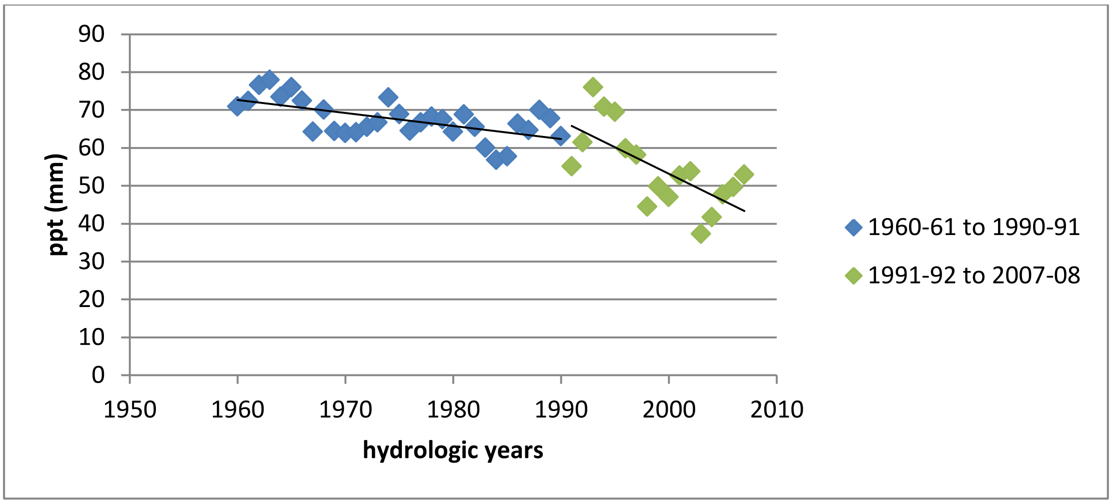

Figure 121: Irbid district's 10 years MA monthly precipitation data set for the month of March for the water years 1960-61 to 2016-17

April

The figure implies the trend for April built on 10-year MA, a declining slope for the initial 31 years, then an increasing 17 years in the end. For the monthly spells, the month of April considered as a dry month within the study period with a 38 dry month (67%) out of 57.

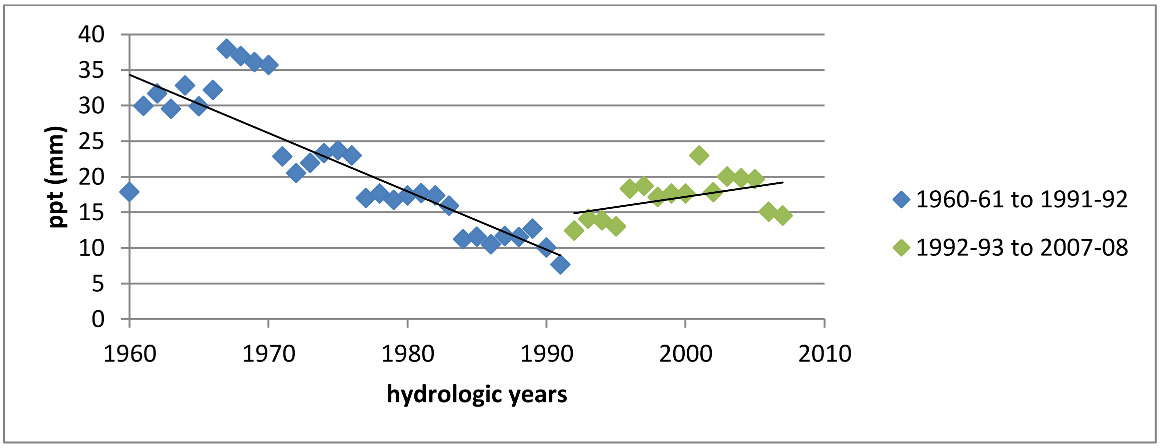

Figure 122: Irbid district's 10 years MA monthly precipitation data set for the month of April for the water years 1960-61 to 2016-17

May

The figure implies the trend for May built on 10-year MA, a mild increasing slope for the whole study period. For the monthly spells, the month of May considered as a dry month within the study period with a 39 dry month (68%) out of 57.

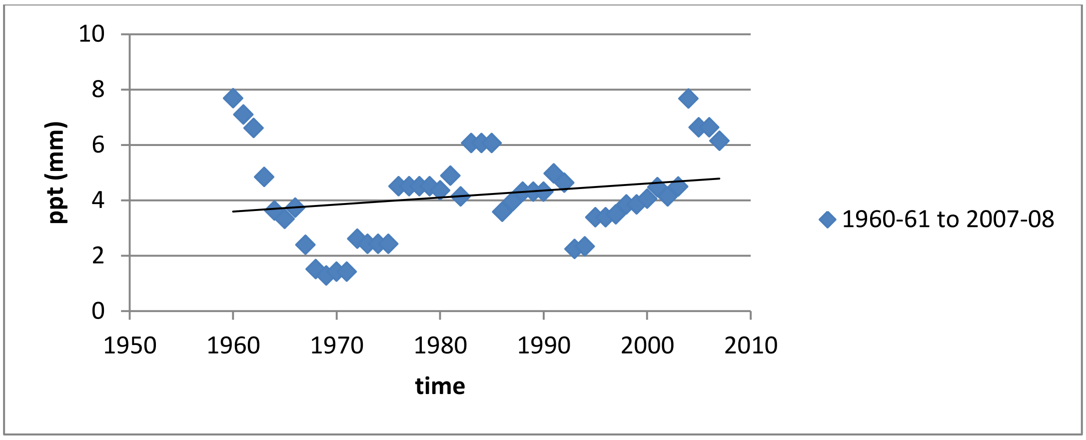

Figure 123: Irbid district's 10 years MA monthly precipitation data set for the month of May for the water years 1960-61 to 2016-17

4.11 Meteorological District: Balqa

Table 40: Monthly precipitation data with the statistical measures of Balqa district for hydrological years started in 1960-61 until 2016-17 in (mm)

Year\month	October	November	December	January	February	March	April	May	TOTAL
1960-61	0	62	29	155	147	15	29	17	454
1961-62	3	13	164	84	54	1	17	19	354
1962-63	5	0	42	40	118	38	9	14	267
1963-64	19	23	143	82	136	93	5	4	505
1964-65	0	69	53	152	45	45	38	0	403
1965-66	20	13	59	31	56	97	0	0	276
1966-67	20	3	200	143	55	185	4	6	615
1967-68	24	53	39	142	25	16	22	14	335
1968-69	5	31	116	148	32	170	15	0	516
1969-70	14	31	16	104	22	123	20	0	329

Year\month	October	November	December	January	February	March	April	May	TOTAL
1970-71	6	11	87	55	91	65	235	0	551
1971-72	0	42	173	61	69	71	34	6	456
1972-73	5	34	8	128	26	75	17	6	298
1973-74	0	77	34	315	131	45	38	0	641
1974-75	53	40	47	45	136	43	8	0	372
1975-76	0	27	61	46	90	99	19	2	343
1976-77	8	70	7	83	17	73	59	0	317
1977-78	34	5	116	47	30	80	15	0	327
1978-79	12	9	83	68	20	69	4	0	265
1979-80	35	132	173	92	113	104	13	0	661
1980-81	2	12	187	82	64	55	9	0	411
1981-82	0	48	10	75	151	104	9	25	423
1982-83	5	64	31	136	142	112	13	5	507
1983-84	1	36	5	89	34	125	38	0	327
1984-85	17	16	37	21	216	31	18	9	365
1985-86	12	22	31	62	114	19	8	23	292
1986-87	29	179	69	78	31	47	14	0	447
1987-88	31	5	147	81	171	65	11	0	511
1988-89	5	22	153	74	41	88	0	0	384
1989-90	4	51	62	123	51	51	33	0	374
1990-91	5	31	1	119	56	111	17	16	358
1991-92	11	74	271	190	322	42	2	5	918
1992-93	0	60	199	104	73	26	0	11	474
1993-94	9	12	20	121	61	60	5	0	289
1994-95	28	175	128	14	67	23	13	0	449
1995-96	1	23	26	144	17	137	14	0	363
1996-97	11	8	62	136	172	79	4	7	478
1997-98	15	38	90	107	39	102	2	2	395
1998-99	2	1	6	74	46	23	13	0	164
1999-00	3	4	10	143	57	57	3	0	278
2000-01	19	0	95	56	50	7	3	18	247
2001-02	6	41	90	169	47	76	26	4	460
2002-03	6	32	174	60	222	153	18	0	664
2003-04	0	12	73	99	71	28	0	2	284
2004-05	8	122	28	134	97	34	9	5	437
2005-06	2	33	92	68	63	6	117	0	381
2006-07	22	20	65	116	96	99	19	2	438
2007-08	2	52	32	66	109	23	0	10	293

Year\month	October	November	December	January	February	March	April	May	TOTAL
2008-09	22	6	46	9	121	170	10	0	384
2009-10	9	77	90	81	149	32	0	1	439
2010-11	5	0	52	99	75	48	29	21	329
2011-12	0	47	38	120	115	110	0	0	431
2012-13	0	44	75	253	64	3	18	4	460
2013-14	0	9	155	3	3	65	0	33	268
2014-15	0	39	71	126	98	123	46	10	513
2015-16	6	55	104	134	99	143	52	0	593
2016-17	4	22	81	97	108	33	36	1	382
Average	10	39	80	100	86	71	21	5	412
Standard Error	1.49	5.12	8.13	7.32	7.87	6.08	4.60	1.03	17
Median	5.48	31.1	65.3	91.99	69.5	65.4	13.1	1.20	384
Standard Deviation	11.3	38.7	61.36	55.25	59.4	45.9	34.7	7.80	128
Sample Variance	127	1496	3764	3053	3527	2107	1205	60.8	16505
Kurtosis	2.9	4.55	0.41	3.55	3.42	-0.32	26.7	2.43	3.22
Skewness	1.6	1.96	0.94	1.24	1.48	0.58	4.7	1.71	1.29
Range	53	179	270	312	320	184	235	33	753
Minimum	0	0	1	3	2	1	0	0	164
Maximum	53	179	271	315	322	185	235	323	917

4.11.1 Trend of Balqa District's Precipitation Data

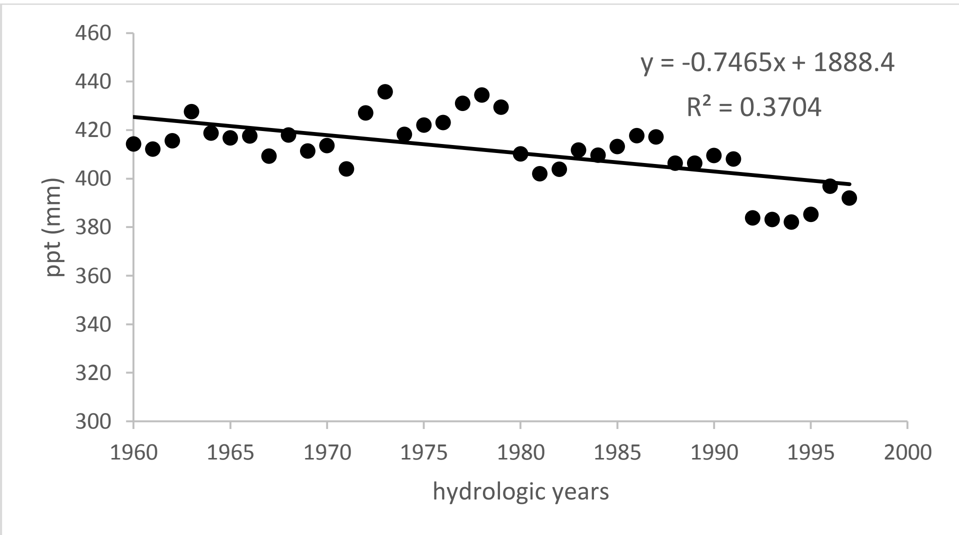

Figure 124: 20-years MA of Balqa district's yearly precipitation data

Result: For Ajlun district the best representative appropriate trend was 20-years MA, having the highest absolute incline value with a decreasing trend (i.e. -0.746 mm per year), where the negative sign signify that the precipitation data has a decreasing trend.

4.11.2 Summary of Balqa District's Quality Tests

Table 41: Results of quality Tests of Balqa district's precipitation data

Test	Tests' results
Normality	Statistical hypothesis = 0.015<0.05. Thus, Balqa's precipitation data was not represented as normally distribution.
Homogeneity	Based on t and F tests, Balqa district's precipitation data is homogeneous with Irbid and Ajlun districts precipitation data sets.
Consistency	Precipitation data of Balqa district was considered to be consistent, Based on DMC carried out among 7 representative stations.
Trend	Trend was not existed in Balqa district's precipitation data based on Mann Kendall and Sen's slope trend tests.
Stationary	Balqa district's precipitation data was considered stationary by Augmented Dickey-Fuller test.

4.11.3 Forecasted Balqa District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The best model was ARIMA (2, 0, 2) which will be used to compute the predicted Precipitation data for the upcoming 10 years. The actual value for the 2016-17 in Balqa was 382 mm and the forecasted value for this model was 401 mm.

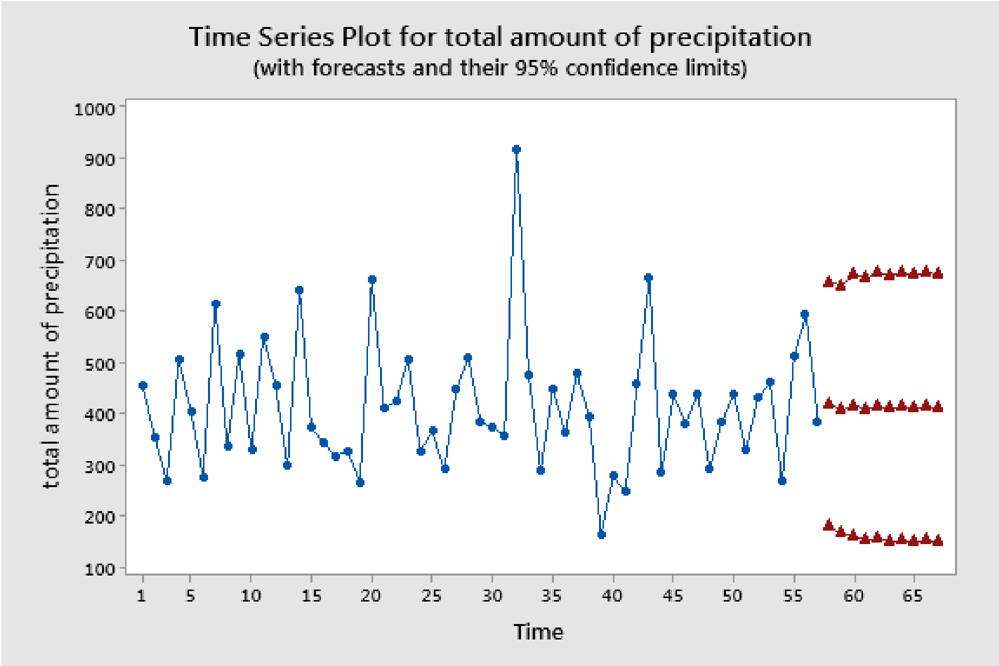

Figure 125: Balqa forecasted 10 years Precipitation data set built on ARIMA (2, 0, 2) model

Table 42: Forecasted yearly Precipitation data for Balqa district built on ARIMA (2, 0, 2) model

Hydrologic Year	Forecasted Yearly Precipitation (mm)
2017-18	418
2018-19	408
2019-20	416
2020-21	409
2021-22	414
2022-23	410
2023-24	414
2024-25	411
2025-26	413
2026-27	411

4.11.4 Analysis of monthly Precipitation data of Balqa district and its trends built on the Hydrological years from 1960-61 to 2016-17

October

The figure implies the trend for October built on 10-year MA, a slightly declining slope for the whole study period. For the monthly spells, the month of October considered as a dry month within the study period with a 37 dry month (65%) out of 57.

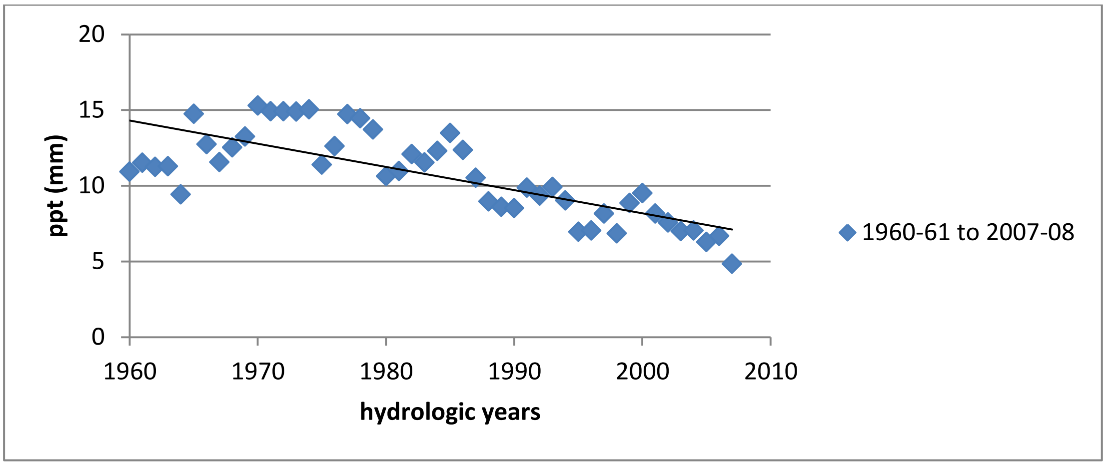

Figure 126: Balqa district's 10 years MA monthly precipitation data set for the month of October for the water years 1960-61 to 2016-17

November

The figure implies 3 different trends built on 10-year MA, an increasing slope for the initial 26 years then a declining slope for the next 9 years, and then an upward slope for 13 years in the end. For the monthly spells, the month of November considered as a dry month within the study period with a 35 dry month (61%) out of 57.

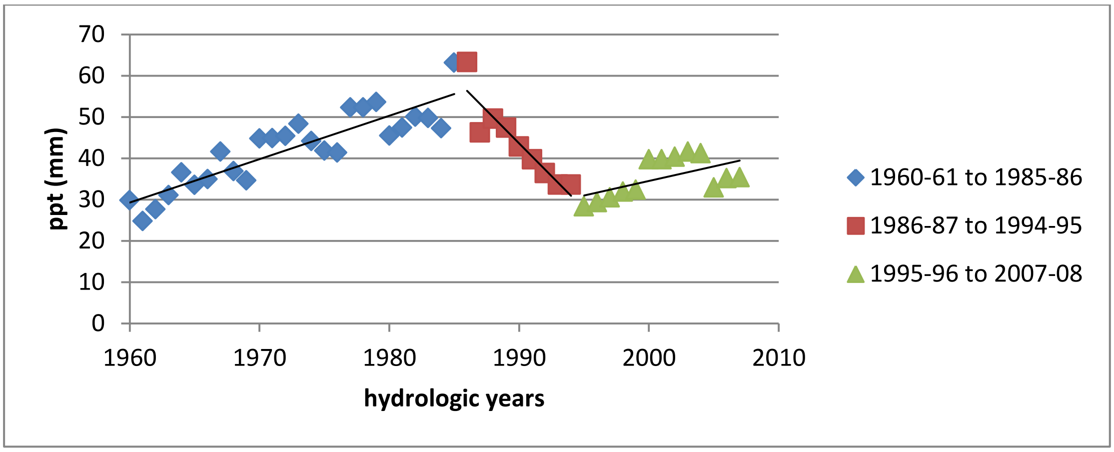

Figure 127: Balqa district's 10 years MA monthly precipitation data set for the month of November for the water years 1960-61 to 2016-17

December

The figure implies the trend for December built on 10-year MA, a declining slope for the initial 10 years, then an increasing slope for the next 19 years, an increasing slope for the last 19 years. For the monthly spells, the month of December considered as a dry month within the study period with a 33 dry month (58%) out of 57.

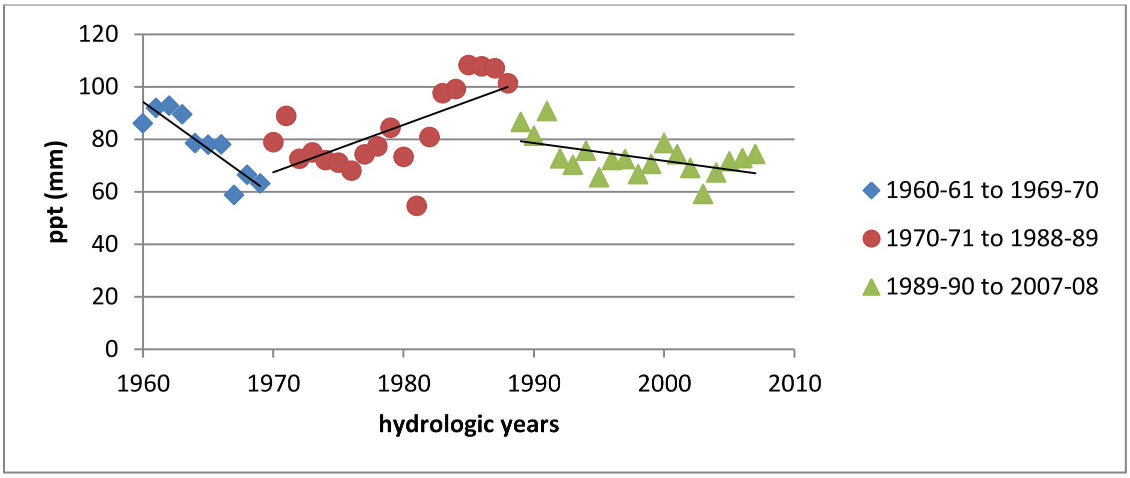

Figure 128: Balqa district's 10 years MA monthly precipitation data set for the month of December for the water years 1960-61 to 2016-17

January

The figure implies the trend for January built on 10-year MA, a declining slope for the initial 14 years, then an increasing slope for the next 17 years, a declining trend for the next 11 years, at last declining 6 years trend. For the monthly spells, the month of January considered as a dry month within the study period with a 32 dry month (56%) out of 57.

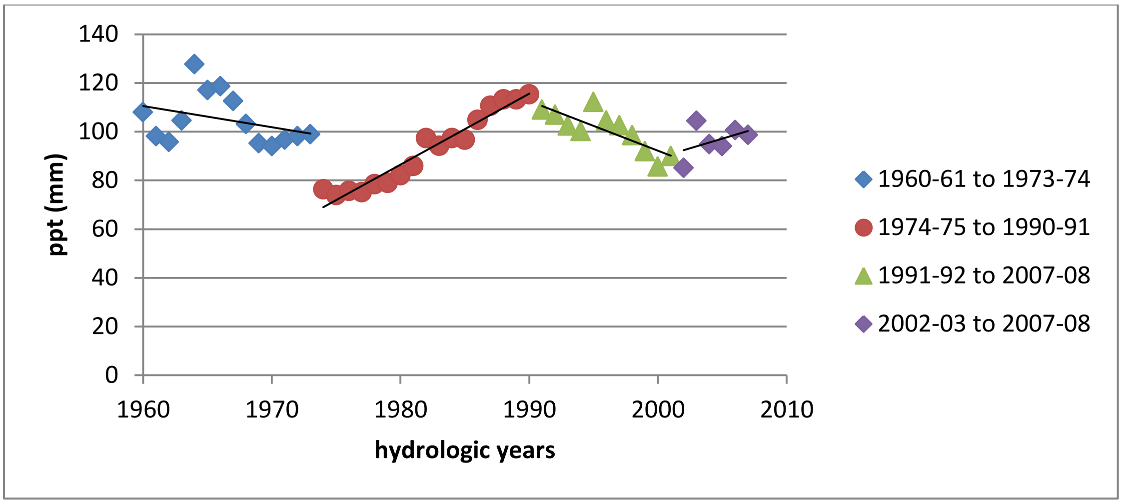

Figure 129: Balqa district's 10 years MA monthly precipitation data set for the month of January for the water years 1960-61 to 2016-17

February

The figure implies 3 different trends built on 10-year MA, an increasing slope for the initial 23 years, then a declining slope for the next 10 years, then an upward slope for 15 years. For the monthly spells, the month of February considered as a dry month within the study period with a 32 dry month (56%) out of 57.

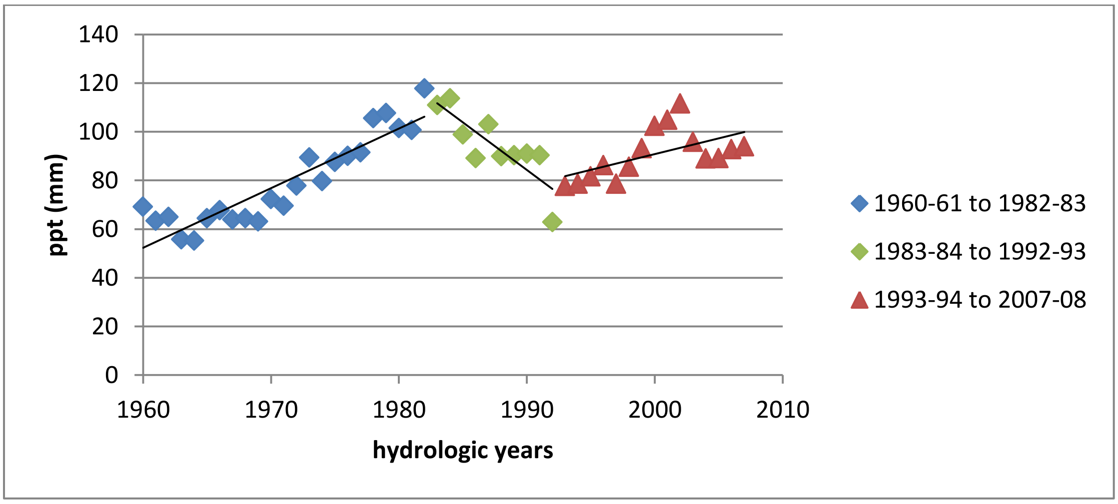

Figure 130: Balqa district's 10 years MA monthly precipitation data set for the month of February for the water years 1960-61 to 2016-17

March

The figure implies the trend for March built on 10-year MA, a declining slope for initial 31 years, and then an increasing slope for the last 17 years. For the monthly spells, the month of March barely considered as a wet month within the study period with a 31 wet month (54%) out of 57.

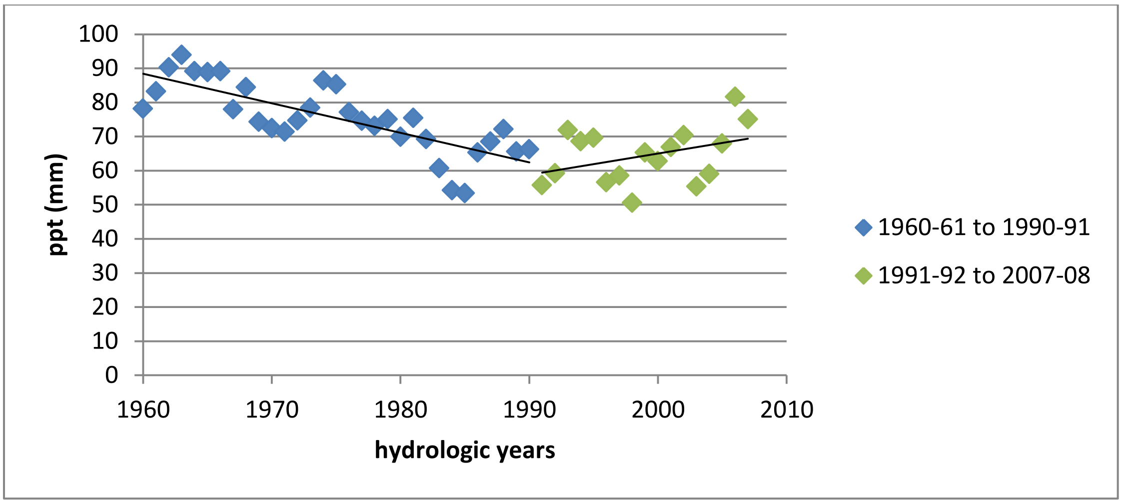

Figure 131: Balqa district's 10 years MA monthly precipitation data set for the month of March for the water years 1960-61 to 2016-17

April

The figure implies the trend for April built on 10-year MA, a declining slope for the initial 32 years, and then an increasing 16 years in the end. For the monthly spells, the month of April considered as a dry month within the study period with a 42 dry month (74%) out of 57.

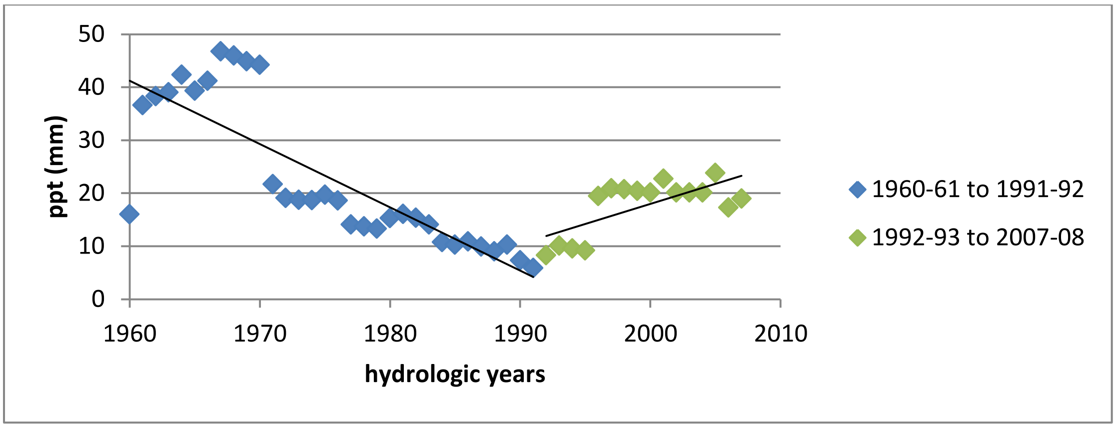

Figure 132: Balqa district's 10 years MA monthly precipitation data set for the month of April for the water years 1960-61 to 2016-17

May

The figure implies the trend for May built on 10-year MA, a mild increasing slope for the whole study period. For the monthly spells, the month of May considered as a dry month within the study period with a 39 dry month (68%) out of 57.

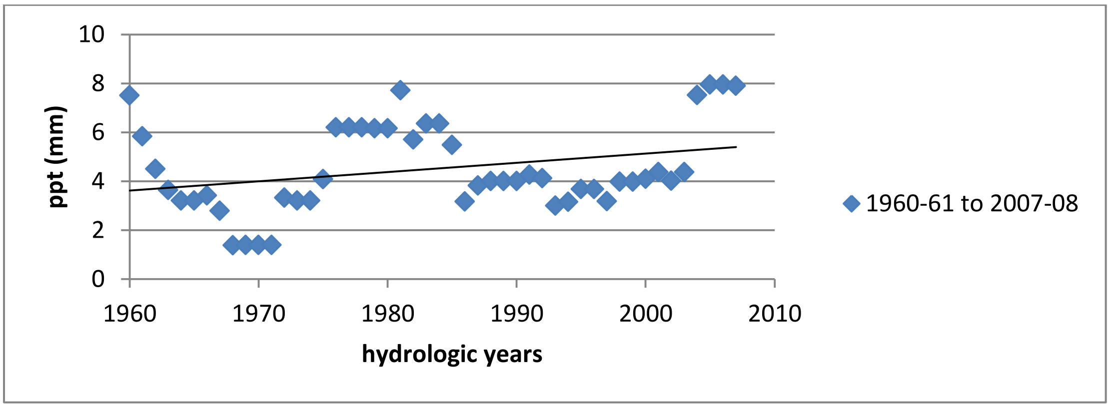

Figure 133: Balqa district's 10 years MA monthly precipitation data set for the month of May for the water years 1960-61 to 2016-17

4.12 Meteorological District: Amman

Table 43: Monthly precipitation data with the statistical measures of Amman district for hydrological years started in 1960-61 until 2016-17 in (mm)

Year\month	October	November	December	January	February	March	April	May	TOTAL
1960-61	0	46	31	133	165	18	24	4	422
1961-62	4	12	221	87	90	4	9	1	427
1962-63	3	0	32	38	114	48	14	32	280
1963-64	14	28	213	105	131	93	5	3	592
1964-65	0	96	52	209	66	63	60	0	547
1965-66	27	21	58	40	60	121	0	0	327
1966-67	43	8	219	217	56	217	3	0	763
1967-68	15	74	59	195	42	20	17	4	426
1968-69	10	22	124	165	39	269	20	0	647
1969-70	13	19	23	121	42	146	22	0	386
1970-71	6	7	70	46	81	83	291	0	583
1971-72	2	39	200	70	83	73	37	8	512
1972-73	0	50	11	166	33	77	2	2	342
1973-74	9	90	51	363	170	30	47	0	761
1974-75	0	49	58	35	211	72	9	0	435
1975-76	3	26	58	81	90	90	18	4	369
1976-77	4	45	5	118	49	89	89	0	399
1977-78	55	7	142	75	49	116	13	0	457
1978-79	10	9	92	93	14	89	3	1	311
1979-80	27	189	177	112	134	127	18	0	784
1980-81	1	10	267	106	83	63	23	0	553
1981-82	0	51	12	113	131	96	13	27	442
1982-83	4	54	35	209	202	154	8	9	673
1983-84	1	37	4	139	57	138	50	0	427
1984-85	16	23	49	32	276	40	13	1	450
1985-86	21	7	43	51	106	19	14	16	276
1986-87	49	211	76	94	35	62	1	0	527
1987-88	30	6	167	86	225	80	14	0	607
1988-89	13	26	166	65	52	98	0	0	420
1989-90	6	36	49	133	59	67	48	0	397
1990-91	8	14	3	147	76	122	13	5	389
1991-92	13	80	362	192	338	48	2	7	1044
1992-93	0	89	164	117	105	25	0	10	509

Year\month	October	November	December	January	February	March	April	May	TOTAL
1993-94	15	21	27	141	66	69	3	1	343
1994-95	21	177	143	11	67	28	12	0	458
1995-96	0	29	25	149	20	129	9	0	360
1996-97	14	9	49	114	168	97	6	4	461
1997-98	16	29	91	123	54	131	2	1	448
1998-99	1	2	4	59	93	21	8	0	188
1999-00	1	2	12	189	55	67	1	0	327
2000-01	24	12	136	66	65	16	4	27	348
2001-02	6	47	112	224	85	88	41	4	607
2002-03	5	24	209	52	209	154	22	0	675
2003-04	5	11	99	135	71	28	3	2	354
2004-05	2	100	34	127	119	32	6	3	422
2005-06	2	22	102	64	73	10	102	0	375
2006-07	11	4	73	124	114	111	8	6	451
2007-08	2	46	25	90	111	4	0	0	278
2008-09	43	2	24	25	243	73	4	0	413
2009-10	26	81	90	107	216	1	0	1	520
2010-11	9	0	58	111	85	31	29	11	334
2011-12	0	67	43	120	163	117	0	0	509
2012-13	0	27	78	244	41	4	21	4	421
2013-14	0	17	180	2	7	128	0	26	361
2014-15	7	175	42	136	114	9	59	1	543
2015-16	30	94	25	244	124	65	32	0	614
2016-17	3	2	227	68	62	6	5	0	373
Average	11	44	91	117	103	75	22	4	468
Standard Error	1.75	6.47	10.5	8.9	9.15	7.27	5.58	1	19.9
Median	6	26	58	113	83	72	12	1	427.4
Standard Deviation	13.2	48.8	78.9	67.2	69.1	54.9	42	7.52	150.1
Sample Variance	175	2385	6229	4517	4774	3009	1773	56.5	22518
Kurtosis	2.23	3.6	1.2	2	1.61	1.75	30.2	5.93	2.884
Skewness	1.6	1.9	1.2	1	1.3	0.99	4.99	2.54	1.32
Range	55	211	359	361	331	268	291	32	855
Minimum	0	0	3	2	7	1	0	0	188
Maximum	55	211	362	363	338	269	291	32	1043

4.12.1 Trend of Amman District's Precipitation Data

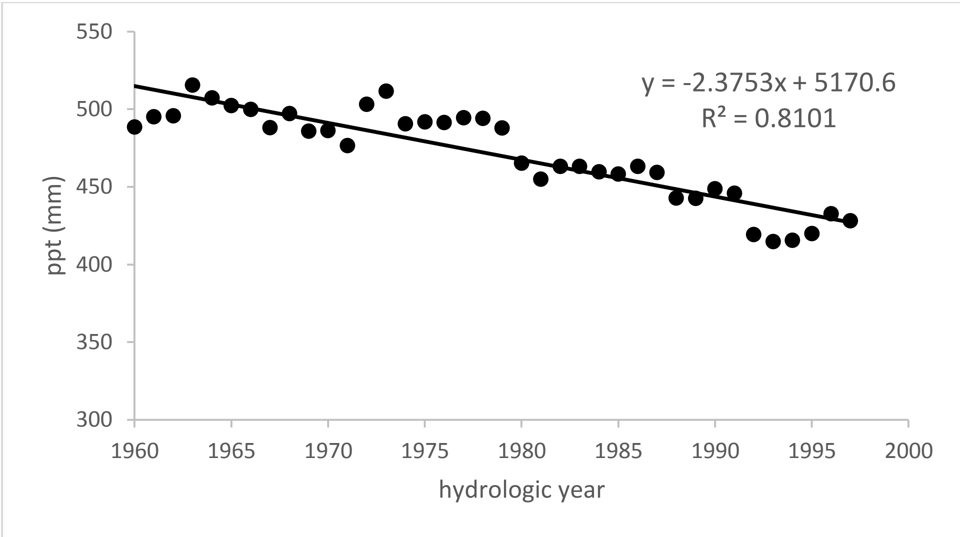

Figure 134: 20-years MA of Amman district's yearly precipitation data

Result: For Ajlun district the best representative appropriate trend was 3-years MA, having the highest absolute incline value with a decreasing trend (i.e. -2.37 mm per year), where the –ve sign implies a decreasing trend.

4.12.2 Summary of Amman District's Quality Tests

Table 44: Quality Tests results of Amman district's Precipitation data

Test	Tests' results
Normality	Statistical hypothesis is <0.005. Thus, Amman's precipitation data was not represented as normally distribution.
Homogeneity	Based on t and F tests, Amman district's precipitation data is homogeneous with Ajlun district precipitation data sets.
Consistency	Precipitation data of Amman district is considered to be consistent, based on DMC carried out among 6 representative stations.

Trend	Trend was not existed in Amman district's precipitation data based on Mann Kendall and Sen's slope trend tests.
Stationary	Amman district's precipitation data was considered stationary by Augmented Dickey-Fuller test.

4.12.3 Forecasted Amman District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The best model was Winter's model which will be used to compute the predicted Precipitation data for the upcoming 10 years. The actual value for the 2016-17 year in Amman was 373 mm and the forecasted value for this model was 480 mm.

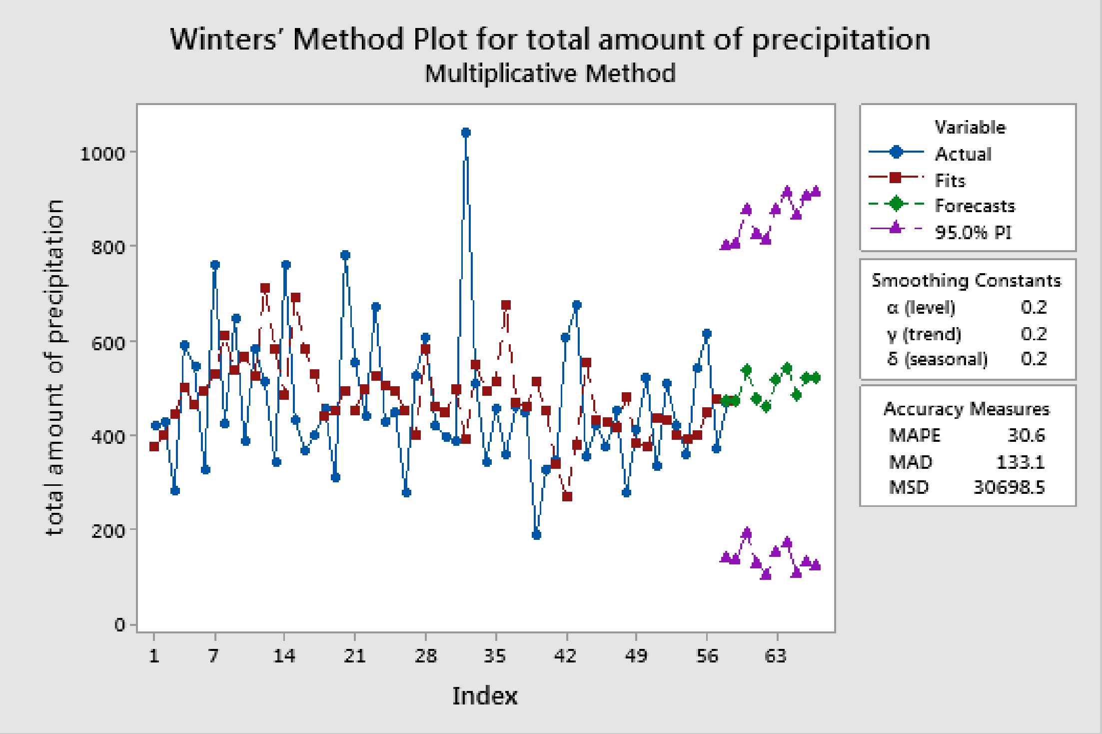

Figure 135: Amman forecasted 10 years precipitation data set built on winter's model

Table 45: Forecasted yearly Precipitation data for Amman district built on winter's model

Hydrologic Year	Forecasted Yearly Precipitation (mm)
2017-18	471
2018-19	472
2019-20	536
2020-21	476
2021-22	461
2022-23	517
2023-24	544
2024-25	487
2025-26	522
2026-27	521

4.12.4 Analysis of monthly Precipitation data of Amman district and its trends built on the Hydrological years from 1960-61 to 2016-17

October

The figure implies the trend for October built on 10-year MA, a slightly declining slope for the whole study period. For the monthly spells, the month of October considered as a dry month within the study period with a 36 dry month (63%) out of 57.

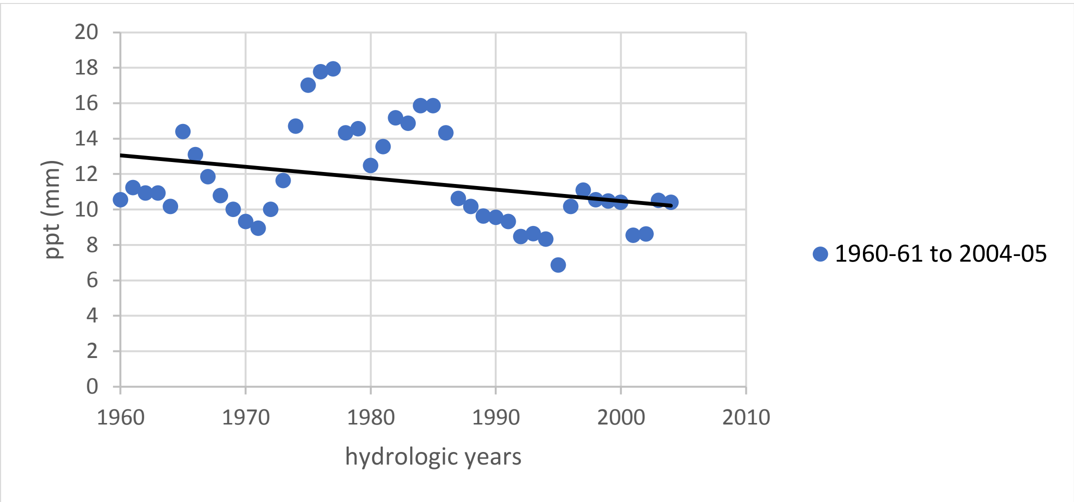

Figure 136: Amman district's 10 years MA monthly precipitation data set for the month of October for the water years 1960-61 to 2016-17

November

The figure implies 3 different slopes built on 10-year MA, an increasing slope for the initial 24 years, then a declining trend for the next 12 years, then an upward slope for 9 years in the end. For the monthly spells, the month of November considered as a dry month within the study period with a 36 dry month (63%) out of 57.

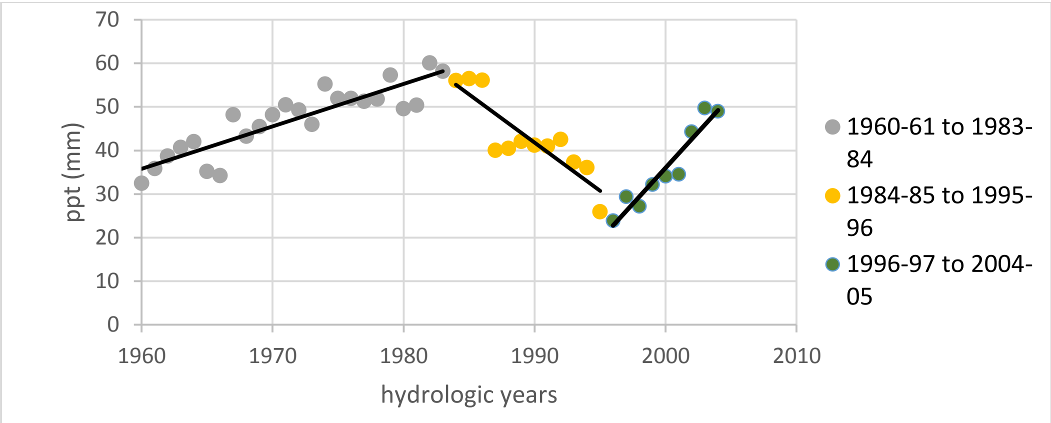

Figure 137: Amman district's 10 years MA monthly precipitation data set for the month of November for the water years 1960-61 to 2016-17

December

The figure implies the trend for December built on 10-year MA, a declining slope for the initial 10 years, then an increasing slope for the next 19 years, an increasing slope for the next 19 years. For the monthly spells, the month of December considered as a dry month within the study period with a 36 dry month (63%) out of 57.

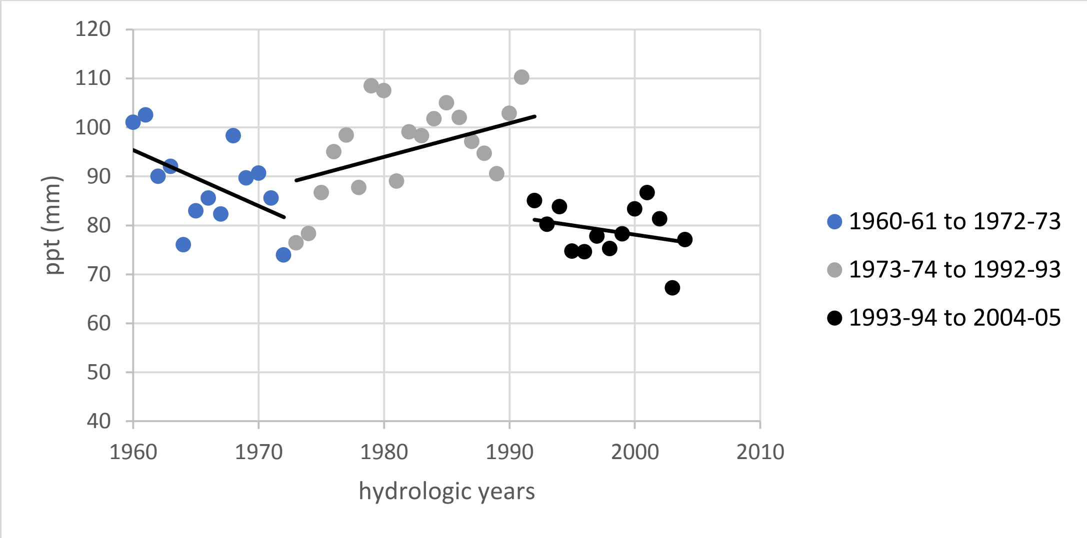

Figure 138: Amman district's 10 years MA monthly precipitation data set for the month of December for the water years 1960-61 to 2016-17

January

The figure implies the trend for January built on 10-year MA, a declining slope for the whole study period. For the monthly spells, the month of January considered as a dry month within the study period with a 31 dry month (54%) out of 57.

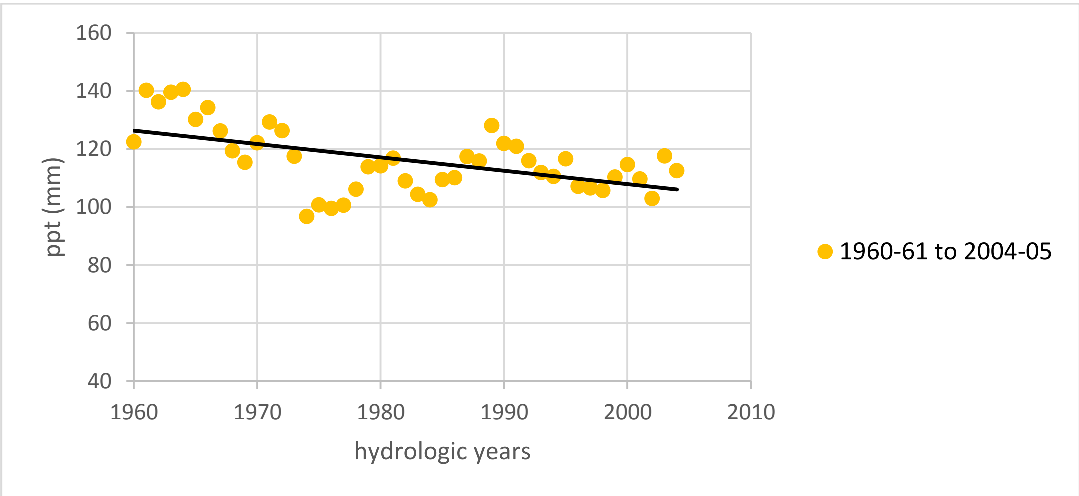

Figure 139: Amman district's 10 years MA monthly precipitation data set for the month of January for the water years 1960-61 to 2016-17

February

The figure implies the trend for February built on 10-year MA, a declining slope for the initial 7 years, then an increasing slope for the next 13 years, a declining slope for the next 25 years. For the monthly spells, the month of February considered as a dry month within the study period with a 34 dry month (60%) out of 57.

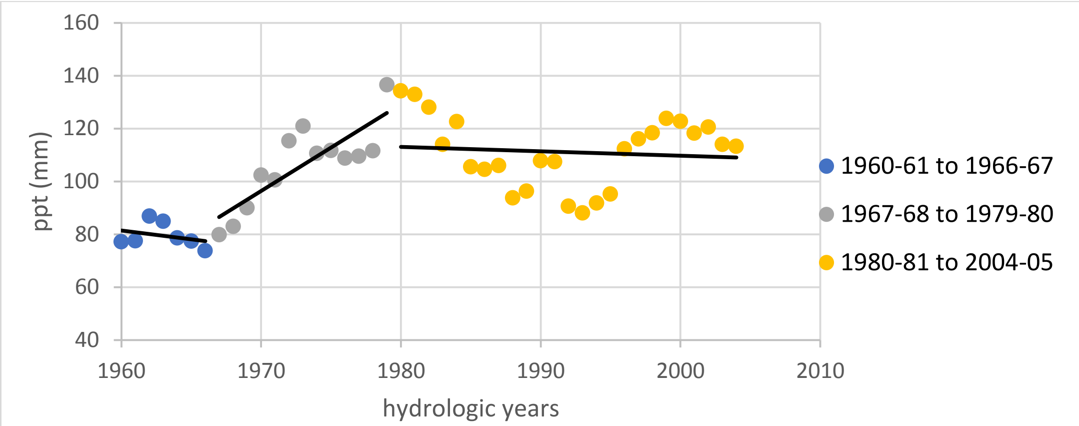

Figure 140: Amman district's 10 years MA monthly precipitation data set for the month of February for the water years 1960-61 to 2016-17

March

The figure implies the trend for March built on 10-year MA, an increasing slope for initial 7 years afterward a declining slope for the last 34 years. For the monthly spells, the month of March barely considered as a wet month within the study period with a 31 wet month (54%) out of 57.

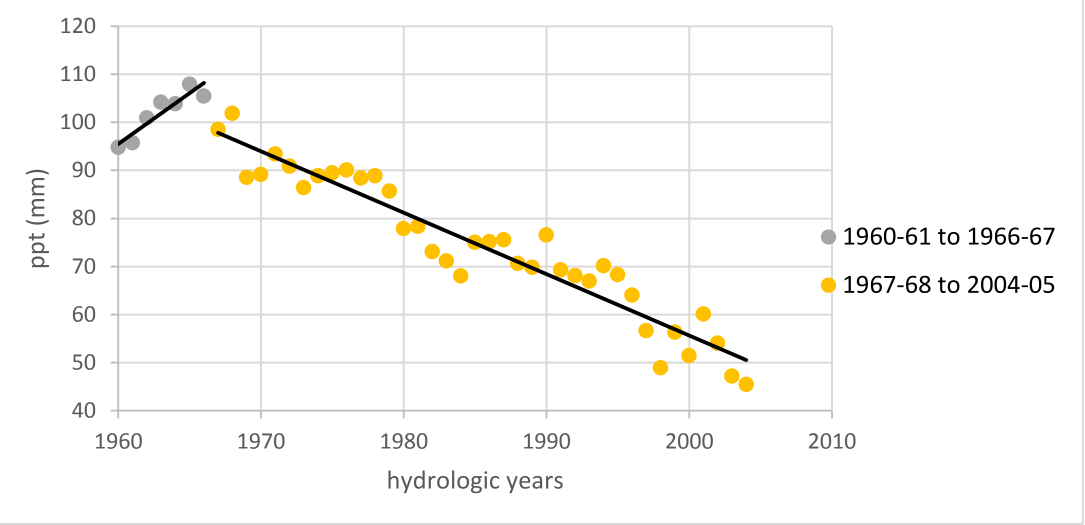

Figure 141: Amman district’s 10 years MA monthly precipitation data set for the month of March for the water years 1960-61 to 2016-17

April

The figure implies 3 different trends built on 10-year MA, an increasing slope for the initial 11 years, then a declining slope for the next 22 years, then an upward slope for 12 years in the end. For the monthly spells, the month of April considered as a dry month within the study period with a 43 dry month (75%) out of 57.

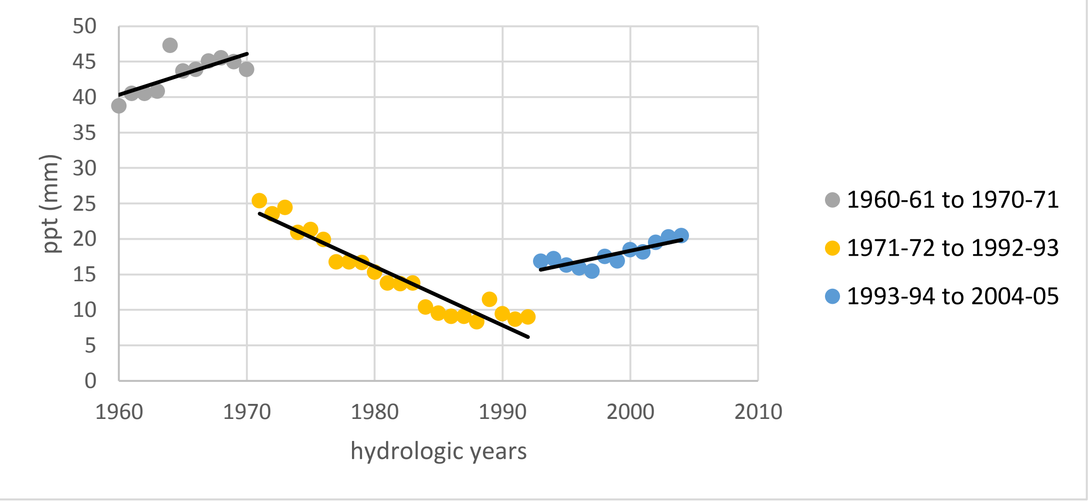

Figure 142: Amman district’s 10 years MA monthly precipitation data set for the month of April for the water years 1960-61 to 2016-17

May

The figure implies the trend for May built on 10-year MA, a mild increasing slope for the whole study period. For the monthly spells, the month of May considered as a dry month within the study period with a 39 dry month (68%) out of 57.

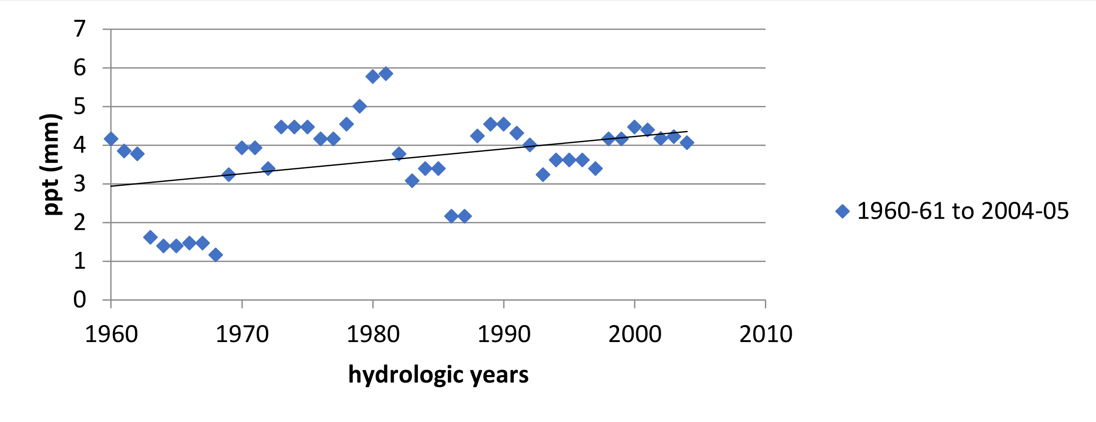

Figure 143: Amman district's 10 years MA monthly precipitation data set for the month of May for the water years 1960-61 to 2016-17

4.13 Meteorological District: Aqaba

Table 46: Monthly precipitation data with the statistical measures of Aqaba district for hydrological years started in 1960-61 until 2016-17 in (mm)

Year\months	October	November	December	January	February	March	April	May	TOTAL
1960-1961		1.8	1.4	13.8	16.5				34
1961-1962	4		51	4.9	1				61
1962-1963			0.2	0.6	3.4	3	39.9	0.8	48
1963-1964	0.5	0.6	8.8	7.3			2.2		19
1964-1965			19.5	27		4.8	1.8		53
1965-1966	0.2	1		36.8	12.1	3.5			54
1966-1967		0.4	0.2	0.4	0.9	1.9			4
1967-1968	2	0.6		1.2	6.1	1.9	1.6	28.4	42
1968-1969		27.2	0.8	16.1		25.7	5.7		76
1969-1970	0.7	3.4		1.2		0.2			6
1970-1971		0.4		17.8	0.7	6.1	21.7		47

Year\months	**October**	**November**	**December**	**January**	**February**	**March**	**April**	**May**	**TOTAL**
1971-1972		2.6	20.9	5.6	1.6	4.6	1		36
1972-1973		15.6					1.2		17
1973-1974	2	12.8	0.3	8.5	6.4	5.5			36
1974-1975		1.5	14.1	1	67.2	0.3	0.1		84
1975-1976			17.3			6.3			24
1976-1977		0.1	1.5	0.7		0.1	12		14
1977-1978			13.5	7.6	15.4				37
1978-1979			17.3		19.2				37
1979-1980					0.7	3.7	0.2		5
1980-1981			43.3	1.8		1.6	0.6		47
1981-1982				9.5	17.4	4.7	11.5		43
1982-1983		11.7			5.7	7.8			25
1983-1984			0.7	2.8		5.1			9
1984-1985									0
1985-1986			15.7		2		10.7	13.9	42
1986-1987		8.7	0.6		11.4	9.4			30
1987-1988	21.8		17.9	20.6	3	6.1			69
1988-1989	0.4	0.2	2	1	1.8	5			10
1989-1990						9.5	12.4		22
1990-1991				4.5		13.9			18
1991-1992	1.3		3.6	6.4	2.1				13
1992-1993		10.6	0.5	5.6	4.3				21
1993-1994	9.3		33.1	37.3	1	4.7	0.2		86
1994-1995	0.2	5.4			6.2		3.4		15
1995-1996				0.8	0.5	0.2			2
1996-1997		0.2	0.4	9	0.7	3.3			14
1997-1998	28		0.3	0.8	0.3	1.3	0.3		31
1998-1999		0.3		0.7	28.3	1.9			31
1999-2000				2.4	12.5				15
2000-2001		1.6	10.2	0.4			14		26
2001-2002			1.8	4.2	4.4				10
2002-2003	7.9	1.5	1	0.3		0.5	0.1		11
2003-2004		2	2.5	6.5	3.5		4.2		19
2004-2005	0.2		1.3	0.4		0.9	0.2		3
2005-2006				1.2	0.4		2.3		4
2006-2007			0.6	2.8	2	0.2	2.2		8
2007-2008	0.1			4	1.9				6
2008-2009	1.1				0.3	0.2			2

Year\months	October	November	December	January	February	March	April	May	TOTAL
2009-2010				17	4.9	1.3		0.2	23
2010-2011			0.5	0.8	2.7		5.2		9
2011-2012			0.2	1.1					1
2012-2013	2.6	1		5.9	17			0.3	27
2013-2014			3.1	2.5	11.6	8.6	1.5		27
2014-2015	1.6	1.2	3.6	14	9.4	9.4	0.6		40
2015-2016	25.6	1.8	0.4	2	2.4	23.6	8		64
2016-2017	8.2		2.4		3	5.2	16.6		35

Table 47: Statistical yearly measures of Aqaba precipitation data

Mean	27.90
Standard Error	2.86
Median	23.60
Standard Deviation	21.58
Sample Variance	465.61
Kurtosis	0.35
Skewness	0.91
Range	85.60
Minimum	0.00
Maximum	85.60

4.13.1 Trend of Aqaba District's Precipitation Data

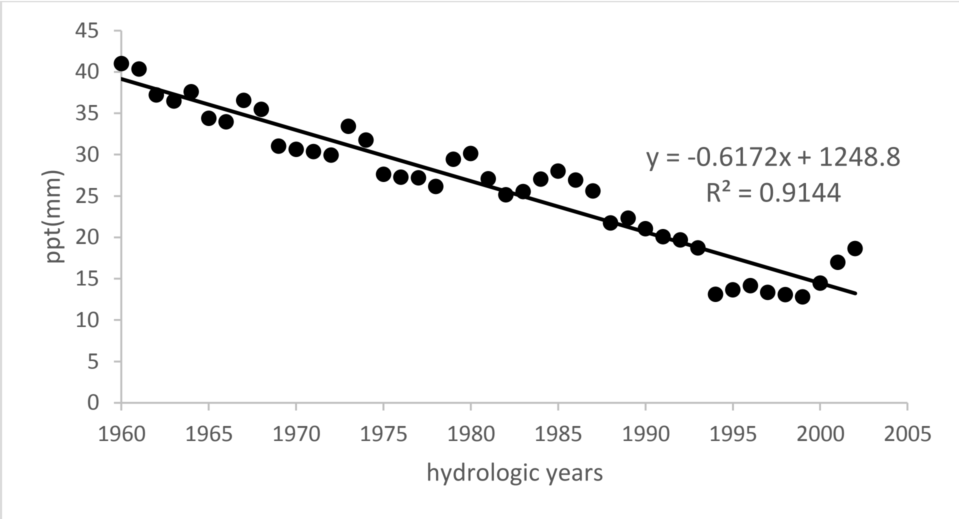

Figure 144: 15-years MA of Aqaba district's yearly precipitation data

Result: For Aqaba district the best representative appropriate trend was 15-years MA, having the highest absolute incline value with a decreasing trend (i.e. -0.617 mm per year), where the negative sign signify that the precipitation data are decreasing by 0.617 mm per year.

4.13.2 Summary of Aqaba District's Quality Tests

Table 48: Quality Tests Results of Aqaba Precipitation Data

Test	Tests' results
Normality	Statistical hypothesis = 0.007<0.05. Thus, Aqaba's precipitation data was not represented as normally distribution.
Homogeneity	Based on t and F tests, Aqaba district's precipitation data is not homogeneous with any other district in the kingdom.
Consistency	N/A because only one station is representing Aqaba district.

Trend	Trend exists in Aqaba district's precipitation data based on Mann Kendall and Sen's slope trend tests.
Stationary	Aqaba precipitation data is not stationary and has a unit root based on ADF test.

4.13.3 Forecasted Aqaba District's Yearly Precipitation Data Set for water Years from 2017-18 until 2026-27

The best model was ARIMA (2, 0, 2) model which will be used to compute the predicted Precipitation data for the upcoming 10 years. The actual value for the 2016-17 year in Aqaba was 35 mm and the forecasted value for this model was 36 mm.

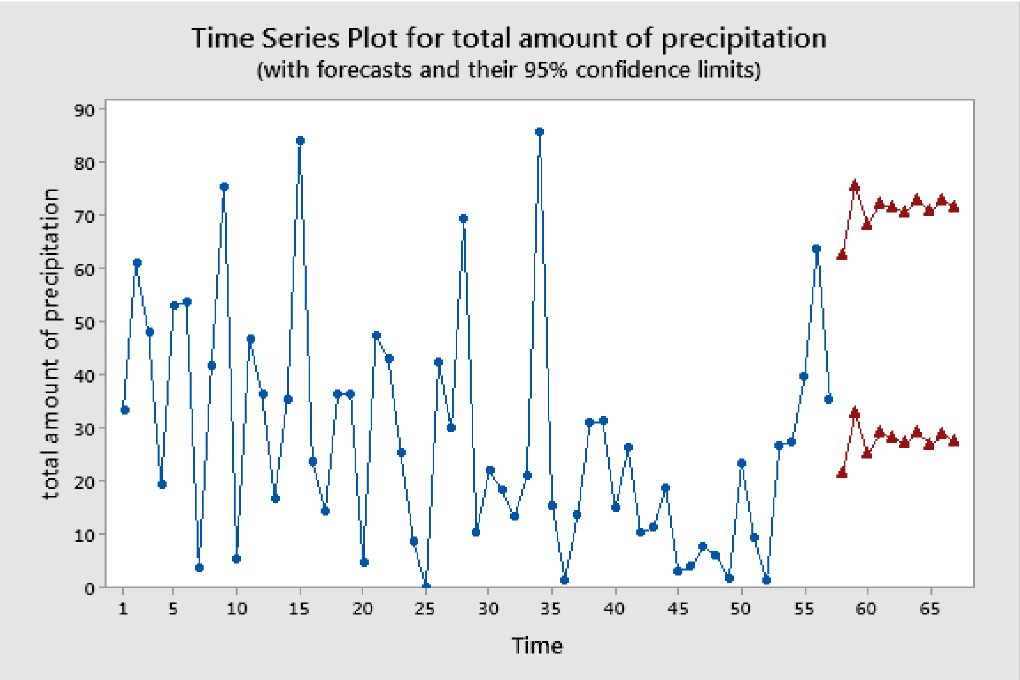

Figure 145: Aqaba forecasted 10 years Precipitation data set built on ARIMA (2, 0, 2) model

Table 49: Forecasted yearly Precipitation data for Aqaba district built on ARIMA (2, 0, 2) model

Hydrologic Year	Forecasted Yearly Precipitation (mm)
2017-18	21
2018-19	33
2019-20	25
2020-21	29
2021-22	28
2022-23	27
2023-24	29
2024-25	27
2025-26	29
2026-27	27

Next table shows the wetness and the dryness hydrologic monthly spells for each district (from October to May), all months presented as a dry months in the study period except March in Irbid with a wetness percentage of 51% which barley considered as wet month. The spells trailed with statistical measures for each month, at the same time it’s exemplify the whole 12 districts as one district based on the 66 selected stations for each month.

Table 50: Dryness monthly spells and its statistical measures of each district

District\Month	October	November	December	January	February	March	April	May
Ajlun	63%	61%	63%	56%	56%	51%	61%	67%
Amman	63%	63%	63%	54%	60%	54%	75%	68%
Aqaba	61%	70%	67%	60%	56%	63%	65%	75%
Balqa	65%	61%	58%	56%	56%	54%	74%	68%
Irbid	65%	58%	58%	56%	56%	49%	67%	68%
Jarash	61%	61%	58%	58%	61%	60%	70%	75%
Karak	68%	67%	61%	58%	58%	56%	72%	72%
Ma'an	61%	70%	67%	60%	56%	63%	65%	75%
Madaba	68%	74%	65%	54%	67%	58%	72%	79%
Mafraq	61%	65%	61%	60%	60%	51%	63%	67%
Tafilah	74%	75%	63%	63%	53%	62%	70%	84%

District\Month	October	November	December	January	February	March	April	May
Zarqa	68%	60%	67%	54%	72%	60%	70%	68%
Mean	65%	65%	63%	57%	59%	57%	69%	72%
Standard Error	0.012	0.016	0.010	0.008	0.016	0.014	0.013	0.016
Standard Deviation	0.040	0.057	0.035	0.029	0.054	0.050	0.044	0.055
Sample Variance	0.002	0.003	0.001	0.001	0.003	0.002	0.002	0.003
Kurtosis	0.839	-1.101	-1.322	-0.662	1.940	-1.437	-0.975	0.182
Skewness	1.038	0.509	-0.062	0.435	1.477	-0.165	-0.311	0.966
Minimum	61%	58%	58%	54%	53%	49%	61%	67%
Maximum	74%	75%	67%	63%	72%	63%	75%	84%

And for randomness trials of ARIMA, 9 models were applied on each district's precipitation data. As per discussed before, Runs and Ljung-Box tests were selected to find out which model is the best in order to forecast the precipitation data for each district.

Table 51: Results of ARIMA models for all the districts

Districts	**Randomness test**	**ARIMA Models**								
		(1,0,1)	**(2,0,2)**	**(1,0,2)**	**(2,0,1)**	**(1,2,1)**	**(2,2,2)**	**(1,2,2)**	**(2,2,1)**	**(2,1,1)**
Ajlun	Ljung-box	✓	✓	✓	✓	✓	✓	x	✓	✓
	Runs test	✓	✓	✓	x	✓	✓	✓	✓	x
Amman	Ljung-Box	✓	✓	✓	✓	✓	✓	x	x	✓
	Runs test	x	✓	x	x	x	✓	✓	✓	✓
Balqa	Ljung-Box	✓	✓	✓	✓	✓	✓	x	✓	✓
	Runs test	x	✓	x	x	✓	✓	✓	✓	✓
Aqaba	Ljung-Box	x	✓	x	x	x	x	x	x	x
	Runs test	✓	✓	x	x	x	x	✓	✓	x
Irbid	Ljung-Box	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Runs test	x	x	x	x	✓	✓	x	x	x
Jarash	Ljung-Box	✓	✓	✓	✓	✓	✓	x	✓	✓
	Runs test	x	x	x	x	✓	x	✓	✓	✓
Karak	Ljung-Box	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Runs test	x	✓	x	x	✓	✓	✓	✓	x
Ma'an	Ljung-Box	x	✓	✓	x	x	✓	x	x	✓
	Runs test	x	✓	x	x	x	x	✓	✓	x
Madaba	Ljung-Box	✓	✓	✓	✓	✓	x	x	x	✓
	Runs test	✓	x	x	x	x	x	✓	✓	✓

Mafraq	Ljung-box	✓	✓	✓	✓	✓	✓	x	✓	✓
	Runs test	✓	x	x	x	x	x	✓	x	x
Tafilah	Ljung-Box	✓	✓	✓	✓	✓	✓	x	✓	✓
	Runs test	x	✓	x	x	✓	✓	✓	✓	x
Zarqa	Ljung-Box	✓	✓	✓	✓	✓	✓	x	✓	✓
	Runs test	✓	✓	x	✓	✓	x	✓	x	x

The next table describes the synopsis of the Precipitation data set parameters for each district and the best fit time series model of each district, in addition to the best probability distribution model with the models equation.

Table 52: The Synopsis of the parameters of rainfall data and the models of time series for meteorological district

District	Quality data check				Probability distribution		Time series models	Dry/Wet
	Normality test	**Consistency test**	**Trend analysis test**	**Stationary test**	**Best model**	**Equation**	**Best model**	
Ajlun	OK	OK	No trend	Stationary	Log-Normal	$y = logx = 2.6 + 0.12\ Z$	ARIMA (2,2,1)	53% Dry
Amman	Reject	OK	No trend	Stationary	Log-Normal	$y = logx = 2.65 + 0.13\ Z$	Winter's Model	65% Dry
Aqaba	Reject	OK	Has a trend	Reject	-	-	ARIMA (2,0,2)	58% Dry
Balqa	Reject	OK	No trend	Stationary	Log-Normal	$y = logx = 2.6 + 0.13\ Z$	ARIMA (2,0,2)	56% Dry
Irbid	Reject	OK	No trend	Stationary	Log-Normal	$y = logx = 2.6 + 0.12\ Z$	ARIMA (2,2,2)	56% Dry
Jarash	OK	OK	Has a trend	Reject	Log-Normal	$y = logx = 2.4 + 0.14\ Z$	Winter's Model	56% Dry
Karak	OK	OK	No trend	Stationary	Log-Normal	$y = logx = 2.5 + 0.14\ Z$	Winter's Model	53% Dry
Ma'an	OK	OK	Has a trend	Reject	Log-Normal	$y = logx = 2.2 + 0.2\ Z$	Winter's Model	56% Dry
Madaba	OK	OK	No trend	Reject	Log-Normal	$y = logx = 2.4 + 0.15\ Z$	ARIMA (1,0,1)	53% Dry
Mafraq	OK	OK	No trend	Stationary	Log-Normal	$y = logx = 2.2 + 0.13\ Z$	Winter's Model	53% Dry
Tafilah	OK	OK	No trend	Stationary	Log-Normal	$y = logx = 2.3 + 0.19\ Z$	ARIMA (1,2,1)	54% Dry
Zarqa	OK	OK	No trend	Stationary	Log-Normal	$y = logx = 2.13 + 0.14\ Z$	ARIMA (2,0,1)	54% Dry

Chapter 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

- In this study, it has been observed that all the selected districts, the study sample of 57 years is adequate and sufficient to apply any statistical test or time series models.
- Five quality tests were applied on the 12 meteorological districts; Normality test, Homogeneity test, Consistency test, Trend test and Stationary/ Unit root test, all the districts grant an acceptable results.
- Four probability distribution models were tested on the Precipitation data;, Gamma models, Gamble and Log-normal, a proper model for the gathered district was selected based on the best fitting curve approach. Mainly most of the meteorological districts followed the Log-normal distribution model except Aqaba district that obeys none.
- 10 years forecasting yearly Precipitation data was found for each meteorological district separately throughout the best representative forecasting model among Moving Average (MA), Holts-Winter or ARIMA.
- All meteorological districts gave a dry spells findings on the study period, the range was between 53% and 65% implying that the successive years have a higher possibility of dryness due to global warming.

- The monthly shift studies showed that 99% of the months among the 57 study period time considered as a dry months with strong declination which force us to focus more about the importance of the precipitation studies and consider it on any governmental stipulation regarding water.

5.2 Recommendation

- More calculations and considerations should be done on the water resources of Jordan due to water scarcity and the rapidly growing population.
- More stations must be established especially for boarder districts and the arid districts such as Aqaba.
- The Red sea Dead Sea project should be highlighted due to its importance to solve the water shortage in Jordan.

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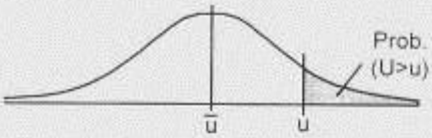
APPENDIX

Normal and Log-normal distributions table



U		0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	U
0.0		50000	49601	49202	48803	48405	48006	47608	47210	46812	46414	0.0
0.1		46017	45620	45224	44828	44433	44038	43644	43251	42858	42465	0.1
0.2		42074	41683	41294	40905	40517	40129	39743	39358	38974	38591	0.2
0.3		38209	37828	37448	37070	36693	36317	35942	35569	35197	34827	0.3
0.4		34458	34090	33724	33360	32997	32636	32276	31918	31561	31207	0.4
0.5	0	30854	30503	30153	29806	29460	29116	28774	28434	28096	27760	0.5
0.6		27425	27093	26763	26435	26109	25785	25463	25143	24825	24510	0.6
0.7		24196	23885	23576	23270	22965	22663	22363	22065	21770	21476	0.7
0.8		21186	20897	20611	20327	20045	19766	19489	19215	18943	18673	0.8
0.9		18406	18141	17879	17619	17361	17106	16853	16602	16354	16109	0.9
1.0		15866	15625	15386	15151	14987	14686	14457	14231	14007	13786	1.0
1.1		13567	13350	13136	12924	12714	12507	12302	12100	11900	11702	1.1
1.2		11507	11314	11123	10935	10749	10565	10383	10204	10027	98525	1.2
1.3		96800	95098	93418	91759	90123	88508	86915	85343	83793	82264	1.3
1.4		80757	79270	77804	76359	74934	73529	72145	70781	69437	68112	1.4
1.5		66807	65522	64255	63008	61780	60571	59380	58208	57033	55917	1.5
1.6		54799	53699	52616	51551	50503	49471	48457	47460	46479	45514	1.6
1.7	0.0	44565	43633	42716	41815	40930	40059	39204	38364	37538	36727	1.7
1.8		35930	35148	34380	33625	32884	32157	31443	30742	30054	29179	1.8
1.9		28717	28067	27429	26803	26190	25588	24998	24419	23852	23295	1.9
2.0		22750	22216	21692	21178	20675	20182	19699	19226	18763	18309	2.0
2.1		17864	17429	17003	16506	16177	15778	15386	15003	14629	14262	2.1
2.2		13903	13553	13209	12874	12545	12224	11911	11604	11304	11011	2.2
2.3		10724	10444	10170	99031	96419	93867	91375	88940	86563	84242	2.3
2.4		81975	79763	77603	75494	73436	71428	69469	67557	65691	63872	2.4
2.5		62097	60366	58677	57031	55426	53861	52336	50849	49400	47988	2.5
2.6		46612	45271	43965	42692	41453	40246	39070	37926	36811	35726	2.6
2.7	0.0^2	34670	33642	32641	31667	30720	29798	28901	28028	27179	26354	2.7
2.8		25551	24771	24012	23274	22557	21860	21182	20524	19884	19262	2.8
2.9		18658	18071	17502	16948	16411	15889	15382	14890	14412	13949	2.9
3.0		13499	13062	12639	12228	11829	11442	11067	10703	10350	10008	3.0
3.1		96760	93544	90426	87403	84474	81635	78885	76219	73638	71136	3.1
3.2		68714	66367	64095	61895	59765	57703	55706	53774	51904	50094	3.2
3.3		48342	46648	45009	43423	41889	40406	38971	37584	36243	34946	3.3
3.4	0.0^3	33693	32481	31311	30179	29086	28029	27009	26023	25071	24151	3.4
3.5		23263	22405	21577	20778	20006	19262	18543	17849	17180	16534	3.5
3.6		15911	15310	14730	14171	13632	13112	12611	12128	11662	11213	3.6
3.7		10780	10363	99611	95740	92010	88417	84957	81624	78414	75324	3.7
3.8		72348	69483	66726	64072	61517	59059	56694	54418	52228	50122	3.8
3.9		48096	46148	44274	42473	40741	39076	37475	35936	34458	33037	3.9
	0.0^4											
4.0		31671	30359	29099	27888	26726	25609	24536	23507	22518	21569	4.0
4.1		20658	19783	18944	18138	17365	16624	15912	15230	14575	13948	4.1
4.2		13346	12769	12215	11685	11176	10689	10221	97736	93447	89337	4.2
4.3		85399	81627	78015	74555	71241	68069	65031	62123	59340	56675	4.3
4.4		54125	51685	49350	47117	44979	42935	40980	39110	37322	35612	4.4
	0.0^5											
4.5		33977	32414	30920	29492	28127	26823	25577	24386	23249	22162	4.5
4.6		21125	20133	19187	18283	17420	16597	15810	15060	14344	13660	4.6
4.7		13008	12386	11792	11226	10686	10171	96796	92113	87648	83391	4.7
4.8		79333	75465	71779	68267	64920	61731	58693	55799	53043	50418	4.8
4.9	0.0^6	47918	45538	43272	41115	39061	37107	35247	33476	31792	30190	4.9
U		0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	U

y_n values corresponding to the recorded length for Gumble and Log-Gumble distributions

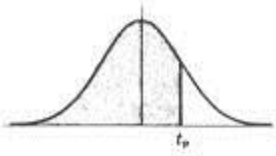
n (yr)	y_n values									
	0	1	2	3	4	5	6	7	8	9
10	0.4952	0.4996	0.5035	0.5070	0.5100	0.5128	0.5157	0.5181	0.5202	0.5220
20	0.5236	0.5252	0.5268	0.5283	0.5296	0.5309	0.5320	0.5332	0.5343	0.5353
30	0.5362	0.5371	0.5380	0.5388	0.5396	0.5402	0.5410	0.5418	0.5424	0.5430
40	0.5436	0.5442	0.5448	0.5453	0.5458	0.5463	0.5468	0.5473	0.5477	0.5481
50	0.5485	0.5489	0.5493	0.5497	0.5501	0.5504	0.5508	0.5511	0.5515	0.5518
60	0.5521	0.5524	0.5527	0.5530	0.5533	0.5535	0.5538	0.5540	0.5543	0.5545
70	0.5548	0.5550	0.5552	0.5555	0.5557	0.5559	0.5561	0.5563	0.5565	0.5567
80	0.5569	0.5570	0.5572	0.5574	0.5576	0.5578	0.5580	0.5581	0.5583	0.5585
90	0.5586	0.5587	0.5589	0.5591	0.5592	0.5593	0.5595	0.5596	0.5598	0.5599
100	0.5600									

σ_n values corresponding to the recorded length for Gumble and Log-Gumble distributions

n (yr)	σ_n values									
	0	1	2	3	4	5	6	7	8	9
10	0.9496	0.9476	0.9833	0.9971	1.0095	1.0206	1.0316	1.0411	1.0493	1.0565
20	1.0628	1.0696	1.0754	1.0811	1.0864	1.0915	1.0961	1.1004	1.1047	1.1086
30	1.1124	1.1159	1.1193	1.1226	1.1255	1.1285	1.1313	1.1339	1.1363	1.1388
40	1.1413	1.1436	1.1458	1.1480	1.1499	1.1519	1.1538	1.1557	1.1574	1.1590
50	1.1607	1.1623	1.1638	1.1658	1.1657	1.1681	1.1696	1.1708	1.1721	1.1734
60	1.1747	1.1759	1.1770	1.1782	1.1793	1.1803	1.1814	1.1824	1.1834	1.1844
70	1.1854	1.1863	1.1873	1.1881	1.1890	1.1898	1.1906	1.1915	1.1923	1.1930
80	1.1938	1.1945	1.1959	1.1959	1.1967	1.1973	1.1980	1.1987	1.1994	1.2001
90	1.2007	1.2013	1.2020	1.2026	1.2032	1.2038	1.2044	1.2049	1.2055	1.2060
100	1.2065									

Value of t-test based on different confidence intervals and degree of freedom

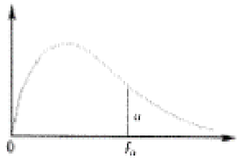
PERCENTILE VALUES (t_p)
for
STUDENT'S t DISTRIBUTION
with degrees of freedom
(shaded area = p)



df	$t_{0.995}$	$t_{0.99}$	$t_{0.975}$	$t_{0.95}$	$t_{0.90}$	$t_{0.80}$	$t_{0.75}$	$t_{0.70}$	$t_{0.60}$	$t_{0.55}$
1	63·66	31·82	12·71	6·31	3·08	1·376	1·000	0·727	0·325	0·158
2	9·92	6·96	4·30	2·92	1·89	1·061	0·816	0·617	0·289	0·142
3	5·84	4·54	3·18	2·35	1·64	0·978	0·765	0·584	0·277	0·137
4	4·60	3·75	2·78	2·13	1·53	0·941	0·741	0·569	0·271	0·134
5	4·03	3·36	2·57	2·02	1·48	0·920	0·727	0·559	0·267	0·132
6	3·71	3·14	2·45	1·94	1·44	0·906	0·718	0·553	0·265	0·131
7	3·50	3·00	2·36	1·90	1·42	0·896	0·711	0·549	0·263	0·130
8	3·36	2·90	2·31	1·86	1·40	0·889	0·706	0·546	0·262	0·130
9	3·25	2·82	2·26	1·83	1·38	0·883	0·703	0·543	0·261	0·129
10	3·17	2·76	2·23	1·81	1·37	0·879	0·700	0·542	0·260	0·129
11	3·11	2·72	2·20	1·80	1·36	0·876	0·697	0·540	0·260	0·129
12	3·06	2·68	2·18	1·78	1·36	0·873	0·695	0·539	0·259	0·128
13	3·01	2·65	2·16	1·77	1·35	0·870	0·694	0·538	0·259	0·128
14	2·98	2·62	2·14	1·76	1·34	0·868	0·692	0·537	0·258	0·128
15	2·95	2·60	2·13	1·75	1·34	0·866	0·691	0·536	0·258	0·128
16	2·92	2·58	2·12	1·75	1·34	0·865	0·690	0·535	0·258	0·128
17	2·90	2·57	2·11	1·74	1·33	0·863	0·689	0·534	0·257	0·128
18	2·88	2·55	2·10	1·73	1·33	0·862	0·688	0·534	0·257	0·127
19	2·86	2·54	2·09	1·73	1·33	0·861	0·688	0·533	0·257	0·127
20	2·84	2·53	2·09	1·72	1·32	0·860	0·687	0·533	0·257	0·127
21	2·83	2·52	2·08	1·72	1·32	0·859	0·686	0·532	0·257	0·127
22	2·82	2·51	2·07	1·72	1·32	0·858	0·686	0·532	0·256	0·127
23	2·81	2·50	2·07	1·71	1·32	0·858	0·865	0·532	0·256	0·127
24	2·80	2·49	2·06	1·71	1·32	0·857	0·685	0·531	0·256	0·127
25	2·79	2·48	2·06	1·71	1·32	0·856	0·684	0·531	0·256	0·127
26	2·78	2·48	2·06	1·71	1·32	0·856	0·684	0·531	0·256	0·127
27	2·77	2·47	2·05	1·70	1·31	0·855	0·684	0·531	0·256	0·127
28	2·76	2·47	2·05	1·70	1·31	0·855	0·683	0·530	0·256	0·127
29	2·76	2·46	2·04	1·70	1·31	0·854	0·683	0·530	0·256	0·127
30	2·75	2·46	2·04	1·70	1·31	0·854	0·683	0·530	0·256	0·127
40	2·70	2·42	2·02	1·68	1·30	0·851	0·681	0·529	0·255	0·126
60	2·66	2·39	2·00	1·67	1·30	0·848	0·679	0·527	0·254	0·126
120	2·62	2·36	1·98	1·66	1·29	0·845	0·677	0·526	0·254	0·126
∞	2·58	2·33	1·96	1·645	1·28	0·842	0·674	0·524	0·253	0·126

Value of F-test based on different degree of freedom

Critical Values of the F Distribution for $\alpha = 0.05$



Denominator Degrees of Freedom (k_2)	Numerator Degrees of Freedom (k_1)																		
	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	∞
1	161.4	199.5	215.7	224.6	230.2	234.0	236.8	238.9	240.5	241.9	243.9	245.9	248.0	249.1	250.1	251.1	252.2	253.3	254.3
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40	19.41	19.43	19.45	19.45	19.46	19.47	19.48	19.49	19.50
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.74	8.70	8.66	8.64	8.62	8.59	8.57	8.55	8.53
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.91	5.86	5.80	5.77	5.75	5.72	5.69	5.66	5.63
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.68	4.62	4.56	4.53	4.50	4.46	4.43	4.40	4.36
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.00	3.94	3.87	3.84	3.81	3.77	3.74	3.70	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.57	3.51	3.44	3.41	3.38	3.34	3.30	3.27	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.28	3.22	3.15	3.12	3.08	3.04	3.01	2.97	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.07	3.01	2.94	2.90	2.86	2.83	2.79	2.75	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.91	2.85	2.77	2.74	2.70	2.66	2.62	2.58	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.79	2.72	2.65	2.61	2.57	2.53	2.49	2.45	2.40
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.69	2.62	2.54	2.51	2.47	2.43	2.38	2.34	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.60	2.53	2.46	2.42	2.38	2.34	2.30	2.25	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.53	2.46	2.39	2.35	2.31	2.27	2.22	2.18	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.48	2.40	2.33	2.29	2.25	2.20	2.16	2.11	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.42	2.35	2.28	2.24	2.19	2.15	2.11	2.06	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.49	2.45	2.38	2.31	2.23	2.19	2.15	2.10	2.06	2.01	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.46	2.41	2.34	2.27	2.19	2.15	2.11	2.06	2.02	1.97	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.42	2.38	2.31	2.23	2.16	2.11	2.07	2.03	1.98	1.93	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.28	2.20	2.12	2.08	2.04	1.99	1.95	1.90	1.84
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.25	2.18	2.10	2.05	2.01	1.96	1.92	1.87	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.23	2.15	2.07	2.03	1.98	1.94	1.89	1.84	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.20	2.13	2.05	2.01	1.96	1.91	1.86	1.81	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.18	2.11	2.03	1.98	1.94	1.89	1.84	1.79	1.73
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24	2.16	2.09	2.01	1.96	1.92	1.87	1.82	1.77	1.71
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22	2.15	2.07	1.99	1.95	1.90	1.85	1.80	1.75	1.69
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.25	2.20	2.13	2.06	1.97	1.93	1.88	1.84	1.79	1.73	1.67
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.24	2.19	2.12	2.04	1.96	1.91	1.87	1.82	1.77	1.71	1.65
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.22	2.18	2.10	2.03	1.94	1.90	1.85	1.81	1.75	1.70	1.64
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.09	2.01	1.93	1.89	1.84	1.79	1.74	1.68	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.00	1.92	1.84	1.79	1.74	1.69	1.64	1.58	1.51
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	2.04	1.99	1.92	1.84	1.75	1.70	1.65	1.59	1.53	1.47	1.39
120	3.92	3.07	2.68	2.45	2.29	2.17	2.09	2.02	1.96	1.91	1.83	1.75	1.66	1.61	1.55	1.50	1.43	1.35	1.25
∞	3.84	3.00	2.60	2.37	2.21	2.10	2.01	1.94	1.88	1.83	1.75	1.67	1.57	1.52	1.46	1.39	1.32	1.22	1.00