An-Najah National University
Faculty of Engineering and
Information Technology

Graduation Project 2

Rainfall-Runoff Analysis of Wadi Kharrouba (Jenin Governorate)

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16.Dec 2020

1 Introduction

1. Background
2. Objectives
3. Methodology

Background

- Indeed, water has always been the most crucial resource which is the most essential and vital need for life.

- Water shortage problem.

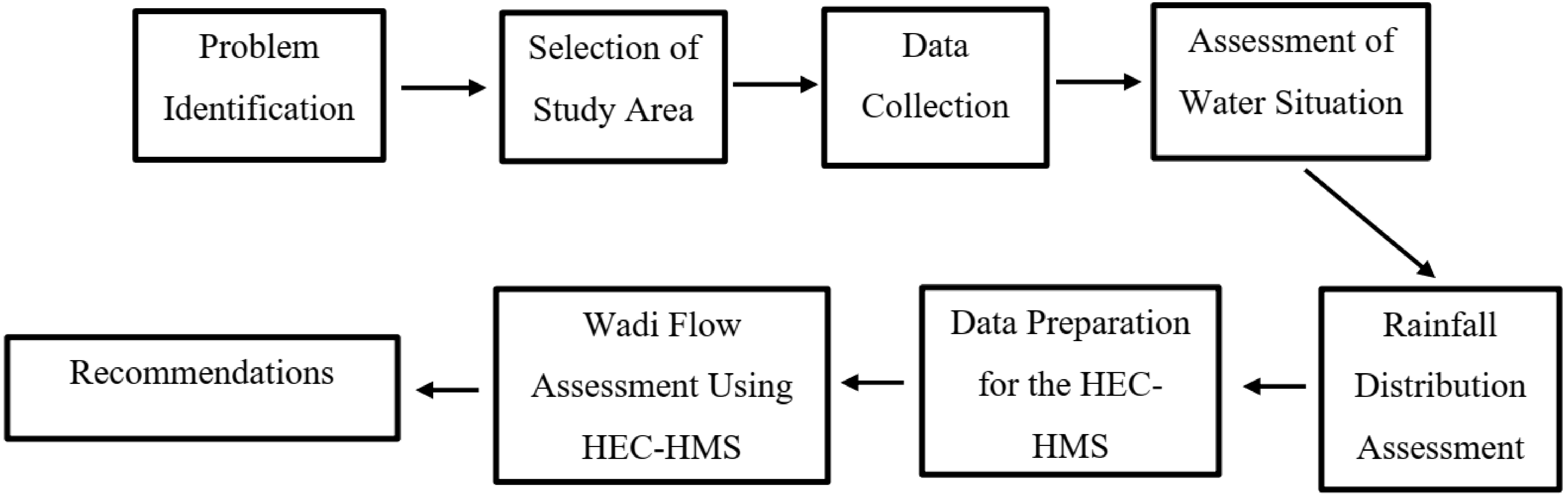
- Kharrouba watershed located in the north-east of Palestine (north of West Bank).

- We chose Kharrouba watershed out of AL-Mouqatta’ sub-catchments for many reasons.

Objectives

- Assess the water situation in Kharrouba watershed.
- Assess the rainfall distribution in the study area.
- Prepare data for the HEC-HMS.
- Assess wadi flow using HEC-HMS.
- Come up with the best way to have maximum use of runoff water.

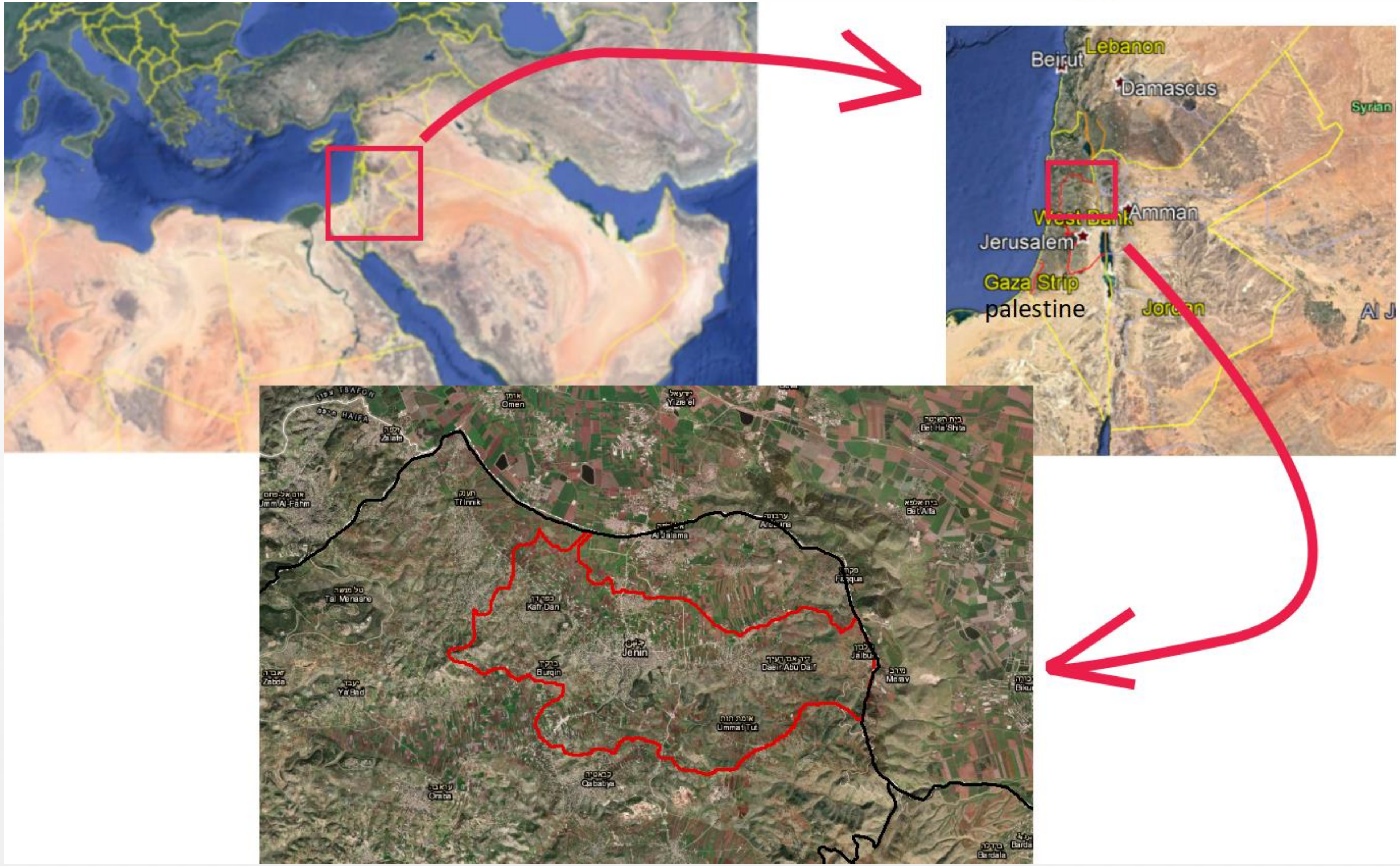
Methodology



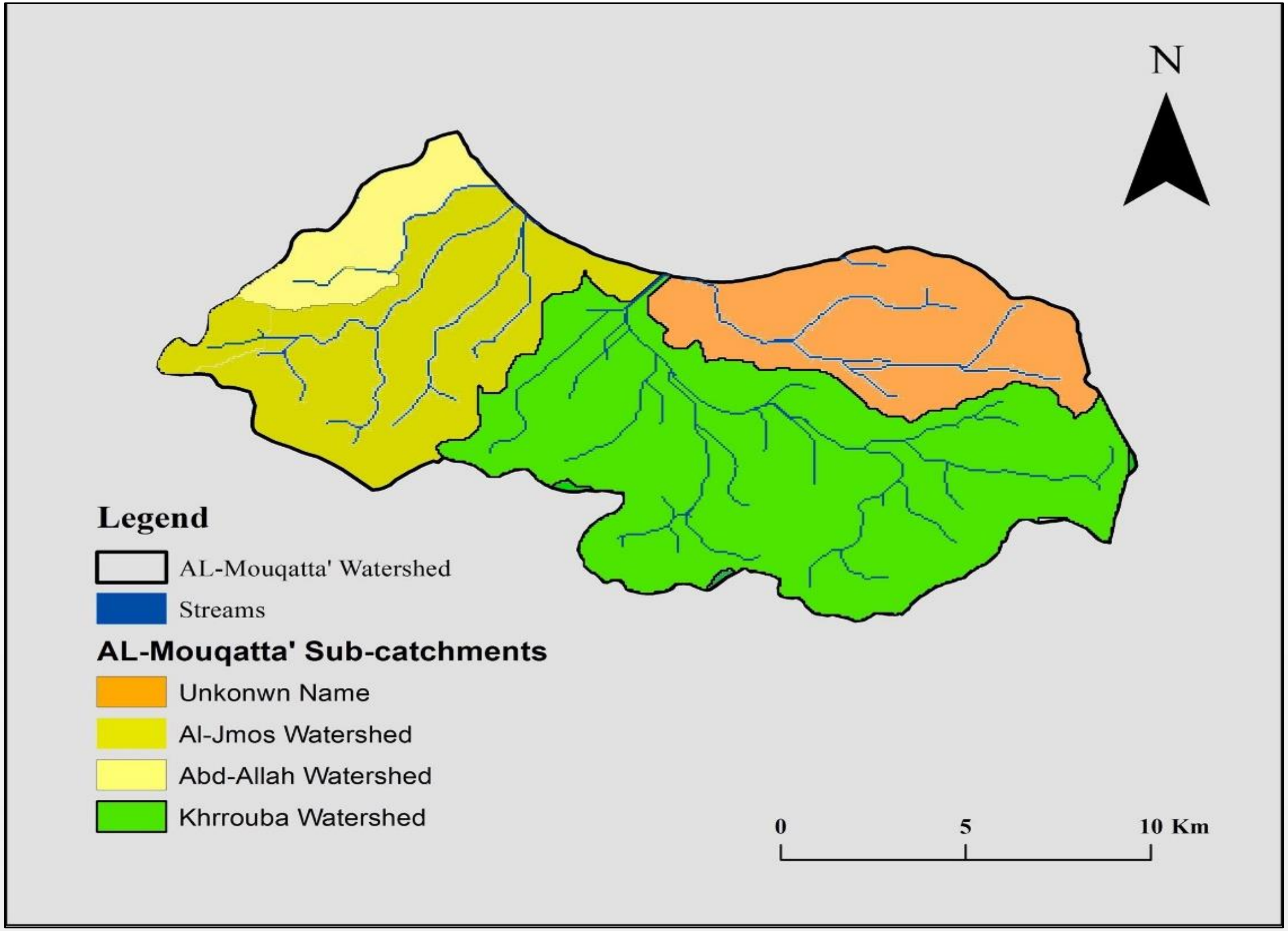
2 Description of the Study Area

1. Introduction
2. General Characteristic in AL-Mauqatta’
3. Characteristics of Kharrouba Watershed

Introduction



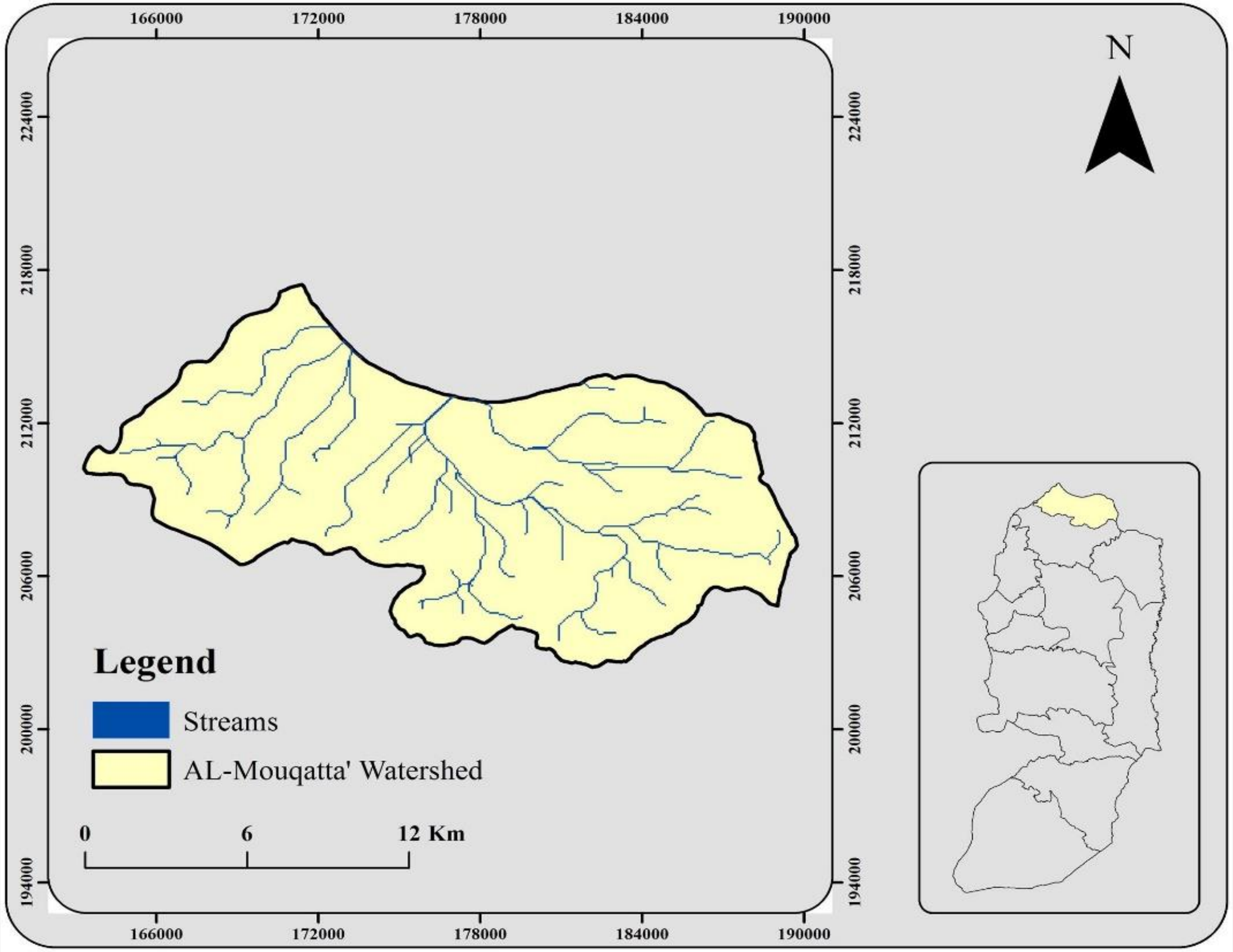
Introduction



General Characteristic in AL-Mauqatta’

- Generally, Al-Mauqatta’ in Jenin is a fertile plain with a total area of 208 km^2 and its perimeter is about 74.5km.

- Altitudes of Al-Mauqatta’ varies from 477m to 82m.

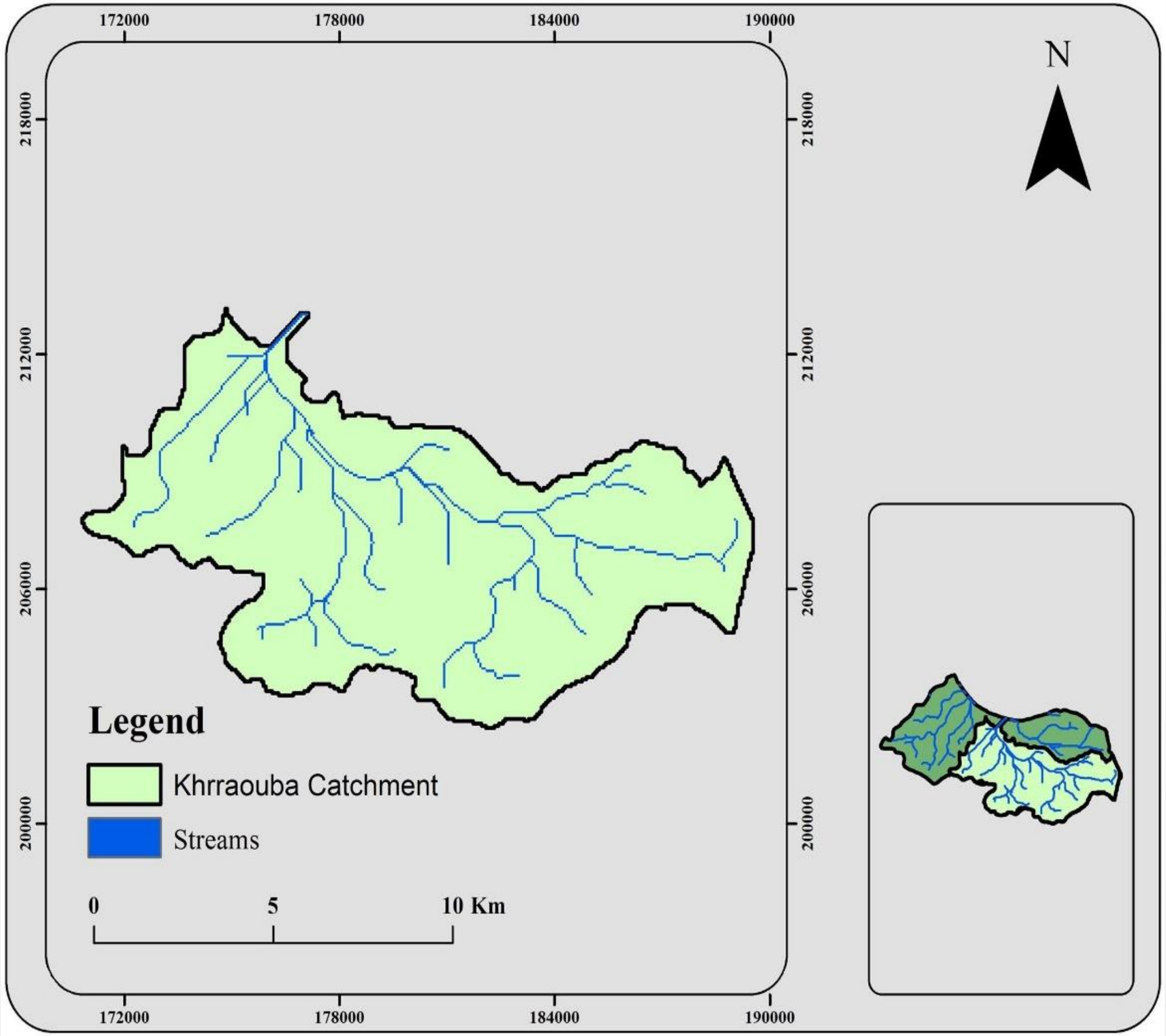


Characteristics of Kharrouba Watershed

1. Geography and Topography

- The streams bed in Khrrouba watershed are classified as caly-bed streams which drains an area of 102 km^2 and have a perimeter of 74.8km.

- Altitudes of Kharrouba watershed varies gently from 477m in the south to 93m in the north.

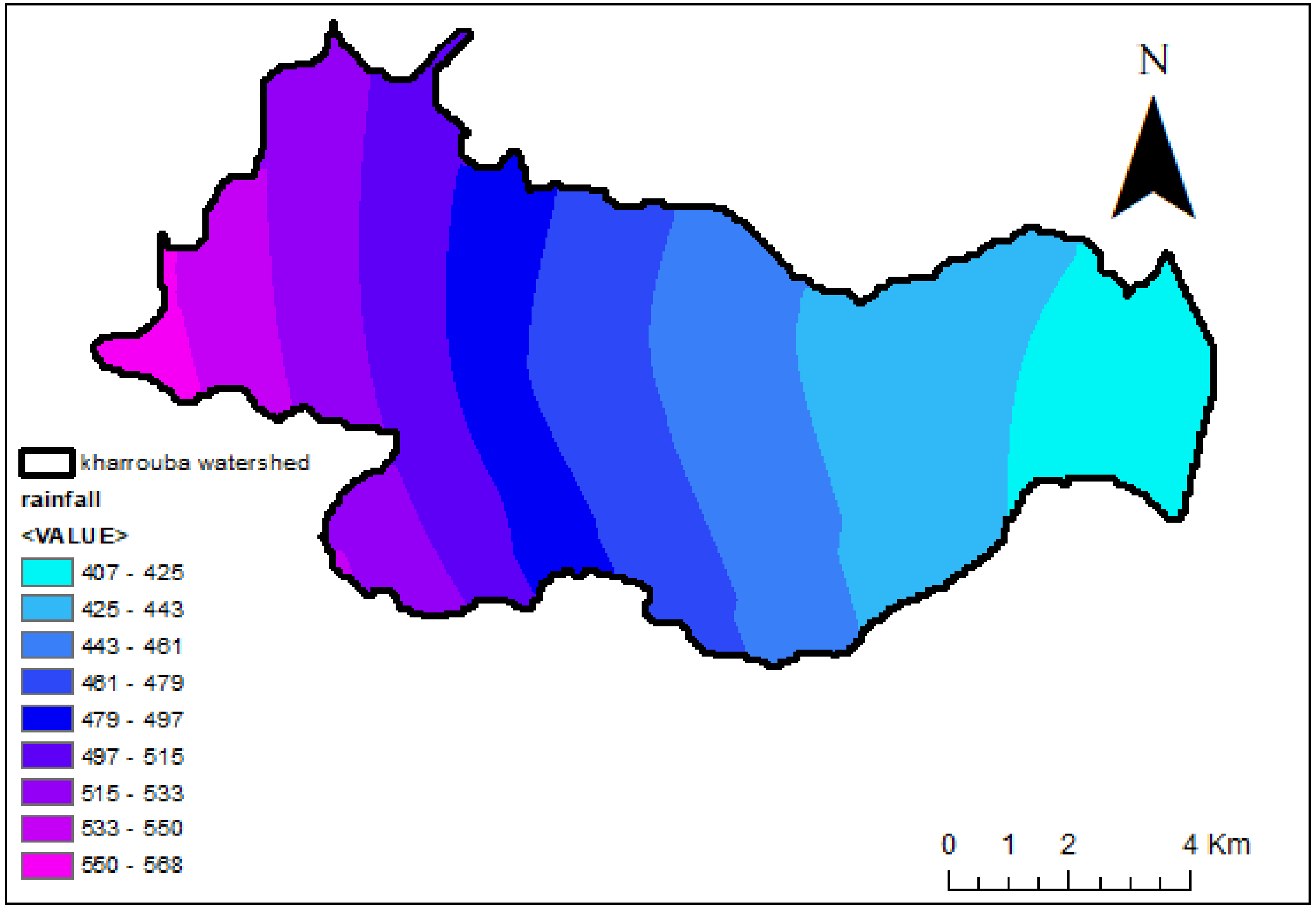


Characteristics of Kharrouba Watershed

2. Climate

- In general, Jenin Governorate has a nearly steady rate of rainfall. Moreover, rainfall is limited to winter season with annual precipitation of 473mm.

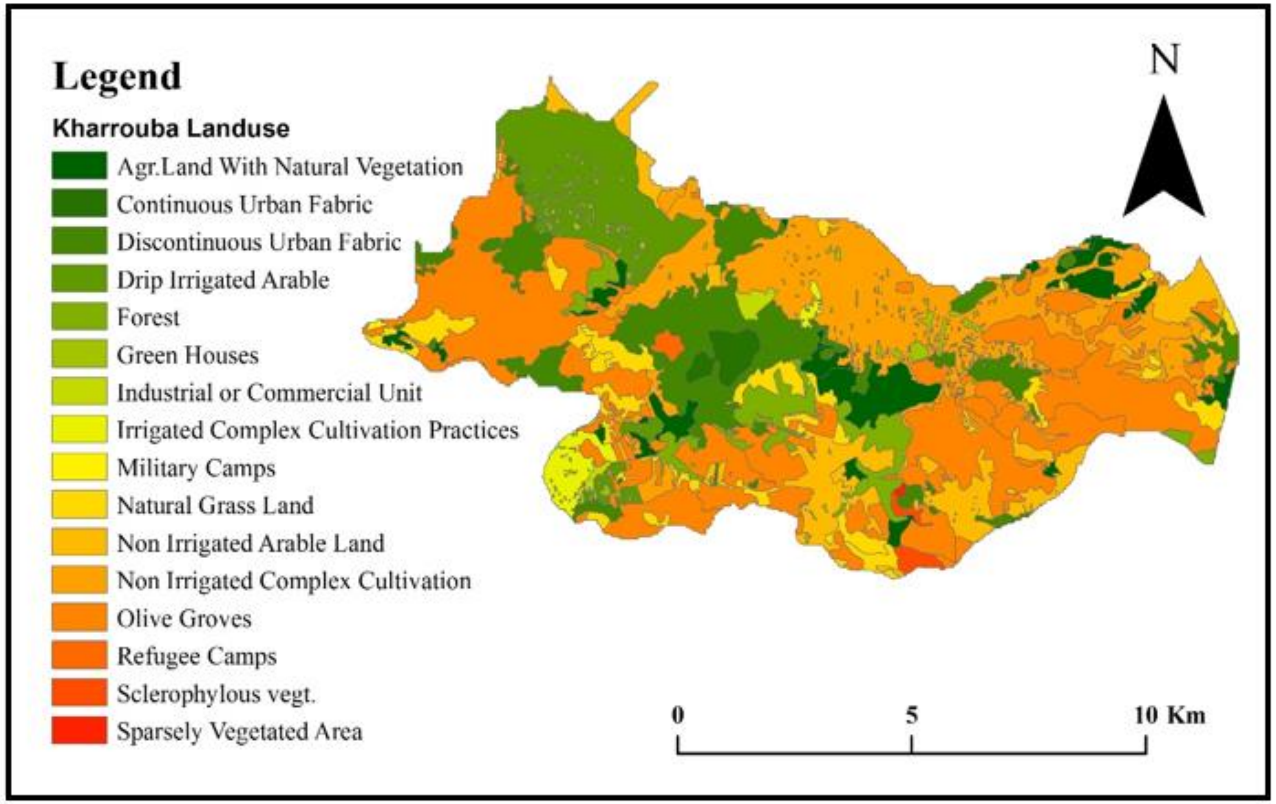
- The average temperature in our study area is ranges from 10°C in winter to 30°C in summer.



Characteristics of Kharrouba Watershed

4. Land use

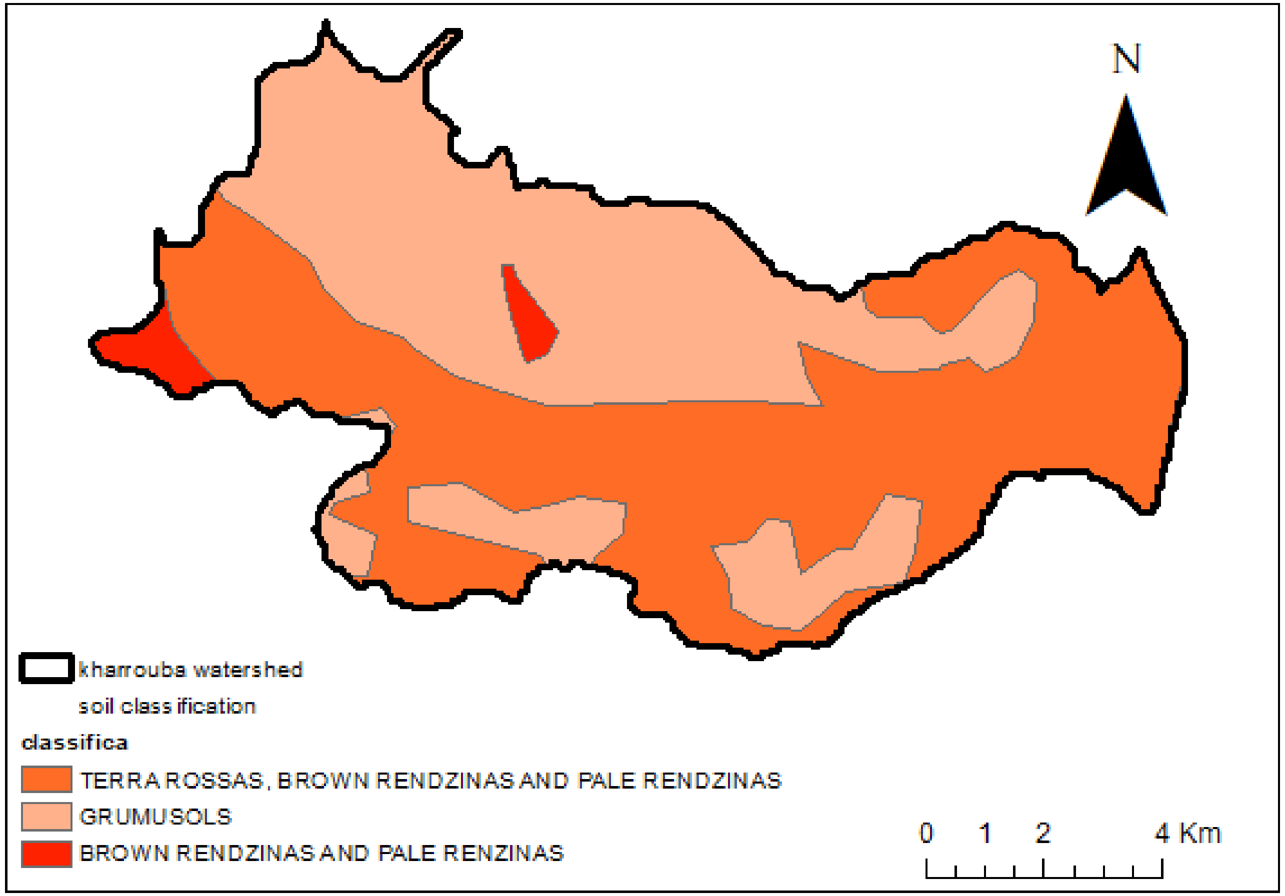
Land Use	Area (km^2)	Persant(%)
Olive Groves	32.2	31.85
Non Irrigated Complex Cultivation	18.3	18.10
Discontinuous Urban Fabric	12.5	12.36
Drip Irrigated Arable	8.6	8.51
Non Irrigated Arable Land	8	7.91
Natural Grass Land	6.1	6.03
Agr.Land With Natural Vegetation	5.6	5.54
Forest	4.2	4.15
Green Houses	1.7	1.68
Irrigated Complex Cultivation Practices	1.5	1.48
Continuous Urban Fabric	1.1	1.09
Industrial or Commercial Unit	0.5	0.49
Sclerophylous vegt.	0.5	0.49
Refugee Camps	0.2	0.20
Military Camps	0.05	0.05
Sparsely Vegetated Area	0.05	0.05
Total	101.1	100



Characteristics of Kharrouba Watershed

4. Soil

Soil	Terra rossa	grumusols	Brown rendzinas
Percentage	53.30%	44.40%	2.30%



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Assessment of Water Situation

1. General Definition
2. Water Demand Sectors

General Definition

- Assessment of water situation help managing water resources effectively.

- Water supply: the volume of water which can be provided to the users.

  Water demand: the volume of water requested by users to satisfy their needs.

- The purpose of this assessment is to find an alternative resource to fill gap between supply and demand.

Water Demand Sectors

1. Agricultural Water Demand

- Agriculture is an important activity in Jenin governorate in terms of food security, economic activity and water use.
- Irrigated agriculture land form 38% from the Agricultural land.

- Factors affect water demand:

1. Crop type.
2. Soil type.
3. Climatic conditions.

- We found that the water demand is 9.6 million cubic meters, and if the area planted two times per year the demand becomes 15.2 million cubic meter per year.

Water Demand Sectors

- Agricultural water demand

	Area (Dunam)	Water Demand (m^3/Dunam)	Water Demand (m^3)
Drip Irrigated Arable	8,636	420	3,627,119
Green Houses	1,725	600	1,035,136
Irrigated Complex Cultivation Practices	1,527	840	1,282,661
Non-Irrigated Complex Cultivation	18,314	200	3,662,775
Total	30,202		9,607,691

Water Demand Sectors

2. Household water demand

- It is the water related to urban, areas rural areas and to commercial centers.
- Factors affect water demand:

1. Population
2. Level of service of the water supply
3. Water quality
4. Local knowledge

- Population and water consumption per capita is used to calculate the household water demand. Water consumption per capita is usually consider as 150 L/C.day.
- We found that the water demand in our study area is 5 million cubic meter per year.

Water Demand Sectors

- Household water demand

	Population (2020)	Demand ($\frac{l}{c.d}$)	Total Water Demand (m^3/day)	Annual Water Demand (m^3/year)
Jenin	63,618	150	9,543	3,483,086
Jalbun	2,967	150	445	162,443
Daeir abu Daif	7,429	150	1,114	406,738
Um al Tut	1,259	150	189	68,930
Aba	343	150	51	18,779
Burqin	7,515	150	1,127	411,446
Kafr Qud	1,638	150	246	89,681
Kafr Dan	6,951	150	1,043	380,567
Total	91,720	-	13,758	5,021,670

4 Rainfall Analysis

1. introduction
2. Assess the rainfall distribution in the study area
3. Rainfall Analysis

Introduction

- Collecting rainfall data was a real challenge to overcome, Kharrouba watershed has no rain gauges.

- The most satisfactory solution is to find nearby gauges which might be in harmony regarding precipitation with our study area.

- We found that Taluza and Kharrouba have the same pattern of rain.

- Due to having only one gauge data, we had assumed that the rainfall is constant over the study area.

Assess the rainfall distribution in the study area

- The collected rainfall data represent the rainfall data in year 2018-2019 only.

- the assessment of the rainfall distribution requires representative and considerable amount of data which is continuous over sequential periods with no missing data.

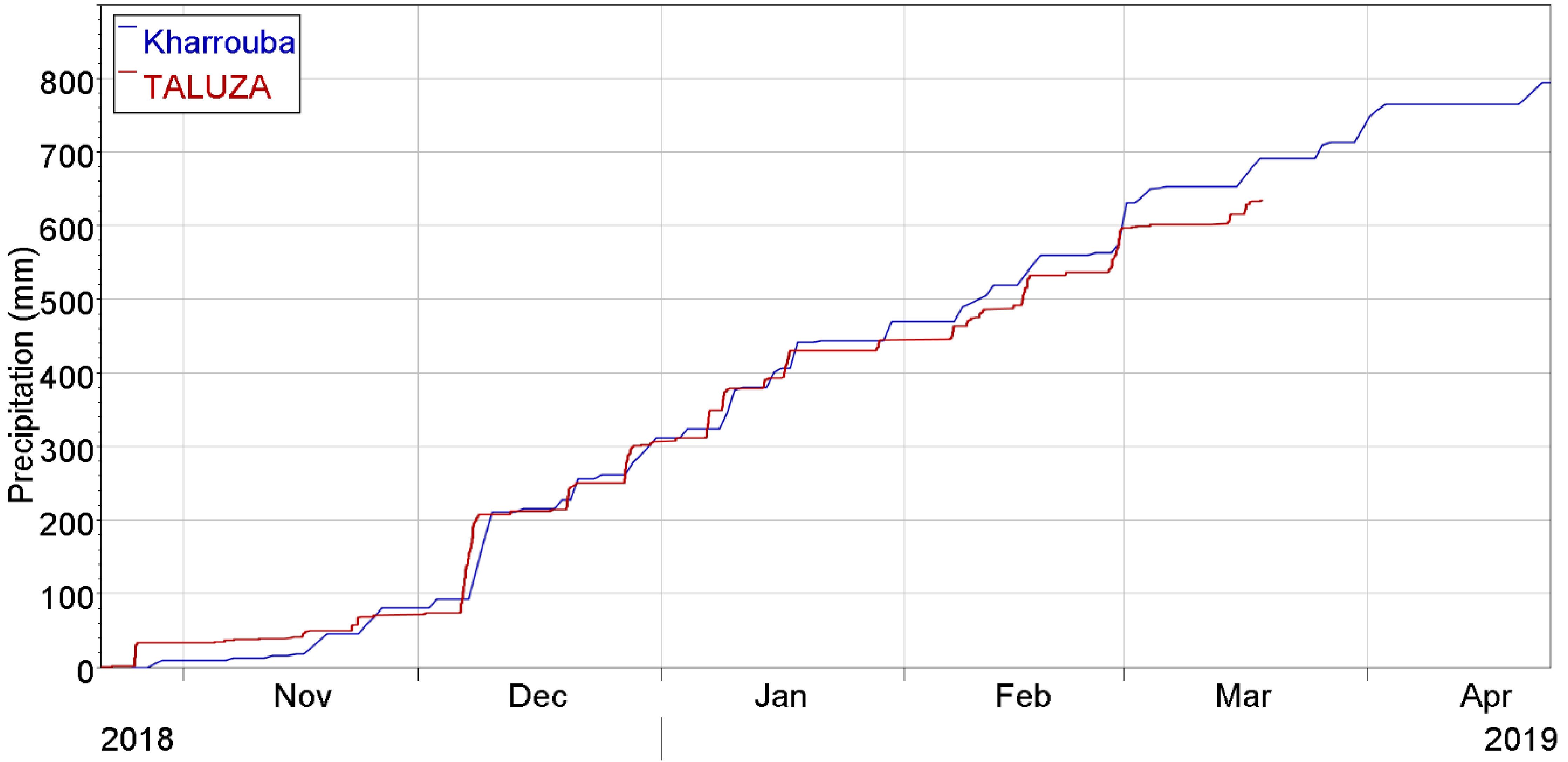
- In addition to that, several rain gauges should be existed and distributed in the study area.

- In fact, these requirements are not found in the study are, so we cannot check the rainfall data using the concepts of consistency and continuity.

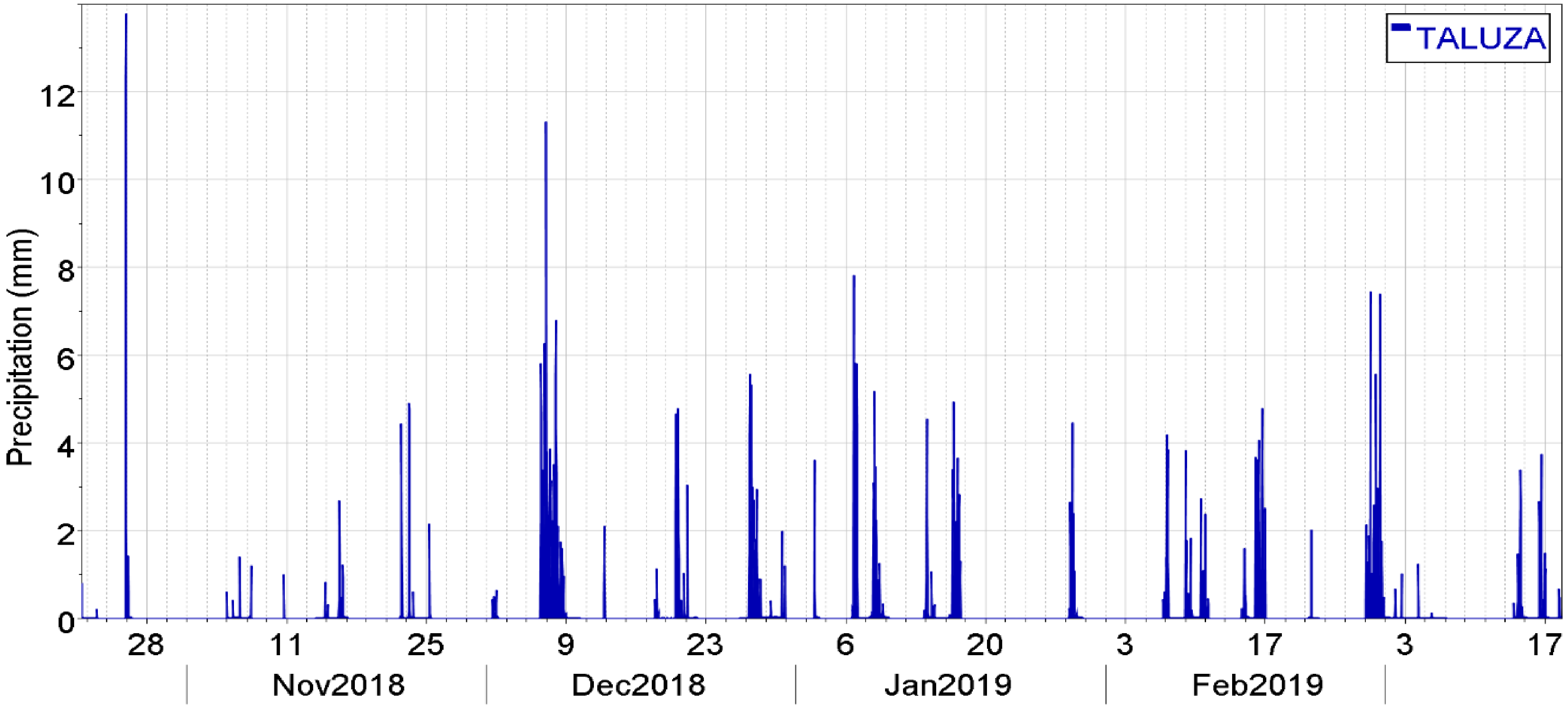
Rainfall Analysis

- The purpose of this section is to end up with continuous hourly hyetograph from daily data.
- Taluza and Kharrouba have nearly the same mass curve , as shown in the following figures.
- Having the same mass curve guide us to the fact that Taluza and Kharrouba have the same pattern of rain.
- this method is the . best way to compensate the lack of kharrouba rain gauge data.

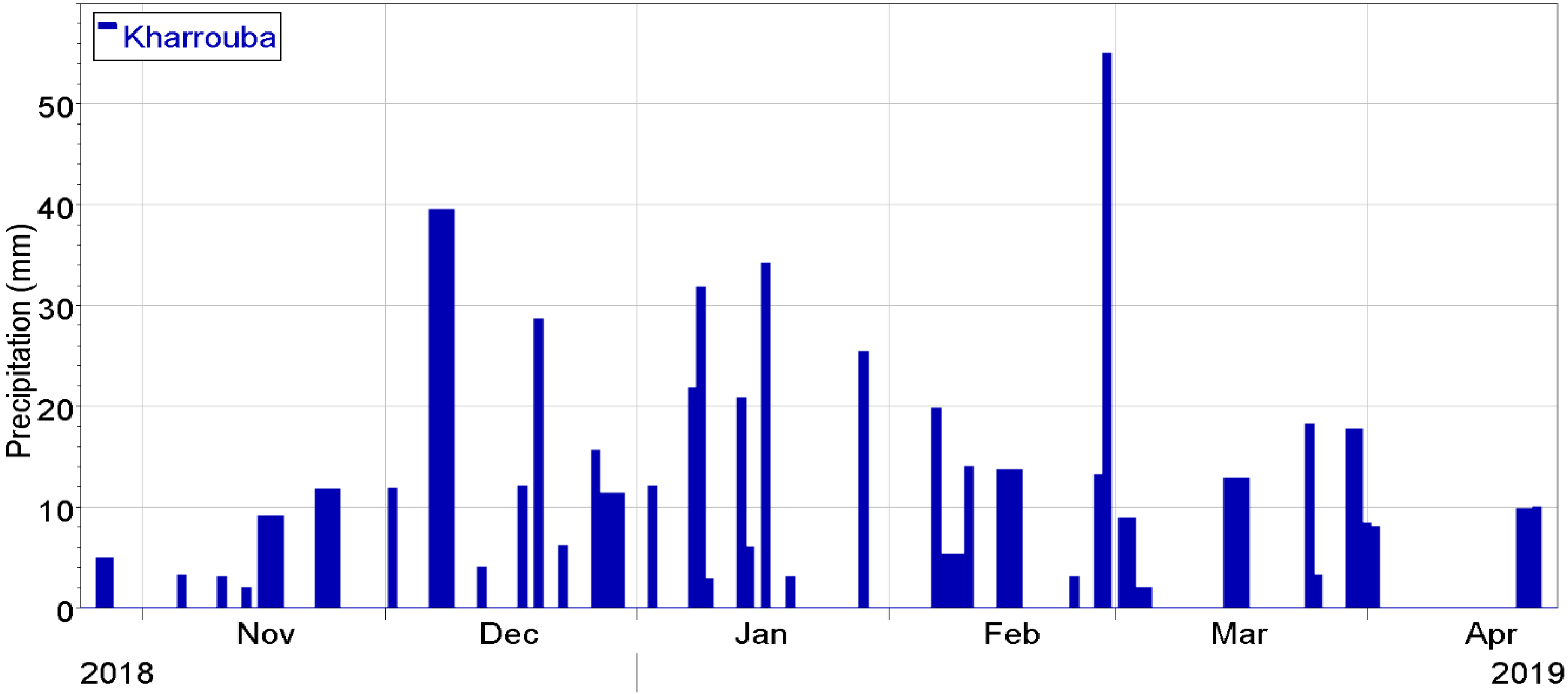
Mass Curve of Kharrouba and Taluza



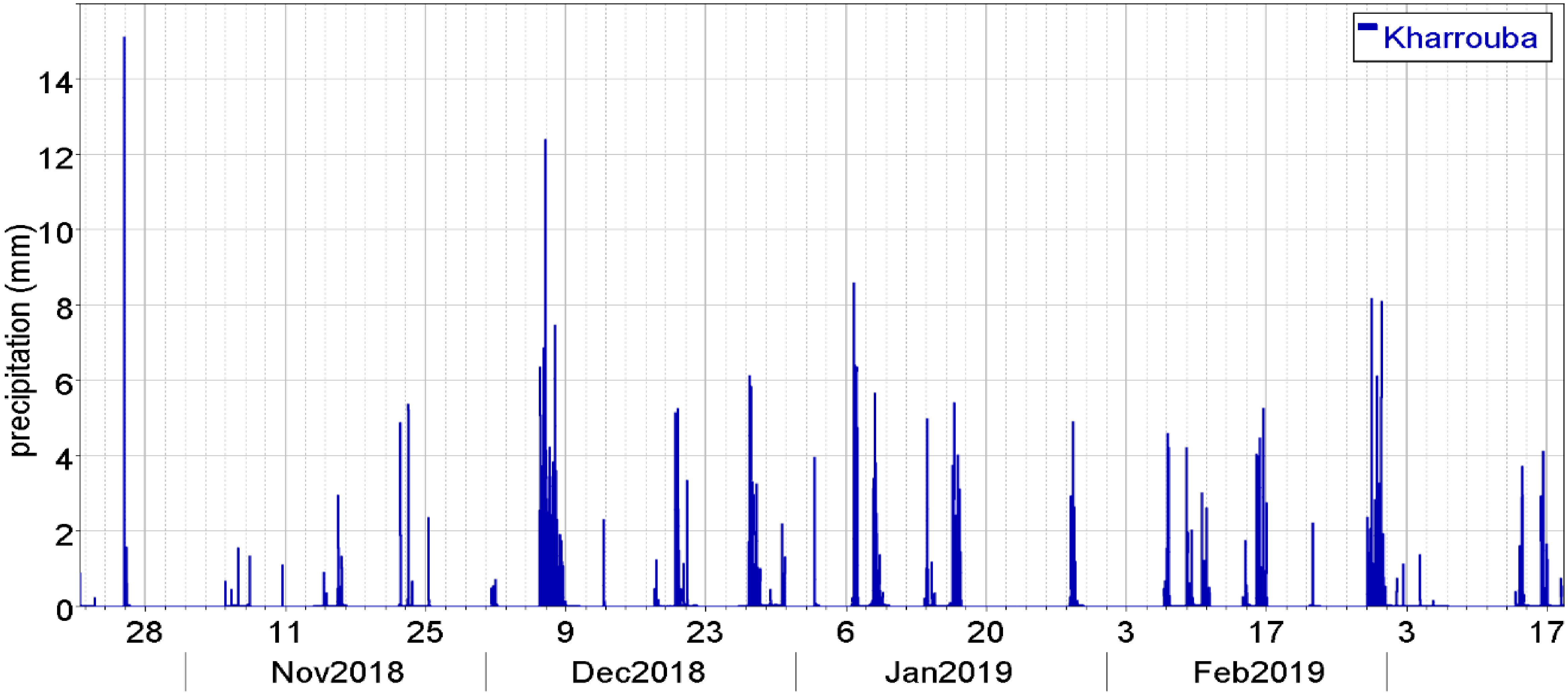
Hourly Hyetograph of Taluza



Daily Hyetograph of Kharrouba



Hourly Hyetograph of Kharrouba



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The Modeling Approach

1. Characteristics of Kharrouba Watershed
2. Development of Unit Hydrograph (UH)
3. Hydrological Losses
4. Continuous Model
5. Calibration of The Model
6. Output

Characteristics of Kharrouba Watershed

- Physical characteristics have to be represented carefully in the model as they have considerable effects on runoff water.

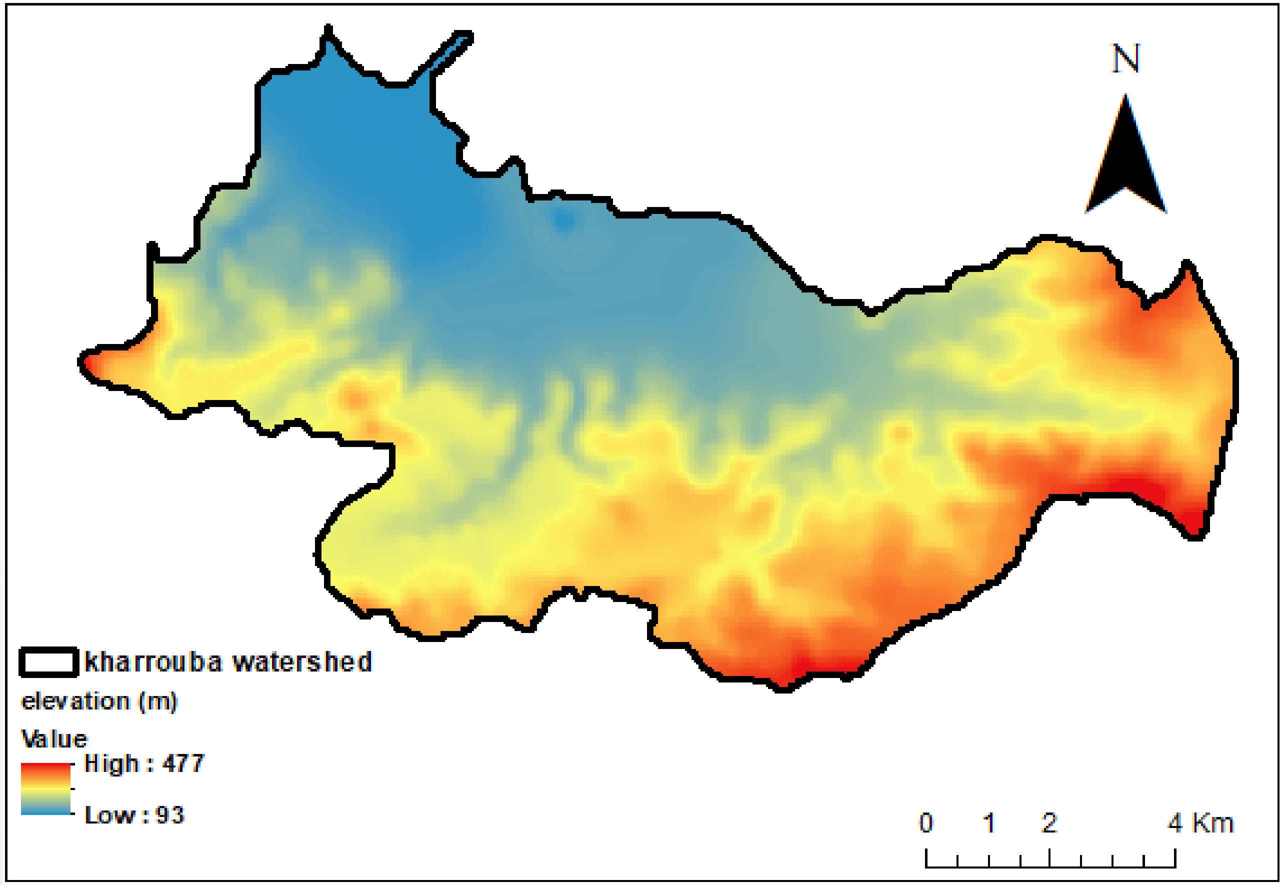
- GIS plays an important role in this step, we will use some GIS tools to analyze the Digital Elevation Model (DEM) of Kharrouba watershed in order to present the physical characteristics of the watershed.

Characteristics of Kharrouba Watershed

1. Digital Elevation Model (DEM)

- The DEM is a raster representation of a continuous surface terrain elevation in xyz coordinates.

- The first step in terrain preprocessing is to develop a hydrologically corrected DEM.

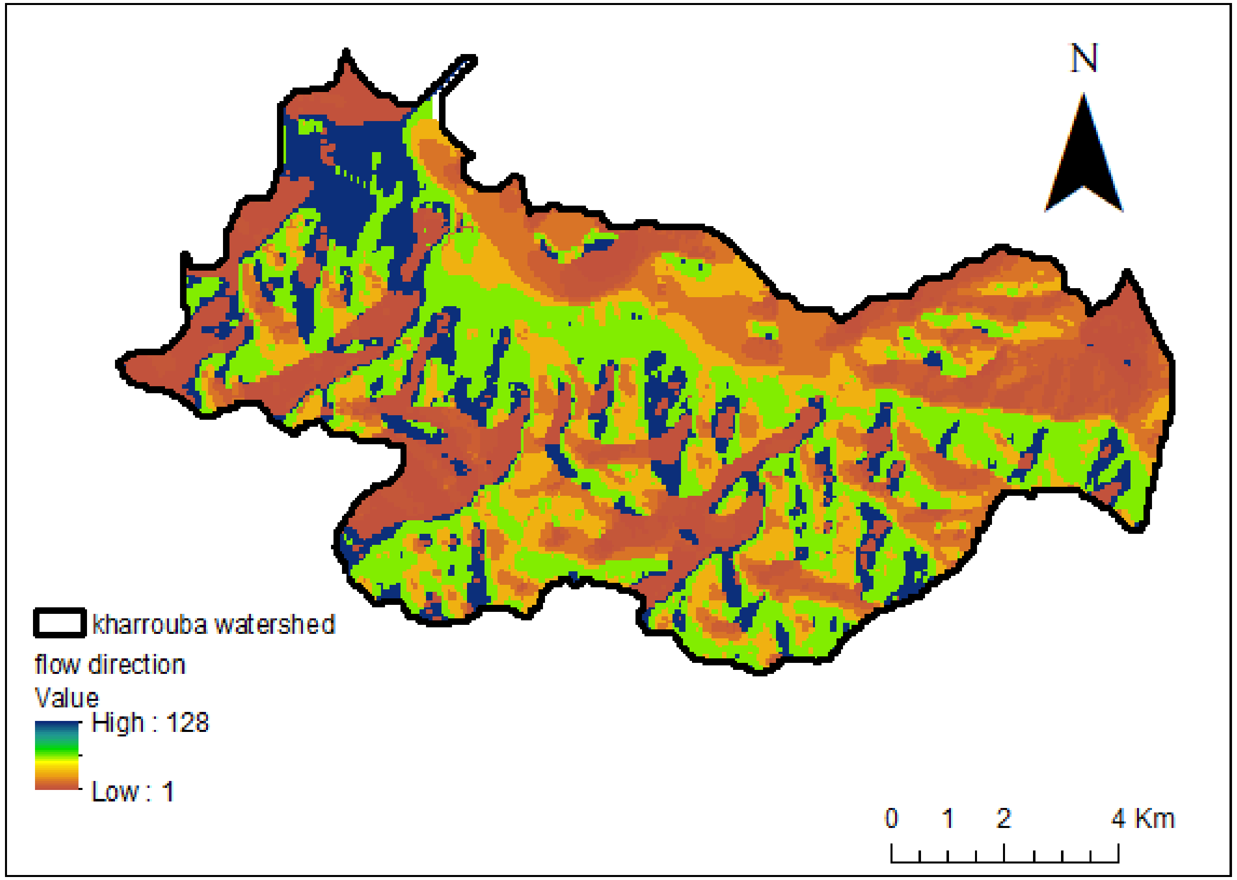


Characteristics of Kharrouba Watershed

2. Flow Direction

- When the digital elevation model was generated, the flow direction grid was derived directly depending on the D-8 drainage model which depicts the direction of drainage between the central cell and one of its eight neighbors.

- The GIS analyzes the depressionless terrain data by applying the 8-point pour model, where water flows across the landscape from cell to cell based on the direction of the greatest elevation gradient.



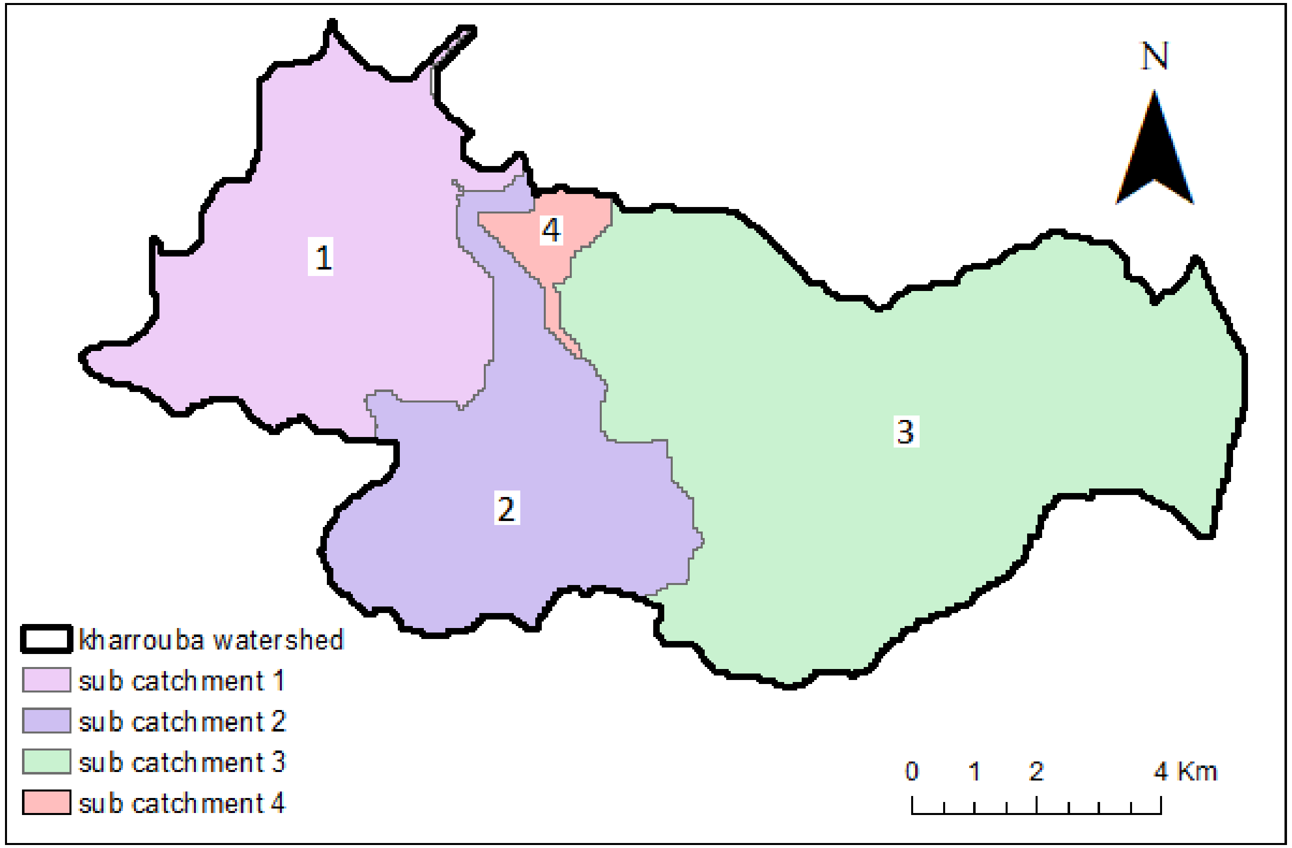
Characteristics of Kharrouba Watershed

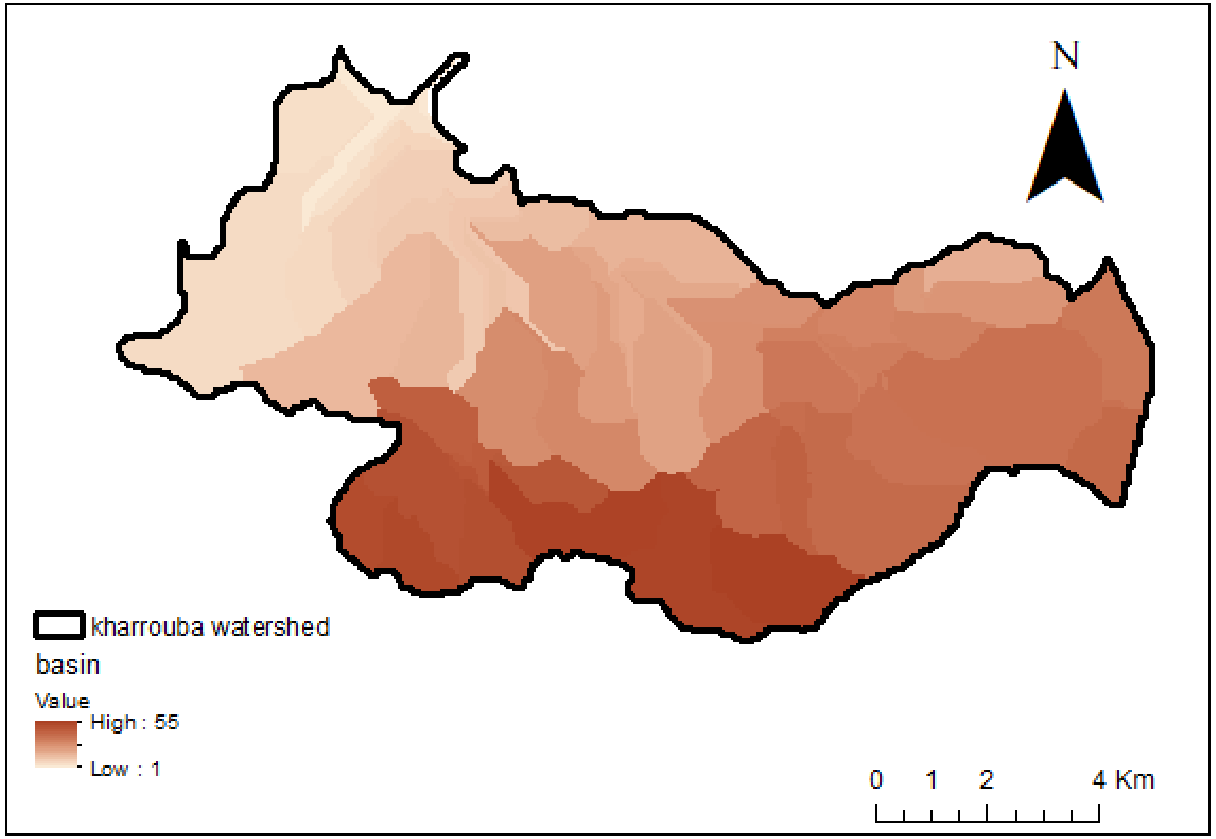
3. Watershed Delineation

- Kharrouba watershed was delineated using flow direction raster.
- Delineation of watershed is performed using the basin merge tool.
- We ended up with four sub-catchments:

	Area (Km^2)	Elevation (m)
Sub_catchment 1	26.6	448-93
Sub_catchment 2	20.6	359-99
Sub_catchment 3	52.8	477-122
Sub_catchment 4	2.2	151-97
Kharruba Watershed	102	477-93

Kharrouba Watershed Delineation and Sub-catchments



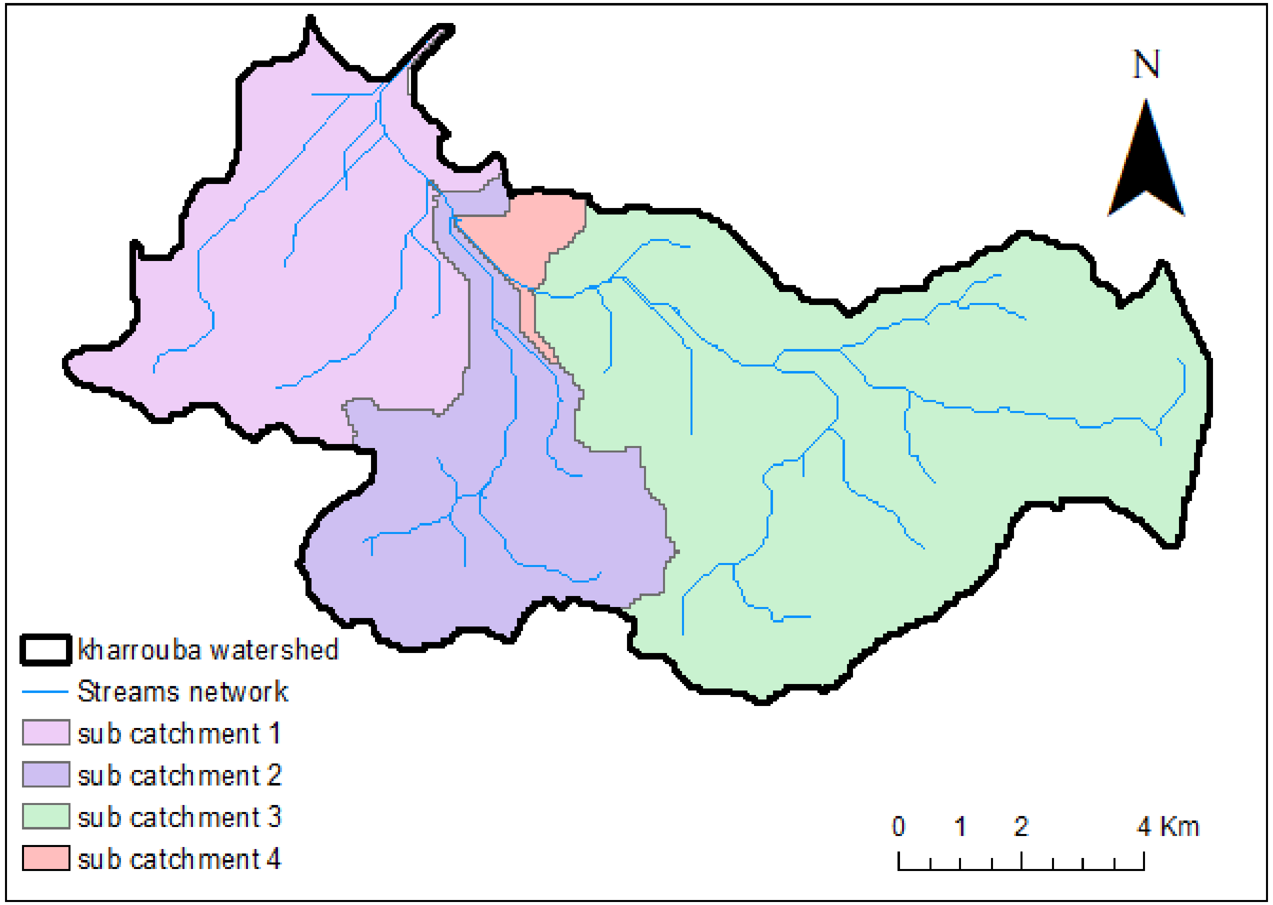


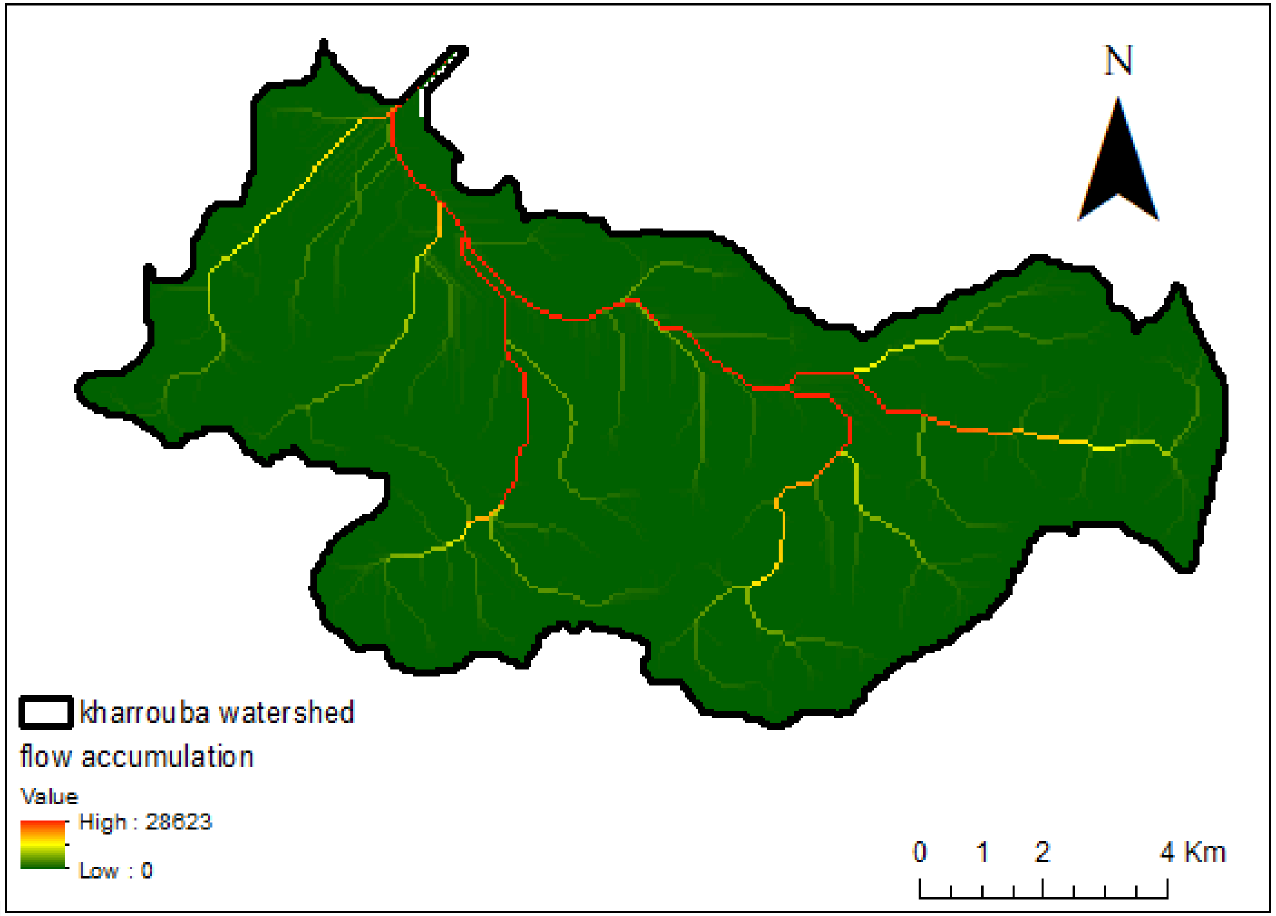
Characteristics of Kharrouba Watershed

4. Stream Networks

- The stream network of Kharrouba was defined using the output of the flow accumulation grid.
- Flow accumulation is one of the most important grids in identifying the stream network, it is presented by:
  1. The areas with high flow accumulation indicate concentrated flow and resulted with stream channel.
  2. The areas with a flow accumulation of zero are local topographic highs and may be used to identify ridges.

Flow Accumulation and Stream Network for Kharrouba Watershed





Development of Unit Hydrograph (UH)

- Unit hydrograph (UH) can either be determined using gauges' data or it can be derived using empirically-based synthetic unit hydrograph procedures.

- In Kharrouba watershed, the absence of reliable long-term data makes the construction of a unit hydrograph one of the most difficult parts we have faced. Therefore, the unit hydrograph is determined synthetically.

Development of Unit Hydrograph (UH)

The SCS Model

- To construct the SCS unit hydrograph, the following parameters should be determined for each sub-catchments:

$$T_{lag} = L^{0.8} \times \frac{[\left(\frac{25400}{CN} - 254\right) + 25.4]^{0.7}}{4238 \times So^{0.5}}$$

$$CN = \frac{CN_1 * A_1 + CN_2 * A_2 + \cdots + CN_n * A_n}{\sum_{i=1}^{n} A_i}$$

Development of Unit Hydrograph (UH)

The SCS Model

- The lag time is the main parameter needed to construct the unit hydrograph.

- Determining the lag time for each sub-catchment of Kharruba Watershed requires having precise estimation of the curve number and the slope.

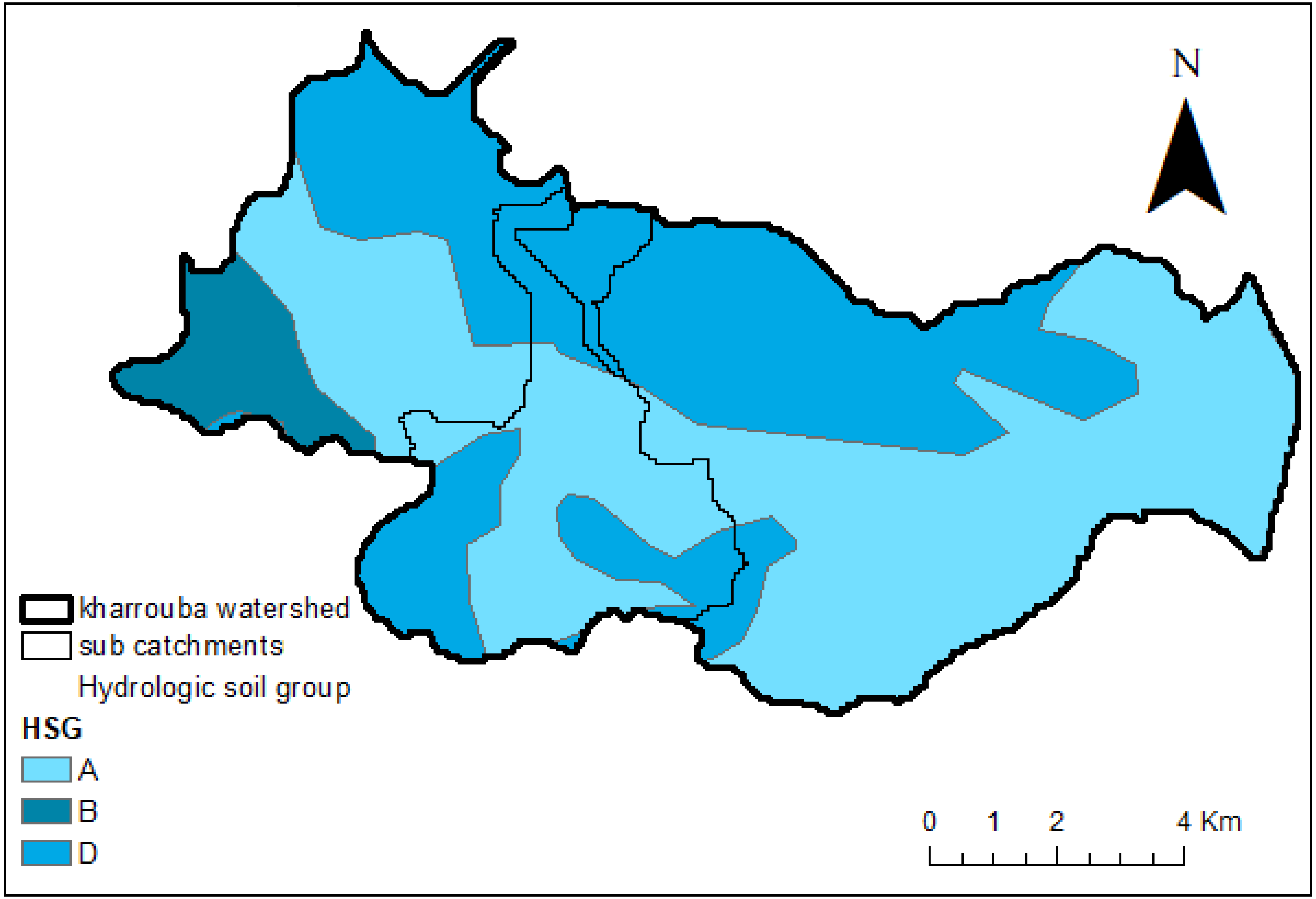
- The hydrologic soil group and land cover and land use is needed to determine the curve number.

USDA and Soil Type According to Soil Texture Classes

HSG	Soil texture
A	Sand, loamy sand, or sandy loam
B	Silt or loam
C	Sandy clay loam
D	Clay loam, silt clay loam, sandy clay, silty clay, or clay

Soil type	Soil texture
Regosols	Sandy loam
Grumusols	Clay
Terra rossas	Clay
Loessial serozems	Sandy loam
Brown rendzinas and pale rendzinas	Clay loam
Brown lithosols and loessial arid brown soils	Loam

Hydrologic Soil Group of Kharruba Watershed



The SCS Model

- Sub-catchments area HSG of Kharruba watershed

	unit	A	B	D
Sub-catchment 1	m^2	10,306,844	5,704,958	9,659,590
Sub-catchment 2	m^2	11,113,712	-	9,510,493
Sub-catchment 3	m^2	32,941,520	-	19,858,029
Sub-catchment 4	m^2	252	-	2,195,404
total	m^2	54362328.2	5704958	41223515.8

Development of Unit Hydrograph (UH)

The SCS Model

- Soil group D has the highest runoff potential, and covers 40.7% of Kharrouba watershed area, while soil group A has the lowest runoff potential and covers 53.6% of the area.

- The curve number was founded by weighting each curve number according to its area.

Development of Unit Hydrograph (UH)

The SCS Model

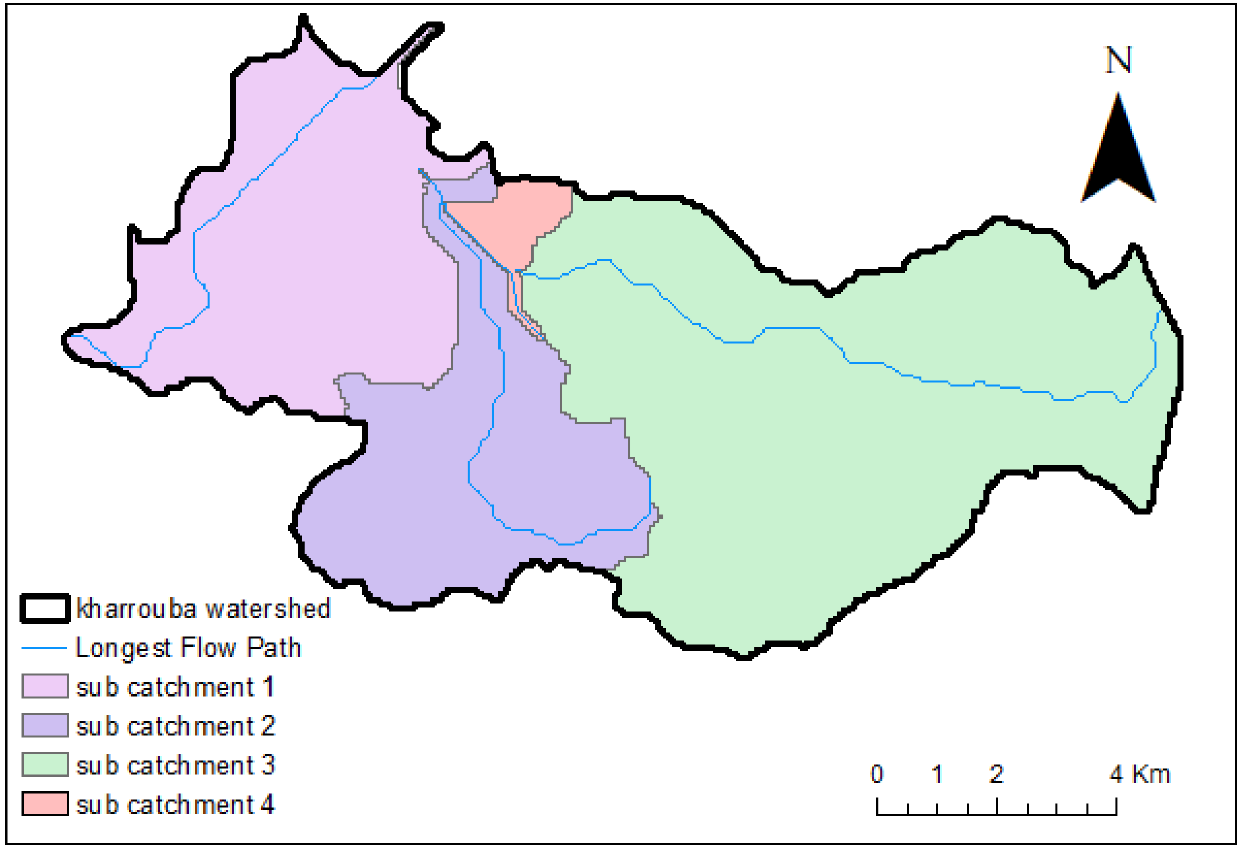
- Curve number for each sub-catchment

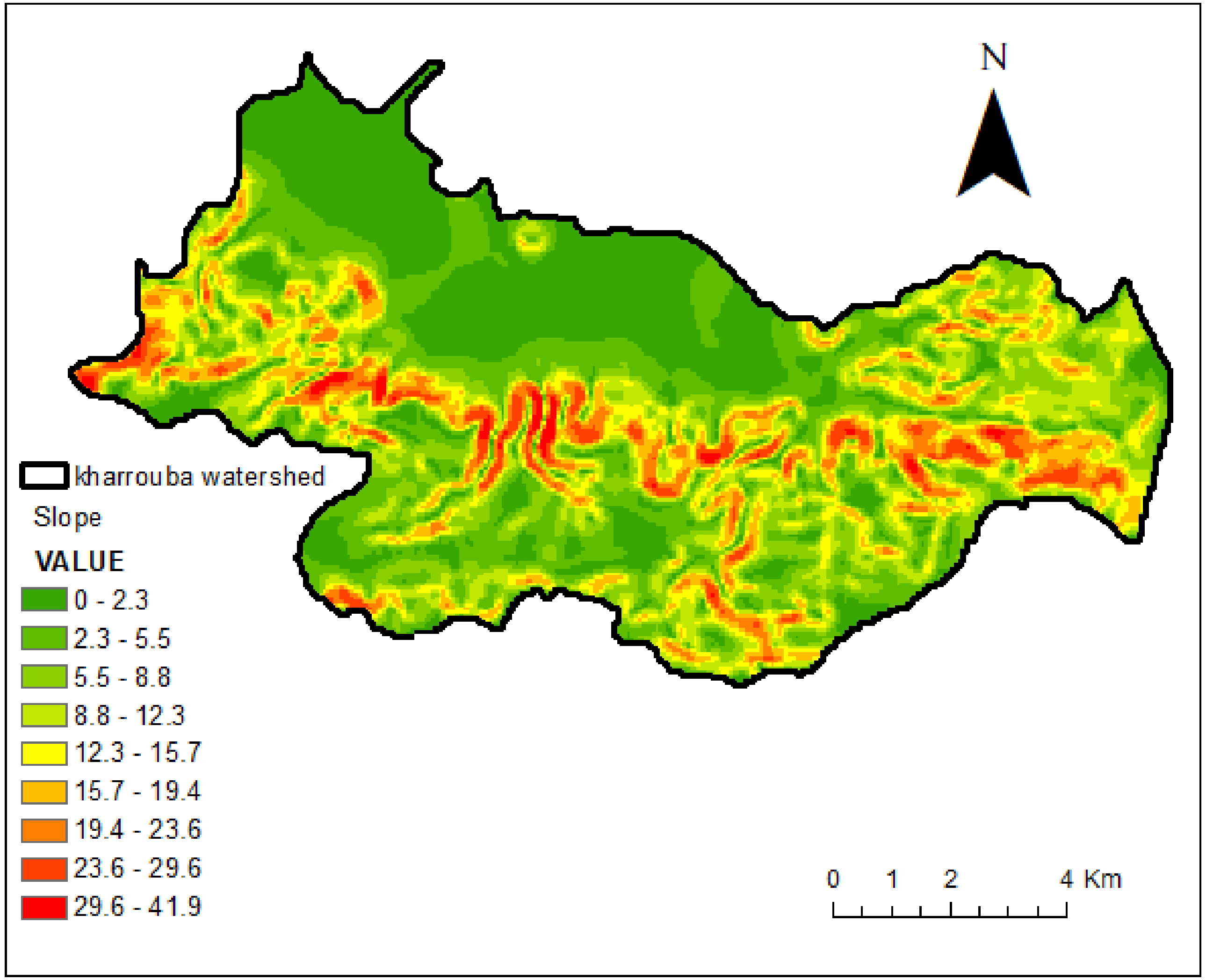
	CN2
Sub-catchment 1	80
Sub-catchment 2	78
Sub-catchment 3	78
Sub-catchment 4	87

- The longest path flow for Kharrouba watershed and average slope was estimated using the DEM.

	Longest flow path (m)	Average slope (%)
Sub-catchment 1	10,095	7.6
Sub-catchment 2	10,499	7.8
Sub-catchment 3	14,884	8.9
Sub-catchment 4	2,969	2.9
Kharrouba Watershed	-	8.2

Longest Flow Path and Average Land Slope for Kharrouba Sub-catchments





The SCS Model

- SCS Model Parameters

	CN2	lag time (hr.)
Sub-catchment 1	80	3.2
Sub-catchment 2	78	3.4
Sub-catchment 3	78	4.2
Sub-catchment 4	87	1.5

Hydrological Losses

- HEC-HMS gives variety of choices for calculating the hydrological losses, depending on what data you have, availability of resources, and other considerations. In our project, we decided to select SCS curve number method.

SCS Curve Number Method

- SCS-CN method estimates excess rainfall as function of cumulative rainfall, soil cover, land use, and antecedent moisture. This method requires only one input parameter which is the curve number.

	CN2
Sub-catchment 1	80
Sub-catchment 2	78
Sub-catchment 3	78
Sub-catchment 4	87

Routing

- The Kinematic wave routing method is considered one of the popular routing methods, It is considered one of the most efficient methods especially when there is no gauge data which is costs a lot of money and effort.

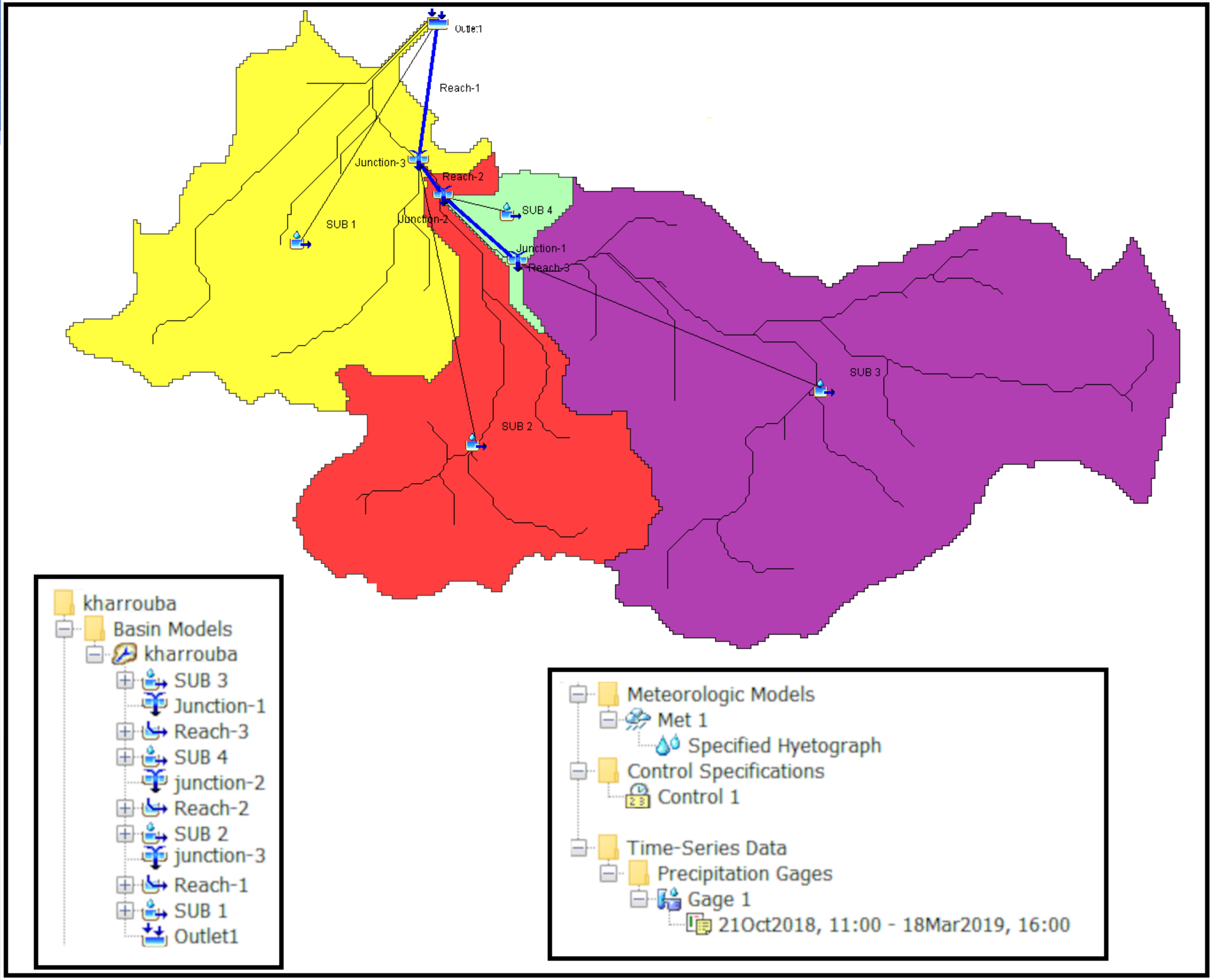
	length (m)	slope	n	Width (m)
reach 1	4000	0.0026	0.035	3
reach 2	828	0.0006	0.035	3
reach 3	1748	0.0136	0.035	10

Continuous Model

- The development of hydrological models provides adequate tools to predict runoff volume and peak discharge. Rainfall-runoff model is a simplified system that is used to represent real life systems.

- the simulation time period ranges from 21 October 2018 to 18 Mars 2019, and an hourly time step was used.

HEC-HMS model



Calibration of The Model

- In order to obtain realistic model, the best reflect an understanding of the physical system and its simulation outputs are closest to the observed data.

- Kharrouba Watershed is still ungauged watershed.

- For continues model, the calibration should be on water volume, but because the watershed is still ungauged, we use the peak discharge.

- The water depth at the outlet of sub-basin 3 is estimated to be .4m, and using manning equation, the peak discharge equal 8.8 m^3/s.

Continuous Model Output Before Calibration

	Peak Discharge (m^3/s)	precipitation volume ($1000m^3$)	Loss Volume ($1000m^3$)	Excess Volume ($1000m^3$)
sub catchment 1	31	17,762	1,800	15,962
sub catchment 2	25	14,261	1,615	12,646
sub catchment 3	58	36,510	4,136	32,374
sub catchment 4	4	1,521	95	1,426
total	-	70,054	7,645	62,408

Calibrated continuous Model output

	CN
Sub-catchment 1	12
Sub-catchment 2	12
Sub-catchment 3	12
Sub-catchment 4	13

	Peak Discharge (m^3/s)	precipitation volume (1000 m^3)	Loss Volume (1000 m^3)	Excess Volume (1000m^3)
sub catchment 1	6.1	17,762	16,589	1,173
sub catchment 2	4.4	14,261	13,400	861
sub catchment 3	12.7	36,510	34,306	2,204
sub catchment 4	0.8	1,521	1,390	132
total	-	70,054	65,684	4,369

Calibrated continuous Model output

- the total precipitation volume is nearly 70 million cubic meters.
- the direct runoff volume is nearly 4.4 million cubic meters.
- the runoff volume to precipitation volume ratio is 6.2%.
- direct runoff volume to total water demand volume is 21.7%.
- the direct runoff volume to agricultural water demand volume is 29%.

6 Conclusion

Conclusion

- AL-Mouqata' watershed has four sub-catchments which are Al-Jamous with area $52km^2$, Wadi Abd-Allah with area 15 km^2, Kharrouba with area 102 km^2, and the last one doesn't have a specific name with area 39 km^2.

- The total amount of agricultural water demand in Kharrouba Watershed is 15.2 million cubic meters per year. In fact, 38% of agricultural areas are irrigated agriculture. In the other hand, the total amount of household water demand is 5 million cubic meter per year.

- the direct runoff volume is nearly 4.4 million cubic meters.

- Runoff volume to precipitation volume ratio is 6.2%.

7 recommendations

recommendations

- It is essential to clean up the streams beds to enable the water to flow properly and not to dirt the water. Two to three weeks before an expected storm will be satisfied. Refer to Appendices.
- Meteorological stations should be installed in Kharrouba watershed in order to have rainfall data that could be used for hydrological modeling. It is preferable to have tipping bucket rain gauges to ensure having hourly rainfall data.
- Rainwater harvesting pounds can be used at the outlet to collect maximum amount of rainwater.
- The calibration of the HEC-HMS model should include evapotranspiration and infiltration, and using runoff gauges, so as, a more precise model will be developed.

THANK YOU