An-Najah National University

Faculty of Graduate Studies

Developing and Mapping Rainfall Intensity, Duration, and Frequency Curves in Al-Faria Catchment

By

Hussein Fathi Hussein Haji

Supervisor

Dr. Anan Jayyousi

Co-Supervisor

Dr. Sameer Shadeed

This Thesis is Submitted in Partial Fulfillment of the Requirements for the Degree of Master OF Water and Environmental Engineering, Faculty of Graduate Studies, An-Najah National University, Nablus, Palestine.

2017

Developing and Mapping Rainfall Intensity, Duration, and Frequency Curves in Al-Faria Catchment

By

Hussein Fathi Hussein Haji

This Thesis was defended successfully on 23/5/2017 and approved by:

Defense Committee Members	**Signature**
– **Dr. Anan Jayyousi / Supervisor**	………………..
– **Dr. Sameer Shadeed / Co-Supervisor**	………………..
– **Dr. Fathi Anayah / External Examiner**	……………….
– **Dr. Abdelhaleem Khader / Internal Examiner**	……………......

Dedicated

my beloved family

Acknowledgment

In the name of Allah, the Most Gracious and the Most Merciful. Alhamdulillah, all praises to Allah for the strengths and His blessing in completing this thesis. Special appreciation goes to my supervisors, Dr. Anan Jayyousi and Dr. Sameer Shadeed for their supervision and sharing their pearls of wisdom with me during the course of this research. Their invaluable help of constructive comments and suggestions throughout the experimental and thesis work have contributed to the success of this research. Many thanks to IMAP for their financial support. Also not forgetting my parents for their endless love, prayers and encouragements throughout my journey. Thanks to my sisters for helping me in writing this thesis. Thank you all very much.

الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Developing and Mapping Rainfall Intensity, Duration, and Frequency Curves in Al-Faria Catchment

أقر بأن ما اشتملت عليه هذه الرسالة إنما هو نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد ، وأن هذه الرسالة ككل ، أو أي جزء منها لم يقدم من قبل لنيل أي درجة أو لقب علمي أو بحثي لدى أي مؤسسة تعليمية أو بحثية أخرى.

<u>Declaration</u>

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

Student's Name: **اسم الطالب :**

Signature: **التوقيع :**

Date: **التاريخ :**

Table of contents

List of Figures

List of Tables

Developing and Mapping Rainfall Intensity, Duration, and Frequency Curves in Al-Faria Catchment

By
Hussein Fathi Hussein Haji
Supervisor
Dr. Anan Jayyousi
Co-Supervisor
Dr. Sameer Shadeed

Abstract

Rainfall intensity duration frequency (IDF) relationship is one of the most ordinarily used tools in water resources engineering, mainly to identify rainfall intensity at a duration and return period. In light of this, the present study is aimed at developing rainfall IDF relationship for Al-Faria catchment. The ground surface elevation in the catchment varies significantly. With a mild rainy winters and moderately dry, hot summers, the climate in Al-Faria catchment is Mediterranean, semi-arid region. Al-Faria catchment is gauged by six rainfall stations; these stations are Nablus, Talluza, Tammun, Tubas, Beit Dajan and Al-Faria with approximately 48 year of data. The analysis of the extreme values of annual rainfall data was achieved. The results proved that Gumbel distribution fits the data and can be used for future estimations. After all available data was assessed and completed the IDF curves were developed for stations, maps for the catchment were developed from these curves using inverse distance weight (IDW) as an interpolation tool through ArcGIS. These maps can be used to find rainfall intensity which also could be found directly (without using curves or maps) using the program that was created by Matlab. ArcGIS gives an IDF map for a certain period and duration while using Matlab will allow displaying an IDF curve for any point, any return period and duration.

Chapter One

Introduction

1.1 Background

Statistics and evaluation the data of extreme rainfall are essential in planning and management of water resources for design purposes in construction of sewer and storm systems and determination of the mandatory discharge capacity of canals. So they are important to prevent flooding, thus reducing the loss of lives Insurance of water damage, and evaluation of risky meteorological conditions. Studies on the rainfall intensity–duration–frequency relationship have received plenty of attention in the past few decades (AlHassoun, 2011).

Rainfall intensity–duration–frequency (IDF) curves represent the main source of data used by engineers to predict rainfall intensity. IDF curves are a probabilistic tool useful in planning and design studies, those curves enable assessment of the extreme characteristics of rainfall and provide a simple means of communicating information about local extremes (Guo, 2006). Urban drainage design is often based on the values provided through IDF curves (Guo, 2006).

Rainfall intensity–duration–frequency IDF curves are graphical representations of the amount of water that falls within a given period in catchment areas (Dupont and Allen, 2000). IDF curves are used to aid the engineers while designing urban drainage works. The establishment of IDF relationships was done as early as 1932 by Bernard (Chow, 1988), (Dupont and Allen, 2006). Since then, many sets of IDF relationships have been constructed for several parts of the globe. However, such relationships have not been accurately constructed in many developing countries (Koutsoyiannis et al., 1998).

Al-Faria catchment has a high spatial and temporal rainfall variability. Seven locations were involved in rainfall measurement: Nablus, Talluza, Tammun, Tubas, Beit Dajan, salim and Al-Faria stations. Rainfall gauges (daily data measurement) are available in six locations (Nablus, Talluza, Tammun, Tubas, Beit Dajan and Al-Faria). In addition, four tipping bucket (A type of recording rain gage; measures rainfall with a cycle of 0.2 millimeter) rain gages were installed in Talluza, Tubas, Tammun and Salim.

1.2 Research importance

The IDF curves is a tool developed from statistical analysis of extreme rainfall data, used for prediction of rainfall intensity. Then, by using empirical formula like rational method, we can find the water peaks amounts from a certain watershed. Those water peaks are necessary for designing storm systems, culvert design, channel design, dams desgtyign and other hydraulic structure design. The water peaks also play an essential role in water resource management planning.

1.3 Research Question

This research will mainly answer the question “How to develop and map IDF curves under data deficit conditions in semi-arid regions?”

1.4 Research Objectives

The main objective of this research is to contribute to a better understanding of the temporal and spatial variability of IDF curves in Al-Faria catchment, through:

1. Analyzing of available rainfall data.
2. Developing of IDF curves.
3. Mapping of IDF curves considering temporal and spatial variability.

1.5 Research Methodology

After the identification of the research problem, the first step in the research was to review the previously existing literature to develop ideas and draw a general picture of the whole situation. After data of rainfall was collected, The next step was to assess the data and check its suitability and coverage for rainfall analysis followed by the creation of suggested rainfall stations because of the lack of coverage to the entire area of Al-Faria catchment. After that, an estimation of the missing data was established through the creation of relation between daily rainfall data (DRD) and fine resolution data (FRD) which is 10 minute, 20 minute, 30 minute, 1 hour, 2 hour, 4 hour, 6 hour, and 12 hour data (which were selected because they are the most commonly used) and by using equation of weighted filling missing data. After that a significance analysis of DRD – FRD relations was done. Moreover, an analysis was made for the data to find the type of distribution it follows (which is mostly Gumbel distribution). After this, the IDF curves were developed for both available and suggested stations. In order to reach the point where we can find the rainfall intensity of any point among Al-Faria catchment, spatial mapping and temporal development of IDF curves were carried out by both ArcGIS and Matlab. Finally, conclusions and recommendations were presented. The overall methodology followed in this study is explained in **Figure 1.1**

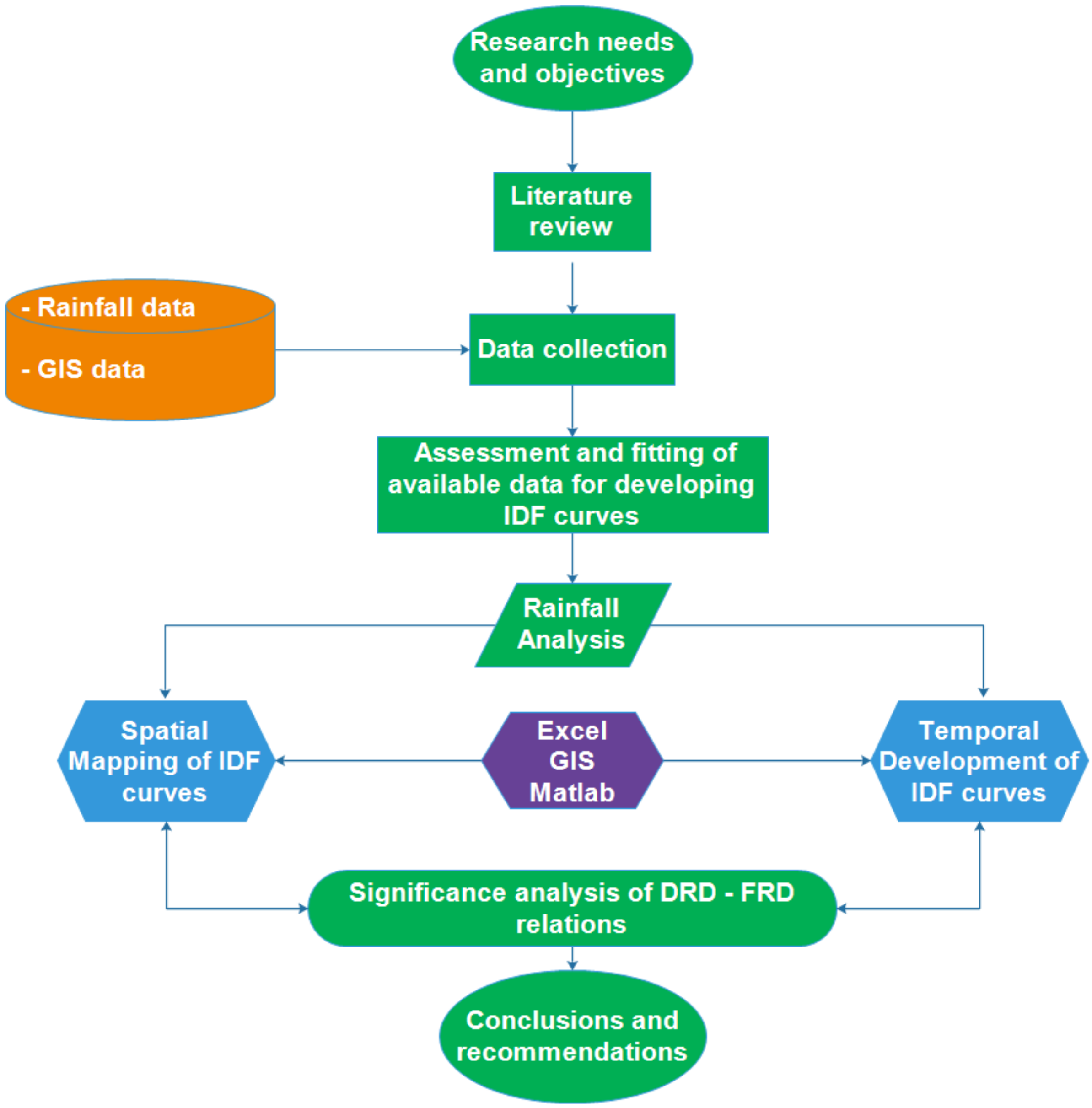

Figure 1. 1: Research Methodology Flowchart

Chapter Tow

Literature Review

The most common engineering tool to design flood structures is rainfall IDF curves. IDF curves clarify the relation between duration, intensity and return period. Generating IDF curves requires historical data of rainfall maximum intensities with fine time resolution. (Elsebaie, 2011)

IDF curves are used with runoff estimation formulae (e.g. rational method) to predict the peak runoff amounts from a certain watershed. The information from the curves are used in hydraulic design to size culverts and pipes. (Dupont and Allen, 2000)

The foundation of the relationships between intensity, duration and return period goes back to 1932 (Bernard, 1932). Different sets of relationships have been assembled from many parts around the world. The geographical locations of intensity-duration-frequency relationships in several developed countries has been studied and several maps have been established to provide the rainfall intensities or depths for different return periods and durations. (Koutsoyiannis et al, 1988)

Several rainfall maps for different return periods and durations were established by Harshfied to provide an excellent design for rain depths (Harshfied, 1961). Chen (1983) developed a formula for geographical rainfall variation in any place around the USA, using three base rainfall depth formula, which is similar but more accurate than the one previously developed, requiring only the 10- year 1- hour rainfall depth instead of three. Then a relationship was presented between the intensity of rainfall and two years return period, with duration 24 hr for India by Kouthyari and Garde (1992).

A year later, rainfall data of 14 rain gauge stations of Punpun basin located in Bihar was collected for regional rainfall frequency analysis to find the robust distribution for these daily rain gauge stations, having data availability of 9-17 years using the L-moment approach. The robust distribution was used to find the IDF relationship and curves for short duration rainfall for Punpun basin. From the IDF curves, parameters of empirical equations for the gauged locations were determined, then contour maps were generated, followed by developing of IDF curves for ungauged locations using GIS. Finally, a generalized IDF curve incorporating return period and the duration of rainfall for the particular station was developed. (Venkata et al, 2008)

AlHassoun (2011) worked on an empirical formula aiming to estimate design rainfall intensity IDF curves, The formula was derived using the analysis of results from three different frequency methods, namely: Gumbel, Log Pearson III, and Log normal. A good match was achieved between its results and other analytical methods results such as Gumbel method. Furthermore, it allows incorporating data from non-recording stations, thus alleviating the problem of forming IDF curves in places with a sparse network of rain-recording stations. (AlHassoun, 2011)

From the Nigerian Meteorological Agency, Calabar, Nigeria, twenty-three years peak rain storm intensity data with their corresponding durations were collected aiming at developing and comparing different IDF models. This research tells that the logarithmic model yields comparatively moderate intensity-duration-frequency models that would ensure adequate sizing and forecast of relevant hydraulic structures in the study area. (Antigha and Ogarekpe, 2013)

For Al-Faria catchment, Shadeed (2012) developed a Spatio-temporal drought analysis in Al-Faria catchment to determine the least rainfall amount essential to avoid drought initiation. Shadeed developed a probability distribution of Al-Faria catchment rainfall to calculate the distribution characteristics of the semi-arid region’s rainfall (Shadeed et al, 2005). Furthermore, Shadeed and AL-Masri (2007) established a statistical analysis of long-term rainfall data for Al-Faria catchment to analyze the long-term rainfall data of Nablus meteorological station in order to evaluate the temporal variation of rainfall in the area. Moreover, there are some IDF curves for Nablus and other places developed by the Palestinian Water Authority (2016).

The existing stations in Al-Faria catchment are not enough to characterize the rainfall spatial variation especially in the lower and central parts of the catchment. According to the statistical analysis, the optimal number of rain stations needed is 14 stations to have a clear picture of the spatial distribution of rainfall in Al-Faria catchment and to obtain the minimum required number of rainfall stations is 14 (Shadeed, 2005) , 8 imaginary stations were selected randomly in the catchment. To quantify the effect of topography, Shadeed (2005) developed a spatial-oriented formula using multiple linear regression analysis on observed mean annual rainfall data and predictor variables of X, Y (local Palestinian coordinates) and elevations for the six rainfall stations within the Faria catchment. (Shadeed, 2008)

Chapter Three

Study Area

3.1 Geography

With a total area of about 320 km^2, Al-Faria catchment is located in the northeastern part of the West Bank, Palestine, extending from the edges of Nablus Mountains down the eastern slopes of the Jordan River. Al-Faria catchment overlies three districts of the West Bank: Nablus, Tubas and Jericho district. It lies within the Eastern Aquifer Basin, which is considered as one of the three major groundwater aquifers forming the West Bank groundwater resources (See **Figure 3.1**). (Shadeed, 2005)

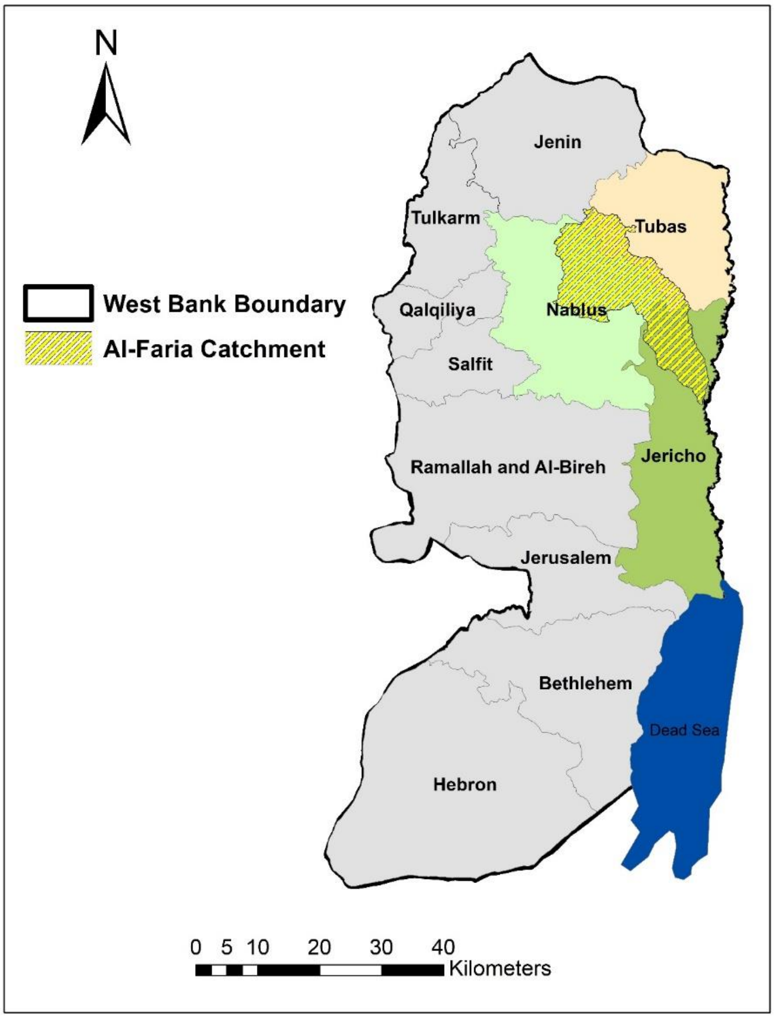

Figure 3. 1: Al-Faria Catchment within West Bank

3.2 Topography

From about 900 m above mean sea level at Nablus Mountains to about 350 m below mean sea level at the confluence with the Jordan River, the ground surface elevation in the catchment varies significantly. The water in the catchment runs through a stream of an irregular shape and direction and it is generally directed from west to east (**See Figure 3.2)**. (Shadeed, 2005)

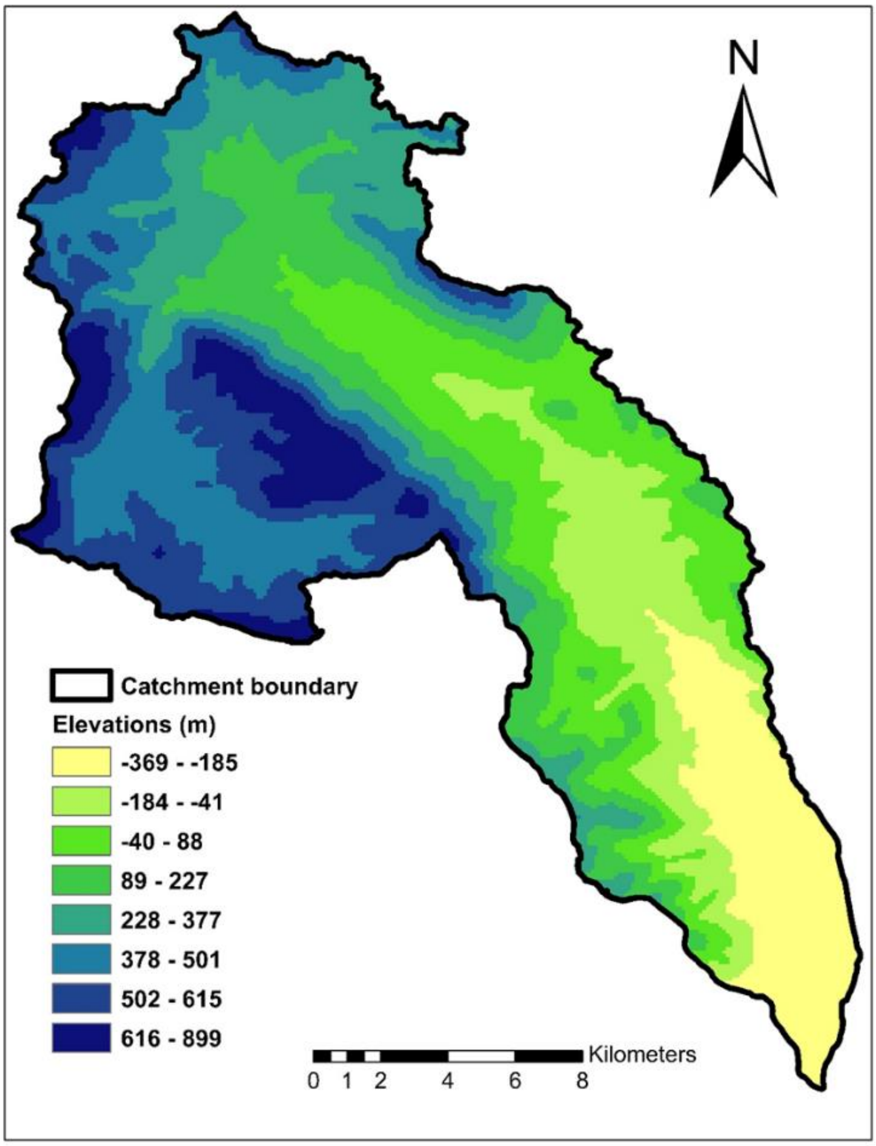

Figure 3. 2: Topography of Al-Faria Catchment

3.3 Climate

With mild rainy winters and moderately dry, hot summers, the climate in the Faria catchment is Mediterranean. Within a few kilometers, the area changes from a Mediterranean climate to a semi-arid climate, where rainfall is limited to a couple of months instead of well-marked six-long-rainy months. This highly variable climate is influenced by both elevation and the circulation of the air-stream. The upper and western parts of are affected by moist, west-oriented air streams originating from the Mediterranean Sea which are responsible for most of the rainfall in the wet season and increases the relative air moisture in the dry season. (Shadeed, 2005)

3.4 Rainfall

Al-Faria catchment is classified as a semiarid region, with rainfall distribution ranges from 150 mm to 640 mm, where the maximum rainfall amount is through winter.

There are six stations gauge the rainfall amount at AL-Faria catchment; Nablus, Talluza, Tammun, Tubas, Beit Dajan and Al-Faria stations. The exact location for Al-Faria station is at the lower part of Al-Faria catchment in a village called Al-Jiftlik. Whereas Nablus station is metrological, the other five stations are simple rain gauges located in schools of these villages to measure daily rainfall. (Shadeed, 2005)

There are four tipping bucket rain gages beside the ones installed in the schools of Talluza, Tubas, Tammun and Salim. The four stations have been measuring data for roughly seven years giving a rainfall data every 0.2 mm cycle (See **Figure 3.3**). **Table 1** represents the available data from the stations with their elevations. (Shadeed, 2005)

Table 1.1: The Stations Rainfall Data (PWA, 2016)

Rainfall Station	Description	Elev.	Type of Data			
			Annual	Monthly	Daily	Hourly
		(m)	Period			
Nablus station	**Rainfall station (daily)**	570	1968-2016	1968-2016	1975-2016	No data
Talluza Station	**Rainfall station (daily) & TBRs**	500	1968-2016	1968-2016	1968-2016	2006-2010
Tubas Station	**Rainfall station (daily) & TBRs**	375	1969-2016	1969-2016	1967-2010 &2011-2016	2005-2010
Beit Dajan Station*	**Rainfall station (daily)**	520	1969-2005*	1967-2005*	1967-2005*	No data
Tammun Station	**Rainfall station (daily) & TBRs**	340	1969-2016	1967-1987 &1990-2016	1967-1987 &1990-2016	2005-2015
AL faria station**	**Rainfall station (daily)**	-237	1969-1989**	1969-1989**	1969-1978**	No data
Salim Station	**TBRs**	514	2004-2016	2004-2016	2004-2016	2005-2014

*The station is damaged after 2005

**The station is under Israeli control

TBRs : Tipping Buckets rain gages

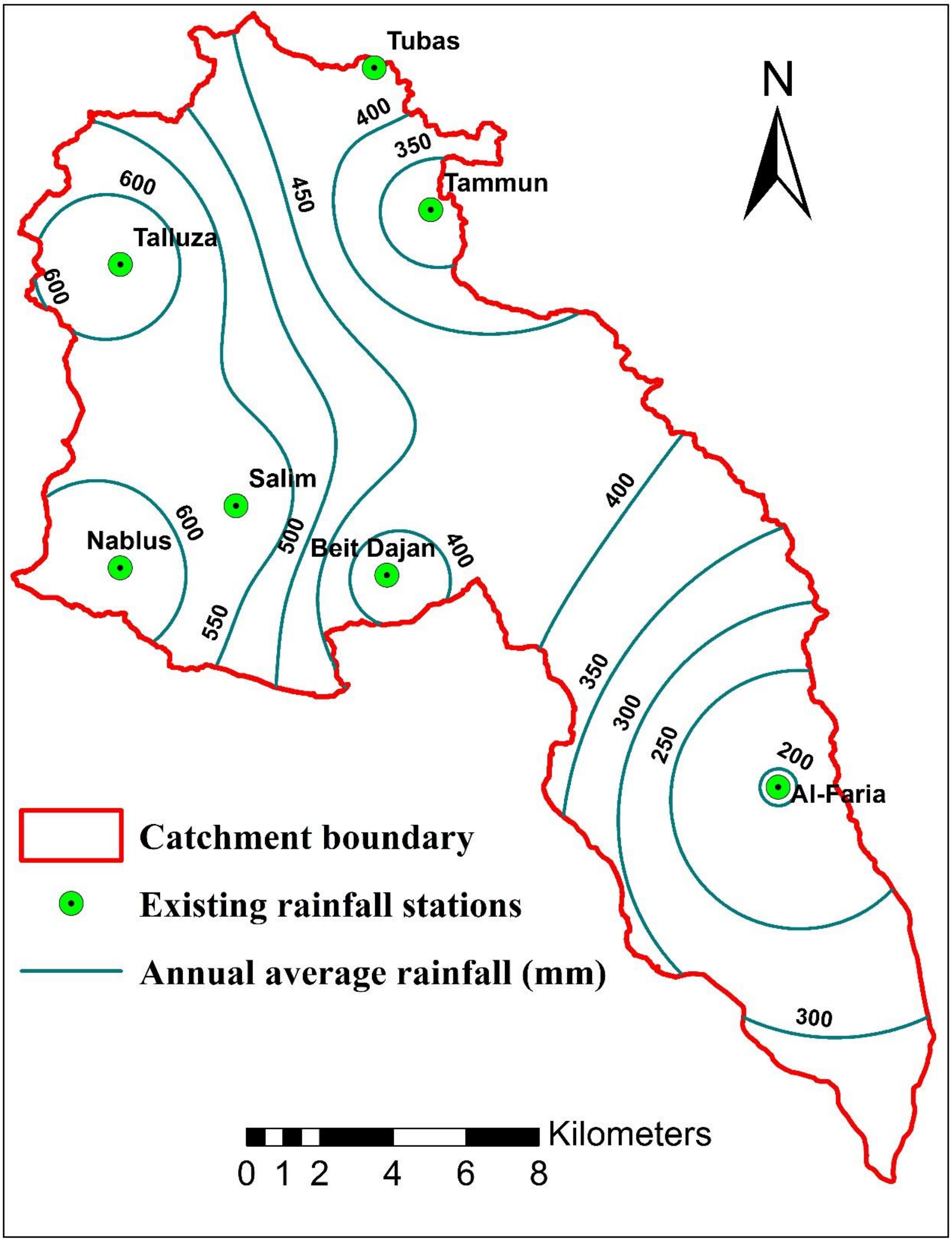

Figure 3. 3: Rainfall Stations and Rainfall Distribution in Al-Faria Catchment

From **Figure 3.3**, the rainfall interpolation in the lowest part of the catchment is inaccurate because there is only one station on that area.

Chapter Four

Rainfall Analysis

4.1 Rainfall Stations

The optimal number of stations needed to measure rainfall data can be determined by using the following equations (Subramanya, 2013) (shadeed, 2008).

$$N = \{\frac{C_v}{E_p}\}^2 \text{ .... (4.1)}$$

Where

N: is the optimal number of stations

$C_{v:}$ is the coefficient of variation of the rainfall from the existing stations in percentage

Ep: the allowable percentage of error in the estimation of mean aerial rainfall

The coefficient of variation C_v was calculated by applying the steps below:

1. Calculate the mean of rainfall from the equation

$$P_{av} = \frac{1}{n}\sum P_i \text{ .... (4.2)}$$

2. Calculate the standard deviation as

$$\sigma_{n-1} = \frac{1}{(n-1)}\sum(P_i - P_{av})^2 \text{ .... (4.3)}$$

3. Compute the coefficient of variation as

$$C_v = \frac{\sigma_{n-1} X\ 100}{P_{av}} \text{ .... (4.4)}$$

The higher the percentage of error is, the fewer the number of stations there.

The previous statistical parameters were calculated using the data from the six stations, with:

P_{av} = 417.2 mm $\sigma_{n-1} = 164.9$ C_v = 39.5

Based on 11% error, the minimum required number of stations is 14.

Existing stations (n) = 6

Additional stations required = (N-n) = 8

4.2 Data Consistency

The first assessment of homogeneity of the rainfall data was tested using double mass curve (Searcy & Hardison, 1960). **Figure 4.1** represents the Double mass plots for the accumulated annual rainfall in Al-Faria, Salim, 8, 9, 10, 11, 12, 13 and 14 stations' data against the accumulated annual average rainfall for mean of surrounding stations (Nablus, Bait Dajan, Tammun, Talluza and Tubas), the figures shows an approximate straight line. As a result of the consistency analysis -plotted in the Figures - all the stations are internally consistent, and the data can be used for statistical analysis.

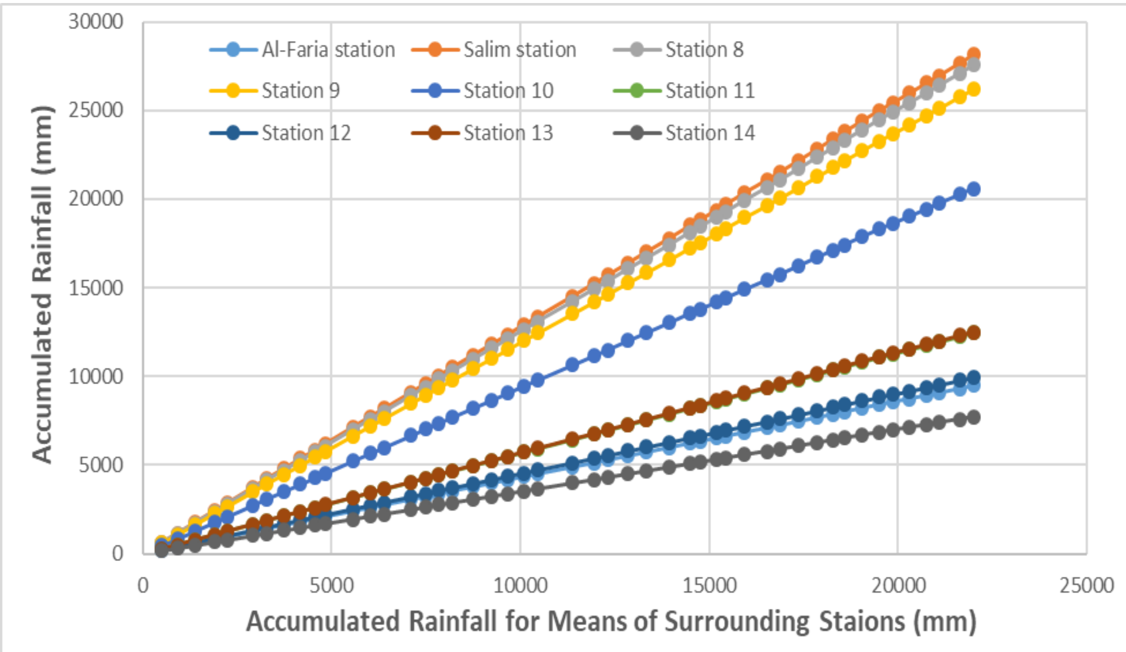

Figure 4. 1: Al-Faria, Salim, 8, 9, 10, 11, 12, 13 and 14 Stations Double Mass Analysis

4.3 Statistical Analysis of Annual and Seasonal Rainfall

Over the period from September 1st to August 31st, the seasonal and annual rainfall data for the hydrological year were classified. Using the rainfall data, many statistical parameters were calculated by the principle statistical analysis. For each station, the skewness, mean, median, kurtosis, maximum and minimum measurements for both the seasonal and annual data were calculated. Summarization for the statistical parameters from the six rain gauges is presented in **Table 2 in the appendix.**

From the parameters obtained, the rainfall temporal variability in Al-Faria catchment was studied. This obviously was done using the stations in the catchment. The annual and seasonal rainfall statistical parameters for Nablus station especially are shown in **Table 2 in the appendix.**

The values inside Table 4.1 manifest the mean and the median annual rainfall of Nablus metrological station as 638 mm and 623 mm respectively, the annual rainfall data is skewed to right, with big range results from the great variance between the minimum and maximum values, and a high variability because of the wide standard deviation.

To determine if the annual rainfall data matches the normal distribution; both skewness and kurtosis were calculated. Starting with skewness -that measures symmetry-, it is positive and does not follow the normal distribution -normal distribution has a zero skewness-. Moving to the kurtosis-that measures flatness-, it has a positive value except in the spring, it also does not follow the normal distribution which must have a zero kurtosis.

Rainfall amount is the highest in winter, rain barely falls in summer. Out of 48 years, the rainfall amount for 23 years of them was above the average. In 1992 specifically, the rainfall amount was twice the average since the value 1402 mm was recorded. In the same year, 80% of rainfall was recorded in winter. Generally, 65% of rainfall is recorded over winter See **Figure 4.2**.

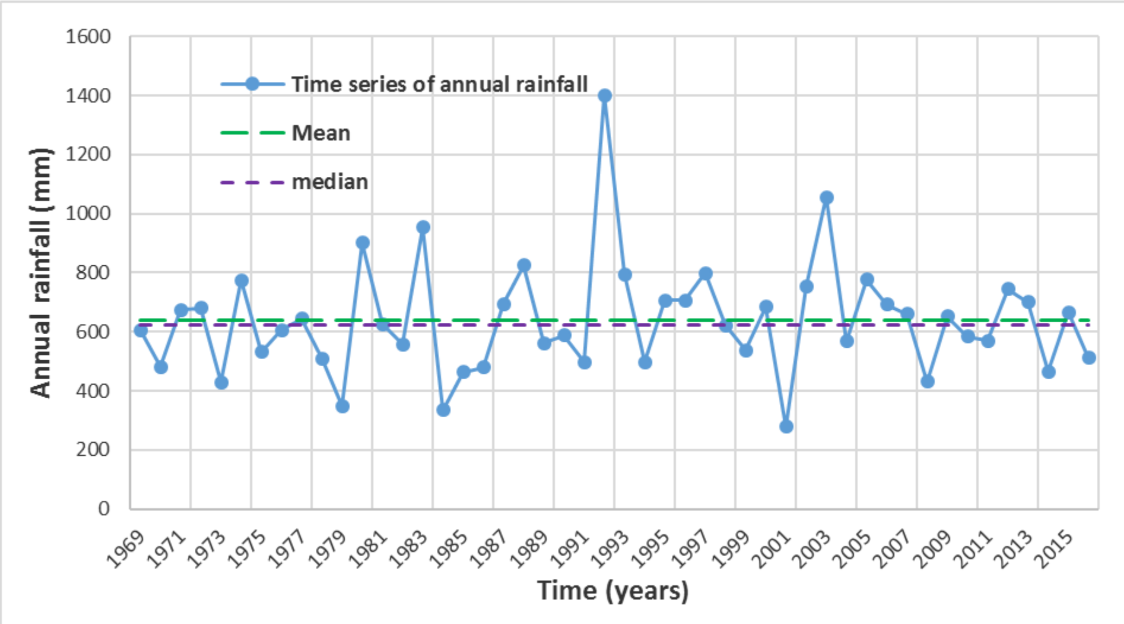

Figure 4. 2: Annual Rainfall Time Series of Nablus

After explaining both seasonal and annual rainfall data, a relationship between them must be made, the correlation coefficient (r) measures the association between both variables. Fall, winter and spring correlation results have positive values with annual rainfall where summer correlation is negative. The correlation values for fall, winter, spring and summer are 0.36, 0.86, 0.35 and -0.02 respectively. It is obvious to say that a near-zero correlation coefficient means that there is no relationship between annual and seasonal rainfall. The following series of **Figures 4.3 through 4.6** illustrate the rainfall in four seasons.

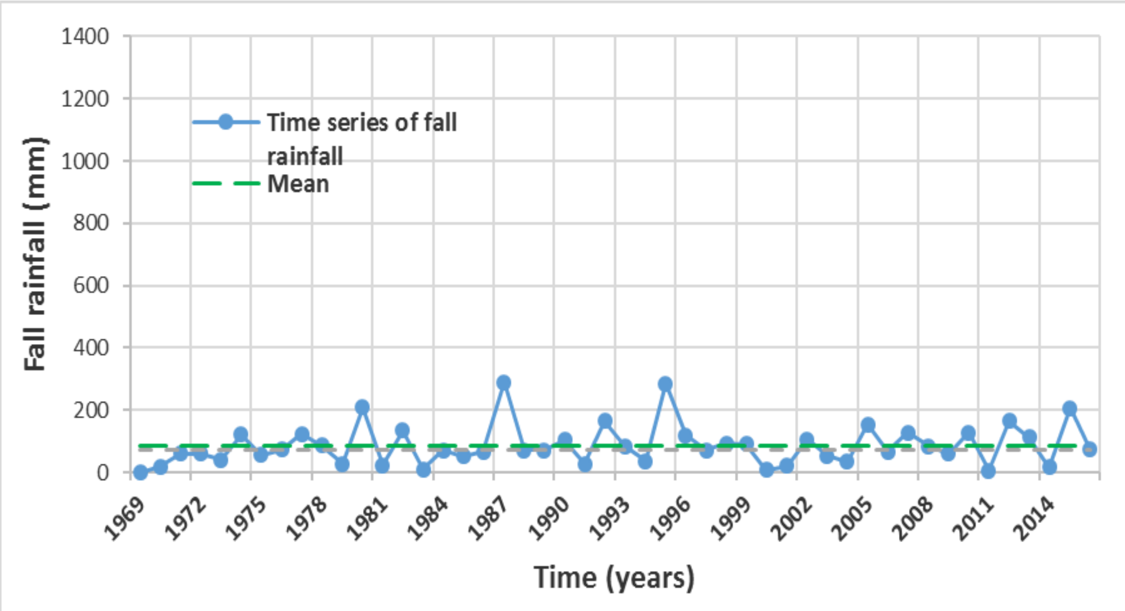

Figure 4. 3: Rainfall Time Series of Fall of Nablus

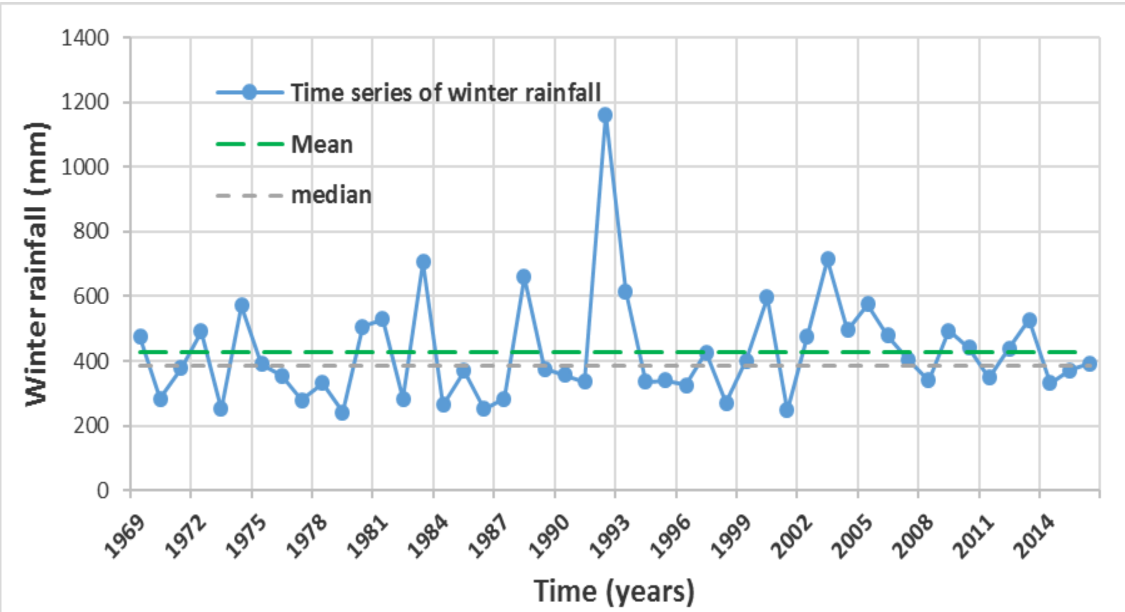

Figure 4. 4: Rainfall Time Series of Winter of Nablus

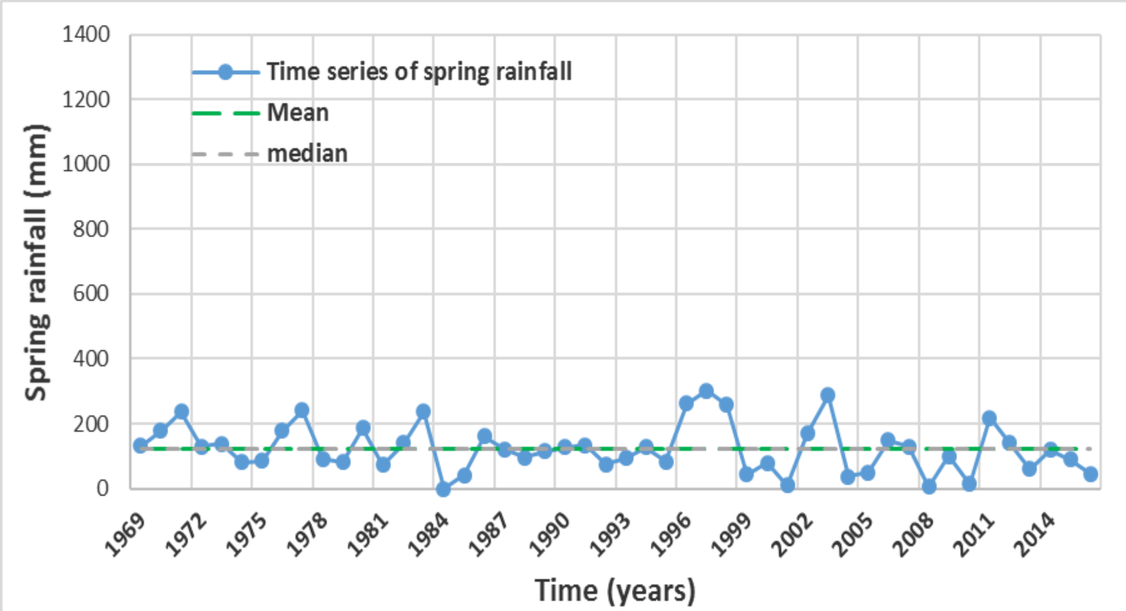

Figure 4. 5: Rainfall Time Series of Spring of Nablus

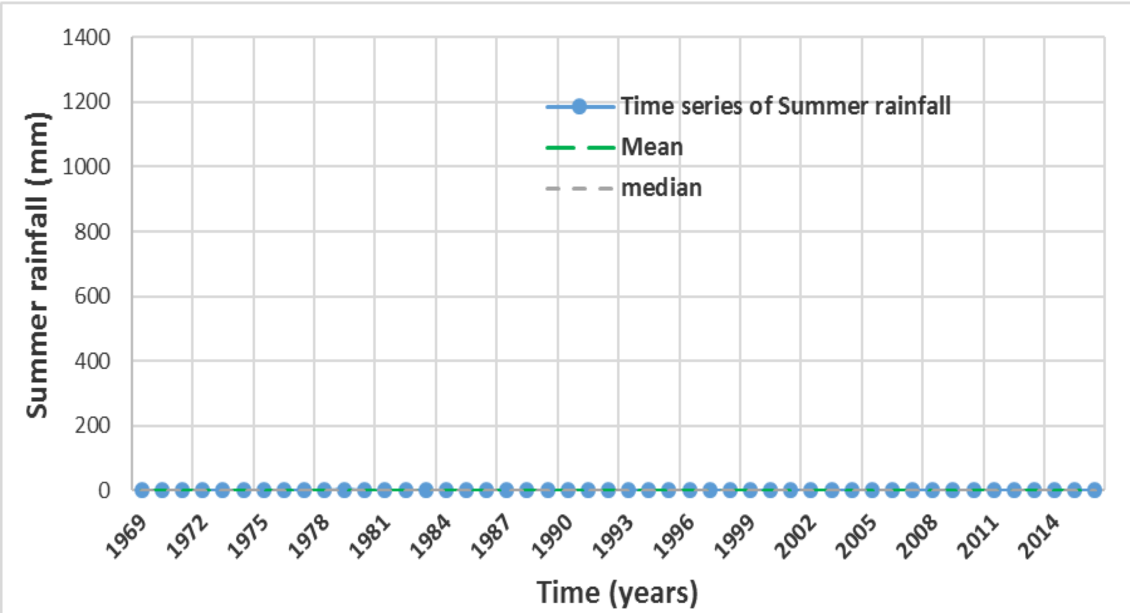

Figure 4. 6: Rainfall Time Series of Summer of Nablus

4.4 Trend Analysis

To evaluate the Trend analysis of annual rainfall. A representation of the trends for of Nablus, Beit Dajan, Tubas, Talluza and Tammun stations is presented in **Figures 4.7** and **4.8** while **Table 3 and 4** organizes the results of the linear regression applied to the annual rainfall values of the stations.

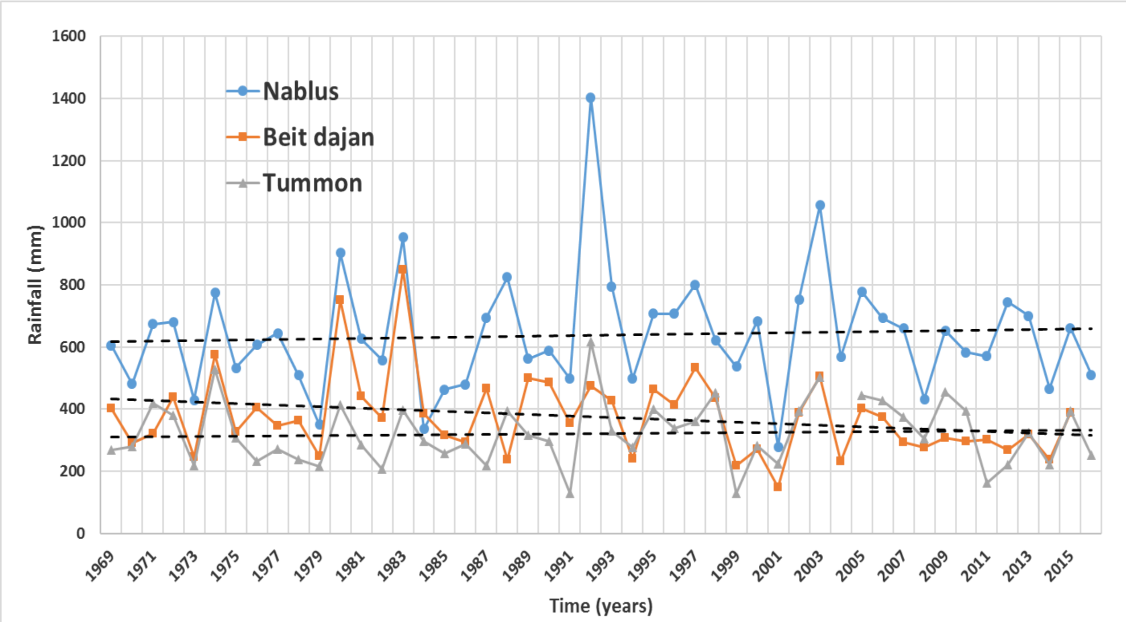

Figure 4. 7: Annual Rainfall of Nablus, Beit Dajan and Tammun

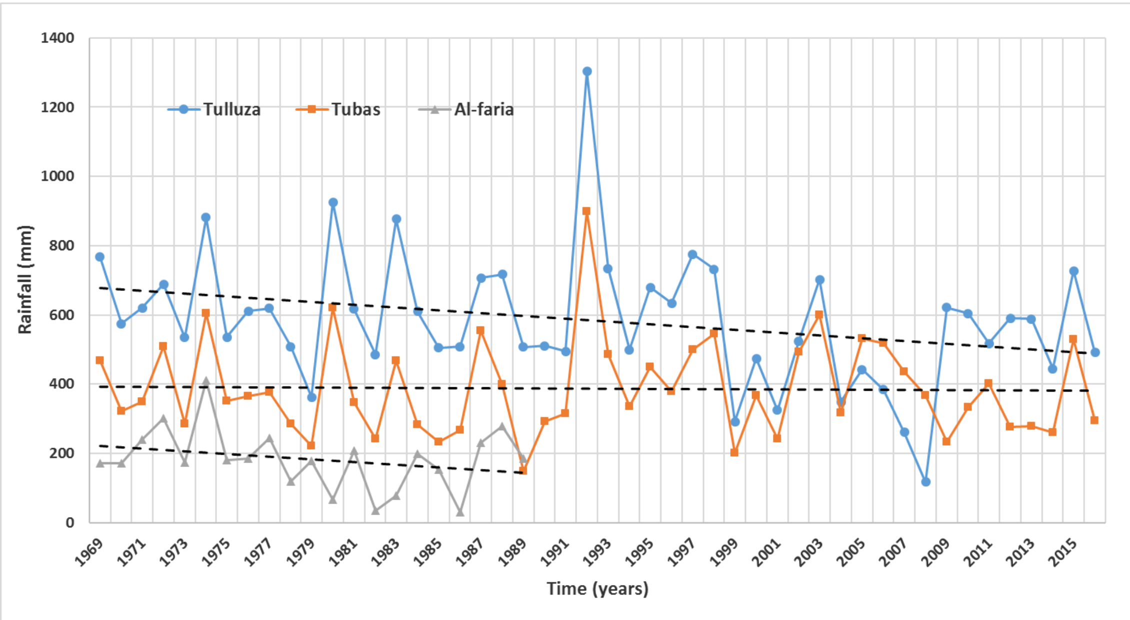

Figure 4. 8: Annual Rainfall of Tubas, Talluza and Al-Faria

Table 4.2: The Average of the Five Stations Trend Equations

Rainfall Station	Trend Equation $Y = B_1X + B_0$
Nablus Station	y = 0.87x -1091
Beit dajan Station	y = -2.37x + 5099
Tubas Station	y = -0.25x + 880
Talluza Station	y = -4.07x + 8692
Tammun Station	y = 0.5x - 680
Al-faria Station	y = -3.06x + 6241

Table 4.3 : T-test for Al-Faria stations

Station	t-statistic	t-critical at 90%	t-critical at 95%	Results (90%)	Results (95%)
Nablus	0.43	1.684	2.021	accept H0	accept H0
Beit dajan	-1.8	1.684	2.021	Reject H0	accept H0
Tubas	-0.17	1.684	2.021	accept H0	accept H0
Talluza	-2.09	1.684	2.021	Reject H0	Reject H0
Tammun	0.47	1.684	2.021	accept H0	accept H0
Al-faria	-1.73	1.703	2.052	Reject H0	accept H0

T-test is a test to determine whether there is a significant trend linear relationship between an independent variable X and a dependent variable Y. The test focuses on the slope of the regression line.

$Y = B_0 + B_1X$……………………………(.4.5)

Where:

B_0 is a constant, B_1 is the slope, X is the value of the independent variable and Y is the value of the dependent variable. If there is a significant linear relationship between the independent variable X and the dependent variable Y, the slope will not equal zero. (Hann, 1977)

Ho: $B1 = 0$

Ha: $B1 \neq 0$

The null hypothesis conditions that the slope is equal to zero, while the alternative hypothesis conditions that the slope does not equal to zero.

We used the sample data to determine if we are going to accept or reject the null hypothesis. The plan identified the following fundamentals:

-confidence interval 90% and 95%

-Testing method. A linear regression (t-test) were used to determine whether the slope of the regression line differs significantly from zero.

Using sample data, the standard error of the slope, the slope of the regression line, the degrees of freedom and t-statistic associated with the test statistic have been found. (Hann, 1977)

$$\text{standard error} = \frac{\sigma}{\sqrt{n}} \quad \text{............(4.6)}$$

Finally, the null hypothesis has been rejected in Beit dajan, Talluza and Al-faria because t-statistic was upper than t-critical for confidence interval of 90%. On the other hand, with confidence interval of 95% the null hypothesis was rejected in Talluza station only. In general there is no significance trend in the stations data so the data used for estimation the missing data.

4.5 Gumbel Distribution

According to the previous researches, the data in Al-Faria catchment follows the gamble distribution (Shadeed et al, 2005). Here, we are making sure that Gumbel distribution fits our data, which will be used to provide averages to understand and evaluate the distribution characteristics of the rainfall in Al-Faria catchment.

For the purpose of extreme value analysis, the following procedure has been followed:

1. The annual rainfall values were arranged in descending order over the recorded period and each value was given a rank, r.

2. For each value of rainfall, denoted by x, the probability of exceedance, P(x) was calculated using the Gringorten formula, which is appropriate for the analysis of extremes (Chow et al., 1988):

$$\mathrm{P(x)} = \frac{(\mathrm{r}-0.44)}{(\mathrm{n}+0.12)} \ldots\ldots\ldots\ldots\ldots\ldots (4.7)$$

where:

X: annual rainfall (mm)

P(x) = the probability of exceedance

r: the rank of x

n: the total number of recorded years

3. The probability of non-exceedance was calculated using the following relation.

$$F(x) = 1 - P(x) = 1 - \frac{(r-0.44)}{(n+0.12)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.8)$$

Where:

F(x): the probability of non-exceedance

x and P(x): as defined previously

4. The Gumbel probability distribution is defined as:

$$F(x) = \exp(-\exp\big(-b(x-a)\big)) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.9)$$

where:

$b = \frac{\pi}{\sigma\sqrt{6}}$ And, $a = \mu - \frac{\gamma}{b}$ $\quad (g = 0.5772)$

μ: The mean of all rainfall values (mm)

σ: The standard deviation of the rainfall values (mm)

5. The estimated Gumbel value of rainfall is defined as follows:

$$x = \frac{[-\ln(-\ln(F(x)))]}{b} + a \text{..........................} (4.10)$$

The above parameters are calculated for the six stations and are listed in **Table 7**. The square values of the correlation coefficient, r^2, are also determined. The Gumbel plots are presented in **Figures 4.11** through **4.16**. From the figures and tabulated results, it is confirmed that Gumbel distribution can be applied to the model of the annual rainfall stations of Faria catchment.

Table 4.4 : Parameters of Gumbel Distribution for the Six Stations

Rainfall Station	Average	STDEV	a	b	r^2
Nablus Station	638.0	191.5	551.8	0.0067	0.981
Beit dajan Station	370.0	132.7	310.2	0.0097	0.981
Tubas Station	387.1	140.4	323.9	0.0091	0.987
Talluza Station	582.8	193.8	495.6	0.0066	0.974
Tammun Station	319.4	107.6	270.9	0.0119	0.989
Al-faria Station	168.2	103.8	121.5	0.0124	0.981

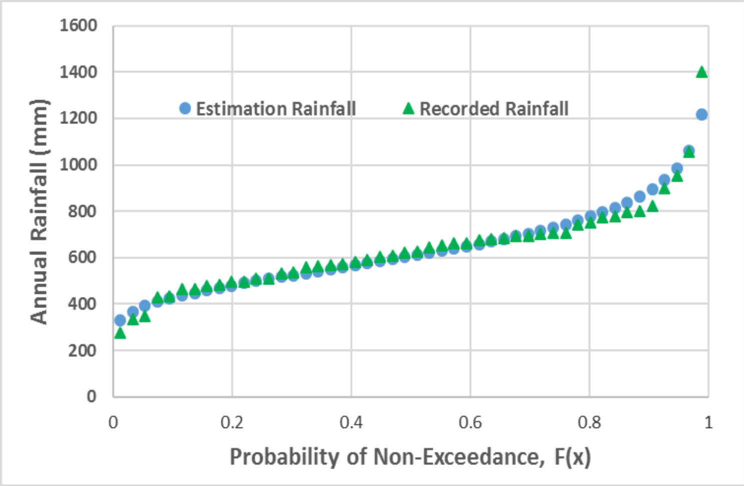

Figure 4. 9: Gumbel Plots of Annual Rainfall for Nablus Station

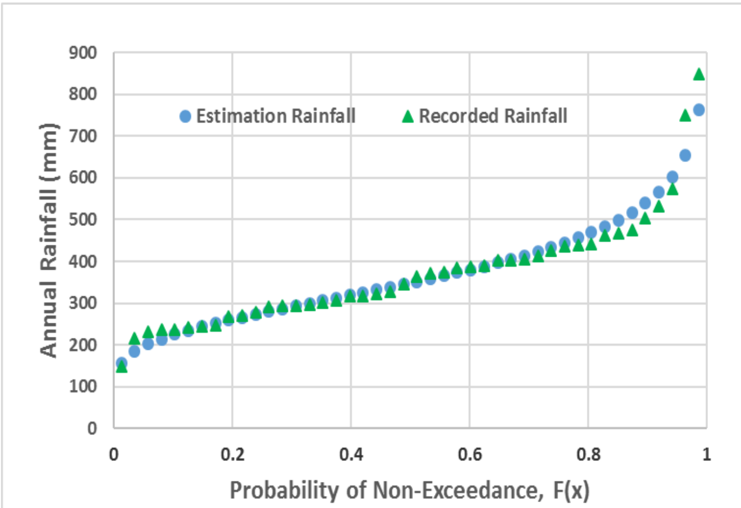

Figure 4. 10: Gumbel Plots of Annual Rainfall for Beit Dajan Station

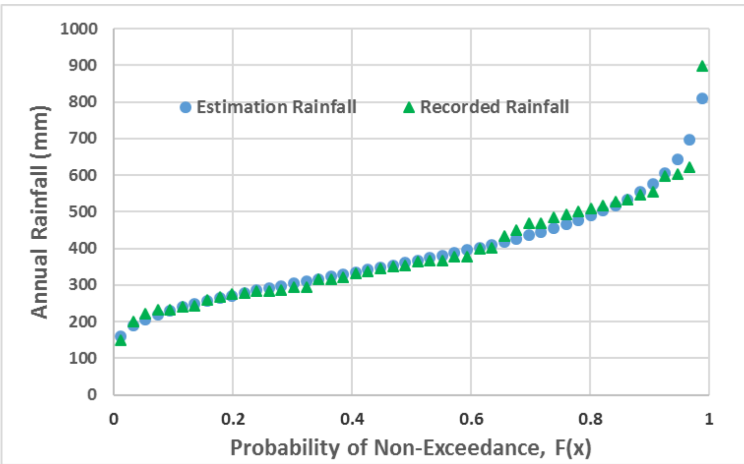

Figure 4. 11: Gumbel Plots of Annual Rainfall for Tubas Station

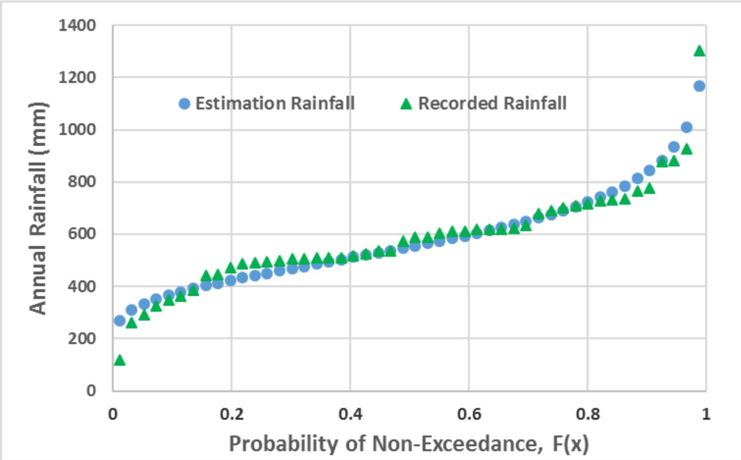

Figure 4. 12: Gumbel Plots of Annual Rainfall for Talluza Station

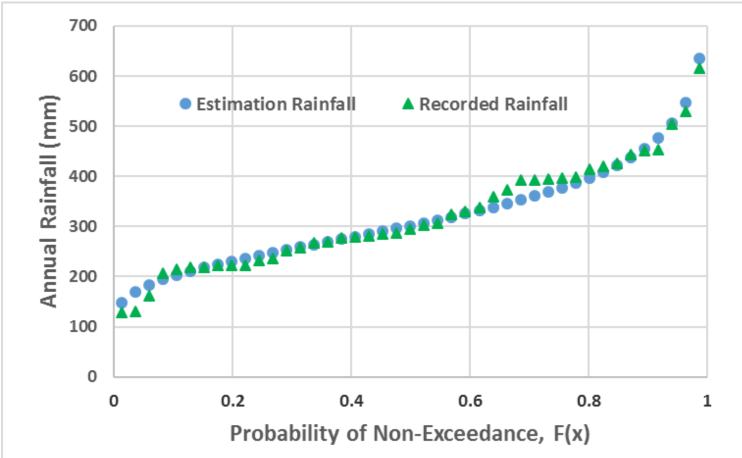

Figure 4. 13: Gumbel Plots of Annual Rainfall for Tammun Station

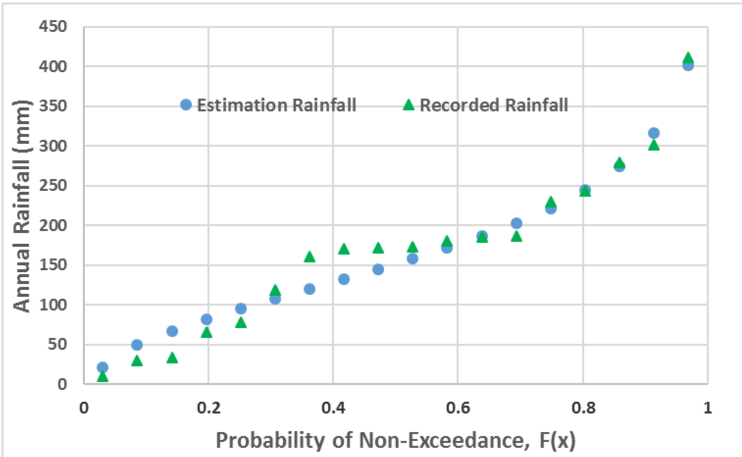

Figure 4. 14: Gumbel Plots of Annual Rainfall for Faria Station

The analysis of the extreme values of annual rainfall data was achieved. The results proved that Gumbel distribution fits the data, because the coefficient of determination (**r^2**) is approximately 0.98 and can be used for future estimations.

Chapter Five

Development of Rainfall Intensity-Duration-Frequency Curves

5.1 Methodology Flow Chart

In this chapter, the methods used to achieve the aims of this study are discussed. The tools are MsExcel, ArcGIS and Matlab. In section 5.2 annual rainfall estimation of new stations will be achieved. In the next section 5.3 filling missing data will be completed. Significance test will be applied on data in section 5.5. After that, IDF curves will be developed then mapped using ArcGIS and Matlab. **Figure 5.1**

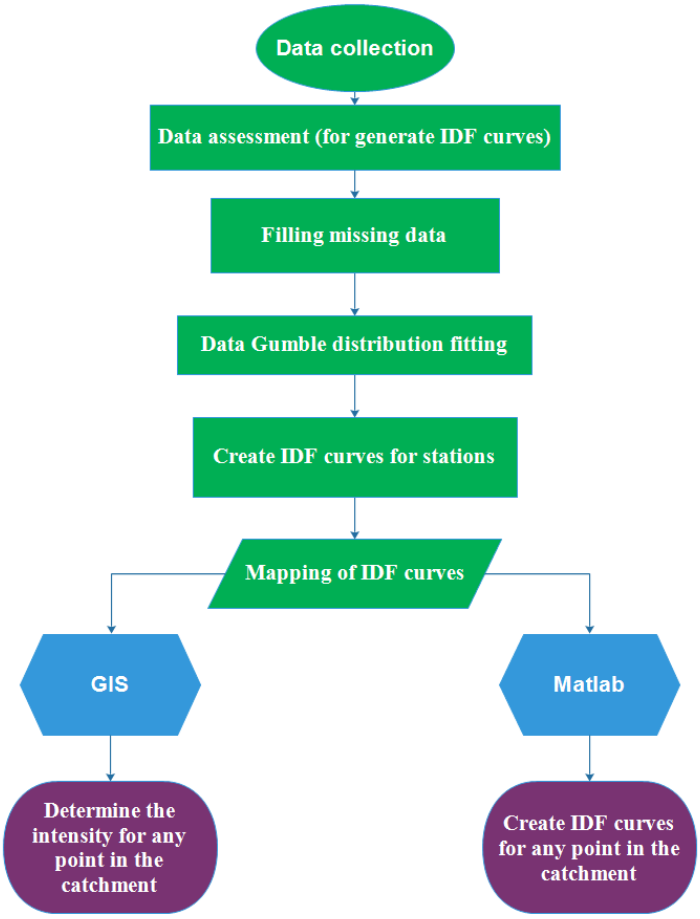

Figure 5. 1: Flowchart for Development of IDF Curves

5.2 Data Assessment (Annual Rainfall Estimation)

Moving on, from the result of **Section 4.1,** the current number of stations is not enough. Because of that, eight rainfall stations were suggested to properly cover the spatial distribution of rainfall over the catchment. Thus mapping of IDF curves will be much more accurate.

In Al-Faria catchment, the rainfall is affected by the variation in elevations. In general, when the elevation increases the rainfall increases. (Shadeed, 2005) developed a spatial-oriented formula to find the rainfall based on the elevations, and geographic location, using multiple linear regression by using five stations (Nablus, Bet dajan, Talluza, Tubas and Tammun) as:

$$R = 8285 - 39.41X - 2.46Y - 0.34Z \qquad (5\text{-}1)$$

Where, R is the annual average rainfall in mm, X is the x-coordinate in km, Y is the y-coordinate in km and Z is the elevation in m. (Shadeed, 2005)

After the equation was computed using five stations, the remaining station (Al-Faria) was used to verify the equation ($r^2 = 0.99$).

To complete the data required to make a good spatial distribution; the other eight stations became a must, we tried to distribute them in the most proper way over the empty region, the stations appear in **Figure 5.2**.

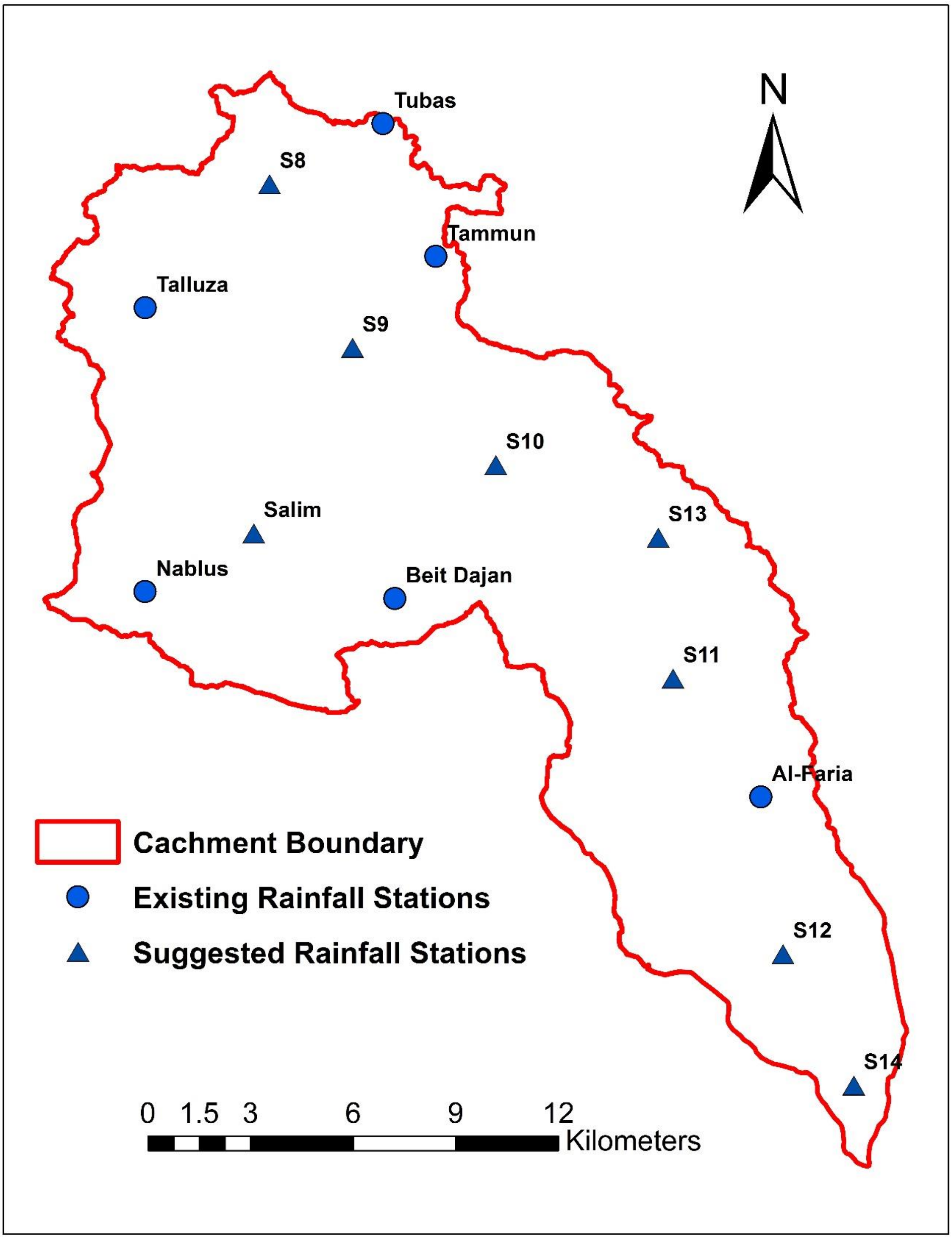

Figure 5. 2: Existing and Suggested Rainfall Stations in Al-Faria Catchment

*Salim is shown as triangle because it’s daily data is invaluable.

For the eight suggested stations, annual rainfall was estimated using the developed formula 5.1. (shadeed, 2005)

5.3 Filling Missing Rainfall Data

Filling missing data was challenging at many levels, every station required a number of steps according to the type of data that was missing. Starting from Tubas, Tammun and Talluza stations, both daily rainfall data (DRD) and fine rainfall data (FRD) were available, but our FRD was limited to 5-10 years. We created a relationship between DRD and FRD, so our FRD was completed.

Talking about Salim which was missing long-term DRD, we started by using the equation 5.2 so we could use the equation result to create the DRD - FRD relation which was created before.

Moving to Nablus and Beit Dajan, we used the equation 5.2 to complete the missing FRD, and then we created the DRD - FRD relation.

The imaginary station that has no data required to create a whole new DRD and FRD using the equation 4.2 then rely on this data to create the final DRD - FRD relation.

$$P_x^y = \left(\frac{P_{avx}}{n}\right) \sum_{i=1}^{n} \left(\frac{P_i^y}{P_{avi}}\right) \quad \text{..........} \ (5\text{-}2)$$

where:

P_x^y *is* the missing rainfall value at station x at time step y; (mm)

P_{avx} is the long-term annual average of station x; (mm)

P_i^y is rainfall value at station i at time step y; (mm)

P_{avi} is the long-term annual average of station i.

Figures 5.3 Shows the relations in Nablus station. Those relations were chosen as the best trend lines between FRD - DRD. Similar figures were developed for the rest of the stations.

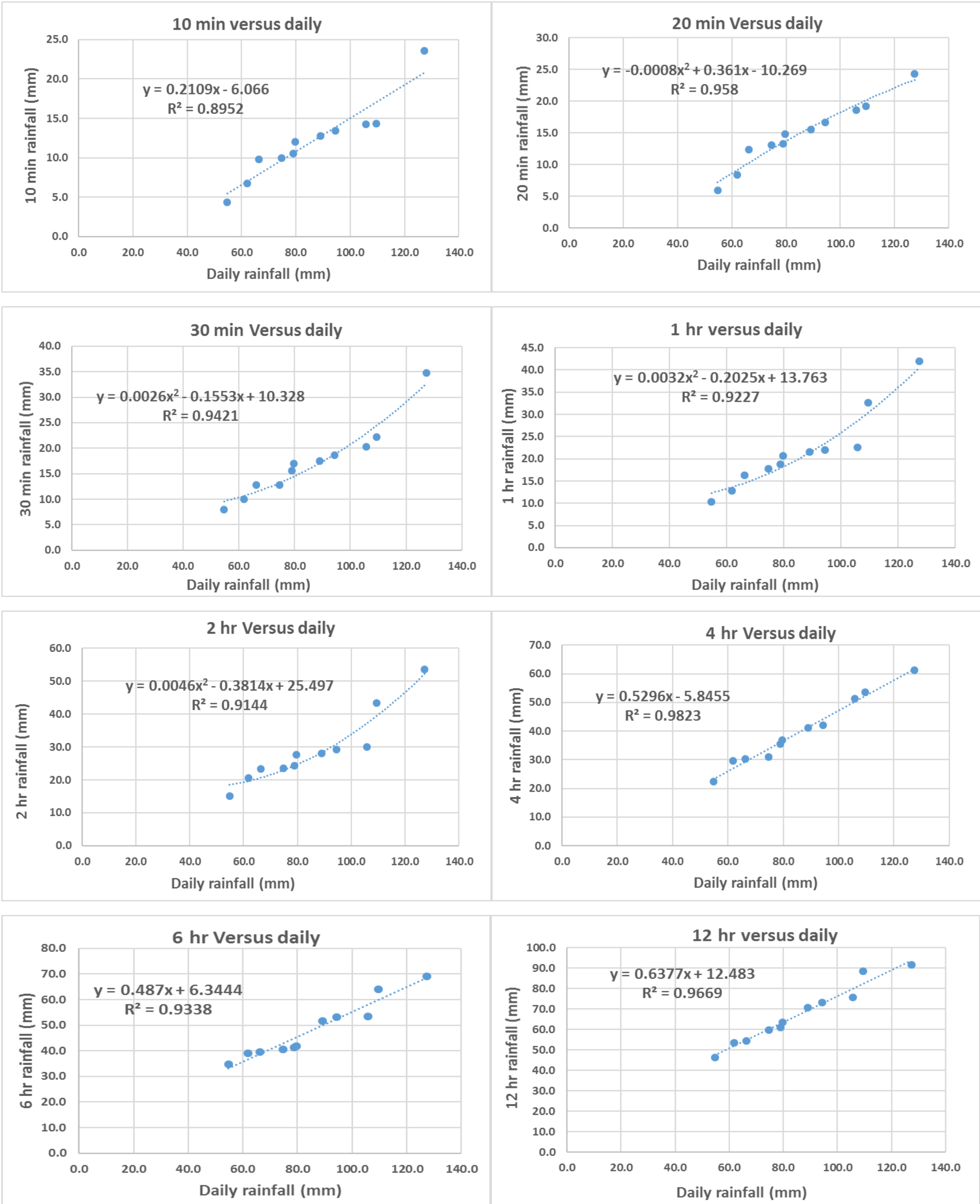

Figure 5. 3: FRD versus DRD Relations

5.4 Significance Test

T-test has been used to determine the significance for DRD – FRD relations for all stations at confidence intervals of 90% and 95% following the same procedure in **sec 4.4** .**Table 8** in the appendix shows that the majority of null hypothesis have been rejected which means that these relations are significant.

5.5 Development of Rainfall Intensity-Duration-Frequency Curves

Table 9 summarizes the available data of the stations in Al-Faria catchment including the existing and suggested stations.

Table 5.5: Typical Characteristics of Rainfall Stations

NO.	Station	X coordinate	Y coordinate	Record length (years)	Elevation (m)	Mean Annual (mm)
1	Nablus	178000	178000	42	570	637.9
2	Talluza	178006	186302	42	500	582.8
3	Tubas	184954	191685	33	375	386.8
4	Beit Dajan	185300	177800	40	520	377.9
5	Tammun	186500	187800	40	340	319.4
6	Al-Faria	196000	172000	47	-237	198.6
7	Salim	181174	179701	48	514	589.5
8	S_8	181636	189910	48	247	577.4
9	S_9	184058	185125	47	90	549.0
10	S_{10}	188254	181698	47	-35	431.7
11	S_{11}	193431	175454	48	-100	261.0
12	S_{12}	196644	167399	47	-251	208.2
13	S_{13}	193002	179575	46	-90	262.1
14	S_{14}	198712	163558	47	-325	161.6

From rainfall measurements, for every year of record, determine the annual maximum rainfall depth over the specific durations. Common durations for design applications are:10-min, 20-min, 30-min, 1-hr, 2-hr, 4hr, 6-hr, 12-hr, and 24-hr. then calculate rainfall intensity fir each rainfall depth.

The development of IDF curves requires that a frequency analysis be performed for each set of annual maxima, one each associated with each rain duration. The maxima data has been sorted and ranked. The basic objective of each frequency analysis is to determine the exceedance probability distribution function of rain intensity for each duration. The frequency analysis used to estimate the rainfall events is Gumbel distribution associated with given exceedance probabilities. Then the relations between rainfall intensity and duration for each return period have been established. **Figures from 5.4 to 5.17** represent these curves. These curves can be used to find the rainfall intensity in these stations for a certain duration and return period.

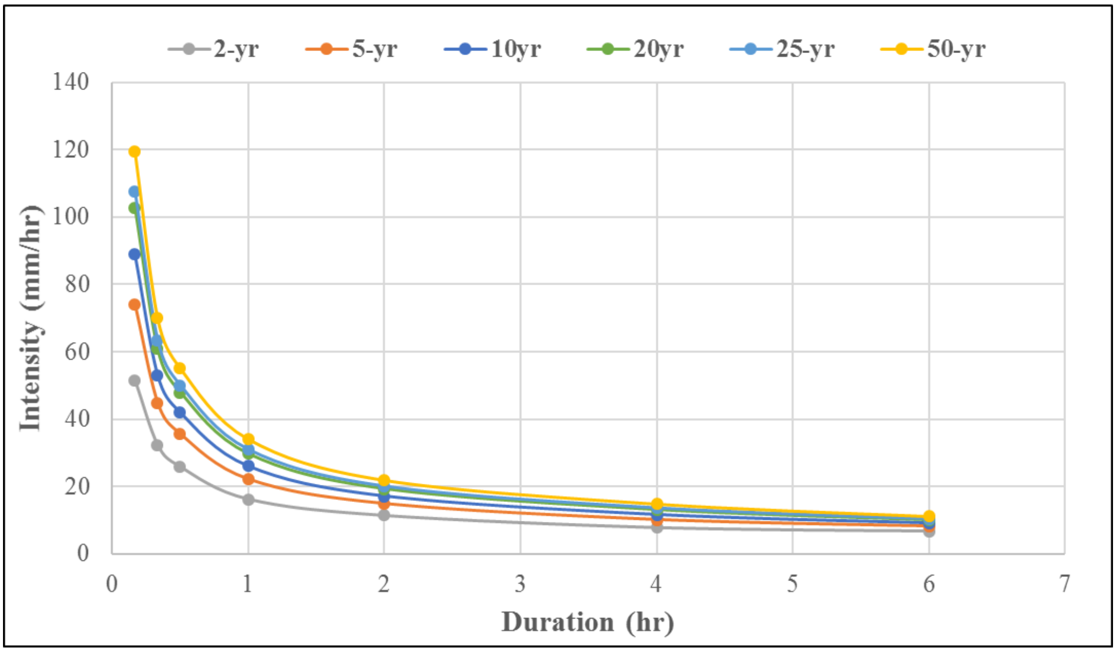

Figure 5. 4: IDF Curves for Nablus Station

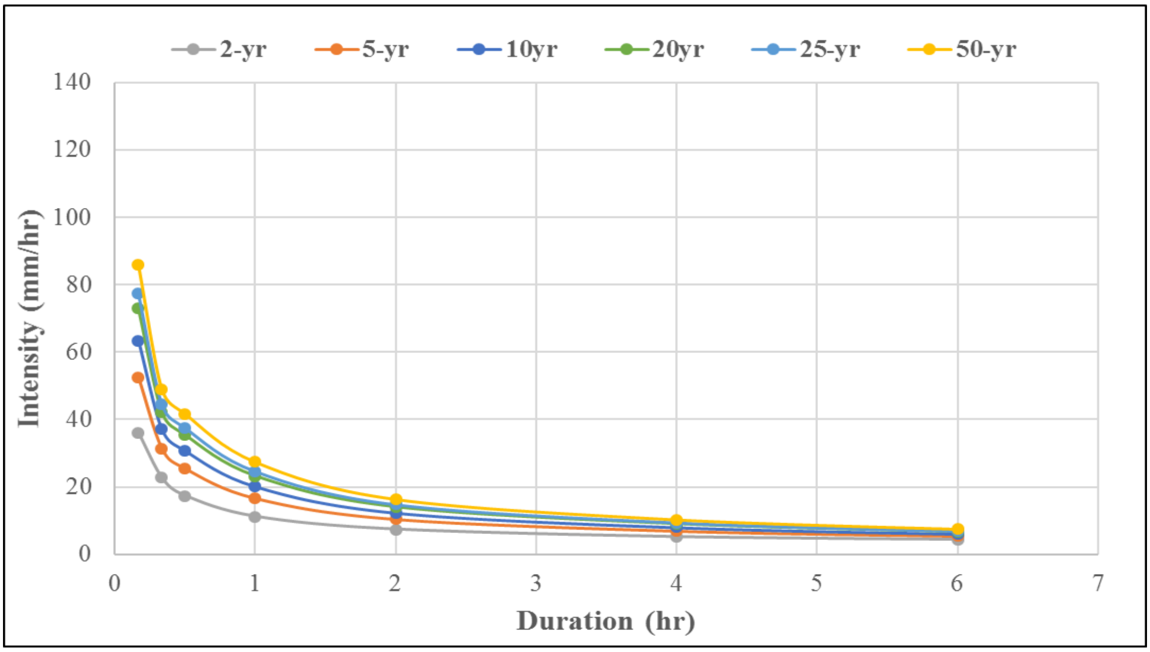

Figure 5. 5: IDF Curves for Beit Dajan Station

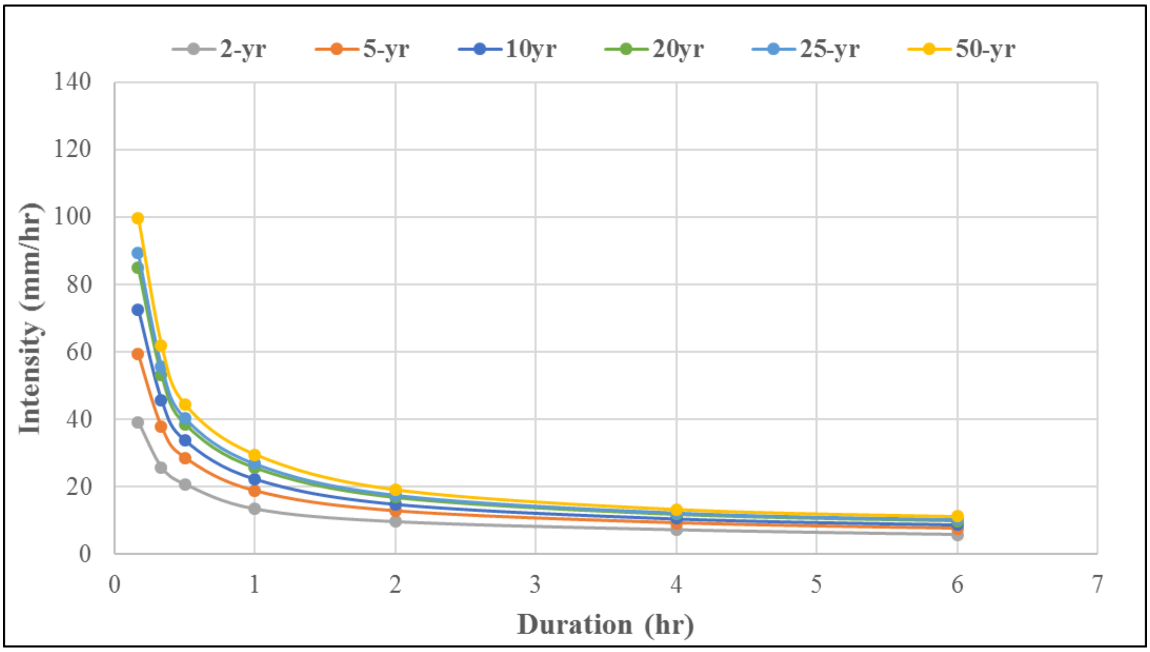

Figure 5. 6: IDF Curves for Talluza Station

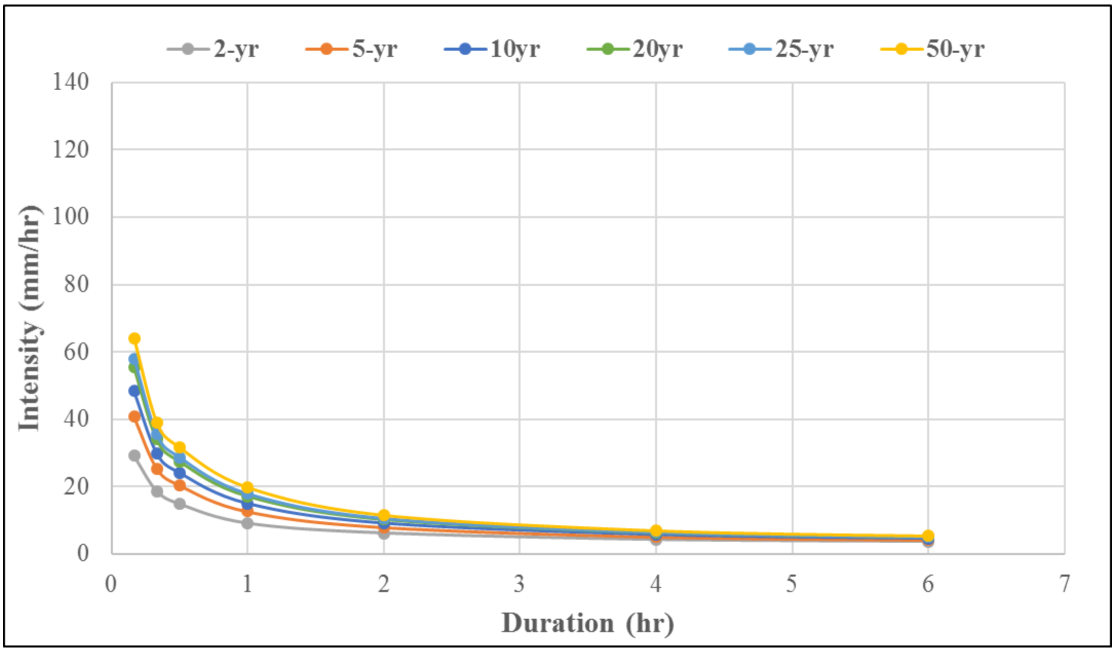

Figure 5. 7: IDF Curves for Tammun Station

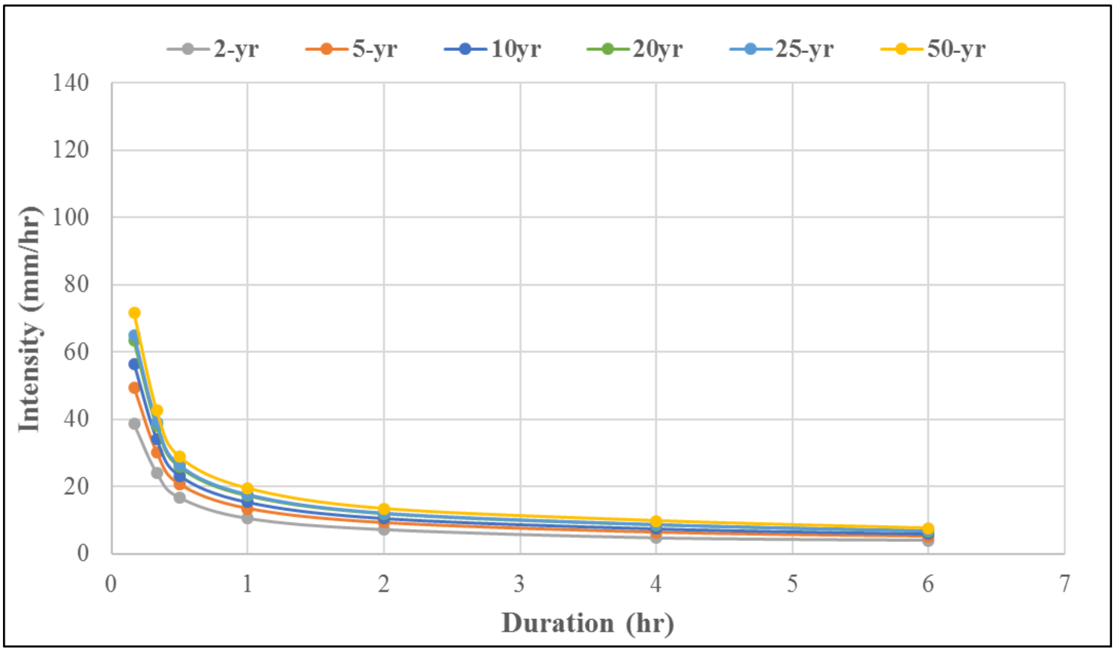

Figure 5. 8: IDF Curves for Tubas Station

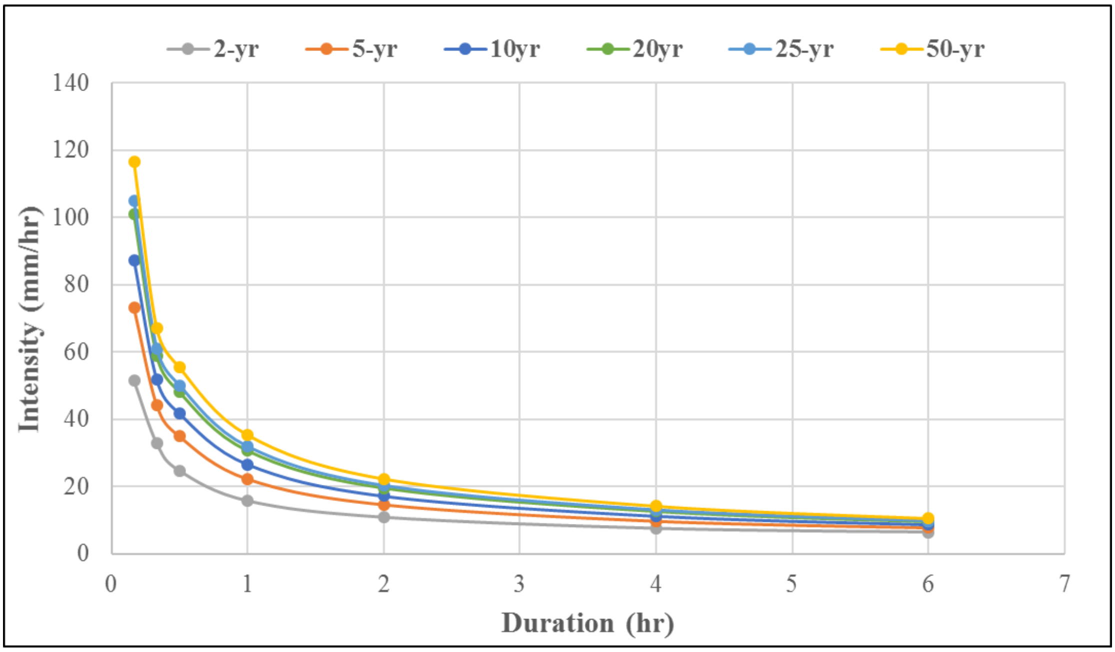

Figure 5. 9: IDF Curves for Salim Station

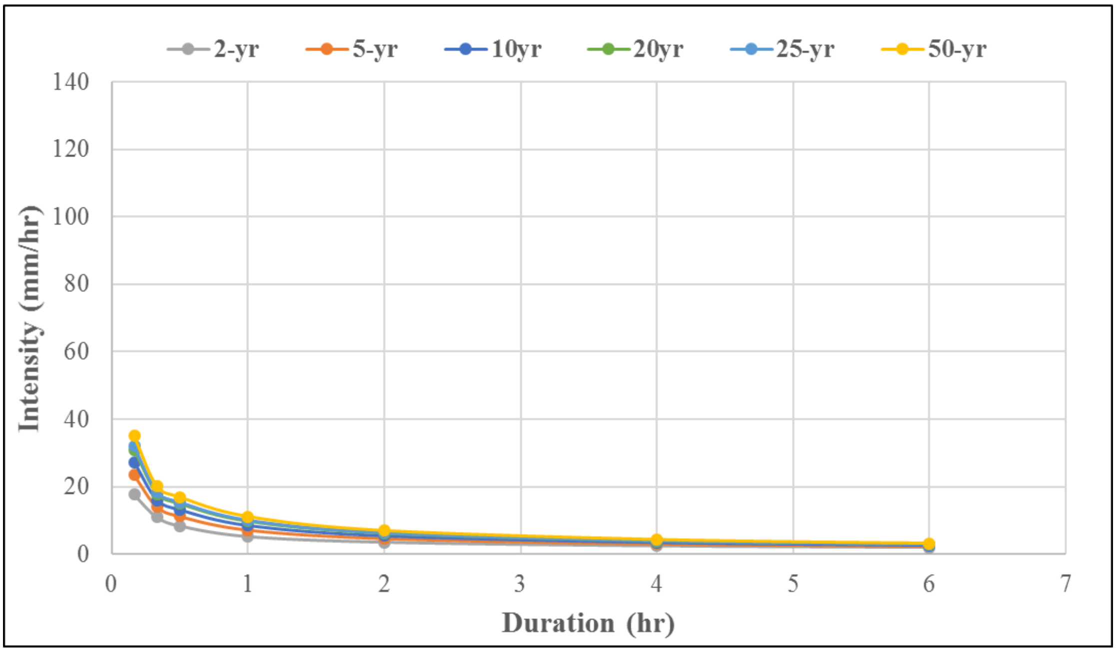

Figure 5. 10: IDF Curves for Al-Faria Station

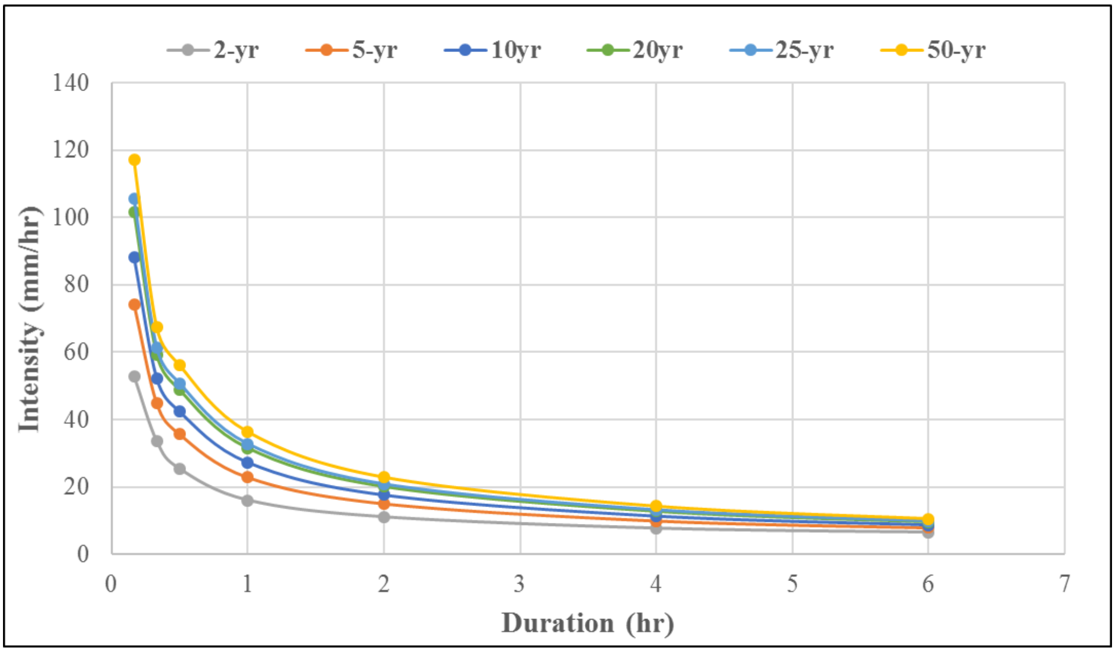

Figure 5. 11: IDF Curves for S_8 Station

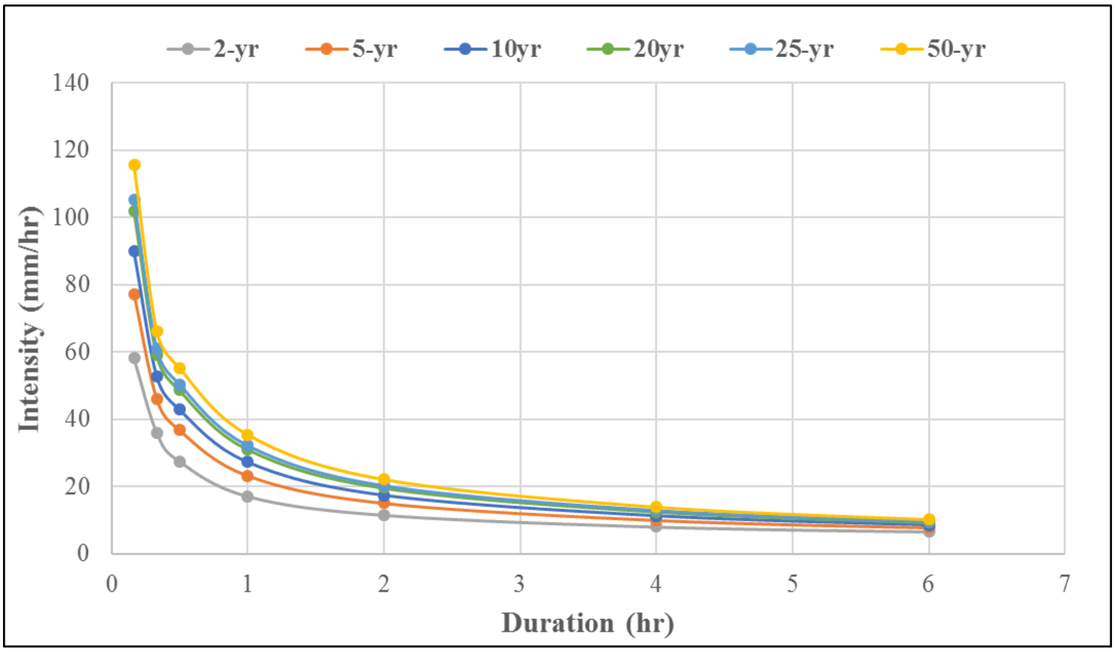

Figure 5. 12: IDF Curves for S_9 Station

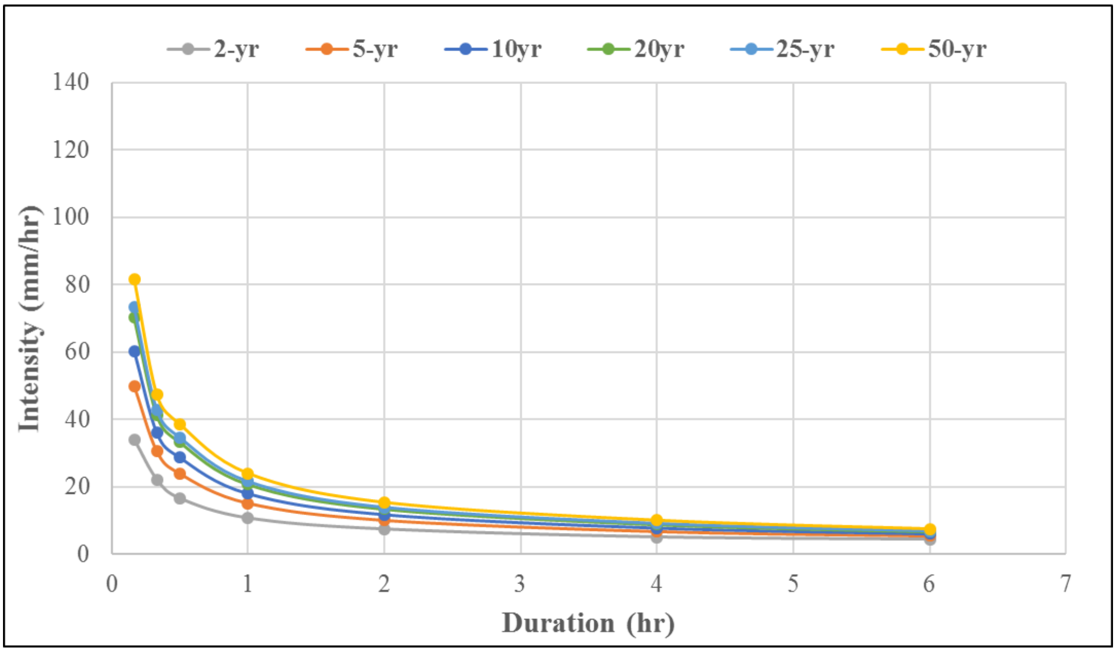

Figure 5. 13: IDF Curves for S_{10} Station

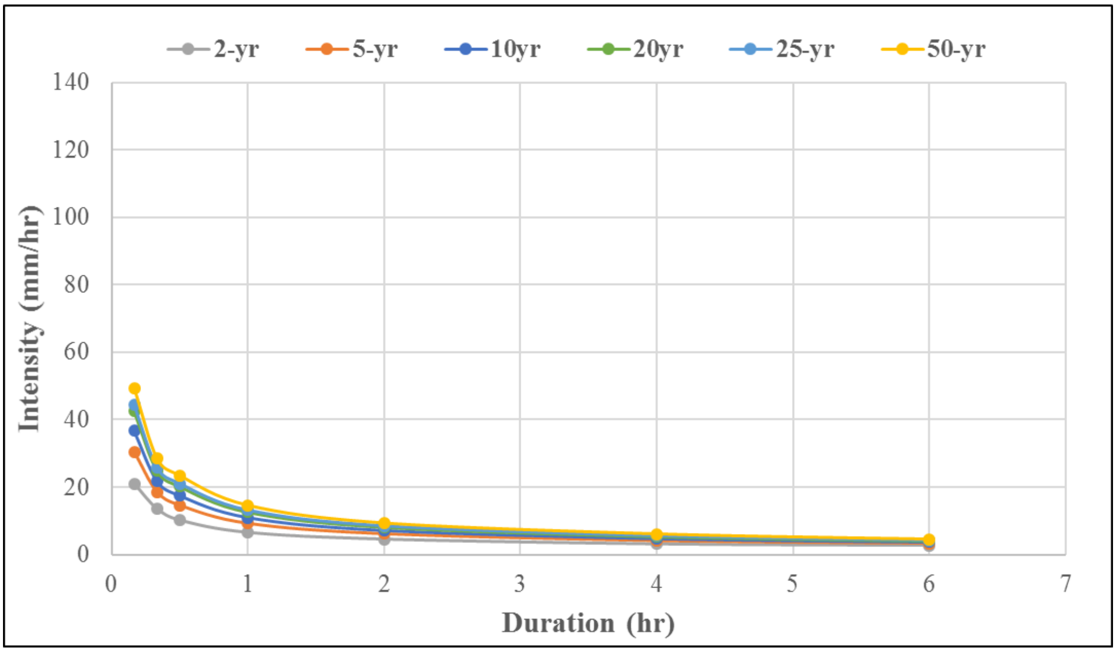

Figure 5. 14: IDF Curves for S_{11} Station

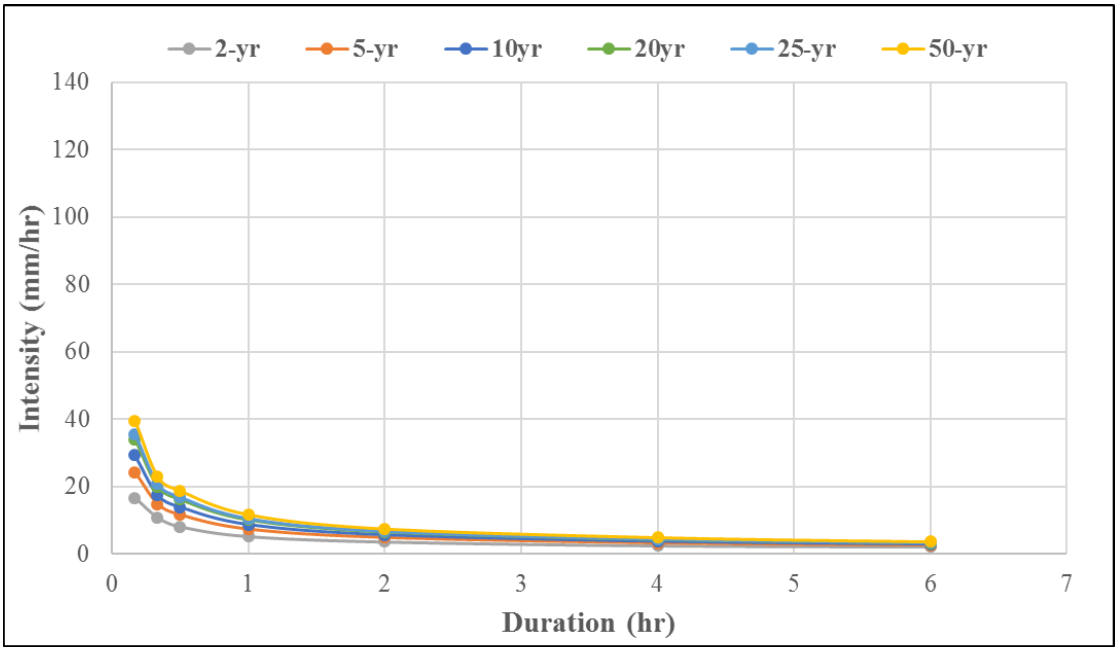

Figure 5. 15: IDF Curves for S_{12} Station

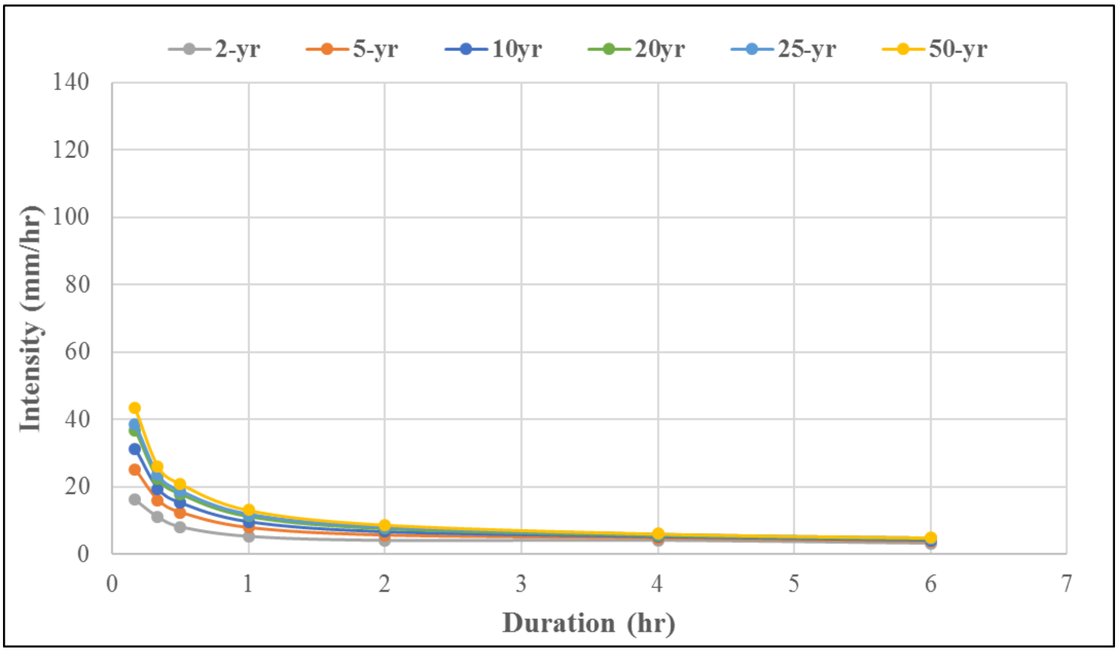

Figure 5. 16: IDF Curves for S_{13} Station

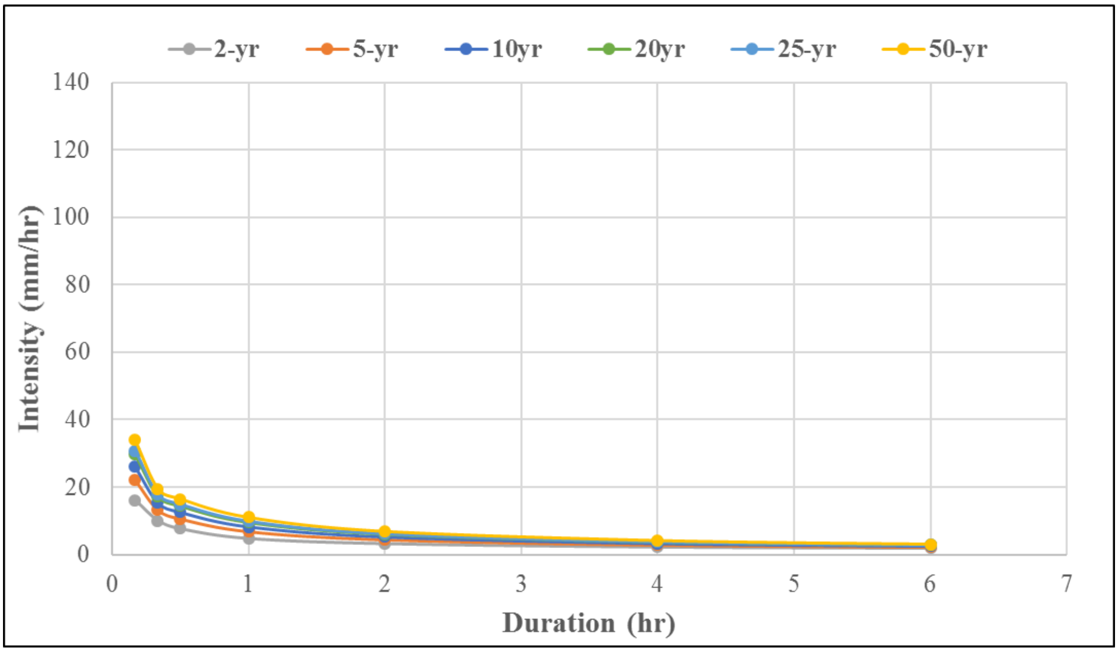

Figure 5. 17: IDF Curves for S_{14} Station

5.6 Mapping of IDF Curves Using ArcGIS

After the IDF curves of the fourteen stations were developed, the curves were used to mapping the spatial distribution of IDF curves over Al-Faria catchment.

The ArcGIS is a system for maps and geographic information, used to create maps, analyze mapped information and compile geographic data. The system was used to enter the rainfall data of the fourteen stations from both excel and the shapefiles of Al-Faria catchment. Then, interpolations were made using Inverse Distance Weight (IDW) interpolation method to find the IDF maps that give the rainfall intensity at any point within the catchment for a given duration and return period. The equation of:

$$Z_p = \frac{\sum_{i=1}^{n}\left(\frac{z_i}{d_i^2}\right)}{\sum_{i=1}^{n}\left(\frac{1}{d_i^2}\right)} \quad \text{.............................} \quad (5\text{-}4)$$

Z_p is the rainfall intensity at the point p (unknown point)

Z_i is the rainfall intensity at the point i (known point)

d_i is the distance between the interpolated point (unknown point) and the known point.

IDW method is the approved method in national weather service in United States. In addition, this tool is suitable for this research objective because it gives more influence for the stations when it is near the location needed, so the influence of the far station is minimum compared with the near one. From the available rainfall data, 54 IDF maps were developed for different duration and return periods as shown in the **Figures from 5.18** to **5.26.** These maps give available information for selected locations, which might help both decision makers, and resources planners to proper evaluate different hydraulic structures. For a particular return period for Al-Faria entire catchment. The maps were used to assign specific rainfall intensity magnitude to specific points via spatial interpolation along studied area.

The limitation of this method is the fact that the maps were developed for a specific durations (10, 20, 30 60, 120, 240, 360, 720, 1440 minutes) and specific return periods (2, 5, 10, 20, 25, 50 years)

Therefore, if another duration needs to be determined between (10-1440 minutes) or return period between (2-50 years), another map must be developed by the same procedure. Furthermore, this method does not give IDF curves for a specific point. Because of that, a different way was applied to reach the objective by using the Matlab program.

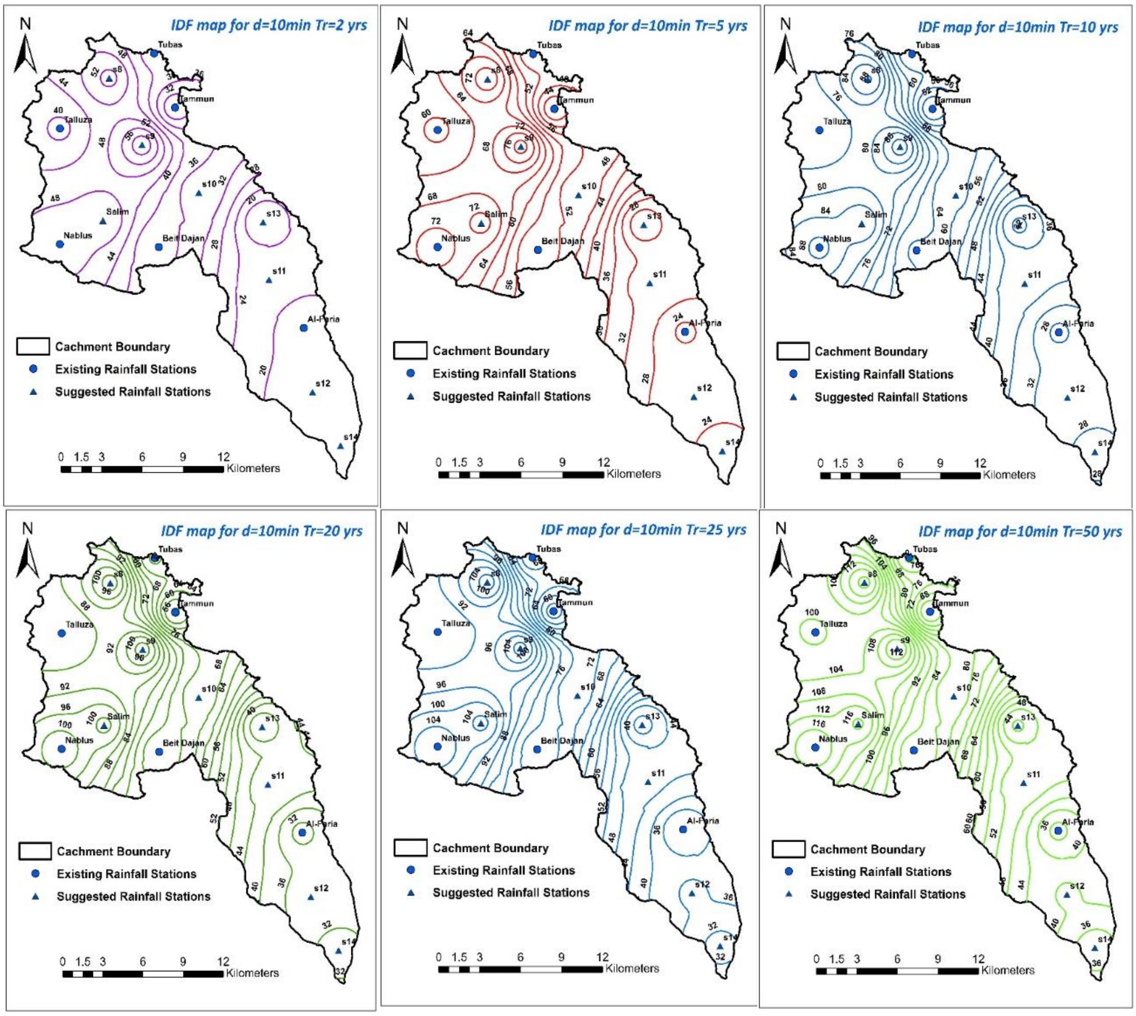

Figure 5. 18: IDF Map of Al-Faria Catchment for 10 min Rainfall Durations and Different Return Period.

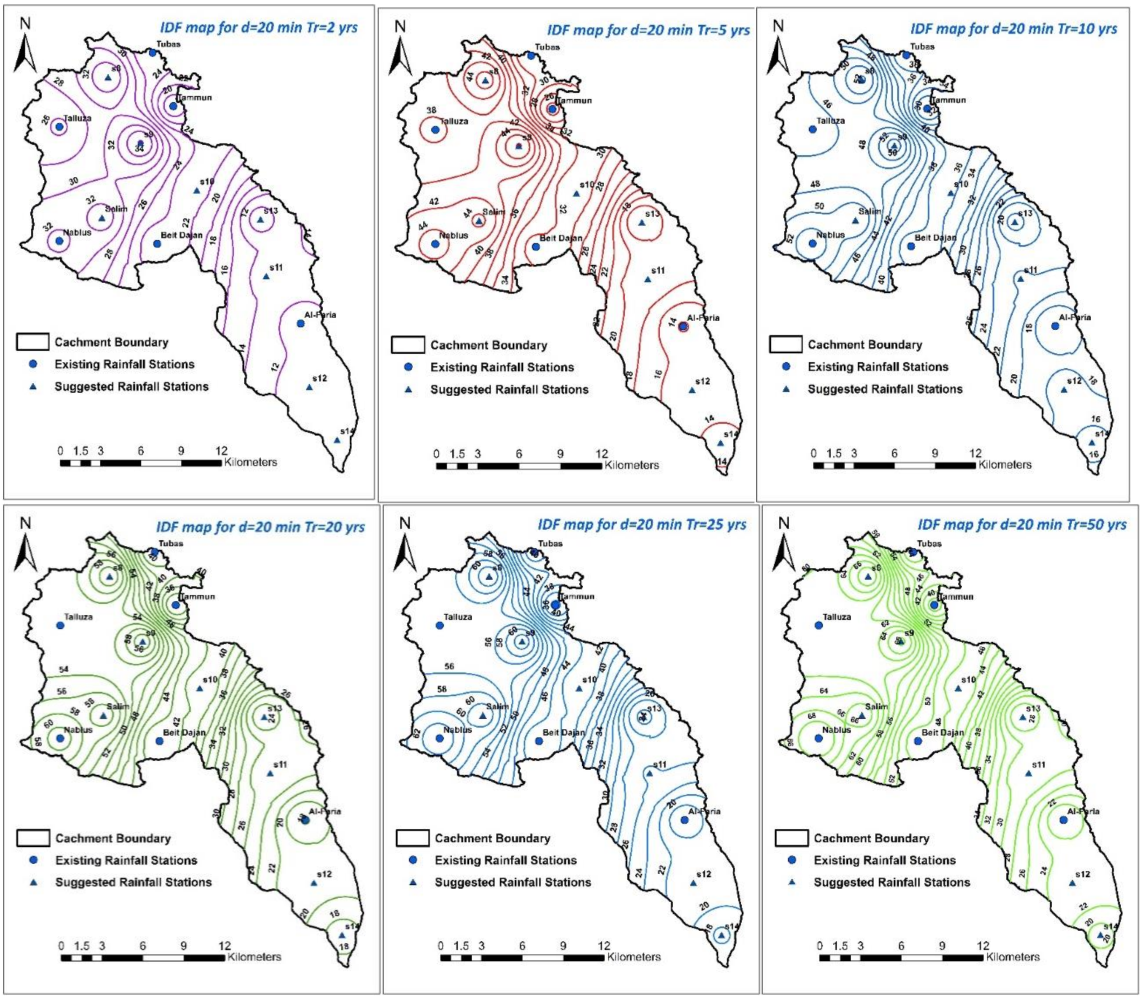

Figure 5. 19: IDF Map of Al-Faria Catchment for 20 minutes Rainfall Durations and Different Return period.

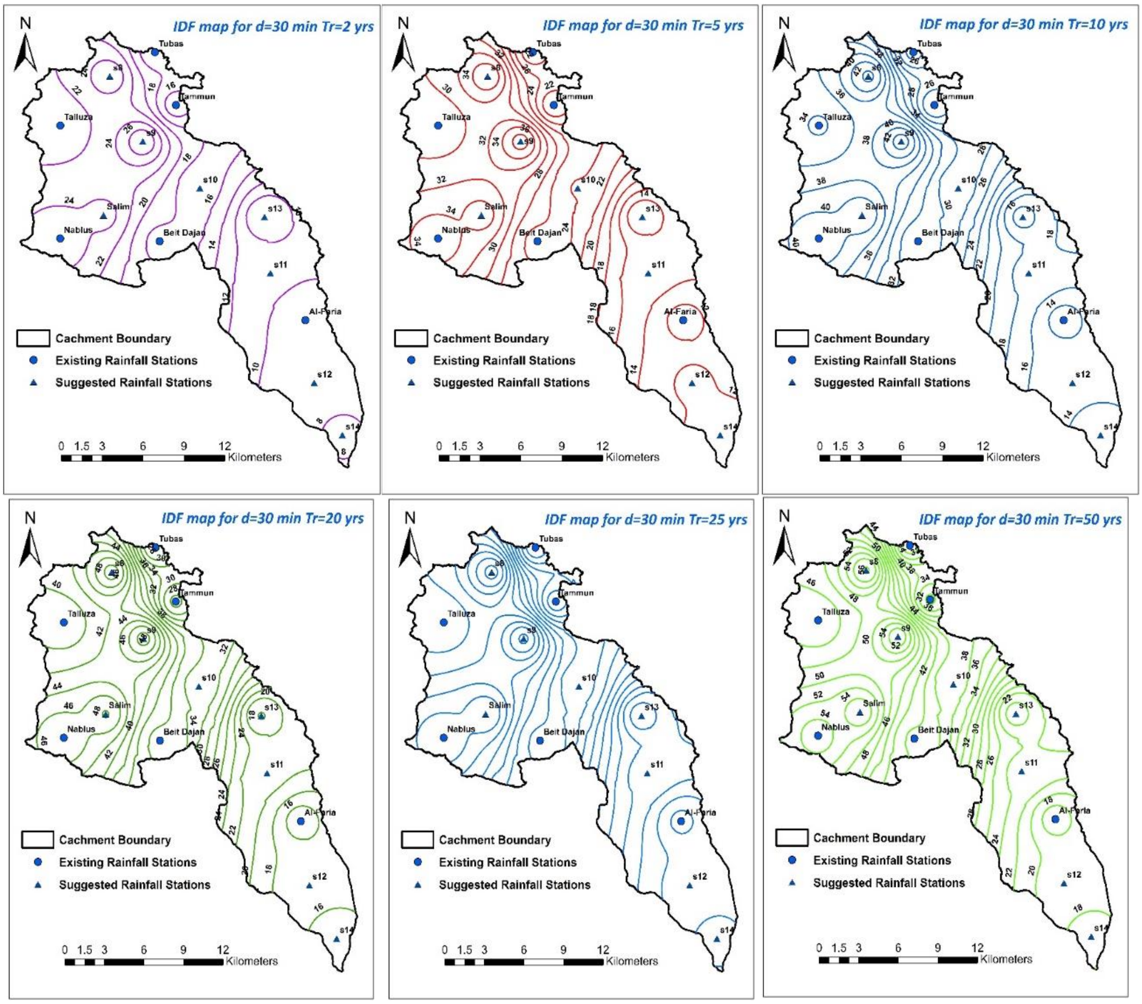

Figure 5. 20: IDF Map of Al-Faria Catchment for 30 minutes Rainfall Durations and Different Return

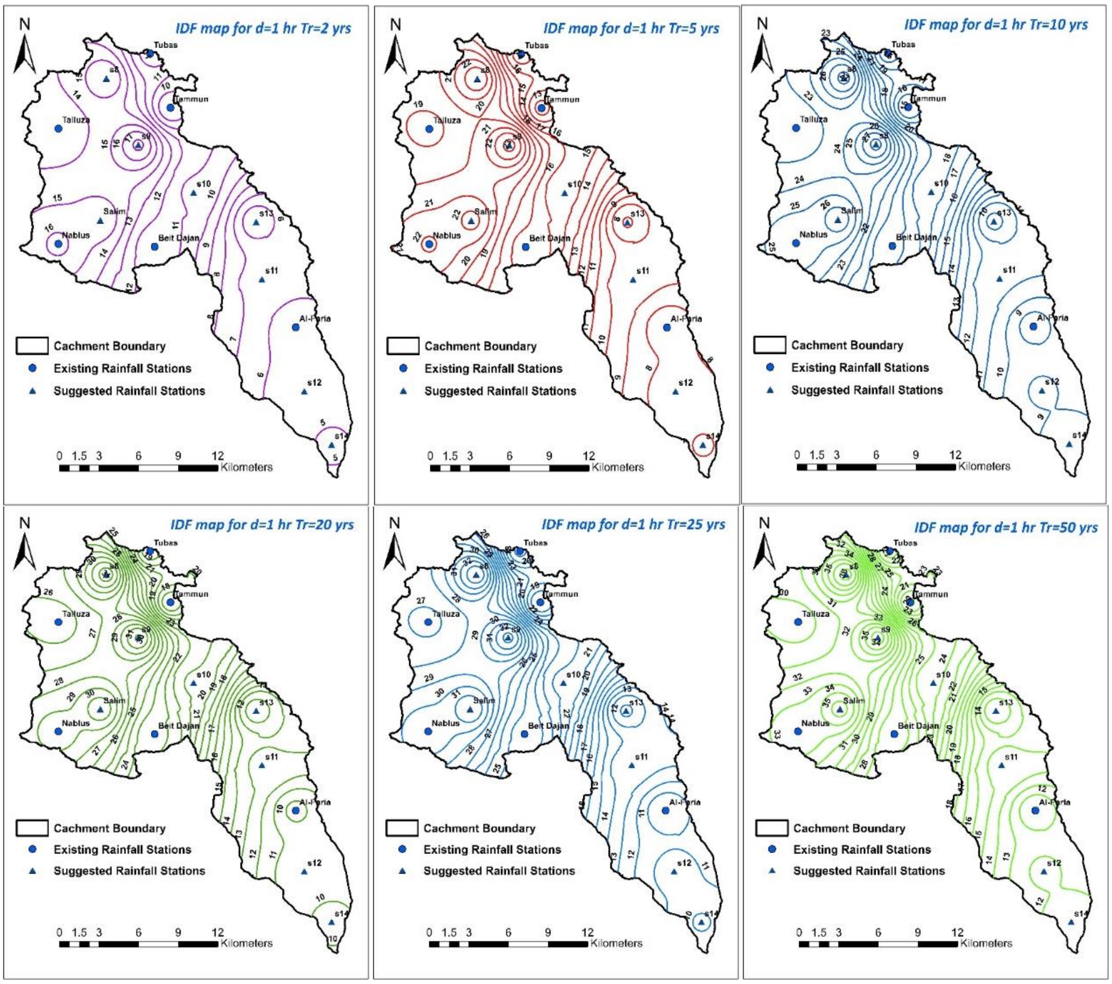

Figure 5. 21: IDF Map of Al-Faria Catchment for 1 hour Rainfall Durations and Different Return period.

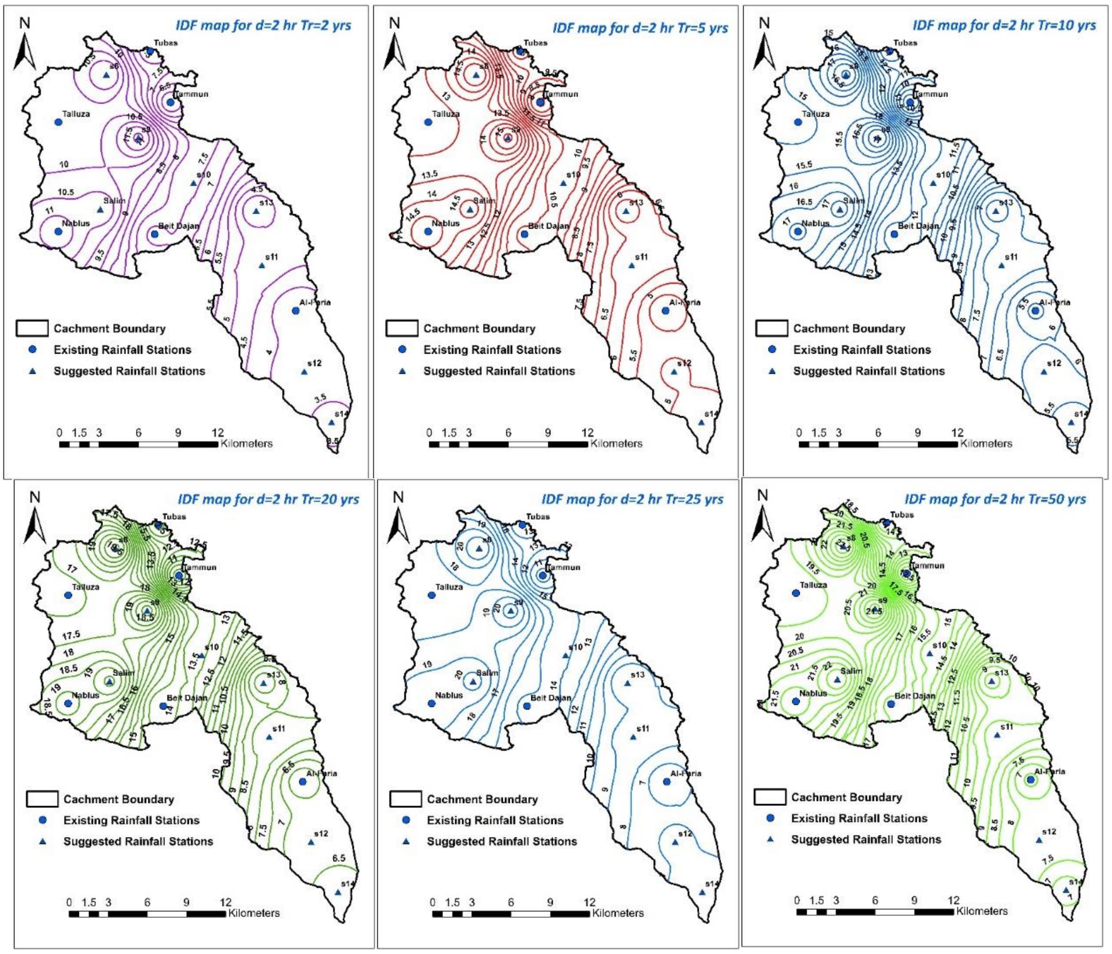

Figure 5. 22: IDF Map of Al-Faria Catchment for 2 hours Rainfall Durations and Different Return Period.

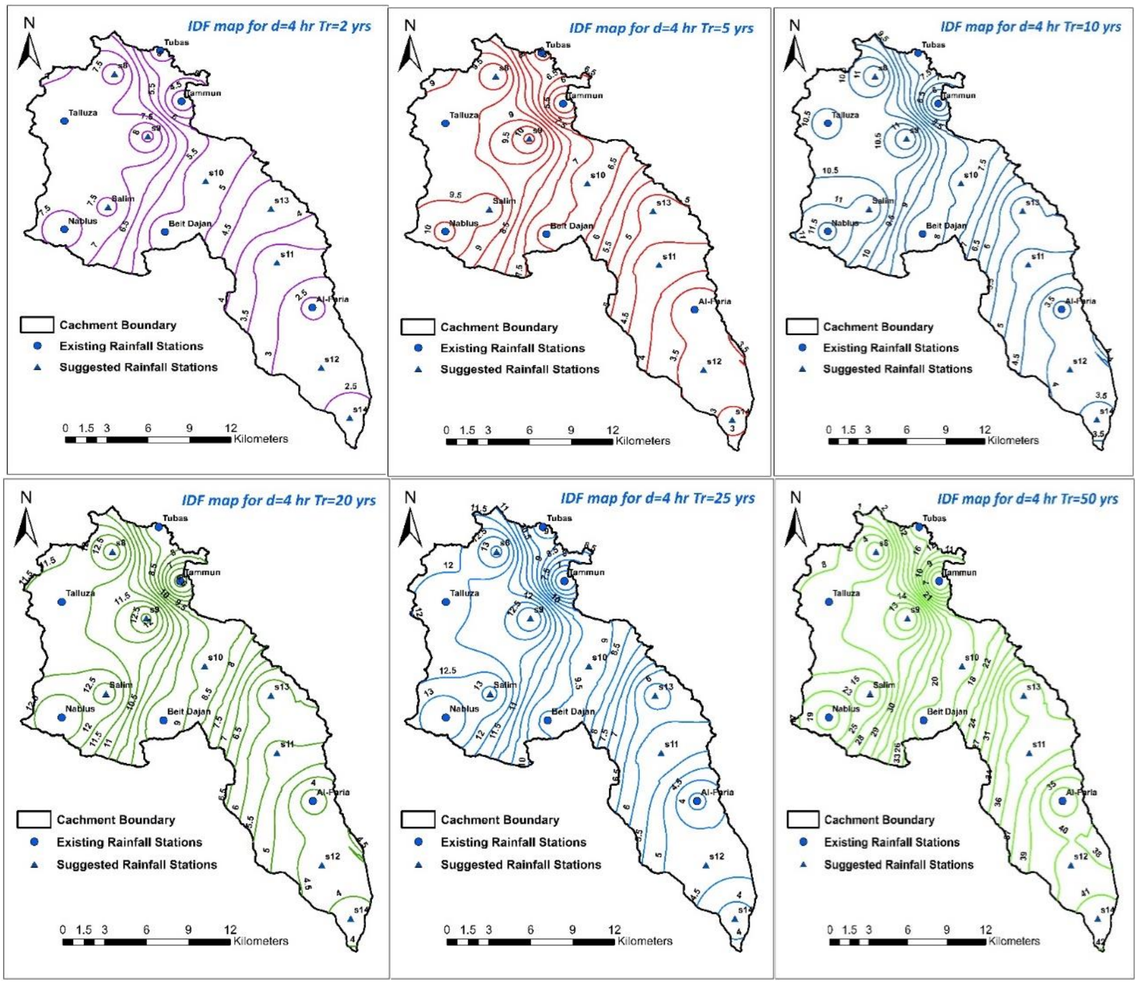

Figure 5. 23: IDF Map of Al-Faria Catchment for 4 hours Rainfall Durations and Different Return Period.

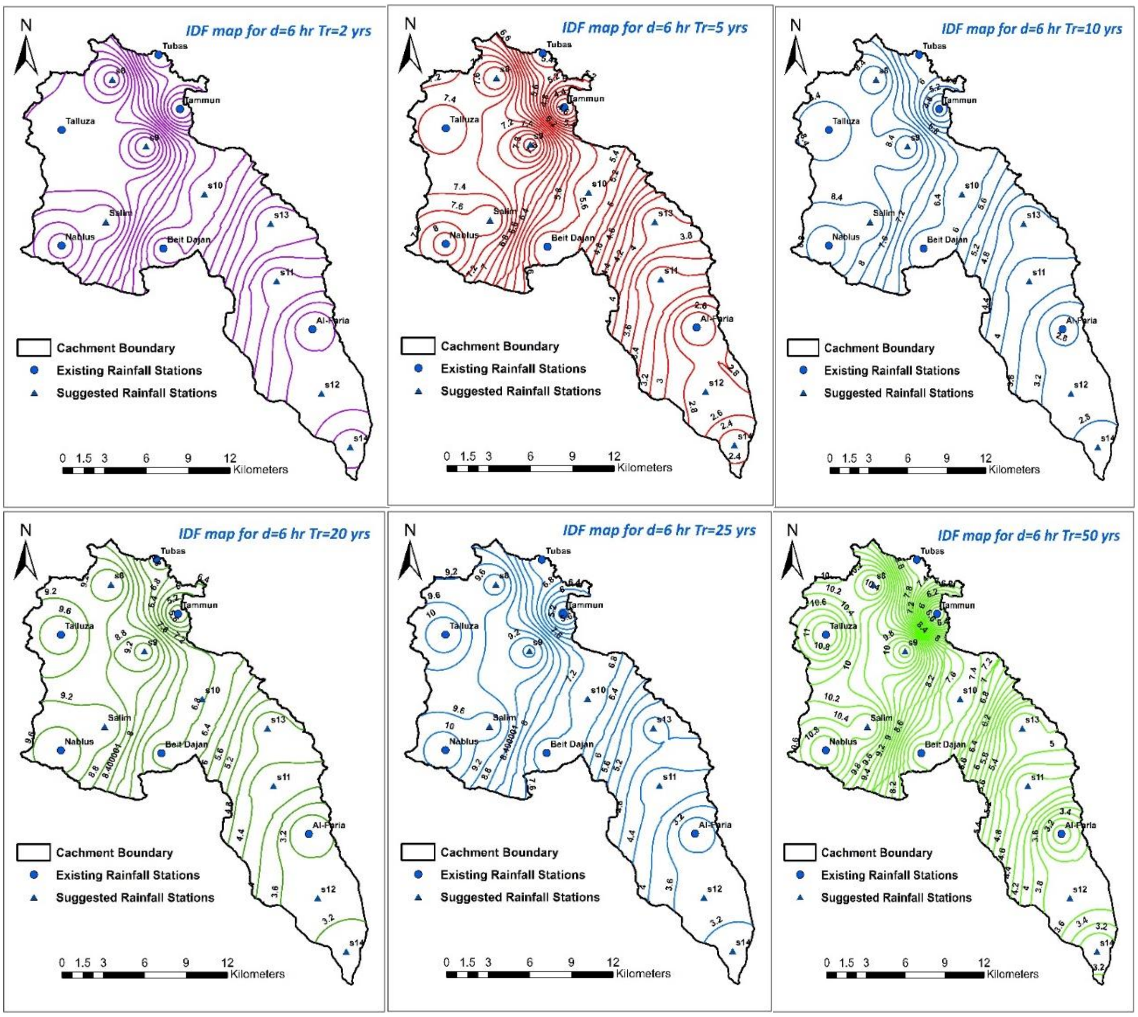

Figure 5. 24: IDF Map of Al-Faria Catchment for 6 hours Rainfall Durations and Different Return Period.

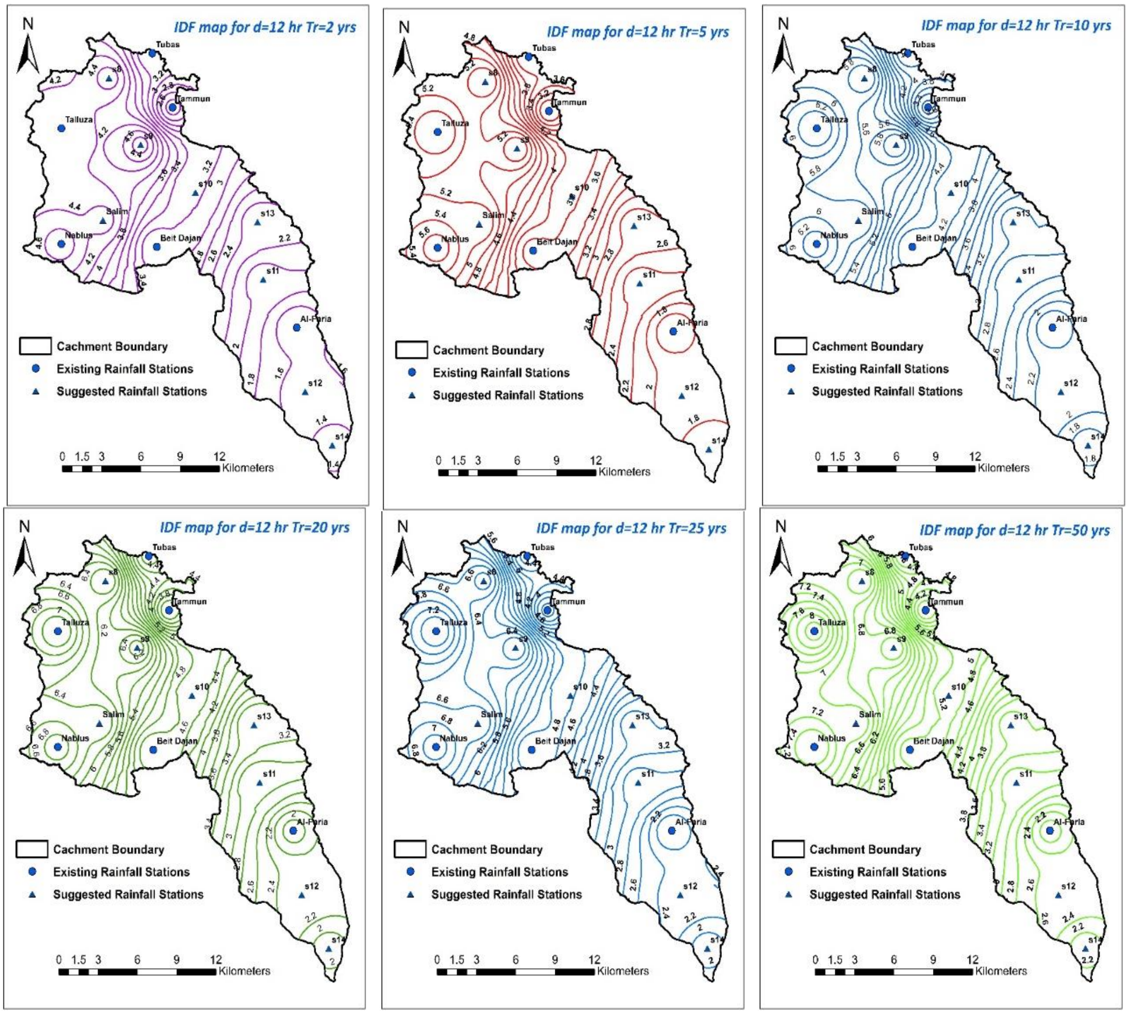

Figure 5. 25: IDF Map of Al-Faria Catchment for 12 hours Rainfall Durations and Different Return Period.

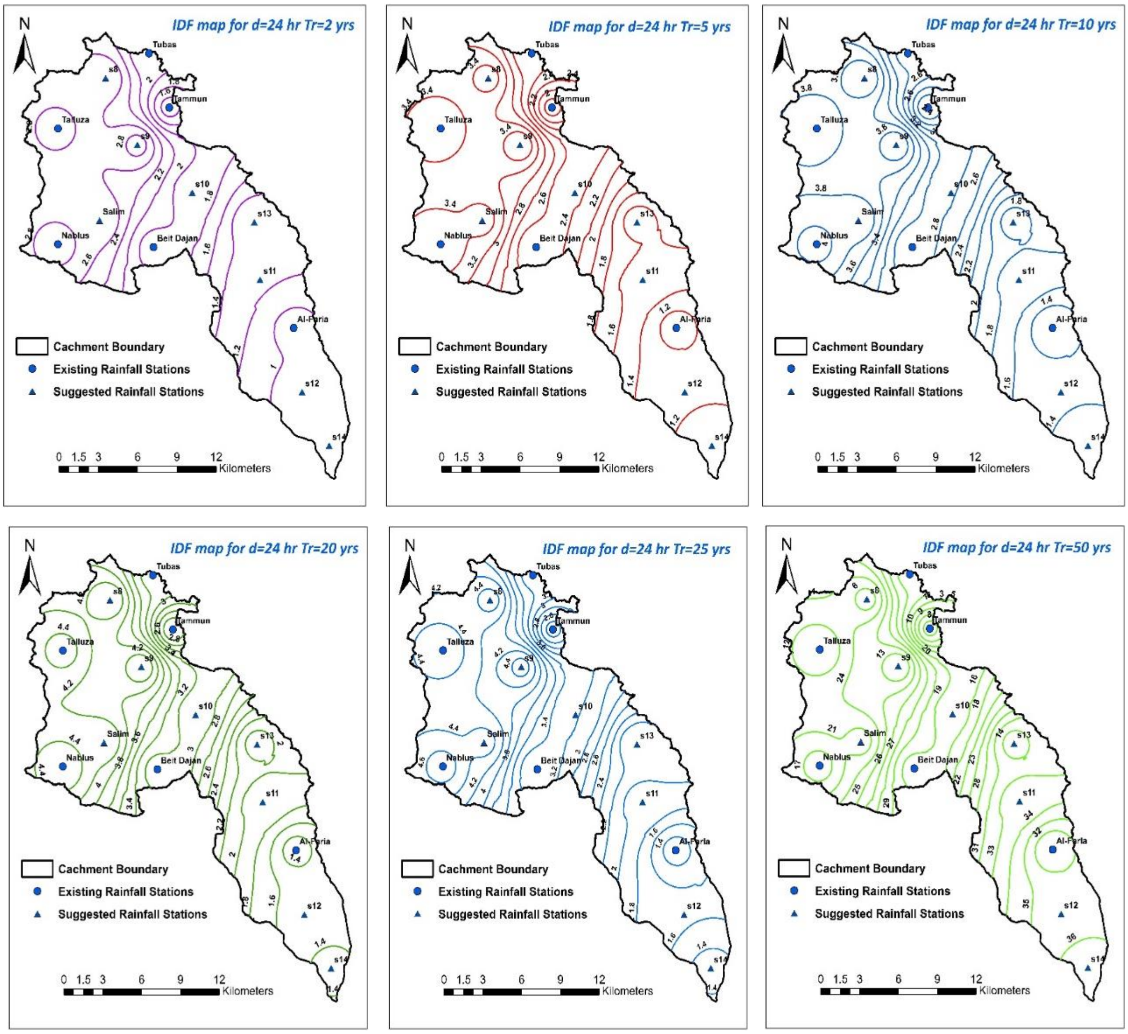

Figure 5. 26: IDF Map of Al-Faria Catchment for 24 hours Durations and Different Return Period

5.7 Mapping IDF Curves Using Matlab

To achieve the aim of the research, Matlab was used to write a program that allows inputting the (x,y) coordinates at any site in Al-Faria catchment for any return period between (2-50) years, and any duration between (10 -1440) minutes, then it computes rainfall intensity and presents the IDF curves in tabular and graphical forms. The interface of the developed program is illustrated in **Figure 5.27.** However the source code is presented in the appendix1.

(2-50) years and (10-1440) duration were chosen because they are the most commonly used for prediction of rainfall intensity.

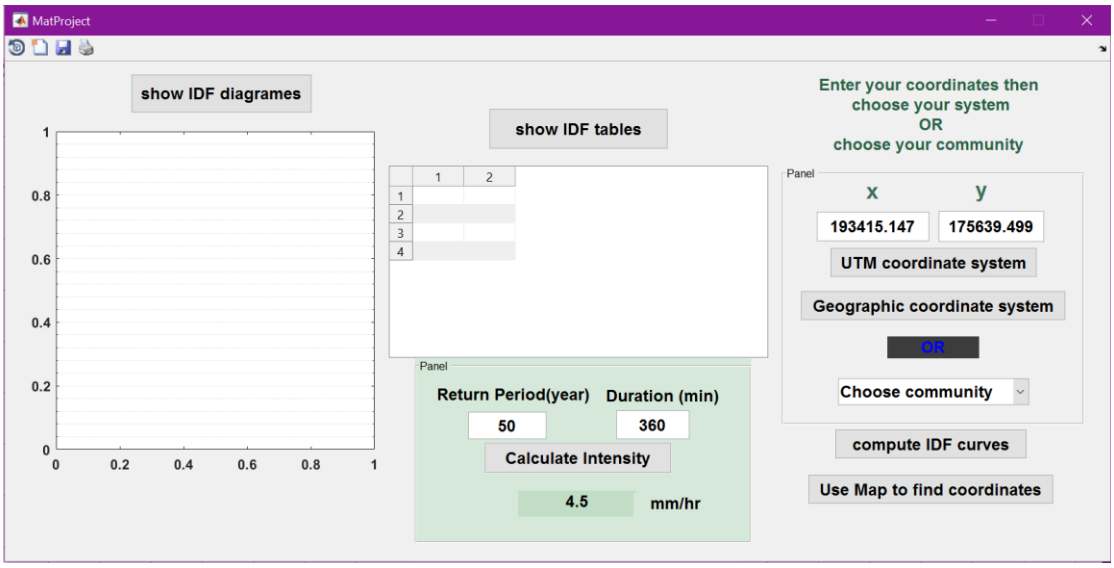

Figure 5. 27: The Matlab User Interface of IDF Curves

All rainfall data available was used as a database for the program. A code of IDW method was written for interpolation techniques. To use this program, the (x,y) coordinates are needed to create IDF diagrams and IDF tables at a point. The program can determine the rainfall intensity at any return period for a given duration.

This program can be used as an alternative to the ArcGIS maps because when the user enters the (x,y) coordinates ,return period and duration, the program gives the rainfall intensity directly. **Table 10, figure 5.28 and figure 5.29** show the comparison used to verify that the output of program matches the results of the maps.

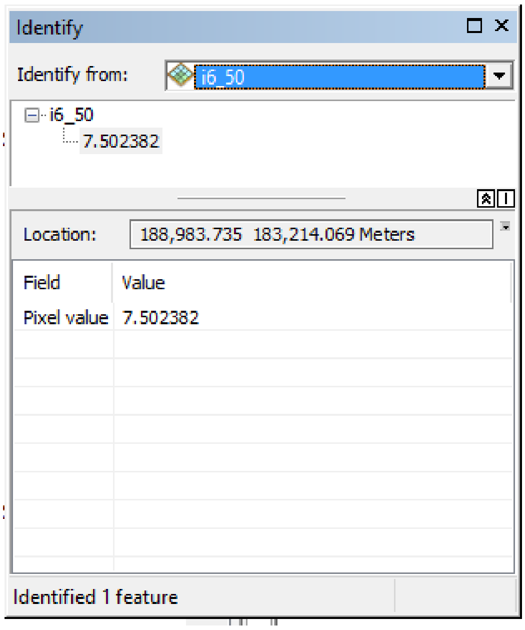

Figure 5. 28: The ArcGIS Result (sample)

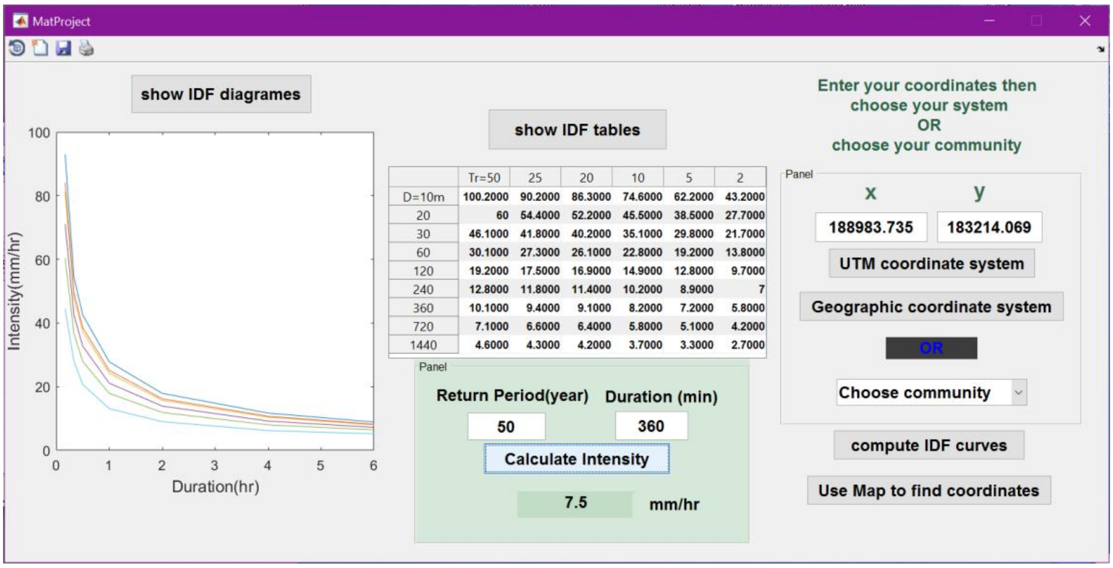

Figure 5. 29: The Matlab Result (sample)

Table 5.6: Matlab and ArcGIS Results

Duration (minutes) / Return period (year)	X	Y	Matlab	GIS
30/25	180105	185789	42.2	41.8
30/25	195015	175825	21.4	21.3
30/25	198471	166677	17.4	17.2
360/50	180173	182943	9.7	9.9
360/50	188984	183214	7.5	7.5
720/20	180106	177725	6.3	6.4

Based on the above, it is fair to say that both ArcGIS and Matlab produce acceptable results. Although, using Matlab will allow displaying an IDF curve for any point and giving a rainfall intensity directly for any return period and duration, while ArcGIS gives an IDF map for a certain period and duration. This map shows the variation of rainfall intensity within the catchment.

Chapter Six

Conclusions and Recommendations

6.1 Conclusions

Al-Faria catchment is located in the northeastern part of the West Bank, Palestine, with a total area of about 320 km^2. From about 900 m above mean sea level at Nablus Mountains, to about 350 m below mean sea level at the confluence with the Jordan River, the ground surface elevation in the catchment varies significantly. With mild rainy winters and moderately dry, hot summers, the climate in the Faria catchment is Mediterranean.

Al-Faria catchment is gauged by six rainfall stations; these stations are Nablus, Talluza, Tubas, Beit Dajan, Tammun and Al-Faria. The optimal number of stations was calculated based on statistical analysis. The minimum required number of stations is 14. The analysis of the extreme values of annual rainfall data was achieved. The results proved that Gumbel distribution fits the data and can be used for future estimations.

After all data available was assessed and completed the IDF curves were developed for 14 stations, 54 maps for the catchment were made using these curves. These maps can be used to find intensity rainfall which also could be found directly using the program that was created using Matlab.

It is fair to say that both ArcGIS and Matlab produce acceptable results. While using Matlab will allow displaying an IDF curve for any point and giving a rainfall intensity directly for any return period and duration, ArcGIS gives an IDF map for a certain period and duration. This map shows the variation of rainfall intensity within the catchment.

6.2 Recommendations

Based on the on the results of this study and the struggles it gone through some points can be recommended for the future researches:

1. Install a recording rainfall gauges (e.g tipping buckets) in the catchment mainly in the lower part to get a real representation of spatial rainfall variation in the catchment.
2. Develop IDF curves for the West Bank similar the ones were developed for Al-Faria catchment.
3. Further development of the Matlab code given more real rainfall data in different catchments to be used for hydraulic engineering structures design.

References

Afrin, S., Islam, M. M., & Rahman, M. M. (2015). ***Development of IDF Curve for Dhaka City Based on Scaling Theory under Future Precipitation Variability Due to Climate Change. International*** **Journal of Environmental Science and Development** (IJESD), 6(4), 332-335. doi:10.7763/ijesd.2015.v6.613

Al-Hassoun, S. A. (2011). ***Developing an empirical formulae to estimate rainfall intensity in Riyadh region***. **Journal of King Saud University –Engineering Sciences,** 23(2), 81-88. doi:10.1016/j.jksues.2011.03.003

Antigha, R. E., & Ogarekpe, N. M. (2013). ***Development of Intensity Duration Frequency Curves for Calabar Metropolis, South- South, Nigeria. International Journal of Environment and Sustainability*** **(IJES),** 2(3), 39-42. Retrieved from Issn: 2319 – 1813 Isbn: 2319 – 1805

Bernard, M. M. (1932). ***Formulas for rainfall intensities of long durations.*** **Trans**, 96, 592-624. Retrieved from ASCE

Chen, C. L. (1983). ***Rainfall Intensity- Duration- Frequency Formulas***. **Journal of Hydraulic Engineering,** 109(12), 1603-1621. doi:10.1061/(asce)0733-9429(1983)109:12(1603)

Chow, V. T. (1988). ***Handbook of applied hydrology: A compendium of water-resources technology*****. New York: McGraw-Hill.**

Dupont, B. S., & Allen, D. L. (2000). ***Revision of the Rainfall Intensity Duration Curves for the Commonwealth of Kentucky.*** **Kentucky**

Transportation Center, College of Engineering, University of Kentucky, USA.

Dupont, B. S., & Allen, D. L. (2006). ***Establishment of Intensity–Duration–Frequency Curves for Precipitation in the Monsoon Area of Vietnam Kentucky Transportation Center,*** **College of Engineering, University of Kentucky, USA**.

Elsebaie, I. H. (2012). ***Developing rainfall intensity–duration–frequency relationship for two regions in Saudi Arabia.*** **Journal of King Saud University - Engineering Sciences**,24(2), 131-140. doi:10.1016/j.jksues.2011.06.001

Guo, Y. (2006). ***Updating Rainfall IDF Relationships to Maintain Urban Drainage Design Standards.*** **Journal of Hydrologic Engineering**, 11(5), 506-509. doi:10.1061/(asce)1084-0699(2006)11:5(506)

Haan, C. T. (1977). ***Statistical methods in hydrology*****. Ames: Iowa State University Press.**

Hershfied, M. D. (1961). ***Estimating the Probable Maximum Precipitation.*** **Journal of the Hydraulic Division,** 99-116. Retrieved from ASCE, HY5

Kothyari, U. C., & Garde, R. J. (1992). ***Rainfall Intensity- Duration Frequency Formula for India.*** **Journal of Hydraulic Engineering,** 118(2), 323-336. doi:10.1061/(asce)0733-9429(1992)118:2(323)

Langousis, A., & Veneziano, D. (2007). ***Intensity-duration-frequency curves from scaling representations of rainfall.*** **Water Resources Research,** 43(2), n/a-n/a. doi:10.1029/2006wr005245

Shadeed, S. (2005). **GIS-Based Hydrological Modeling of Semiarid Catchments (The Case of Faria Catchment)** (Master's thesis, An-Najah National University, Nablus, Palestine).

Shadeed, S. (2008). ***Up To Date Hydrological Modeling in Arid and Semi-arid Catchment, the Case of Faria Catchment, West Bank,*** **Palestine (Doctoral dissertation, Albert-Ludwigs-Universität, Freiburg im Breisgau, Germany).**

Shadeed, S. (2012). ***Spatio-temporal Drought Analysis in Arid and Semi-arid Regions: A Case Study from Palestine***. **Arab J Sci Eng**, 38(9), 2303-2313. doi:10.1007/s13369-012-0504-y

Shadeed, S. M., & Masri, M. N. (2007, January). ***Statistical analysis of long-term rainfall data for a Mediterranean semi-arid region:*** **A Case Study from Palestine**

Shadeed, S., Jayyousi, A., & Shaheen, H. (2005, May). ***Probability Distribution of Faria-Catchment Rainfall.***

Subramanya, K. (2013). Engineering hydrology. Venkata Ramana, R., Chakravorty, B., Samal, N. R., Pandey, N. G., & Mani, P. (2008). ***Development of Intensity Duration Frequency Curves Using L-moment and GIS Technique.*** **Journal of Applied Hydrology,** 21(1-2), 88-100.

Wagesho, N., & Claire, M. (2016). ***Analysis of Rainfall Intensity-Duration-Frequency Relationship for Rwanda.*** **Journal of Water Resource and Protection,** 08(07), 706-723. doi:10.4236/jwarp.2016.87058

Koutsoyiannis, D., Kozonis, D., & Manetas, A. (1998). ***A mathematical framework for studying rainfall intensity-duration-frequency relationships.*** **Journal of Hydrology,** 206(1-2), 118-135. doi:10.1016/s0022-1694(98)00097-3

Appendix (Figures, Tables)

Table.A1: Monthly rainfall of Beit Dajan Station (mm)

Year	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
68-69	0	4	25	110	128	25	100	11	0
69-70	0	22	26	26	74	19	106	19	0
70-71	0	0	3	64	65	54	32	104	0
71-72	0	0	24	118	91	103	83	19	0
72-73	0	0	32	29	95	14	62	9	5
73-74	0	5	59	43	379	53	22	14	0
74-75	0	0	38	71	18	133	65	0	0
75-76	0	7	33	128	41	89	94	11	3
76-77	0	16	67	16	101	22	82	42	0
77-78	0	34	3	168	53	39	59	8	0
78-79	0	20	4	87	62	14	53	8	0
79-80	0	35	185	188	92	111	126	13	0
80-81	0	2	9	168	141	70	43	8	0
81-82	0	0	66	10	78	121	87	8	0
82-83	0	24	97	84	252	220	161	9	0
83-84	0	1	53	14	122	58	108	31	0
84-85	0	14	18	36	39	178	16	17	0
85-86	0	18	19	29	44	85	10	49	39
86-87	0	18	179	103	65	30	71	0	0
87-88	0	46	9	181	0	0	0	0	0
88-89									
89-90									
90-91									
91-92	0	3	45	84	128	179	36	0	0
92-93	0	0	45	198	73	54	44	2	10
93-94	0	8	12	9	102	57	53	0	0
94-95	0	18	174	123	33	67	33	15	0
95-96	0	0	82	37	142	18	122	12	0
96-97	0	17	3	80	134	172	122	0	7
97-98	0	0	42	115	119	62	86	5	7
98-99	0	0	0	31	97	48	27	12	0
99-00	0	0	12	17	241	0	0	0	0
00-01	0	39	0	36	40	21	0	0	12
01-02	0	18	36	118	98	27	65	17	10
02-03	0	25	0	102	50	206	106	17	0
03-04	0	5	23	73	92	21	14	4	0
04-05	0	0	102	36	127	111	14	10	4
05-06	0	5	34	78	78	94	8	78	0
06-07	0	41	0	70	31	80	65	4	5
07-08	0	0	54	51	120	51	2	0	0
08-09	4	9	10	87	7	150	35	7	0
09-10	3	15	37	49	58	127	7	0	2
10-11	0	4	0	63	30	102	65	31	7
11-12	0	3	67	13	80	105	0	0	0
12-13	0	3	46	38	193	16	4	15	4
13-14	0	0	0	160	0	4	50	0	22
14-15	0	19	125	21	94	87	19	23	0

AVG	0.2	11.3	43.1	76.4	93.4	74.8	53.5	14.3	3.1
STD	0.7	12.7	47.2	52.6	69.5	56.8	41.4	20.2	7.0
MAX	3.5	46.4	185.4	198.5	379.4	219.6	161.5	103.9	38.6

Table.A2: Monthly rainfall of Tubas station (mm)

Year	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
68-69	0.0	4.5	16.3	138.3	177.2	24.1	90.0	17.2	0.0
69-70	0.0	24.3	34.0	41.7	100.0	25.8	87.7	7.6	0.0
70-71	0.0	0.2	6.7	66.2	68.1	66.0	33.7	108.5	0.0
71-72	0.0	0.0	64.1	138.4	85.8	107.6	98.1	15.3	0.0
72-73	0.0	0.0	27.7	32.2	139.3	11.2	62.4	7.7	6.0
73-74	0.0	16.3	87.9	45.3	296.5	78.6	34.4	44.9	0.0
74-75	0.0	0.0	0.0	91.1	39.0	158.0	64.1	0.3	0.0
75-76	0.0	2.5	28.9	68.6	49.2	95.2	86.4	23.7	10.0
76-77	0.0	23.9	71.0	35.1	118.0	24.3	65.4	38.7	0.0
77-78	0.0	31.5	2.0	101.0	36.5	37.5	67.0	9.0	0.0
78-79	0.0	16.0	15.0	69.0	58.5	15.5	48.0	0.0	0.0
79-80	0.0	32.5	115.5	206.0	49.0	112.0	100.0	6.0	0.0
80-81	0.0	0.0	0.0	130.0	105.0	58.0	50.0	3.5	0.0
81-82	0.0	0.0	64.0	16.5	69.5	74.5	17.0	0.0	0.0
82-83	0.0	0.0	86.0	46.0	105.0	120.5	102.0	5.0	3.0
83-84	0.0	0.0	48.0	13.0	74.0	38.0	89.5	21.0	0.0
84-85	0.0	22.0	11.0	32.0	20.0	106.0	13.0	28.0	0.0
85-86	0.0	10.0	29.0	40.0	52.0	93.5	0.0	38.0	5.0
86-87	0.0	16.0	171.0	96.0	148.0	34.0	89.5	0.0	0.0
87-88	0.0	27.0	8.0	119.0	80.0	150.0	15.0	0.0	0.0
88-89	0.0	19.0	45.0	84.0	0.0	0.0	0.0	0.0	0.0
89-90	0.0	15.0	76.0	94.0	108.0	0.0	0.0	0.0	0.0
90-91	0.0	8.5	16.0	123.0	81.0	77.0	10.5	0.0	0.0
91-92	0.0	0.0	114.5	291.0	188.0	261.0	26.5	18.5	0.0
92-93	0.0	41.0	40.0	234.0	51.0	69.0	39.0	1.5	10.0
93-94	0.0	8.5	23.5	9.5	136.5	60.0	95.5	3.0	0.0
94-95	0.0	16.5	167.0	150.0	19.0	48.0	30.0	20.0	0.0
95-96	0.0	0.0	63.5	22.0	140.0	15.5	123.0	14.5	0.0
96-97	0.0	29.5	57.5	8.0	106.5	181.5	107.5	9.5	0.0
97-98	0.0	34.5	22.5	117.5	123.0	72.8	172.5	3.3	0.0
98-99	0.0	0.0	0.0	45.0	69.5	40.5	31.5	15.0	0.0
99-00	0.0	1.5	5.9	23.5	229.5	60.8	45.7	0.0	0.0
00-01	0.0	26.2	1.0	99.9	46.8	47.2	0.0	0.0	22.0
01-02	0.0	30.5	48.5	118.5	156.5	40.5	72.0	24.0	3.5
02-03	0.0	3.0	24.0	133.5	68.2	264.8	105.5	0.0	0.0
03-04	0.0	0.0	13.0	74.0	130.0	87.5	9.5	3.0	0.0
04-05	0.0	0.4	141.2	48.6	122.2	190.6	20.0	9.4	0.0
05-06	0.4	1.6	50.8	89.4	98.2	125.2	17.6	131.8	0.0
06-07	0.0	64.6	20.6	63.4	98.4	136.2	52.0	0.0	0.0
07-08	0.4	0.4	69.0	54.4	144.0	87.6	7.2	1.6	2.8
08-09	9.4	0.2	0.0	0.0	0.0	102.6	113.4	7.6	0.0
09-10	10.8	25.0	93.2	98.8	74.4	30.0	1.0	0.0	0.0
10-11	0.0	3.5	0.0	74.0	106.5	69.3	117.0	26.0	5.5
11-12	0.0	0.0	0.0	0.0	54.2	130.8	85.6	0.0	4.4
12-13	0.0	0.0	20.0	68.4	115.0	31.0	0.6	25.6	7.4
13-14	0.0	0.0	2.6	182.4	2.2	5.0	65.4	0.0	2.8
14-15	0.0	32.5	123.5	40.0	150.6	137.5	16.0	28.5	0.0

15-16	0.0	11.5	22.5	47.5	124.0	53.5	21.0	13.5	0.0
AVG	0.4	12.5	44.7	81.7	96.1	80.3	54.1	15.2	1.7
STD	2.0	14.6	44.8	60.6	57.6	60.5	41.8	25.0	3.9
MAX	10.8	64.6	171.0	291.0	296.5	264.8	172.5	131.8	22.0

Table.A3: Monthly rainfall of Talluza station (mm)

Year	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
68-69	0.0	15.3	33.7	191.3	321.0	33.4	146.8	25.1	0.0
69-70	0.0	25.9	45.8	63.8	167.5	51.7	178.5	38.4	3.2
70-71	0.0	3.7	3.4	106.8	95.0	138.3	69.2	203.5	0.0
71-72	0.0	0.0	50.1	201.6	132.7	174.6	104.6	24.9	0.0
72-73	0.0	0.0	41.3	56.1	198.1	23.6	188.7	10.5	16.3
73-74	0.0	11.0	117.8	88.5	453.6	135.2	40.8	34.4	0.0
74-75	0.0	0.0	31.1	131.8	58.8	223.0	88.8	2.7	0.0
75-76	7.0	0.0	45.7	135.6	96.4	144.0	138.0	43.9	0.0
76-77	0.0	24.8	120.4	46.2	153.7	71.6	139.2	62.6	0.0
77-78	0.0	60.8	2.0	221.5	72.2	51.5	90.4	9.5	0.0
78-79	0.0	40.0	23.2	99.5	108.7	17.5	67.9	5.5	0.0
79-80	0.0	32.2	177.0	266.7	120.5	160.1	154.0	14.5	0.8
80-81	0.0	13.2	8.1	198.6	223.9	100.7	63.1	9.2	0.0
81-82	0.0	3.7	120.0	19.8	93.5	136.6	96.5	4.0	11.3
82-83	0.0	0.2	101.8	106.0	215.0	261.4	170.5	16.9	5.0
83-84	0.0	6.5	98.0	24.6	185.2	68.3	169.7	57.7	0.0
84-85	0.0	12.6	48.0	49.4	71.7	265.9	19.2	38.3	0.3
85-86	0.0	13.4	55.6	51.8	94.7	157.3	48.7	27.2	59.6
86-87	0.0	25.4	236.4	120.3	149.2	50.9	122.5	2.3	0.0
87-88	0.0	45.9	15.5	180.9	109.3	249.4	104.0	11.4	0.0
88-89	0.0	9.6	53.0	253.3	68.4	28.0	91.8	3.0	0.0
89-90	0.0	21.5	75.5	109.6	126.0	92.5	56.4	29.1	0.0
90-91	0.0	22.9	31.5	12.0	230.5	70.1	106.6	16.6	4.8
91-92	0.0	3.6	150.7	384.0	265.8	396.9	61.0	4.6	36.5
92-93	0.0	0.0	54.4	366.3	141.9	84.2	76.2	2.4	9.0
93-94	0.0	29.0	23.7	25.4	203.6	86.1	131.0	0.0	0.0
94-95	0.0	25.2	248.8	177.3	59.5	105.6	37.2	25.2	0.0
95-96	0.0	0.0	90.3	58.8	198.3	20.2	231.0	35.1	0.0
96-97	0.0	40.0	10.6	77.9	170.4	259.7	187.2	19.5	10.0
97-98	0.0	16.3	50.2	205.7	184.8	76.8	192.4	5.4	0.0
98-99	0.0	0.0	7.5	48.7	125.6	48.6	39.3	22.5	0.0
99-00	0.0	0.0	0.0	15.2	350.8	55.7	51.5	0.5	0.0
00-01	0.0	39.9	6.6	103.2	53.0	101.3	5.5	1.5	13.8
01-02	0.0	27.2	47.5	124.9	191.0	27.1	76.4	27.3	2.9
02-03	0.0	6.5	34.2	137.8	65.8	281.9	142.8	33.5	0.0
03-04	0.0	0.0	24.4	74.6	141.5	94.7	12.4	1.5	0.0
04-05	0.0	0.0	107.7	32.6	123.2	149.3	18.7	10.9	0.0
05-06	0.0	4.9	32.9	79.8	73.0	110.7	14.0	68.9	0.0
06-07	0.0	0.0	1.0	60.4	101.5	98.3	0.0	0.0	0.0
07-08	0.0	0.0	41.9	53.8	21.1	0.0	0.0	0.0	0.0
08-09	0.0	0.0	0.5	146.9	17.8	346.2	90.4	18.9	0.0
09-10	2.0	41.7	113.7	87.5	97.0	235.1	19.5	1.0	6.2
10-11	0.0	6.2	0.0	195.9	72.0	91.0	101.5	41.6	8.9
11-12	0.0	4.0	132.5	41.1	120.0	193.3	99.1	0.0	0.0
12-13	0.0	2.5	38.7	81.9	356.7	48.9	5.3	46.5	7.5
13-14	0.4	3.8	3.3	296.6	2.5	8.1	96.7	0.0	33.4
14-15	0.0	23.8	175.7	53.8	208.2	181.2	24.8	53.2	6.6

15-16	6.8	32.4	25.7	58.1	221.6	96.5	34.7	15.9	0.0
AVG	0.3	14.5	61.6	119.2	148.2	123.0	87.6	23.5	4.9
STD	1.4	15.5	60.4	88.1	91.2	91.1	59.2	32.0	11.1
MAX	7.0	60.8	248.8	384.0	453.6	396.9	231.0	203.5	59.6

Table.A4: Monthly rainfall of Tammun station (mm)

Year	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
68-69	0.0	11.0	27.0	76.3	23.4	19.6	94.0	15.5	0.0
69-70	0.0	0.0	4.0	59.1	62.3	46.5	22.0	85.1	0.0
70-71	0.0	0.0	50.0	122.3	83.5	76.6	79.0	8.0	0.0
71-72	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
72-73	0.0	0.0	29.1	31.9	93.3	7.4	52.6	4.3	0.0
73-74	0.0	3.4	89.4	35.3	254.6	93.2	28.4	24.6	0.0
74-75	0.0	0.0	22.9	60.1	44.6	126.3	51.5	1.0	0.0
75-76	0.4	0.0	24.4	35.2	28.7	51.1	74.2	19.2	0.0
76-77	0.0	12.5	67.0	19.9	97.3	17.8	46.8	9.0	0.0
77-78	0.0	34.6	2.2	109.8	34.1	21.7	33.8	0.0	0.0
78-79	0.0	27.2	5.3	70.7	49.7	13.4	47.8	0.0	0.0
79-80	0.0	13.5	88.9	132.2	59.6	72.6	47.3	0.0	0.0
80-81	0.0	6.0	1.2	107.1	97.7	39.9	33.2	0.0	0.0
81-82	0.0	0.0	50.9	10.1	37.4	65.9	42.4	0.0	0.0
82-83	0.0	0.0	67.3	43.0	90.2	119.0	72.1	5.4	0.0
83-84	0.0	0.0	61.3	13.2	101.0	30.0	72.2	17.1	0.0
84-85	0.0	6.8	24.1	32.3	33.9	120.8	10.1	30.0	0.0
85-86	0.0	6.7	26.1	32.1	47.8	78.7	21.5	49.6	24.2
86-87	0.0	23.2	8.8	65.3	65.3	55.0	0.0	0.0	0.0
87-88	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
88-89	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
89-90	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
90-91	0.0	0.0	0.0	1.3	128.6	0.0	0.0	0.0	0.0
91-92	0.0	5.3	88.1	194.9	127.2	161.1	39.5	0.0	0.0
92-93	0.0	0.0	30.0	158.5	48.5	56.7	32.9	3.5	0.0
93-94	0.0	19.0	15.6	9.7	105.6	60.1	63.3	3.5	0.0
94-95	0.0	6.5	175.6	113.7	17.7	40.1	32.9	8.5	3.5
95-96	0.0	0.0	55.2	28.0	106.7	14.5	110.8	22.0	0.0
96-97	0.0	0.0	0.0	0.0	114.0	137.8	98.7	9.8	0.0
97-98	0.0	14.1	27.2	113.2	106.3	65.2	122.0	3.0	0.0
98-99	0.0	0.0	0.0	10.7	54.1	29.4	18.2	15.5	0.0
99-00	0.0	0.0	3.5	11.6	227.0	39.5	0.0	0.0	0.0
00-01	0.0	20.5	0.0	75.5	49.0	68.4	4.5	0.0	5.5
01-02	0.0	31.5	43.7	100.3	123.5	27.3	51.2	16.3	1.0
02-03	0.0	1.0	29.7	128.4	47.6	188.3	82.4	26.2	0.0
03-04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
04-05	0.0	0.2	96.0	38.0	121.2	155.4	20.8	11.2	0.0
05-06	0.2	2.2	44.6	91.4	79.8	97.6	16.2	94.0	0.0
06-07	0.0	49.8	14.0	68.8	85.0	108.8	47.0	0.0	0.0
07-08	0.2	0.0	65.4	50.2	108.2	72.4	5.2	0.6	1.0
08-09	8.4	26.6	19.8	83.2	16.0	158.6	133.0	8.4	0.0
09-10	1.0	26.2	81.6	70.4	62.6	98.4	46.2	0.4	5.6
10-11	0.0	2.4	0.0	75.0	78.0	7.2	0.0	0.0	0.0
11-12	0.0	0.0	0.0	0.0	47.2	84.8	88.4	0.0	0.0
12-13	0.0	0.0	18.2	68.0	163.2	41.8	3.8	19.4	3.0
13-14	0.0	0.2	0.2	121.2	0.4	4.8	58.8	0.0	36.0
14-15	0.0	12.5	118.5	27.5	118.0	96.0	9.0	12.0	0.0

15-16	0.0	13.0	16.5	24.0	117.0	53.0	14.0	14.5	0.0
AVG	0.2	7.8	33.2	56.7	74.1	60.9	40.2	11.2	1.7
STD	1.2	11.5	37.8	47.8	54.2	49.3	35.4	19.3	6.2
MAX	8.4	49.8	175.6	194.9	254.6	188.3	133.0	94.0	36.0

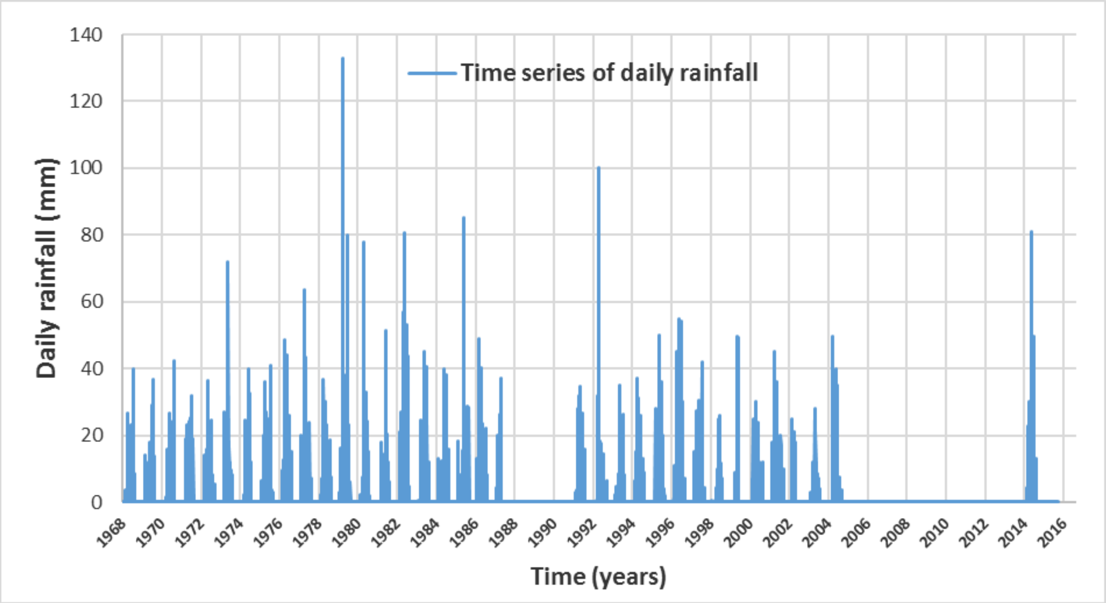

Figure.A1: Beit dajan daily time Series

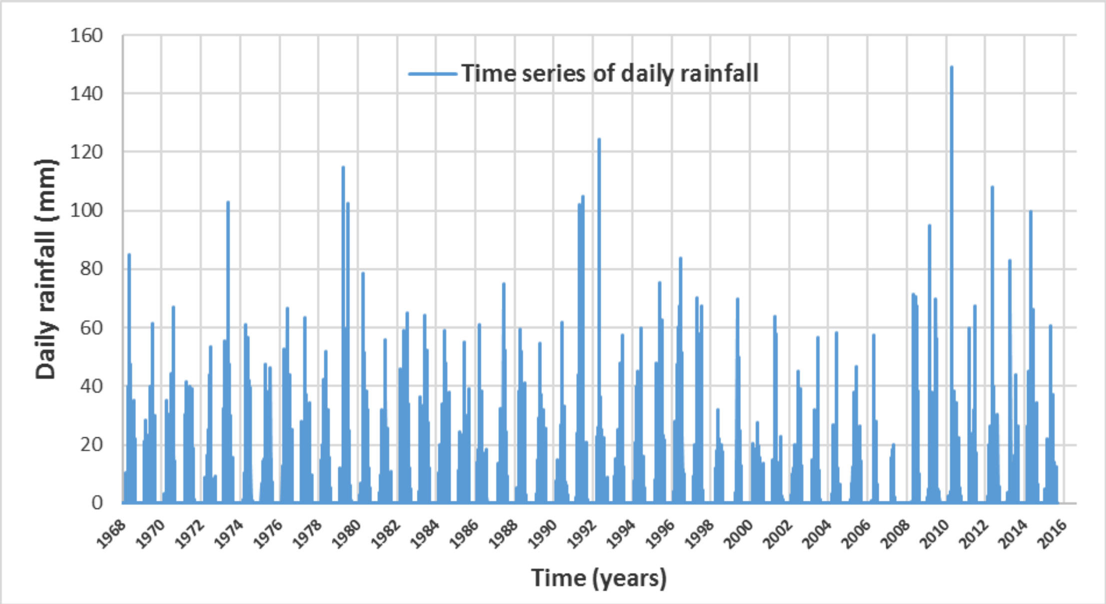

Figure.A2: Talluza daily rainfall time Series

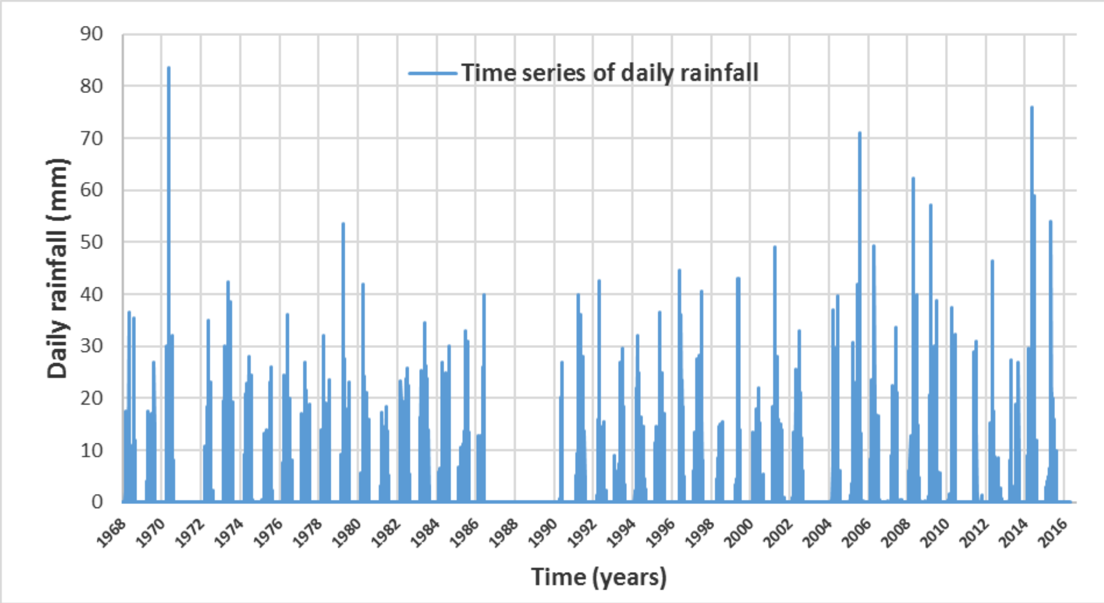

Figure.A3: Tummon daily rainfall time Series

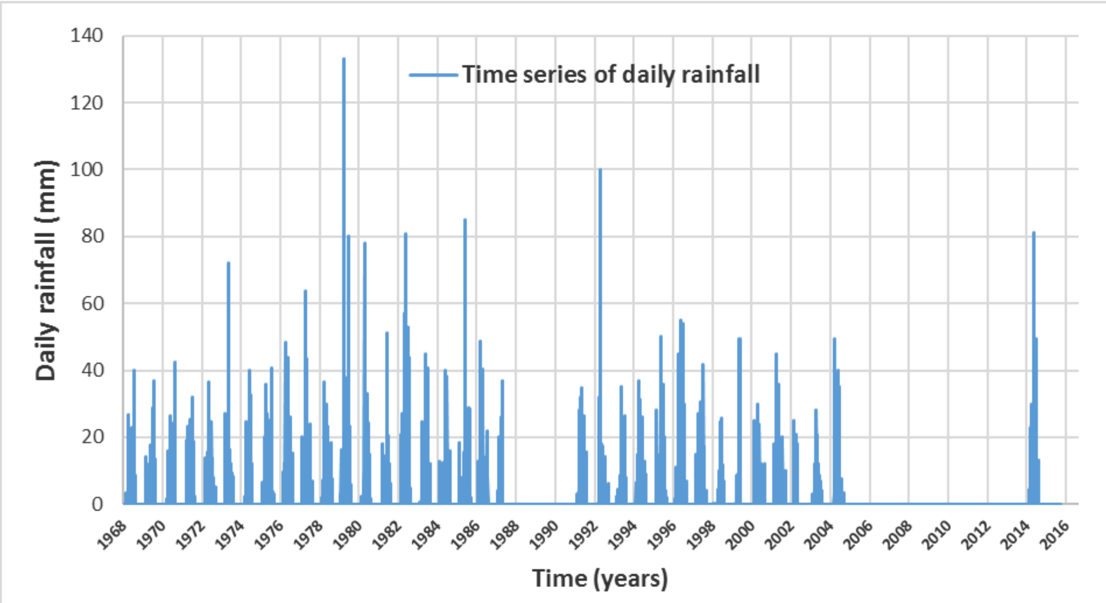

Figure.A4: Tubas daily rainfall time Series

Table 7: The six stations annual and seasonal rainfall data statistics parameters

Annual Rainfall								
Station/Parameter	**Mean**	**Median**	**STD***	**Skewness**	**Kurtosis**	**Max**	**Min**	**Range**
Nablus	637.9	623.5	204.5	1.3	3.8	1402.4	278.4	1124.0
Al Faria	177.5	172.6	98.9	0.5	0.7	411.3	29.6	381.7
Beit Dajan	377.9	384.9	147.2	1.2	2.7	847.1	127.0	720.1
Tubas	386.8	352.5	141.9	1.1	2.2	899.5	148.0	751.5
Talluza	582.8	581.4	193.8	0.8	3.3	1303.1	116.8	1186.3
Tammun	319.4	294.8	107.6	0.5	0.1	616.1	127.9	488.2
Fall Rainfall								
Station/Parameter	**Mean**	**Median**	**STD**	**Skewness**	**Kurtosis**	**Max**	**Min**	**Range**
Nablus	90.9	74.0	68.4	1.2	1.6	289.8	0.0	289.8
Al Faria	42.2	30.4	42.9	1.7	3.2	161.0	0.0	161.0
Beit Dajan	59.0	39.5	54.4	1.8	2.6	220.5	1.0	219.5
Tubas	56.4	39.0	48.5	1.1	0.7	187.0	0.0	187.0
Talluza	75.7	61.0	64.5	1.4	1.9	274.0	0.0	274.0
Tammun	46.0	34.6	39.5	1.3	2.2	182.1	0.0	182.1
Winter Rainfall								
Station/Parameter	**Mean**	**Median**	**STD**	**Skewness**	**Kurtosis**	**Max**	**Min**	**Range**
Nablus	426.7	373.3	172.0	2.1	7.0	1161.1	240.7	920.4
Al Faria	103.7	104.0	78.4	0.5	0.3	280.2	0.0	280.2
Beit Dajan	245.0	222.6	104.9	1.1	1.2	556.2	97.0	459.2
Tubas	260.2	271.5	110.9	1.8	6.4	740.0	84.0	656.0
Talluza	389.1	347.5	153.1	1.8	6.2	1046.7	74.9	971.8
Tammun	212.7	192.9	82.3	1.0	1.4	483.2	94.2	389.0
Spring Rainfall								
Station/Parameter	**Mean**	**Median**	**STD**	**Skewness**	**Kurtosis**	**Max**	**Min**	**Range**
Nablus	120.3	107.6	78.0	0.7	-0.2	302.4	0.0	302.4
Al Faria	31.7	28.8	31.7	0.7	-0.8	91.3	0.0	91.3
Beit Dajan	73.9	66.9	46.4	0.1	-1.0	170.2	0.0	170.2
Tubas	69.7	64.4	44.2	0.3	-0.8	175.8	0.0	175.8
Talluza	116.0	104.3	68.5	0.4	-0.4	272.7	0.0	272.7
Tammun	59.9	52.3	39.0	0.3	-0.8	141.4	0.0	141.4
Summer Rainfall								
Station/Parameter	**Mean**	**Median**	**STD**	**Skewness**	**Kurtosis**	**Max**	**Min**	**Range**
Nablus	0.1	0.0	0.2	-	-	1.4	0.0	1.4
Al Faria	0.0	0.0	0.0	-	-	0.0	0.0	0.0
Beit Dajan	0	0	0	-	-	0.0	0.0	0.0
Tubas	0.3	0.0	1.5	-	-	10.0	0.0	10.0
Talluza	0.0	0.0	0.0	-	-	0.0	0.0	0.0
Tammun	0.2	0.0	1.1	-	-	6.8	0.0	6.8

- The obtained numbers are not identified

*Standard deviation

Table 8 : T-test for DRD - FRD relations

Rainfall stations	Relation	t-stat	t-critical at 90%	t-critical at 95%		
Nablus	10 min Versus daily	8.77	1.812	2.228	Reject H0	Reject H0
	20 min Versus daily	13.47	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	9.64	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	8.61	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	7.79	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	22.37	1.812	2.228	Reject H0	Reject H0
	6 hr Versus daily	11.27	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	16.21	1.812	2.228	Reject H0	Reject H0
Talluza	10 min Versus daily	3.44	2.132	2.776	Reject H0	Reject H0
	20 min Versus daily	2.58	2.132	2.776	Reject H0	accept H0
	30 min Versus daily	3.38	2.132	2.776	Reject H0	Reject H0
	1 hr Versus daily	6.14	2.132	2.776	Reject H0	Reject H0
	2 hr Versus daily	3.72	2.132	2.776	Reject H0	Reject H0
	4 hr Versus daily	3.29	2.132	2.776	Reject H0	Reject H0
	6 hr Versus daily	3.53	2.132	2.776	Reject H0	Reject H0
	12 hr Versus daily	3.12	2.132	2.776	Reject H0	Reject H0
Tubas	10 min Versus daily	3.67	2.015	2.571	Reject H0	Reject H0
	20 min Versus daily	3.67	2.015	2.571	Reject H0	Reject H0
	30 min Versus daily	3.83	2.015	2.571	Reject H0	Reject H0
	1 hr Versus daily	11.18	2.015	2.571	Reject H0	Reject H0
	2 hr Versus daily	13.19	2.015	2.571	Reject H0	Reject H0
	4 hr Versus daily	6.37	2.015	2.571	Reject H0	Reject H0
	6 hr Versus daily	7.32	2.015	2.571	Reject H0	Reject H0
	12 hr Versus daily	9.15	2.015	2.571	Reject H0	Reject H0
Beit Daja	10 min Versus daily	8.77	1.812	2.228	Reject H0	Reject H0
	20 min Versus daily	13.47	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	9.64	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	8.61	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	7.79	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	22.37	1.812	2.228	Reject H0	Reject H0
	6 hr Versus daily	11.27	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	16.21	1.812	2.228	Reject H0	Reject H0
Tammun	10 min Versus daily	10.16	1.812	2.228	Reject H0	Reject H0
	20 min Versus daily	10.11	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	16.89	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	13.07	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	9.52	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	9.19	1.812	2.228	Reject H0	Reject H0
	6 hr Versus daily	6.77	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	22.65	1.812	2.228	Reject H0	Reject H0
Al-Faria	10 min Versus daily	8.77	1.812	2.228	Reject H0	Reject H0

	20 min Versus daily	13.47	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	9.64	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	8.61	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	7.79	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	22.37	1.812	2.228	Reject H0	Reject H0
	6 hr Versus daily	11.27	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	16.21	1.812	2.228	Reject H0	Reject H0
Salim	10 min Versus daily	8.77	1.812	2.228	Reject H0	Reject H0
	20 min Versus daily	13.47	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	9.64	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	8.61	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	7.79	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	22.37	1.812	2.228	Reject H0	Reject H0
	6 hr Versus daily	11.27	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	16.21	1.812	2.228	Reject H0	Reject H0
S8	10 min Versus daily	8.77	1.812	2.228	Reject H0	Reject H0
	20 min Versus daily	13.47	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	9.64	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	8.61	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	7.79	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	22.37	1.812	2.228	Reject H0	Reject H0
	6 hr Versus daily	11.27	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	16.21	1.812	2.228	Reject H0	Reject H0
S9	10 min Versus daily	8.77	1.812	2.228	Reject H0	Reject H0
	20 min Versus daily	13.47	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	9.64	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	8.61	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	7.79	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	22.37	1.812	2.228	Reject H0	Reject H0
	6 hr Versus daily	11.27	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	16.21	1.812	2.228	Reject H0	Reject H0
S10	10 min Versus daily	8.77	1.812	2.228	Reject H0	Reject H0
	20 min Versus daily	13.47	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	9.64	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	8.61	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	7.79	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	22.37	1.812	2.228	Reject H0	Reject H0
	6 hr Versus daily	11.27	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	16.21	1.812	2.228	Reject H0	Reject H0
S11	10 min Versus daily	8.77	1.812	2.228	Reject H0	Reject H0
	20 min Versus daily	13.47	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	9.64	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	8.61	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	7.79	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	22.37	1.812	2.228	Reject H0	Reject H0

	6 hr Versus daily	11.27	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	16.21	1.812	2.228	Reject H0	Reject H0
S12	10 min Versus daily	8.77	1.812	2.228	Reject H0	Reject H0
	20 min Versus daily	13.47	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	9.64	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	8.61	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	7.79	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	22.37	1.812	2.228	Reject H0	Reject H0
	6 hr Versus daily	11.27	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	16.21	1.812	2.228	Reject H0	Reject H0
S13	10 min Versus daily	8.77	1.812	2.228	Reject H0	Reject H0
	20 min Versus daily	13.47	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	9.64	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	8.61	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	7.79	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	22.37	1.812	2.228	Reject H0	Reject H0
	6 hr Versus daily	11.27	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	16.21	1.812	2.228	Reject H0	Reject H0
S14	10 min Versus daily	8.77	1.812	2.228	Reject H0	Reject H0
	20 min Versus daily	13.47	1.812	2.228	Reject H0	Reject H0
	30 min Versus daily	9.64	1.812	2.228	Reject H0	Reject H0
	1 hr Versus daily	8.61	1.812	2.228	Reject H0	Reject H0
	2 hr Versus daily	7.79	1.812	2.228	Reject H0	Reject H0
	4 hr Versus daily	22.37	1.812	2.228	Reject H0	Reject H0
	6 hr Versus daily	11.27	1.812	2.228	Reject H0	Reject H0
	12 hr Versus daily	16.21	1.812	2.228	Reject H0	Reject H0

جامعة النجاح الوطنية

كلية الدراسات العليا

تطوير ورسم خرائط الشدة المطرية والفترة الزمنية والتكرار لحوض الفارعة

اعداد

حسين فتحي حسين حجي

اشراف

د.عنان جيوسي

د.سمير شديد

قدمت هذه الاطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة المياه والبيئة في جامعة النجاح الوطنية في نابلس، فلسطين

2017

تطوير منحنيات الشدة المطرية -الاستدامة -التكرار زمانيا ومكانيا في حوض وادي الفارعة

اعداد
حسين فتحي حسين حجي
اشراف
د.عنان جيوسي
د.سمير شديد

الملخص

تعتبر العلاقة بين الشدة المطرية - الفترة الزمنية - التكرار واحدة من أكثر الأدوات المستخدمة في هندسة الموارد المائية، وذلك لتحديد الشدة المطرية عند فترة زمنية وسنة رجوع. في ضوء ذلك، تهدف الدراسة الحالية إلى تطوير علاقة الشدة المطرية - الفترة الزمنية - التكرار لحوض الفارعة. يختلف ارتفاع سطح الأرض في حوض الفارعة اختلافا كبيراً.

مع فصل شتاء ممطر معتدل وصيف حار جاف، يتبع حوض الفارعة مناخ البحر الابيض المتوسط، ويصنف كمنطقة شبه جافة .يتم جمع وقياس تساقط الأمطار على مجمع الفارعة باستخدام ستة محطات, هذه المحطات هي نابلس، طلوزة، طمون، طوباس، بيت دجن والفارعة تغطي بياناتها ما يقارب 48 عاماً من الزمن. بعد تحليل القيم القصوى للبيانات السنوية لهطول الأمطار أثبتت النتائج أن توزيع (Gumbel) يناسب البيانات ويمكن استخدامه للتقديرات المستقبلية, وبعد تقييم جميع البيانات المتاحة واستكمالها تم تطوير منحنيات الشدة – المطرية – الاستدامة - التكرار ل 14 محطة، وتم وضع 54 خريطة لمستجمعات المياه من هذه المنحنيات باستخدام (IDW) كأداة للتقريب من خلال ArcGIS .باستخدام هذه الخرائط يمكننا إيجاد شدة الأمطار عند أية نقطة، والتي نستطيع ايجادها مباشرة (دون استخدام منحنيات أو خرائط) مستخدمين البرنامج الذي أنشأناه باستخدام Matlab. باستخدام برنامج نظم المعلومات الجغرافية (GIS) يمكننا الحصول على منحنيات الشدة -المطرية - الاستدامة - التكرار لفترة زمنية محددة خلال فترة رجوع سنوية محددة, أما (Matlab) فهو قادر على اعطائنا هذه المنحنيات لأي فترة زمنية خلال أية فترة رجوع.