Deanship of Graduate Studies
Al-Quds University

Selection Criteria For Water Harvesting Technique in Sanour Plain –Jenin

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MSc. Thesis

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Selection criteria for water harvesting technique in Sanour Plain –Jenin

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Thesis Approval

Selection criteria for water harvesting technique in Sanour Plain –Jenin

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Dedication

بعد عام من العمل لإنجاز هذا البحث أتقدم للإنسان الذي علمني أن عز الإنسان وقيمته في الأشخاص الذين يحبهم ...

لمن علمني أن الصدق مفتاح الحياة والنجاح ....

معكم أحبتي أثق بأن أعظم ما انجزته بعمري هو أنكم بعمري...

أشكركم لأنكم أضفتم لشخصي الكثير ولأنكم موجودون دائماً حتى في أصعب حالاتي ...

أبي وأمي ملجأ أماني، زوجتي الحبيبة بنتي الغالية وأخوتي سندي وعزوتي ، واصدقائي الغالين

شكرًا للوقت والصدفة التى جمعتنا ...

لكم جميعاً اقدم هذا العمل ...

Declaration

I certify that this thesis submitted for the degree of Master is the result of my own research, except where otherwise acknowledged and that this thesis (or any part of the same) has not been submitted for a higher degree to any other University or institution.

Name: Raed Yosef Mohamad Abualrob

Signed: …………………………..…

Date: 17/4/2019

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Finally, I thank all who supported me towards this academic level, especially my lovely wife.

Abstract:

The study handle the flooding of Sanour Basin (16 km2) in the northern part of the West Bank. Due to flooding water during winter season about 60% will cover with water causing restrictions of Land use. The objective of this research is to select optimum collection sites for surface water harvesting in addition to artificial injection boreholes. The methodology used in this research is the combination of land cover-land use, soil curve number (SCN), and GIS technique. Depending on the hydrological data during the period 1953 and 2019, the volume of flooding water range between 0.0 in dry year, and 15 MCM/a in extern wert year 1991/92, with an average of about 2.5 MCM/a. According to this study, 40 collection ponds sites are found to store about 3MCM, and 10 proposed injection boreholes with total capacity of about 0.33 MCM could be installed in the basin and feed the groundwater regim. Due to this fact an annual total volume of 3.33 MCM could be stored and used in improvement of the agricultural sector, and avoid flooding of the basin.

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List of abbreviation

MoA: Ministry of Agriculture

GIS: Geographic Information System

RS: Remote Sensing

USDA: United State Department of Agriculture

SCS: Soil Conservation Services

HSG: Hydrological Soil Group

MCM: Million Cubic Meter

DEM: Digital Elevation Model

CN: Curve Number

NRCS: Natural Resources Conservation Service

USDA: United States Department of Agriculture

Chapter One

Introduction

1.1 General Introduction

Historical Palestine is one of the Mediterranean countries, where it is located on the eastern coast of the Mediterranean Sea with latitude (31.9522°N) and longitude (35.2332°E) with an overall area of 27,000 Km^2. However it is in the semi – arid region, where the general climate is dry hot in the summer, rainy warm in winter. The average rainfall is ranging between 100 mm in the south up to 700 mm in the north coastal area. Out of this area West Bank and Gaza strip (The current Palestinian zones) is forming 21% (6350 Km^2).

In this area live more than 4 million Palestinian, more than half is living in West Bank which is forming around 90% of the area (5655 Km^2). These territories area classified into five climatic zones (coastal, semi coastal, central plains, eastern slopes, and Jordan valley). The West Bank is divided into eleven administrating governorates; one of them is Jenin with 10% of the area, where it is located in the northern part of West Bank.

Sanour Plain (The case study) is located in the southeastern part of Jenin governorate. It is a close flat area surrounded with mountains and hills from all sides, with no outlet for surface water that flow to the plain from the surrounding hills after any rain event that cause runoff. The area of the plains is estimated to be around 16 km^2, where the catchment area of the plain is about 58 km^2. The slope inside the flat area is gentile where the elevation is ranging between 350-370 a.s.l. This is causing the sedimentation of the fine particles in the flat plains. With time the soil depth increased and it is described as thick, heavy soil dominated by clay. The groundwater Depth is between 170-270 m depth. Many boreholes taping groundwater annually are available in the catchment. Among these (MOA-SP, 2015), among these boreholes only one is allocated for drinking, the raining are used for irrigation.

The plains area is surrounded by seven villages with a population about (28,200) people (according to the census of the Central Bureau of Statistics, 2014).

Table1: The most important population characteristics in Sanour plain area in 2012 according to the data of the seven group management.

Site	Area	Population	Number of male	Number of female	Number of family	Average family size	Number of building
Maithalon	12495	7960	4059	3901	1400	5.7	1460
Serees	12593	5500	2821	2679	1100	5	1127
Sanour	11804	4700	2400	2300	950	4.9	1005
Aljdedi	6360	5500	2805	2695	1060	5.2	1050
Seer	12499	1200	606	594	181	7	200
Mislyi	9048	2616	1340	1276	512	5	498
Aljarba	3250	62	32	30	18	3.5	19
Total	**68049**	**27538**	**14063**	**13475**	**5221**	**5.2**	**5359**

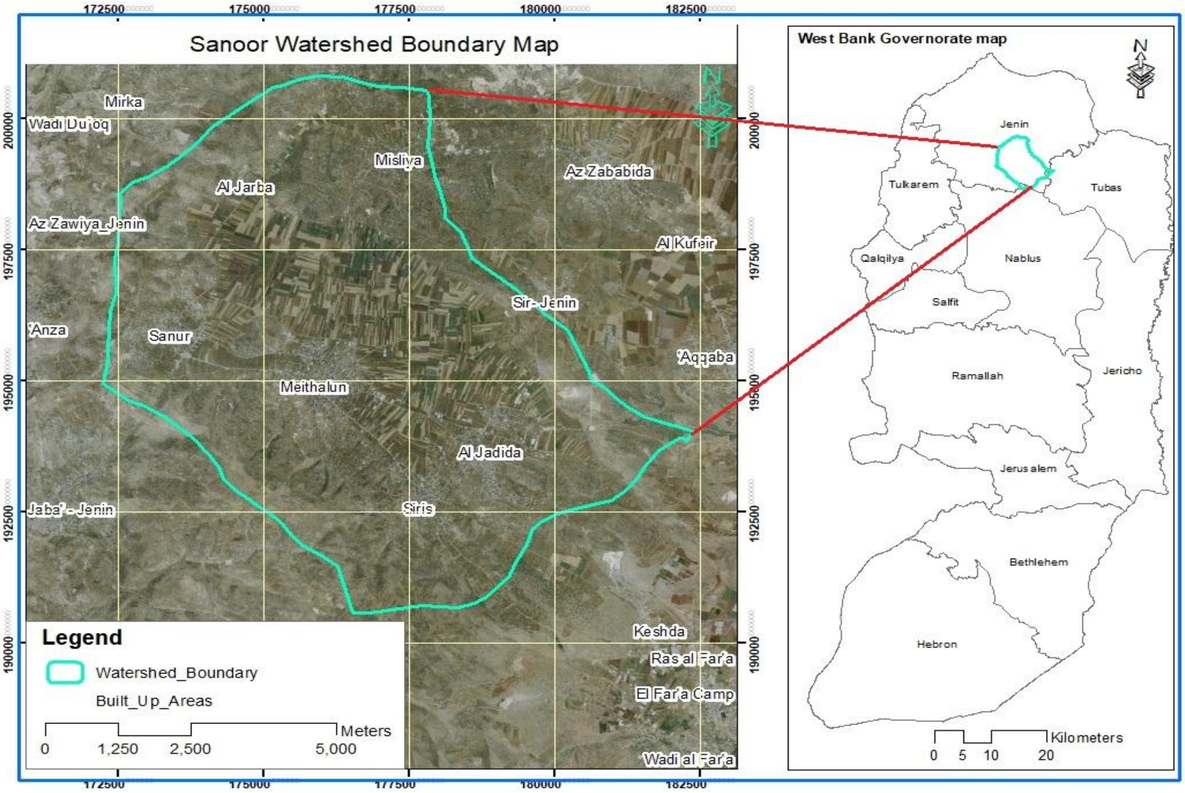


Figure 1: location of the Sanour plain

The number of agricultural holdings in these villages according to the statistics of the Palestinian Agricultural Census for 2010 is about (4000) agricultural holdings, Agriculture is the main income source for about 65% of the population, while for the rest consider as minor source. The total area of the seven villages is about 68 thousand dunums, and the rest locate outside Sanour plain catchment area about 54604 dunums (Figure 1) . (Department of Statistics, ministry of agriculture)

1.2 Water Resources

Groundwater is the main source of water in the area, in addition to water collected during the rainy season by earth bonds constructed recently (2015). There are 51 groundwater wells drilled in Sanour plain. Groundwater is taping from Jenin sub aquifer system where the basin is located within the boundaries of the north-eastern groundwater basin (Nablus-Jenin basin).

The agricultural wells tapped water from different depths with abstraction rate range between 50and 60m3/h aquifer system noticed, the fluctuation of the groundwater level in the agricultural wells in was noticed and show a decline in the level of groundwater of about 70 m during the period between 1969 and 2015. This significant decline in the level of groundwater was due to the over abstraction and the impact of drought period.(MOA-SP ,2015)

The annual quantity of water used for agriculture is estimated at about 2.38 MCM, and the amount of domestic water is about 0.715 MCM annually and coming from Sanour well and Maithalon well. The annual water extracted from Maithalon well is expected to reach 0.625 MCM. The amount of water collected from the rainwater was estimated in the collection wells at about 0.11 million cubic meters.(MOA-SP ,2015)

Table (2) : water sources in Sanour plain basin.

Sources	**Quantity (mmc)**
Private agricultural well	**2.270**
Maithalon deep well	**0.625**
Sanour well	**0.090**
Rain water harvesting wells	**0.110**
Total	**3.100**

As a Mediterranean Region, the area effected by the climate change, especially in the rain-fall pattern (distribution, intensity, number of rainy event during the rainy season…), added to the change in temperature (cold and hot fronts). The fluctuation in the rain fall last two decades was the most important phenomena that considered by the decision makers, who work in the planning for the infrastructure regarding with the civil and agricultural sectors.(MOA-SP,2015)

One of the climate change aspects in the area is flash floods caused by intense rain events which leads to flood the soil as in 2012/2013(annual flood), where 110 mm of rain had been registered in 24 hours 2017/2018 (temporal flood) 60 mm in 24 hours, or prolonged dry periods as in 2016/2017 where more than 80 days of no rainfall during January, February, and March. The events of intense rainfall had been increased by climate change as the rain records show. This phenomena lead to reduce the soil infiltration rate and increase the surface run-off rate from the slops around the plain, were huge amount of water flow in to the plain during the intense rain events. Clay soils are characterized with low infiltration rate in Sanour case where there are no outlets for the water in the plain, it is expected that the plain soils will be flooded and the water will be stable in the plain with water depth between 0-2 meter for long time. On the other hand huge area of the clear soil becomes saturated. Wherever, farmers are not able to cultivate more than 20% of the plain area during winter and spring seasons.

1.3.Problem Statement:

The area is facing two aspects problem in the same time due to water regime, where in the wet year the flood during winter is causing sever loses to the agricultural community, and water shortage in the summer also intensify the problem in the area.

The fluctuating of floods and drying in the area has formulated different impacts:

1-Restriction of agricultural practices, where in wet period the farmers have no access to the agricultural area, and the ability of serving their lands is apsent.

2-Degradation in soil characteristics. This is caused by fine particles sedimentation that caused reducing infiltration rate, and reducing porosity, and nutrient removal from root zone by water.

3-decrease in cultivated area during the wet years as a direct impact of flood

4-Reduce the infiltration rate. And closed soil porosity

Figure 2: Sanour plain flooding during the hydrological year 2019.

1.4: Research objectives.

The objectives of this study are represented as following:

The overall objective of this study is participate in minimizing the flood in Sanour plain using the suitable selection criteria's for water harvesting technique in the suitable site..

1.5 Specific objective:

1- To suggest the practical harvesting technique that mostly use in agriculture and it should be suitable for the plain referring to the available and collective information, taking in to consideration the results of the implemented project.

2- To develop a watershed analysis and decision support system for the target area that will evaluate the available surface water resources (runoff) in the watershed. This analysis and support system takes the form of a computer model developed in a Geographic Information Systems (GIS) framework, specifically the Arc G.I.S and Arc View and Arc Sence platforms developed by ESRI.

3- To Estimating the potential runoff volume over the watershed and over each sub basin using the SCS Soil Curve Number Model., and identifying a suitable location for water harvest and storage constructions through identifying the pour point or outlet locations.

4- To evaluate the available constructed collection ponds, the micro scale watersheds where ponds were constructed and the artificial recharge wells.

1.5.1 Research Thesis Contents

The tentative table of contents is chaptered, as follows:

Abstract (Arabic & English)

Chapter 1: Introduction

Chapter 2: Literature Review

Chapter 3: Description of the Case Study

Chapter 4: Materials and methods

Chapter 5: Result

Chapter 6: Conclusion & Recommendations

References

Appendix (es)

Chapter Two

Literature Review

The flood problem in Sanour area is not new, but due to the presence of occupation the development has been restricted, however the available studies on this phenomena in Sanour is limited and not discussing water harvesting deeply as a solution to the problem.

Previous studies that are discussing the selection criteria of water harvesting techniques are available, some of these studied and there result are illustrated as follow :

***MOA-SP, 2015;** Identified the drowning area in the Sanour plain using GIS tools. This project constructed 20 agricultural ponds at the rainwater harvesting points in the flooded area, where it chose the lowest areas.

***AAOD,2005;** Study the area of the Sanour plain geologically and hydrologically and identified the drawning area in the Sanour plain and proposed the construction of two earthworks dams in the Siris area and the second in the Aljdeda.

*** Al-Adamat, R., Diabat, A., & Shatnawi, G. (2010);** Study of the establishment of water harvesting systems in the north of Jordan by using geographic information systems) GIS. The study covers selecting the appropriate place for spreading water collection ponds

*** Kumar,et al 2016**; Determinant Rainwater harvesting and its use have a crucial role in enhancing the production potential within dryland systems. The study measures the performance of small rainwater harvesting structures (farm-ponds) in 5 major rained states of India during the period 2009–2011 which use data from multiple sources and stakeholders. Rainwater which is harvested using structures of various kinds and sizes was utilized for either supplementary irrigation or recharging open wells. In many cases, the farm level rainwater harvesting structures were highly effective for rain-fed farming and had a multiplier effect on farm income.

* **Mahmoud, S. H., & Alazba, A. A. 2015;** study the step one in any rainwater harvesting system that incorporates methods to increase the water quantity stored in the soil composition by trapping or holding the rain anywhere it falls. This could initial small movements of rainwater as surface runoff to concentrate the water in which it is needed most. He presents a geographic information system (GIS) methodology based on a decision support system (DSS) that uses filed survey, remote-sensing data, and GIS to determine potential in situ rainwater harvesting areas.

* **Adham. A,et al 2016;** This study aimed to develop a simple but generally applicable water-harvesting model and test it at sub-catchment level to evaluate and optimize the performance of rainwater harvesting under different design and management scenarios. This model was applied to rainfall data in 25 sub-catchments of the watershed of Wadi Oum Zessar (south-eastern Tunisia) for the period 1980-2004. The performance and analysis of rainwater harvesting in three types of years(dry, and wet) are presented and discussed. This study focuses on the advantages of simulating long-term water balances at the sub-catchment level for improving our understanding of hydrological processes in the rainwater harvesting system and offers several solutions for optimizing rainwater harvesting performance in various possibilities. Changing the spillway heights together with the flow directions had a significant impact on the performance of rainwater harvesting by making 92% of all sub-catchments supply sufficient water for crop requirements, compared to 44% of the sub-catchments in the case of no changes.

* **Ammar, A., Riksen, M., Ouessar, M., & Ritsema, C. (2016) ;**The main objective of this study was to find a general way to select suitable rainwater harvesting sites in arid and semi-arid regions(ASARs) by assembling a list of the main methods and criteria upgraded during the last three decades .They classified and compared four main methodologies of site selection from 48 studies published in reports of international organizations , scientific journals, or sources of information obtained from practitioners. Then they identified three main sets of criteria for selecting rainwater harvesting locations and the main characteristics of the most common rainwater harvesting techniques used in ASARs. The methods have varied, ranging

from those based only on biophysical criteria to more integrated approaches including socio-economic criteria, particularly after 2000. The most important criteria for the selection of suitable sites for RWH were cliffs , soil type, distance to settlements/streams , land use/cover, rainfall, and cost. The success rate of rainwater harvesting projects tended to increase when these criteria were considered, but an objective evaluation of these selection methods is still lacking. Most studies now select rainwater harvesting sites using geographic information systems in combination with hydrological models and multi-criteria analysis.

*** Jha, M. K., Chowdary, V. M., Kulkarni, Y., & Mal, B. C. (2014) ;** This study addresses challenge by providing a fairly robust and effective methodology for assessing the potential for rainwater harvesting and identifying sites/zones for different rainwater harvesting structures using geospatial and multi criteria decision analysis (MCDA) techniques. The proposed methodology is demonstrated using a case study. In the study, they used the remote sensing data and conventional field data to prepare desired thematic layers using ArcGIS© software. They also used distributed Curve Number method to calculate event-based runoffs, based on which annual runoff potential and runoff coefficient maps that were generated in the GIS (geographic information system) environment. Drainage density , thematic layers such as slope, and runoff coefficient and their features were assigned appropriate weights and then they were integrated in a GIS to produce a rainwater harvesting potential map of the study area. Areas suitable for different rainwater harvesting structures were also identified, together with suitable sites for building recharge structures (check dams and percolation tanks along the streams). It has been proven that the study area can be classified into three rainwater harvesting potential zones. Of the 83 sites identified for the recharge structures, 32 recharge sites are especially suited to the inhabitants because of their proximity. This study concludes that the integrated geospatial and MCDA techniques provide a useful and powerful tool for the planning of rainwater harvesting at a basin or sub-basin scale.

*** Krois, J. (2016);**This study presents a method to identify and rank potential sites for soil and water conservation techniques. The method takes into account environmental site assessment criteria and a decision-making method known as the Analytic Hierarchy Process. Spatial data is processed by applying a geographic information system and potential sites are ranked by a multi-criteria evaluation based on meteorological, hydrologic, topographic, agronomic and pedologic criteria. The method is being introduced to locate potential sites for terraces and bund systems in the Ronquillo watershed, located in the northern Andes of Peru. The analysis suggests that 44% of the Ronquillo River catchment is highly suited for the implementation of terraces, and 24% of the catchment area is highly suited for the implementation of bund systems. The preliminary identification of possible sites for soil and water conservation techniques may be a useful tool to carry out resource conservation programs.

*** Napoli, M., Cecchi, S., Orlandini, S., &Zanchi, C. A. (2014) ;** The aim of this study was to find the selection criteria for water harvesting technique to locate possible sites for rainwater harvesting through farm ponds . The methodology, that incorporates GIS with a continuous runoff accounting procedure for SCS – Curve Number model, has been upgraded and evaluated.

the storage capacity of the soil is not enough to meet the needs of agricultural, resulting in a shortage of water from May to September nearly every year. Runoff harvesting structures like farm ponds can be utilized to increase water supplies in agricultural areas. The suitability of the site for a farm pond calls for a careful evaluation of spatially varying parameters like slope, land-cover, and runoff potential. Hence a continuous runoff potential accounting procedure and a spatial analysis, based on the Soil Conservation Service Curve Number (SCS-CN), was used to evaluate the potential water harvesting. Model evaluation has been carried out on the basis of daily runoff events registered in 11 stations between 1996 and 2010. The analysis suggested that the model was able to estimate the observed runoff reasonably well. The sites proposed by the model have been investigated for suitability in the field, and showed an 83% accuracy of the model. Owing to the increasing demand for water requirements in agriculture, this methodology could be effective in other agricultural areas with similar requirements to the “Eight Communities of the Chianti” area.

Chapter Three

Description of the Case Study

3.1Climate Data

The Eastern Mediterranean climate is the dominant climate in the study area, characterized by a long hot dry summers and a cold winter. The region is exposed to cold air fronts coming from Europe across the eastern Mediterranean, causing in the temp and rainfall drops causing rain. The rainy season is from September until the end of April where 75% of the rain occur during December and February. (AOAD,2005).

3.2 Rainfall:

A measurement of rainfall is coming from Maithaloon weather climate Station, which is located at 17592.01 East and194985.4 North. Table 3 is presenting the average monthly rainfall in the area for the past 66 years. Figure 3 shows the annual rainfall variation in the methylene station during the period from 1953/1954 to 2018-2019.

Rainfall in October starts with a spate of showers 3% of the annual rate, which is gradually increasing to 13% in November, 22% in December, 24% in January, 19% in February, 15% in March, 4% in April, and reach 1% in May.

The annual precipitation is ranging from 308mm to 1202 mm with an overall average of 592 mm. The standard deviation of the annual precipitation 158 mm is equivalent to 25% of the annual precipitation rate, which is a large variation, as noted in the available information that the highest annual rainfall occurred during the period mentioned above is 1202 mm, which occurred in 1991/1992. This quantity is very large as it exceeds the annual average by about four times the value of the standard deviation. Therefore, this amount of rainfall is an extreme value and therefore should not be relied upon in any engineering design of hydraulic installations. Its probability distribution can be described using the natural trend as shown in Figure 5, which shows that the normal distribution curve represents the annual rainfall data well. The percentage of rainfall was calculated by taking the percentage and proportionality of the annual rainfall rate .(Moa, Department of Climate Change, ministry of agriculture)

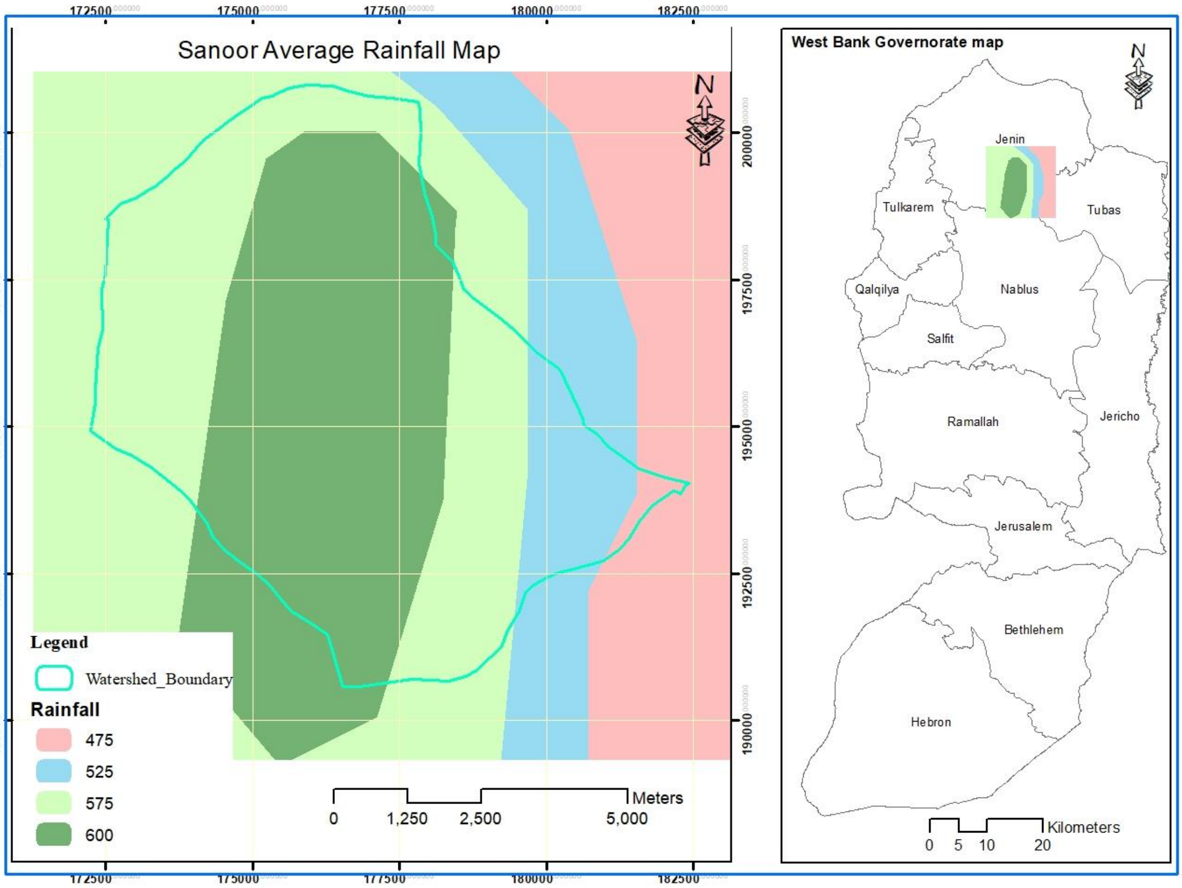


Figure :3 average rainfall in Sanour plain.

Table 3: Monthly average rainfall rates for Maithalon climate station (mm)

station	period	Oct	Nov	Dec	Jun	Feb	Mar	Apr	May	average
Maithalon	1953/2019	17	69	129	149	121	81	21	10	597

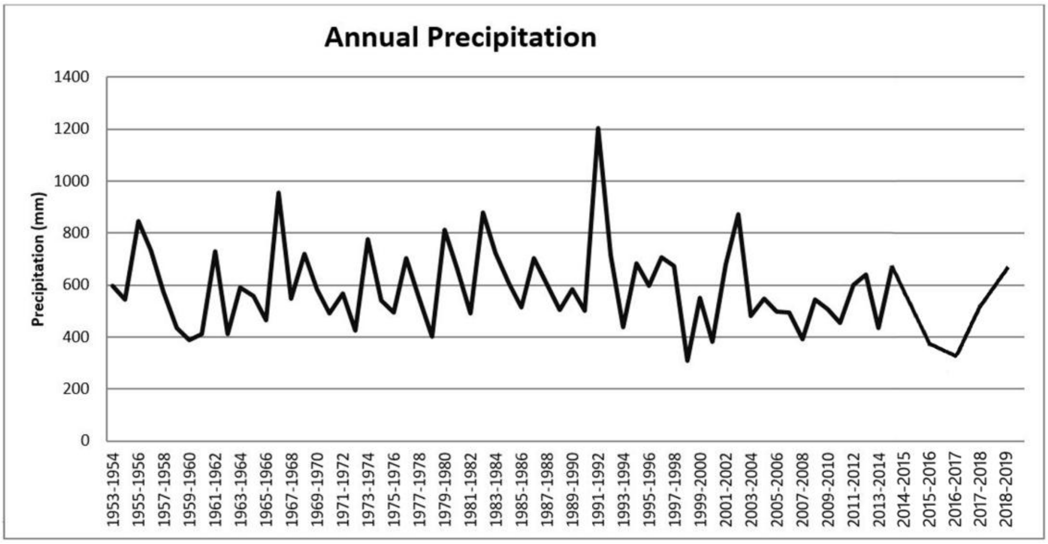


Figure4: Annual rainfall amounts of Maithalon (mm)

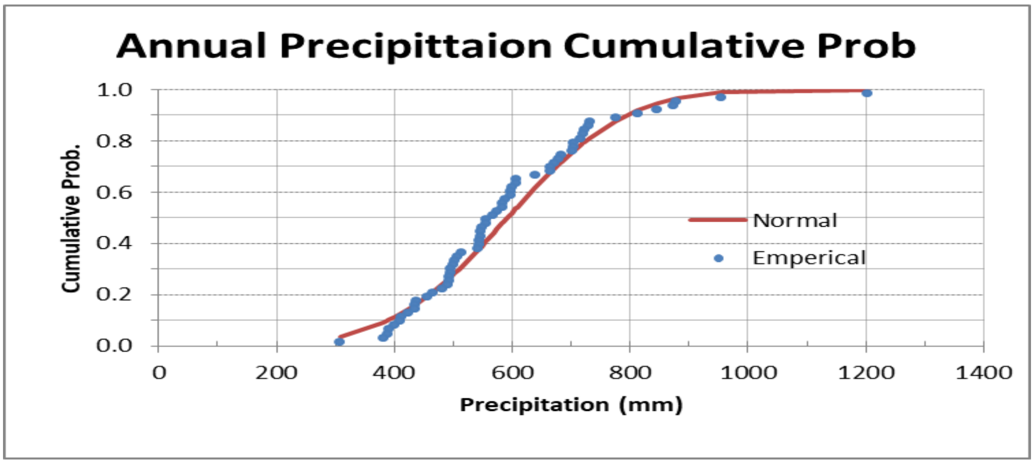


Figure 5: Potential distribution of rainfall in Sanour plain area.

Depending on the distribution curve, the frequency of high rainfall (wet years) and low rainfall years (dry years) were estimated as in Table 3.

Monthly rainfall

Monthly rainfall data available shows that the rainy season starts in September and ends in May. The monthly fall as shown in Figure 6 and Table 4

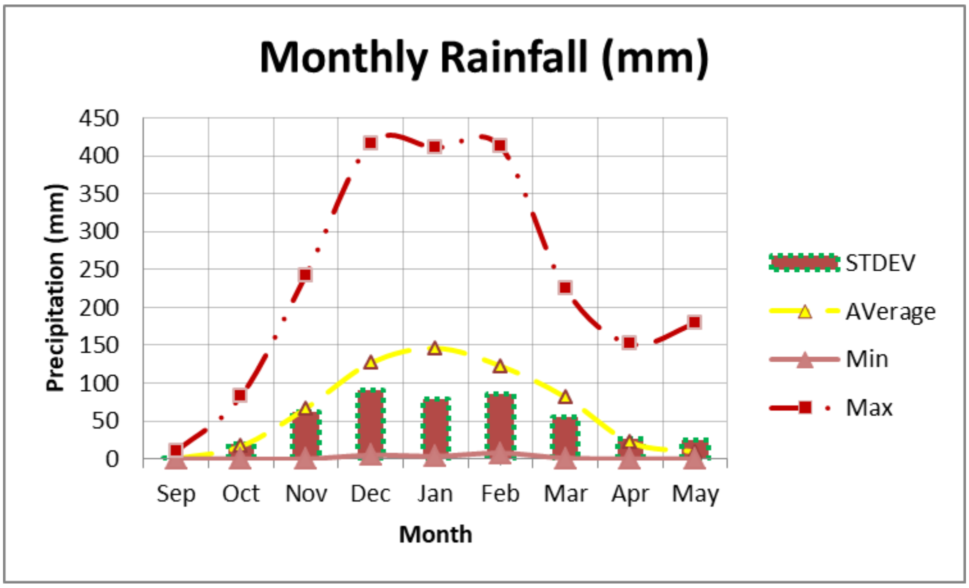


Figure 6: Distribution of the minimum, average, standard deviation, and maximum monthly rainfall.

Table 4: Minimum, Maximum and Middle values of monthly rainfall in the Maithalon weather station for 66 years.

Month	Sep	Oct	Nov	Dec	Jun	Feb	Mar	Apr	May
Average rainfall	0	17	69	129	149	121	81	21	10
Mean	0	8	52	111	134	107	74	19	0
Standard deviation	1	20	63	91	77	86	56	29	26
Less recorded rain	0	0	0	5	4	8	1	0	0
Top Registered Rain	10	83	245	416	411	413	225	152	179

Table4 and figure 6 indicate that most of the precipitation occurs from December, to February. But in March rainfall average is 82 mm, noticed standard deviation of 56 mm. This is equivalent to 68% of the monthly average for March. The large variation in rainfall during March is important in determining the future of the agricultural season which depends on verified. March rains are stored in the soil to supply the plants with water during the growing month of April-May. The growth of fruits for many important crops (field and tree) is a period of high sensitivity to the abundance of water for most agricultural crops. (Moa, Department of Climate Change, ministry of agriculture)

3.3 Temperature

Long term monthly temperatures in the region range between 32.1 ° C daily maximum in August and 4.6 ° C in January with an average of 19.5 ° C Table 5. (MOA-SP,2015)

Table 5: monthly temperature in the study area.

Month/ factor	jun	Fep	Mar	Apr	May	Jun	Jul	Auq	Sep	Oct	Nov	Dec
Maximum Temperature (C°)	14.3	15.8	18.1	23.8	28.4	30.8	32	32.1	31.2	27.9	21.8	16.1
Mean temperature (C°)	4.6	5	6.3	9.1	12	16.3	19.1	19.3	17.3	12.9	8.8	5.8

3.4 Relative humidity

Table 6 shows the distribution of the average monthly relative humidity of air in the study area. The relative humidity value increases in winter with the maximum monthly value in January 69.9% and the lowest in May 57.4%.(Maithaloon metrological station 2015-(MMS,2015)

Table 6: distribution of the average monthly relative humidity of air in study area.

Month /factor	jun	Fep	Mar	Apr	May	Jun	Jul	Auq	Sep	Oct	Nov	Dec
Relative humidity (%)	69.9	68	67.1	57.5	57.4	61.9	16.9	65.7	62.7	61.6	60.1	65

3.5 Evaporation

Monthly evaporation measurements in the study area indicate rates of up to 254.2 mm in July and 62 mm in December and January(MOA-SP,2015). Evaporation and release of monthly meteorological data were estimated to range from 49 mm In December and 189 mm in July, Table 7 . (Maithaloon metrological station 2015-(MMS,2015)

Table 7: evaporation in study area**.**

Month / factor	**Jun**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Auq**	**Sep**	**Oct**	**Nov**	**Dec**
Evaporation (mm)) Pan Evaporation	62	67.7	93	138	201.5	234	254.2	232.5	180	133.3	93	62

3.6 Geomorphology of Sanour plain

The study area of the Sanour plain can be divided into two main geomorphological units:

3.6.1 Highlands

Defined as the lands located above the plain, which bordered with the upper water flow line and isolated the watershed basin than the neighboring watersheds, the top of Hraish mount 750 m a.s.l is the highest point of the watershed, figure 7, the topographic information for the micro watersheds table 9 which are located inside the watershed pointed for high slope with high chance of soil erosion, using Digital Elevation Model (DEM) the following micro watersheds can be characterized

1. Wadi Almalik: located in the north-west of the sanour plain, this valley runs from the north of the town of Mislya and the area of Jarba towards the plain of the meadow, to sub catchment at the level of 392 a.b.s. The area of this sub catchment about 6327 dunums.
2. South Mislya: this area is about 3080 dunums, where rainwater is discharged towards the plain of the towards from the north.
3. Al-Fuhais catchment: It is located on the eastern side of the basin between the Sir and Al Jadida town. The area of this site is 1560 dunums.
4. Sir catchment: it is located in the eastern side of the basin and cover an area 2983 dunums.
5. Fifa catchment: the Fifa Valley enters the prairie from the south-east. This area cover about 5126 dunums.
6. Al-Nasrani catchment:this wadi enters the meadow from the south side and is located between Siris and Al-Jadida and it is cover 9821 dunums.
7. Mithlon catchment: it is located on the southern side of the basin and is about 3447 dunums.
8. Al-Sarar catchment: this Wadi al enters the towards from the south-west side, and it is cover about 8894 dunums.
9. North of Sanur catchment : located in the western side of the meadow and it is area cover 1311 dunums.(Aoad1996)

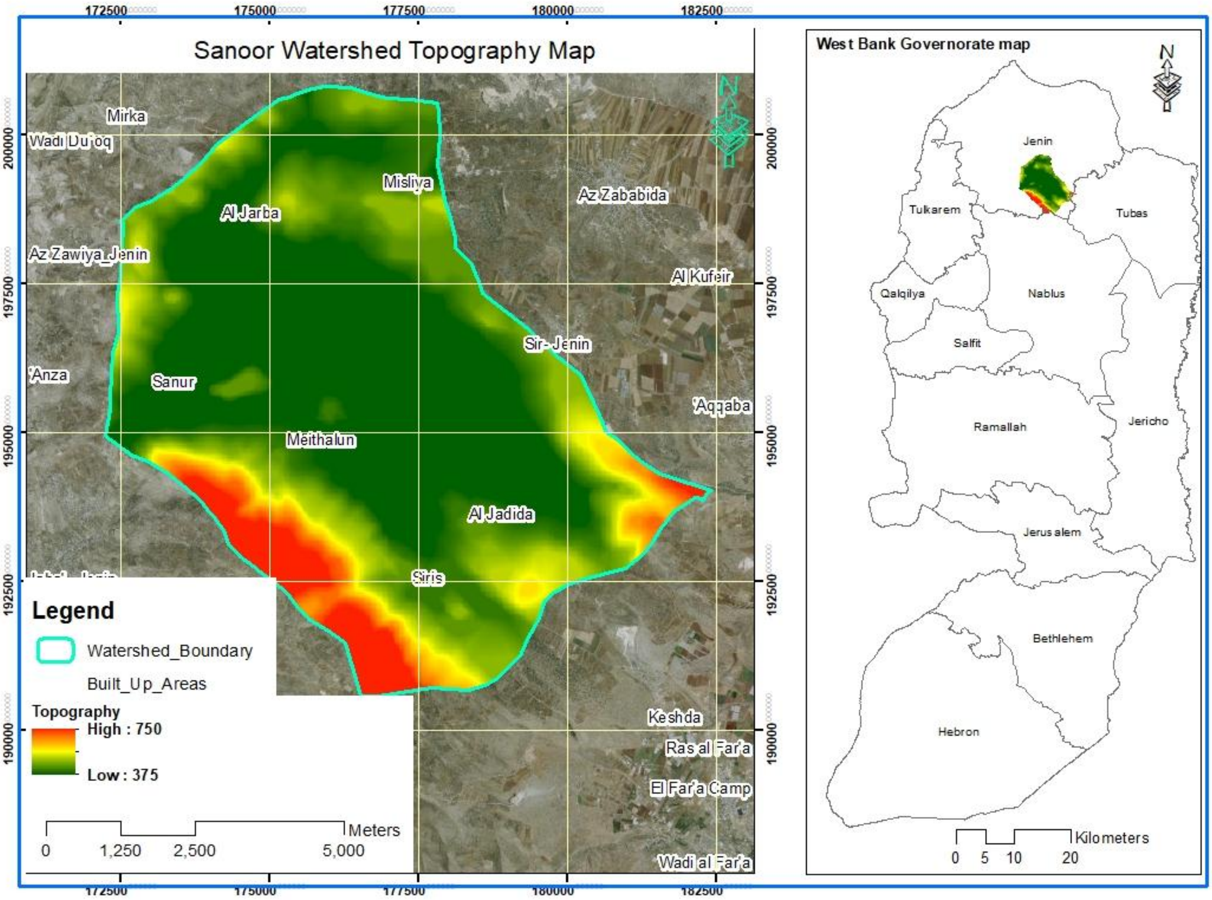


Figure 7: Topographic area of the catchment area in Sanour plain

Table8: Topographic information and sub catchment area of the watershed in Sanour plain basin**:**

Parcel	Area (dunums)	Lowest altitude than sea level(m)	Highest altitude than sea level(m)	Average highest (m)	Average slope (%)
Almalik	6327	359.3	521.9	416.3	15
North sanour	1311	358.5	521	428.5	22.2
Fifa	5126	359.9	660.2	462.8	17.1
Nasrani	9821	361.3	740.4	489.1	17.1
Alsarar	8894	357.5	760.5	444.9	19.9
Sanour plain	16028	352.9	397.8	358.8	1.4
South Mislya	3080	356.2	492	421.3	14.4
Alfohes	1560	359.3	452.2	411.9	8.8
Ser	2983	359.5	661.2	440.5	13.9
Maithalon	3444	362.9	742.2	486	19.7
Average/total	58578			436	14.9

MOA, GIs Department,Ministry of agriculture Palestine.

3.6.2 Sanour plain

The area of the Sanour plain, including the inner hills of the meadow, is approximately 16 km^2 and divided into the following sub cathchment:

1- Center plain:

The center of the Sanour plain is located on the western side of the plain at a height range 348 to 350 meters above sea level.

2- The edges of the plain:

This area is limited to Contour lines (350 and 375 meters) above sea level.

3- The sediment of the sanour plain:

Those sediments locates below the mountainous areas that are cut by the valleys entering the sanour plain.

4- Flood fans:

These sediments are located at different valleys, and valleys or valleys are the largest in the region.

5- Hilly areas:

Locate in the southern margins of the Sanour plain and characterized by two hills between the foothills of Harish mountin and the center of the Sanour plain. Despite the tectonic growth of these hills, they represent the karst hills in the Karstian plains and these hills are:

1. **Alrojom :** located at the center of the plain at the level of (348 m), and represents the lowest point in it and a limited area where the Eocene rocks are exposed.
2. **Ghzay** : is the largest of the existing hills. located in the southwestern part of the plain and takes an oval shape. The highest point is 429 meters above sea level.
3. **Khaibar:** located in the eastern edge of Sanour plain area, northeast of the town of Mithlon, with the highest point at 423 m above sea level.
4. **Alqada:** located far from the center of the plain, it stretches of the Sanour plain through the opening of Wadi al-Nasrani southwest of the town of Siris. This hill located in the center of the tectonic groove and rises from the surrounding land and surrounded by a letter of all sides and an oval shape. (MOA-SP,2015)

3.7. Geology and Hydrogeology:

Sanour plain Located in the middle of the road between the cities of Nablus and Jenin (Fig8), Sanour plain takes a shape closer to the rectangle, extending north-west to south-east. It is a flat plain with low slope. It is located within the coordinates of 198,000 to 193,000 North and 180.00 174,000 East. The village of Sanour its southwestern corner, Siris and Jdeda are its south-eastern corner, and its north-eastern corner, and its north-western corner, is dominated by the village of Maithaloon from the middle of its southern side, The land of Sanour plain is divided among the villages mentioned above. The length of the Sanour plain from the north-west to the south-east is about 7 km and its width is about 3.5 km with total area about 23 km^2 represented by the plain that bordered with the water level line with elevation (375m a.s.l), the northern, western and southern borders are characterized with clear boundary with the side mountains edge. Whereas, the eastern side progressively raising up to (450 m a.s.l) then it is gradually sloped toward Alzababdeh plain.(Arab Organization for Agricultural Development,2005)(AOAD,2005).

Sanour plain is located on the main axis of the Nablus -bet Qa'ad Syncline, which is parallel to the south-east of Faria 'Anticline in the east. It is also parallel to the north-west of Anabta Anticline in the west. (AOAD,2005). The Eocene aquifer overlies the Upper Cenomanian-Turonian aquifer system, with a transition zone of chalk of variable thickness ranging from few meters to 480 m in the middle of the Syncline.

3.8.Ground water:

The Eocene aquifer overlies the Upper Cenomanian-Turonian aquifer system, with a transition zone of chalk of variable thickness ranging from few meters to 480 m in the middle of the Syncline. This system is represented by the Jenin sub-series of the Tertiary age and exposed in 80% of the Jenin area. (Roffe and Rafety, 1965)

The Eocene strata floored by Upper Cretaceous rocks and partly covered by Quaternary sediments of alluvial soil. One third of the total surface area of the northern West Bank is covered by Eocene rock, limestone, chalky limestone, and nummulitic limestone (Rofe & Raffety, 1965). This forms a triangular exposure, with Nablus in the south at the apex and Jenin in the north, in the middle of the base of this triangle Figure 8

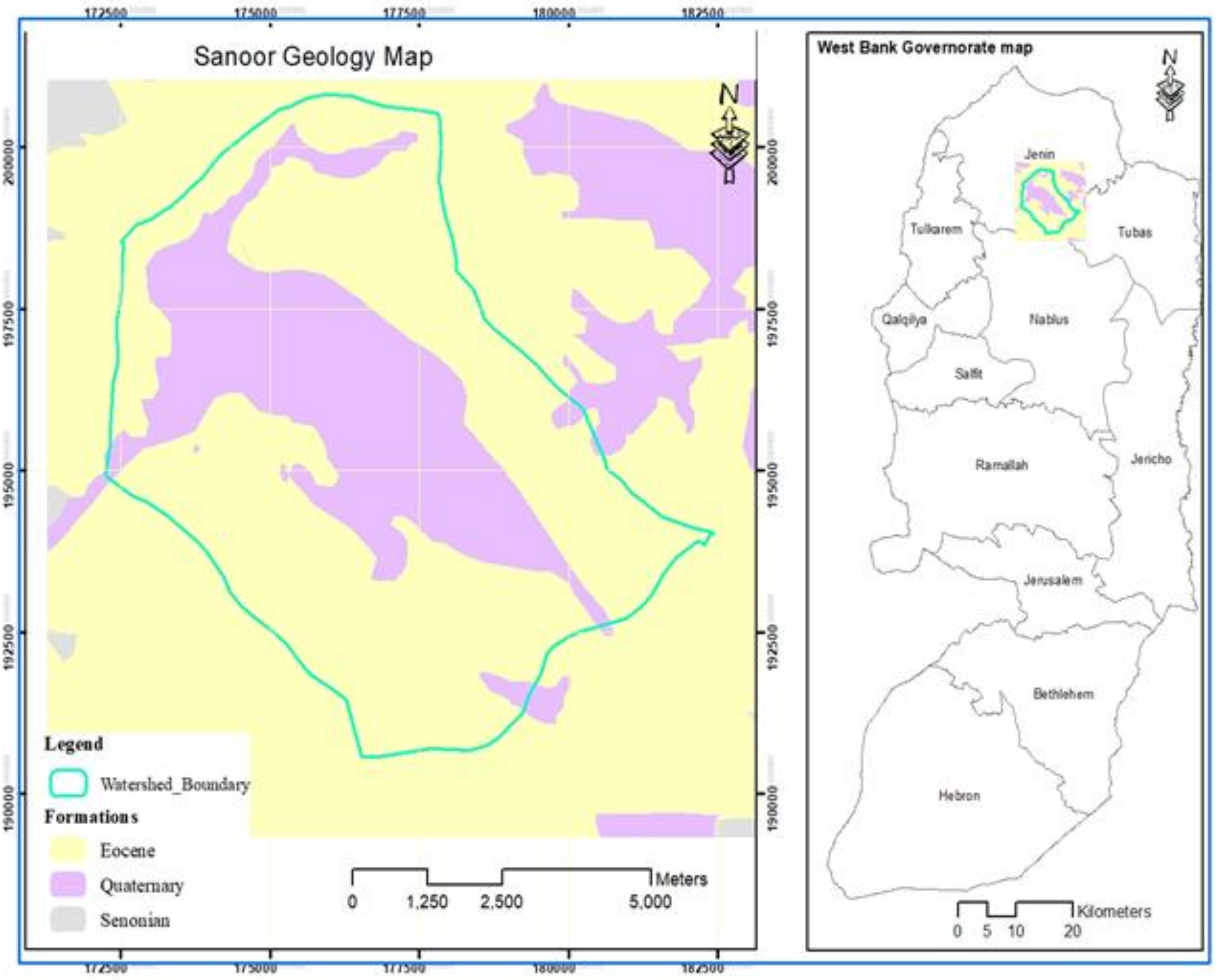


Figure 8: Governorates and groundwater basins formation

The Jenin Subseries includes the following five main layers (Roffe and Rafety, 1965):

(1) Chalk with minor chert nodules ;

(2) Chalk with minor inter-bedded nummulitic limestone;

(3) Limestone with minor inter-bedded chalk;

(4) Massive nummulitic limestone;

(5) Reef limestone

According to the lithological setting of the area, sub-aquifer and perched aquifer systems are formed. In this system, limestone rocks form a karstic aquifer while chalk rocks form an aquiclude, secondary porosity, the widening of joints, fractures and bedding planes by solution erosion, have made this aquifer an important local sources of water aquifer. Rock formation of the Eocene aquifer exposed to the surface in high rainfall zones. (Roffe and Rafety, 1965)

Rofe and Raffety (1965) define two aquifer systems, viz., the shallow Eocene system and the deep Cenomanian-Turonian system. The Eocene system depends directly on the renewable recharge from precipitation, receiving an average annual rainfall of about 500 mm (Marei. A, et al 2015). The water that enters this aquifer moves generally to the north-east, but in many places structural feature like Al Faria graben govern the movement and drive the water to the southeast. (Rofe & Raffety, 1965). Many springs issue from this aquifer and wells have been drilled for agricultural and domestic purposes.

The deep aquifer is related to the Cenomanian-Turonian age, which consists mainly of karstic limestone and dolomites. In the plains around bed rocks exposed along the anticlinal flank. Direct recharge to the deep aquifer systems takes place over both flanks where an average annual precipitation of about 600 mm, however, the yield from the Cenomanian-Turonian system could be not affected by variations in annual rainfall. The groundwater could be move from east and west to the center of the syncline and then to the northeast. (Marei. A, et al 2015). Point to the absence of springs, indicating a lack of impermeable near sub-surface strata. An east-west.

Geological section Figure 10 illustrates the structure of this aquifer.

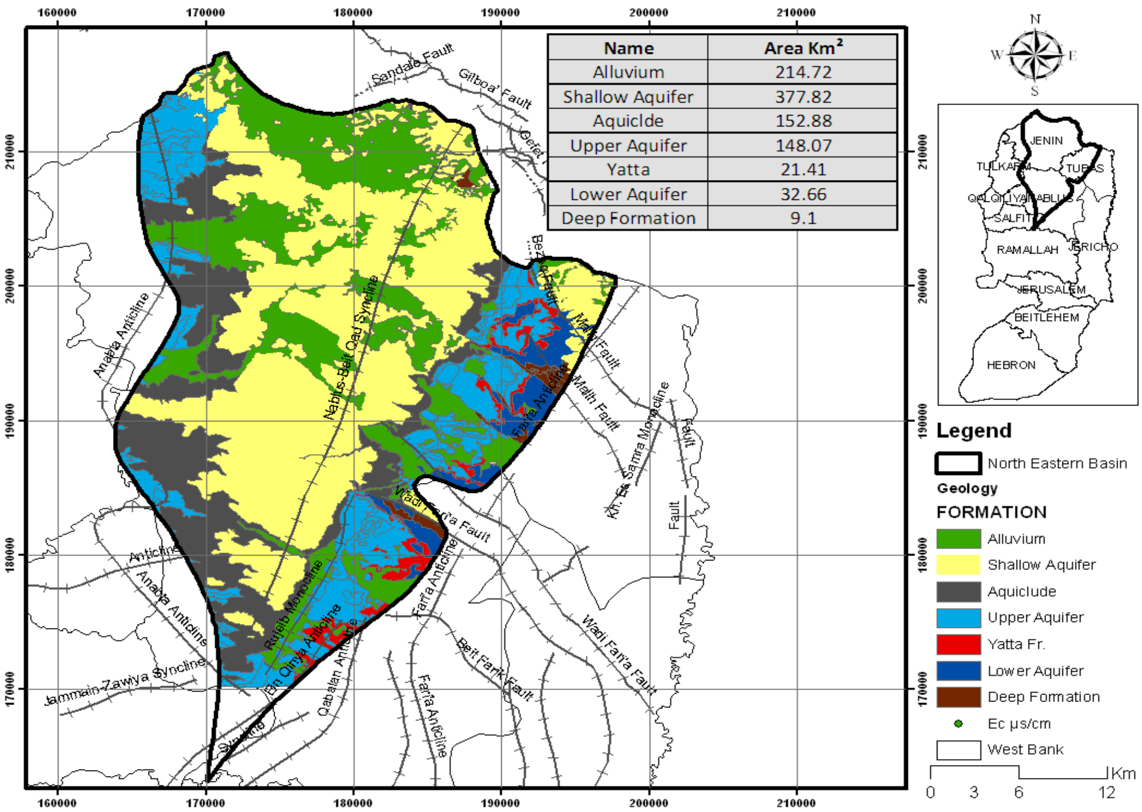


Figure 9: Outcrop of land recharge area of different aquifer system (Marei. A, et al 2015)

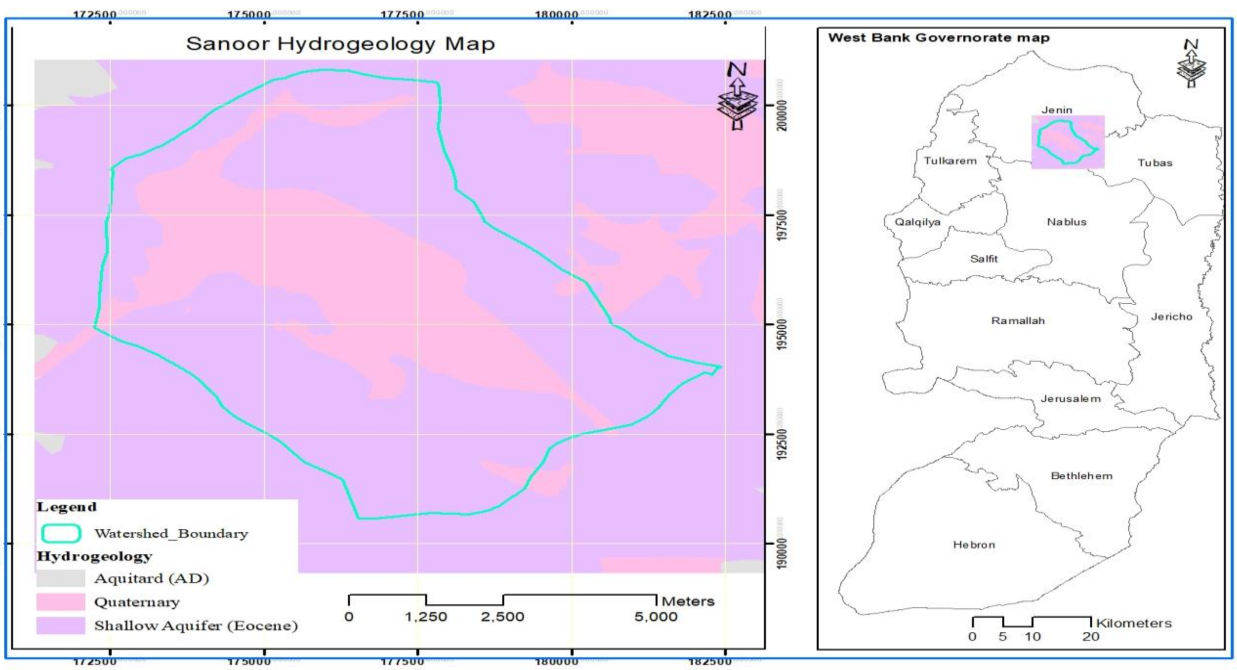


Figure 10:Sanour hydrogeology map.

3.9. Soil characteristic

Soil texture (percentage of sand, silt, and clay) is the major factor inherent in infiltration. Water moves more quickly through large pores of sandy soil than it does through small pores of clayey soil, especially if clay is compacted and has little or no structure or aggregation. (NRCS - USDA)

The characteristics of soil lie in that it is very deep in the plain and its specifications are identical to the specifications of the fertilized soil. The depth of the soil is generally more than 10 meters in the flat area and reaches more than 30 meters in some areas according to previous studies. (MOA-SP, 2015). Moreover, after the examination of all sections in the soil, the presence of a heavy clay layer (Subsoil hard pan) resulted from the accumulation of mud in the horizon under the surface of the soil, and it was found to begin at a depth (55 - 75 cm) under the surface of the soil as a result of increasing the proportion of clay and soil compression due to weight. (MOA-SP, 2015).

3.10.Land cover land use:

The lands are classified as agricultural land, figure 11. Table 9 Shows that most of the lands of the Sanour plain Basin are agricultural lands (about 90%), which indicates the importance of agriculture in the area and the fertility and validity of land for agriculture. Fruit trees, especially olive trees, account for the largest percentage of cultivated area in the basin, with a relatively high area cultivated with field crops and vegetables. The area of the urban area is about 6244 dunums or 10% of the total area. This area is an important cause of flooding. The increase in the population and their need to expand urban areas, which causes the increase of non-water areas and therefore increase the floods in the winter, increasing the problems of drowning in the Sanour plain. (MOA-SP,2015)

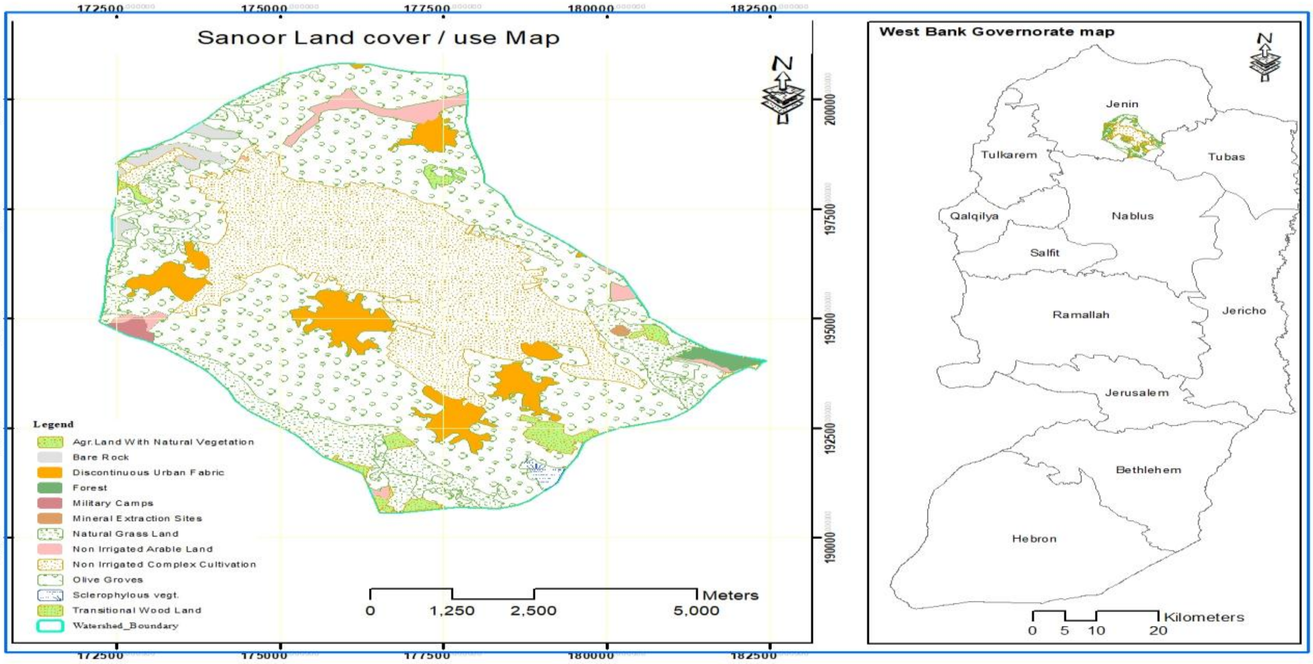


Figure 11: land cover land use

Table 9: land use in Sanor plain Basin in Donoum , while Table 10 summarizes the land use of each of the villages in the village.

Table9: land use in Sanour plain

Land use	Area /dunom
Field Crops	16640
Natural forests	3
Fruit orchards	26241
Forests planted	369
Forest Areas	9085
Urban areas	6244

(MOA-SP,2015)

Table 10: land use in Sanour plain villages

Site	Total area /dun	Agricultural land area/d	Tree area	Area for field and irrigated agriculture	Unplanted land	Forest land
Maithalon	12495	10755	5224	5520	-	-
Sesres	12593	8806	6514	1289	1000	3000
Sanour	11804	8115	5384	2692	22	-
Aljdeda	6360	5550	4273	1248	600	-
Ser	12499	10869	5410	4988	-	-
Mislya	9048	7913	6242	1631	-	254
Aljarba	3250	2596	1319	1226	250	-
Total	68049	54604	33366	20594	1877	3254

(MOA-SP,2015)

Chapter Four

Materials and methods:

4.1. Introduction.

The concept of Water shed management means the integrated approach for dealing and managing all included parameters within specific boundary of land, that achieved the conditions of watershed, like water resources, soil type, land cover, and finally to enhance the resilience of the beneficiaries of that regime through implementing reliable plans and programs to achieve further development for the human and rural communities.

Water shed modelling is defined as the process of using the computer programs and different software to delineate the watershed boundary and to derive all inputs of hydrological parameters, which represents, the sub basin, stream network, stream order, slops aspects and SCN coefficients through analysing the digital terrain dataset and other related database. (Mohammadin, 2003.)

Runoff modelling technique is used to estimate the quantities of surface water flows over a specific target area through wadies channels or rivers. This process involve analysing the historical rainfall data for target area, taking in consideration all losses as infiltration or percolation quantities through the soil or direct recharge to geological formations, addition to that the losses due to evaporation and evapotranspiration and retention quantities due to natural barriers.

All methods and materials used in order to estimation the quantities of runoff surface water from the excess rain fall precipitations using the Soil Conservation Services SCS

Curve Number CN method which is a widely reliable model used for small catchment over the world. This method was developed by the united state agricultural department since 1954. Different kind of data and information related to soil type, soil type, soil physical and chemical properties, land cover land use data, soil water conditions, are highly required as well as good knowledge in terms of watershed properties, environmental and socio economic conditions. (Randkivi, 1978).

Basic methodology was followed in this study to achieve the intended goals that was mentioned in the research objectives, the work was divided into two main parts.

- The first part is the modelling of the spatial variation of the terrain by the remote sensing and GIS packages through deriving all hydrological variations to create digital geodatabase.
- The second part, consist of the field work relatedto collect information on: Land cover, land use, soil type, soil infiltration rate, and soil texture &structure . The Soil data was used to identify the Hydrological Soil Group (HSG) and finally estimating the Curve Number Coefficient (CN), which is also called Runoff Coefficient.

4.2. Data used

- Raster Dataset, represented by Remote sensing data. (Aerial photos 2016, 10cm pixel resolution, SPOT satellite images 2.5-meter resolution).
- Topographic map, scale 1:50000 represent the physical surface of the study area,
- Soil type maps and soil texture data, scale 1:25000
- Meteorological and climatic data, Yearly, monthly and daily average rainfall data. average temperatures, average relative humidity, aridity indices.
- Land cover/land use map, scale 1:25000
- Hydrological maps which represent the catchment features.

- Geological maps, geological formations and outcropping
- Digital Elevation Model, 30-meter cell resolution.
- GPS points, Field work for more verification, investigations and comparing the modelling output results with the reality on the ground.
- Other ancillary data

4.3 GIS software packages: Different tools were used for capturing, storing, manipulating, analysing and displaying spatial data (Vector & Raster), which are geo referenced data. ARCGIS 10.2 is powerful software which included many different extensions for creating thematic maps, charts, raster calculations, interpolation and modelling procedures.

Hydrological modeling extension is mainly used for DEM analysis to deriving at watershed variations, watershed delineation slope aspect, flow accumulation, stream networked stream order and sub basin and pouring points, all these variations will be explained in details later.

The following flowchart is a simple design that is clearing the complete process of the adopted methodology in modelling Sanour watershed Figure12.

4.4. Digital Elevation Model (DEM) Analysis:

DEM is defined as continuous interpolating surface built from contour lines to represent the terrain surface into 3D. DEM determines how the water flows through a specific surface, DEM is represented by raster format includes rows and columns of numeric cells each point on this raster surface determine the value of elevations on specific location. Digital elevation model is the basic input data which mainly used for delineating the watershed and its hydrologic parameters (Fig13). Analysis of raster (DEM) allows us to determine and extract the flow network which represented by flow direction, flow accumulation streams net and stream order, and according to that parameters we can divide the main watershed into sub basins each one has it' separate hydrological conditions, finally identifying the water outlet at specific point at the end of the sub basin. The accuracy of the output results is mainly deepening on the resolution of DEM cell. Many different GIS software technologies are available nowadays for establishing a referred digital database through analyzing DEM, one of these tools is the hydrological modelling tool which is an extension available within ARC GIS software. These tools allow us creating many different raster datasets in terms of computing the DEM Fill, topographic relief, slopes in degrees, aspect (slope directions), flow direction and flow accumulation stream network, sub basins and finally the sub basins outlet. The following factors are considered very highly requirement for modeling mechanism.to extract the hydrological variation for Sanour watershed. Jenson, S. K. (1991).

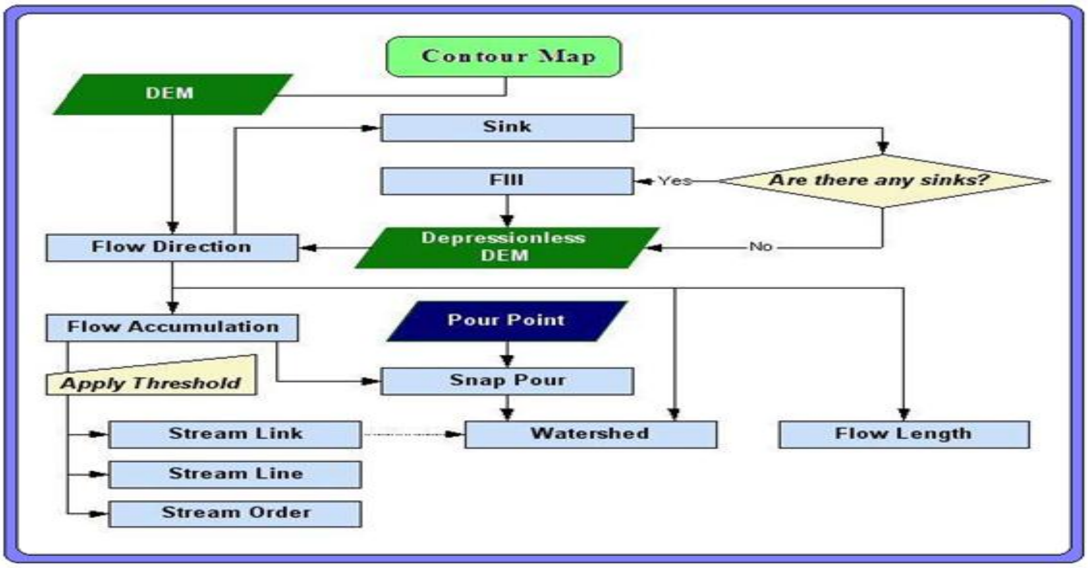


Figure12: Chart represents the steps of DEM Analysis for deriving surface characteristic.

Sanour DEM shows that the maximum elevation on the reality reaches 750 above sea level located at the southern and northeast part of the watershed, while the minimum elevation reaches 375m above sea level which is located over the central part of the watershed, represented by the plane area. (Figure 13)

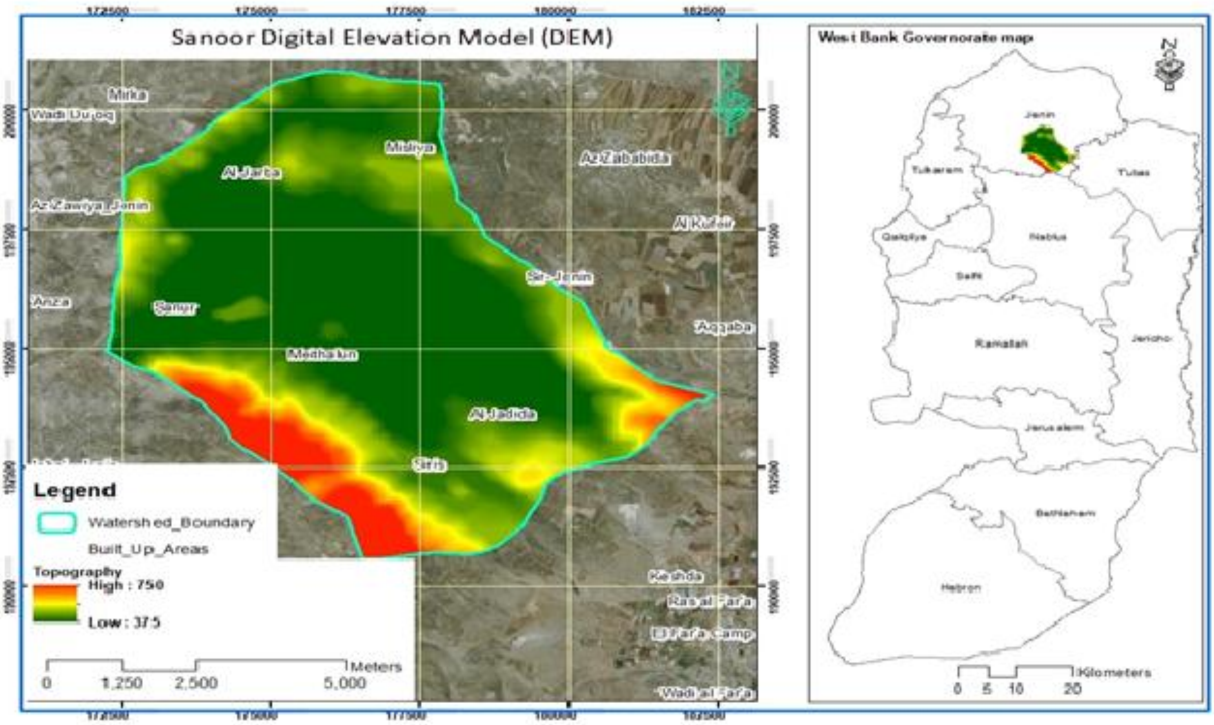


Figure13: Sanour Digital Elevation Model DEM

Figure14: Panoramic view for Sanour watershed showing the plain and the surrounded ridges

Based on the DEM characteristics the following spatial and vector hydrological data were derived:

- **4.5.Delineating the watershed :** the watershed is hydrological concept defined as a specific topographic boundary that was separated by a divider line from any other adjacent topographic surface, these surface of land reserve all drained water flows by channels ,streams or rivers from all inclined surfaces to a specific outlet point located at the lowest part of that surface, Sanour watershed was delineated based on DEM with a resolution 30 m by using the ArcGIS hydrological modelling tool , the area of Sanour watershed was estimated with 58 km^2 and the main boundary of sanour watershed was used as a base to dived it into other 8 sub basin according to flow direction and flow accumulation factors, The aims of dividing is to define the physical and meteorological characteristics for each sub basin and other data related to land use, topography, soil, rainfall and other parameters, In order to estimate the CN coefficient. Each main-sub-basin are listed and shown Figure18 (Jones, N. L., Wright, S. G., & Maidment, D. R. (1990).).

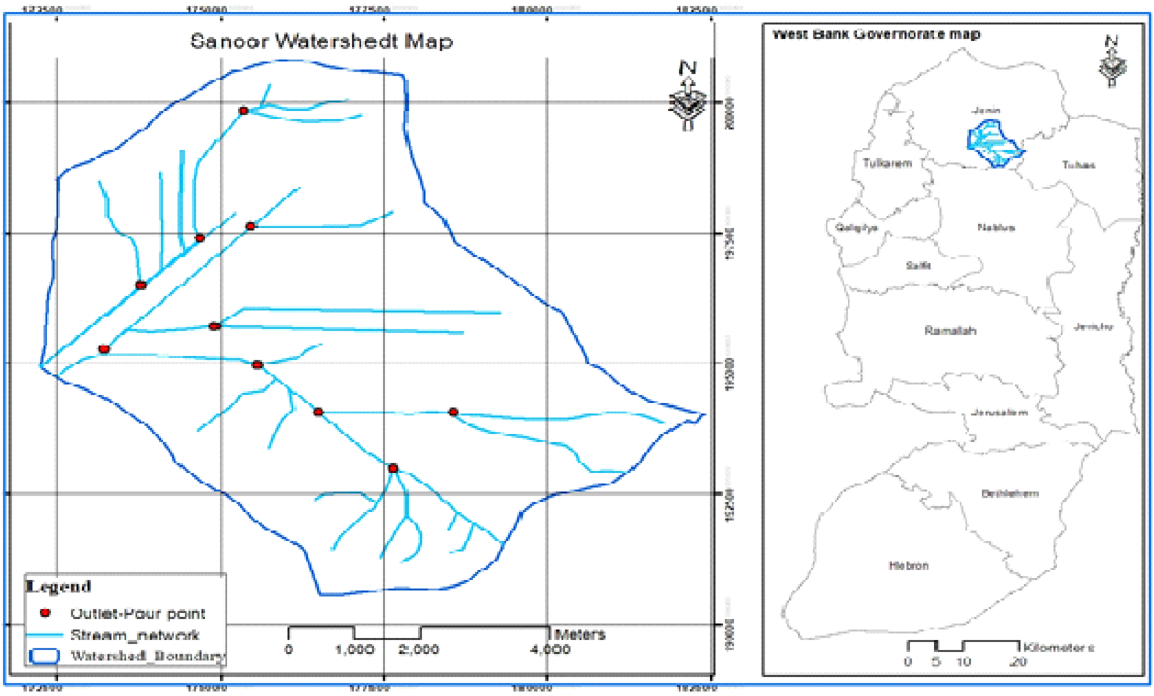


Figure15 :Sanour main watershed map

4.5.1. Fill Sinks:

Sinks are an errors values represented by a depression or peaks which appears on the DEM surface due to the resolution of data or incorrect of approximation for the elevation to the nearest integer value, the process of filling sinks or removal sink is very essential for creating a depression less DEM.To ensure an ideal sub basin and stream delineation. if the sinks are not filled a discourteous drainage network will be formed. Figure20 shows the fill sinks and removal sinks.(Jenkins, D. G., & McCauley, L. A. 2006)

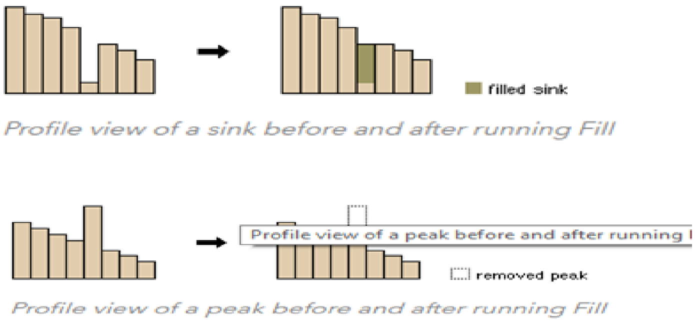


Figure16: filled sink and removed peak

4.5.2.Flow Direction:

The flow direction is the process of calculating and determining the direction of flow for each cell over the raster DEM to the surrounded cells. Flow direction has an integer raster value ranges between 1-255. Figure 17 shows the schematic representation for flow and the value of direction from the center. Many flow directions are existing within Sanour watershed that are represented as following North East, South West, South East, North West, which means that the movement of flow to the watershed is originated from all directions almost. Mitasova, H., Hofierka, J., Zlocha, M., & Iverson, L. R. (1996).

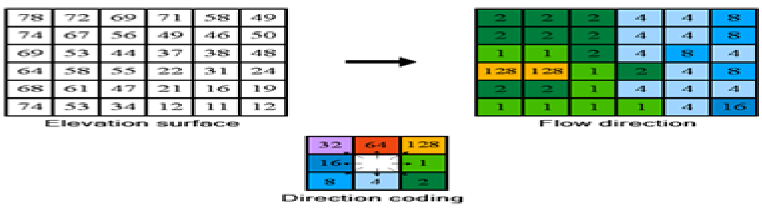


Figure17 : flow direction aspect

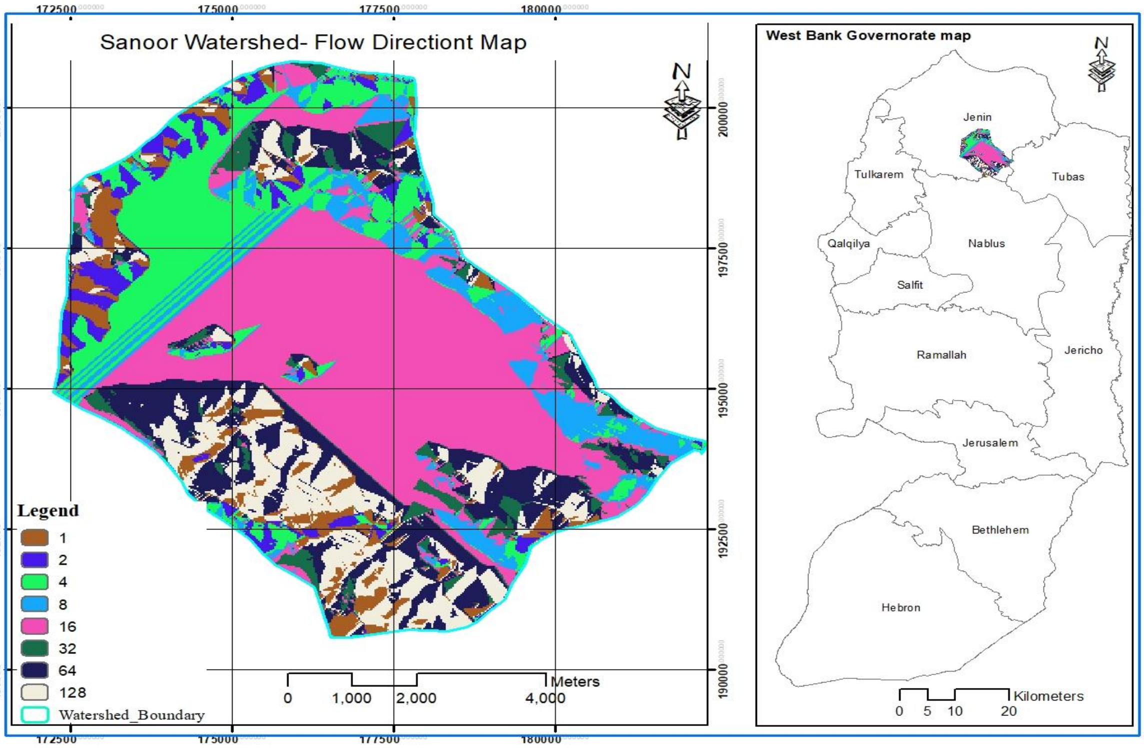


Figure 18: flow direction map

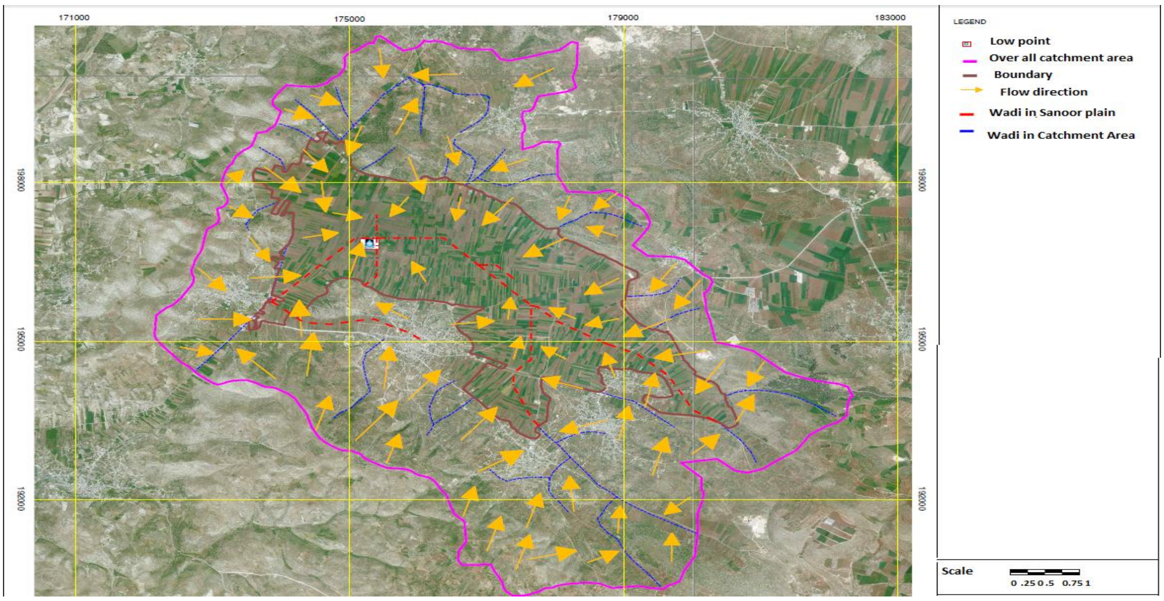


Figure19: Flow direction over the areas of Sanour watershed.

4.5.3Flow Accumulation:

Flow accumulation was determined and calculated from the flow direction input, it calculates the accumulated flows of all cells that flow into each downslope cell in the output raster streams or channels are determined according to the accumulated weight of all cell that have a highly flow accumulation that forms an area with concentrated floe on the surface of raster Dem.

Cells that have **Zero** flow accumulation value is referring to topographic heights and describe as a ridge, value 1is given to all cells that no raster weight was provided. While **higher** accumulation raster value forms Streems, channels and revers.

Flow accumulation with an input raster weight could be determining how much rain has fallen within a specific watershed surface, in that case the weight raster represents the continuous raster of an average rainfall during a given rainfall storm and the output represents the amount of excess rainfall that might flow through each raster cell assuming that these amount of rainfall flows as a pure runoff after extract all losses related to soil infiltration, evaporation and ground water percolation.

Figure 20 represents the direction of travel from each cell and the right figure represent the number of cells that flow into each cell. Schäuble, H., Marinoni, O., & Hinderer, M. (2008).

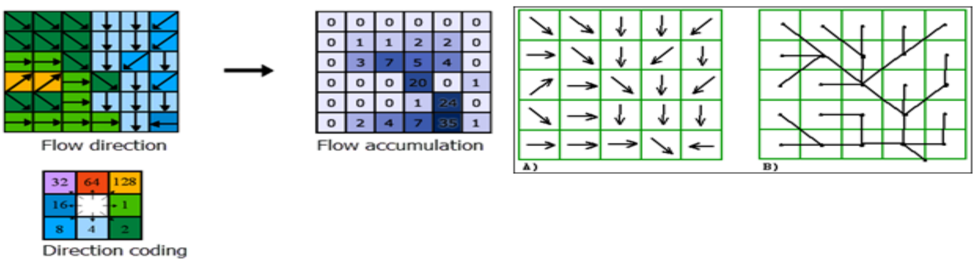


Figure 20: Grid Network A) represent flow direction and B) represent flow accumulation

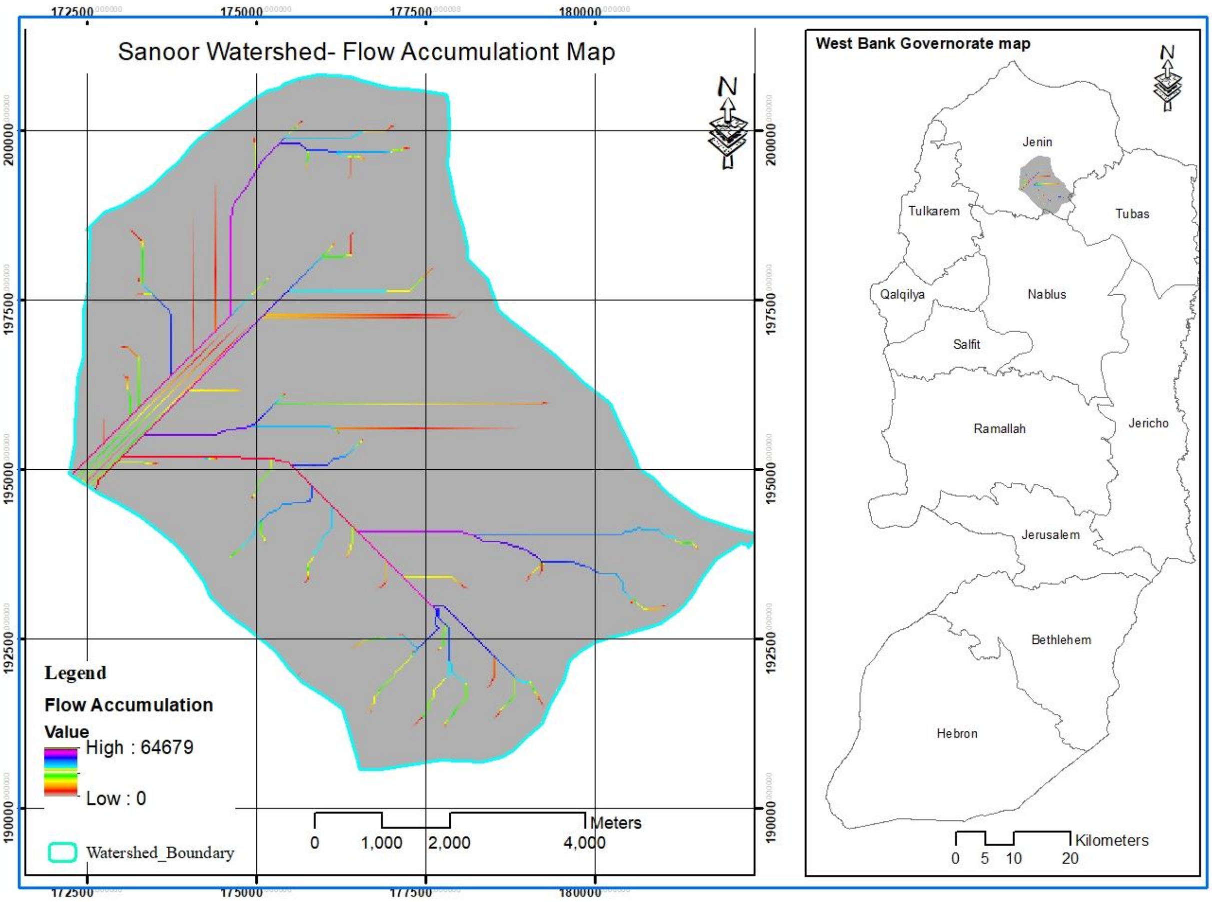


Figure21: Flow accumulation over the areas of Sanour watershed.

4.5.4. Slope & Aspect: Slope is defined as the plane that tangent specific point on the earth surface, it represents the rate of change of elevation for each digital raster cell to its neighbor cell. Slope has two components:

1- Gradient which represent the maximum rate of change of the plan elevation (the angle that the plane formed within the horizontal surface). The topography of earth surface for Sanour watershed in term of slope gradients was divided into five main classes as shown below Figure 22. The first class ranges from 0-3 degree and describes the little or no slope (Flat area) which represents the dominant area (nearly half of the watershed area), the second class is describing the gentle sloppy area ranges from 3—10 degree, the third class is describing the moderately sloppy area ranges from 10-15 degree, the fourth one is describing the steeply area which ranges from 15-25 degree, and finally the last one is describing the very steeply area ranges from 25-33 degree. Chang, K. T., & Tsai, B. W.1991).

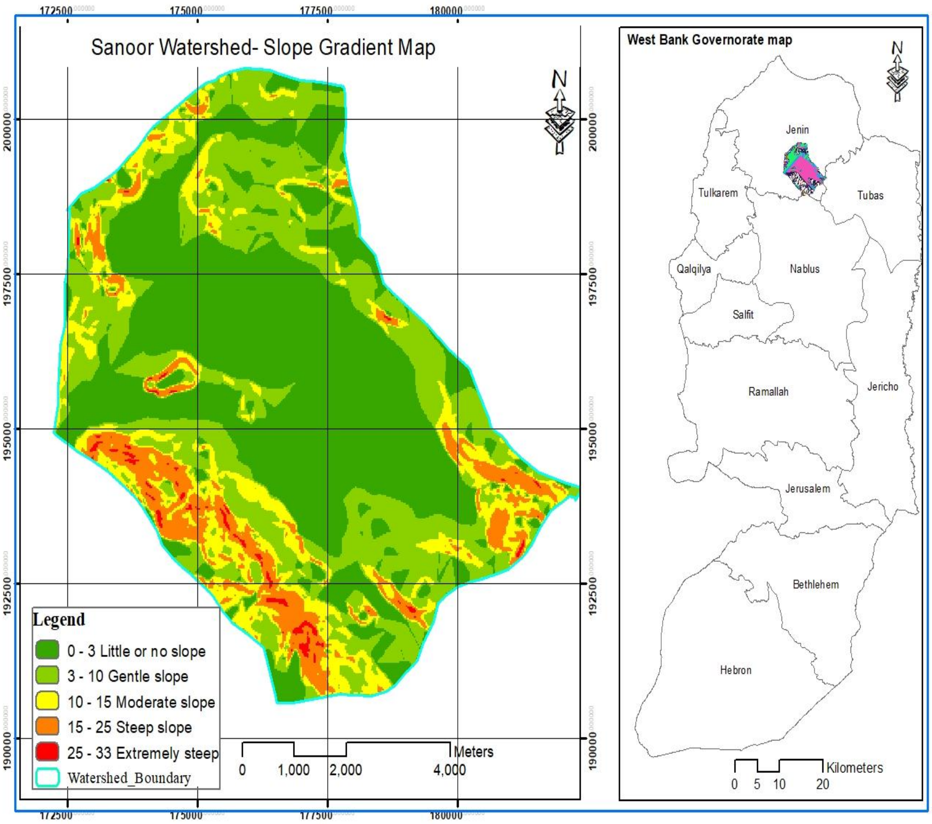


Figure22: Shows the slope variation in degree over the surface of Sanour watershed

2- Aspect which represents the direction of the slope or the plane with respect to Zero value (North direction), the value of each cell in an aspect dataset indicates the compass direction for the cells of the slope faces, or the surface faces at that location. It is measured clockwise in degrees from 0 (north) to 360 (again due north), coming full circle. All areas having no downslope direction are classified as flat surface. Figures 23 illustrated the input elevation dataset and the output is the aspect raster.

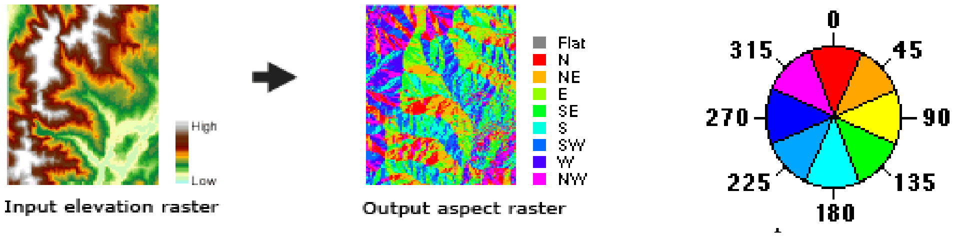


Figure23: aspect slope

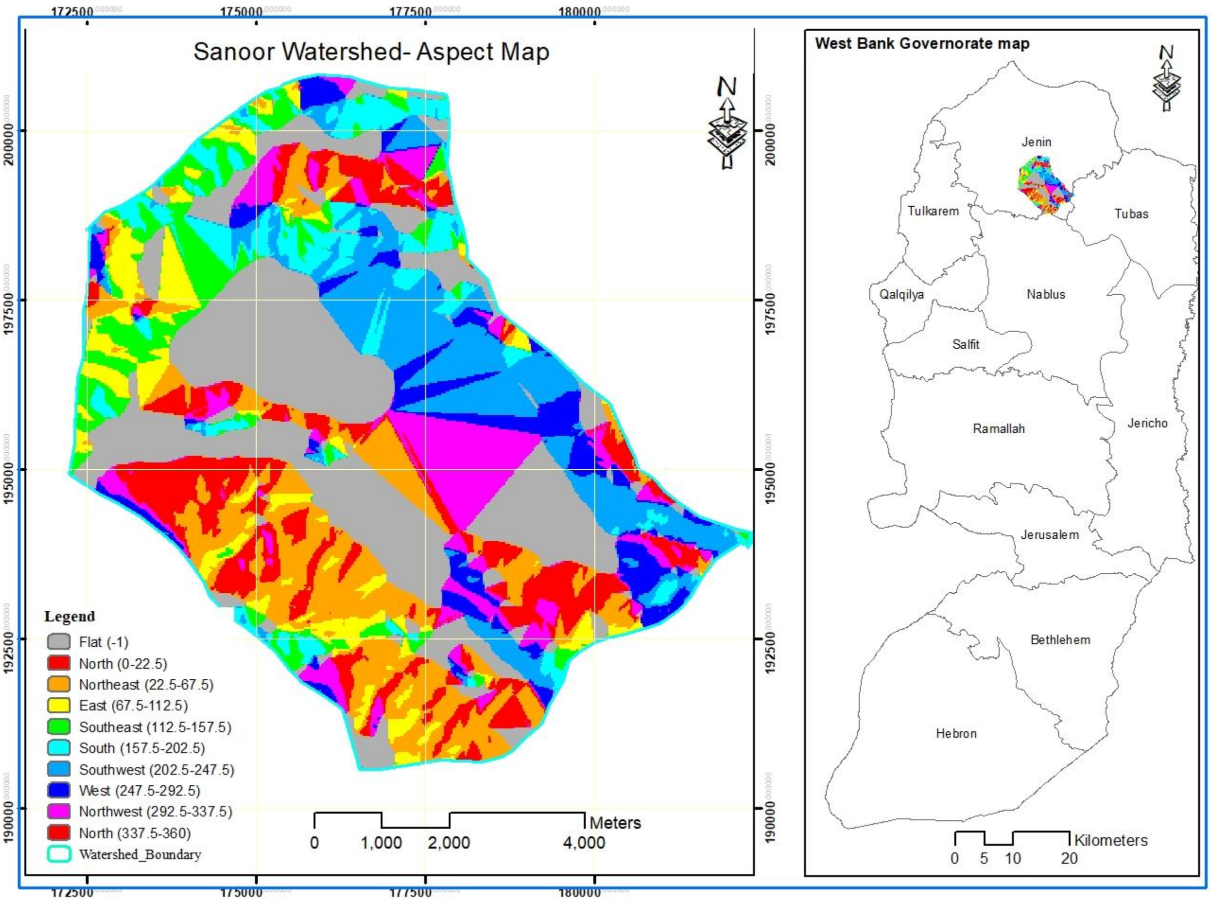


Figure24: Sanour water shed aspect slope

4.5.5Delineating Stream Network

4.5.5.1 Stream Links &Junctions

Stream links are segment or section of stream channels that is connecting two successive junctions & outlet, or junction & drainage. In hydrology the stream segments are called reaches junctions related to an outlet helps in desalinating the border of the watershed, drainage or sub basin boundary.

Stream link has the power to assign a unique value to every link in the raster linear network; it also can be used to attaching the related information to every individual segment of stream.

Stream networks can be delineated from a digital elevation model (DEM) using stream link tool, flow direction and flow accumulation in raster format were used as an input data for extracting the watershed streams. Flow accumulation in its simplest form is the number of upslope cells that flow into each cell. A threshold (amount of raster accumulated cell) value was applied do determine all valuable stream, using the raster calculator extension (map algebra expression) was used with accumulation ≥ 500 to highlight all stream within the threshold value. Identifying the threshold is depending on the accuracy of raster data, and the scale of work, Therefore, it is crucial to be careful when select the threshold area, the minimum limit of threshold means more generated stream and vis versa. All cells more than or equal 500 having value (1) and all cells less than 500 having no data (0). Figure25. Stream links Maidment, D. R., & Morehouse, S. (2002).

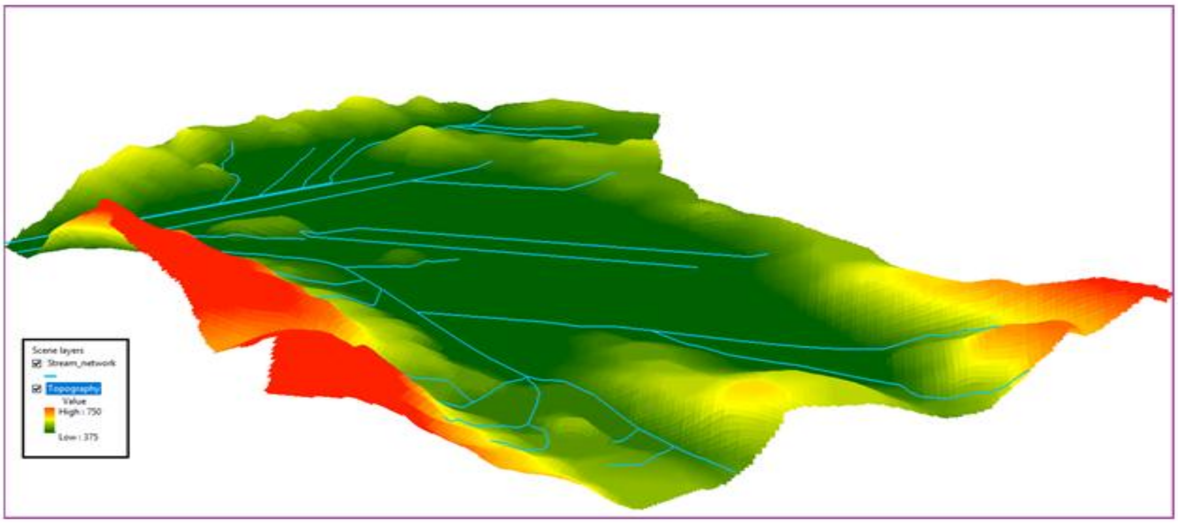


Figure 25: stream network in Sanour plain

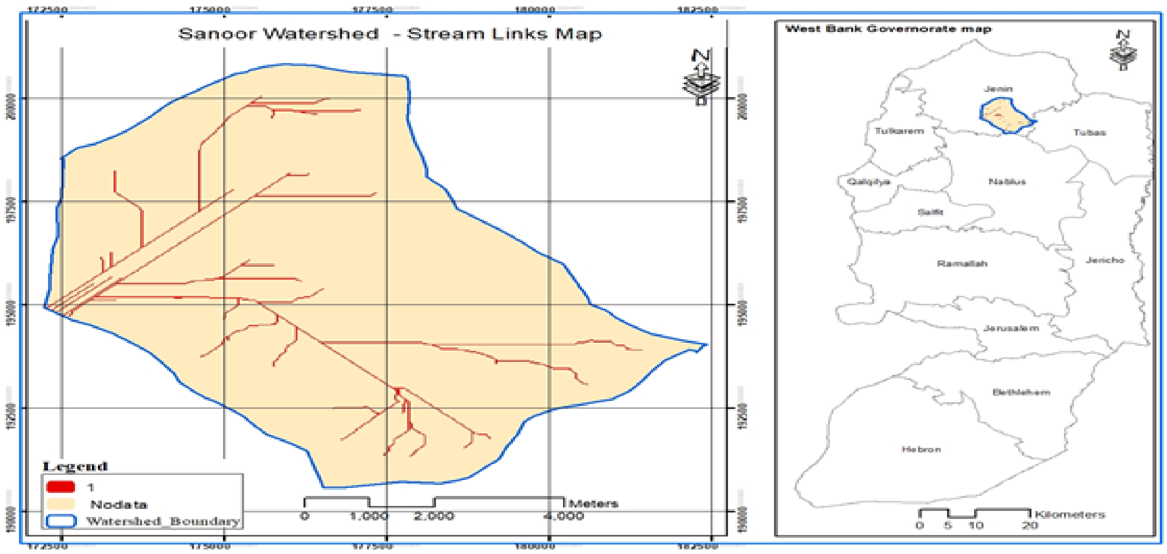
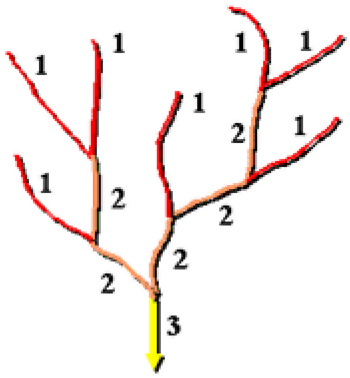


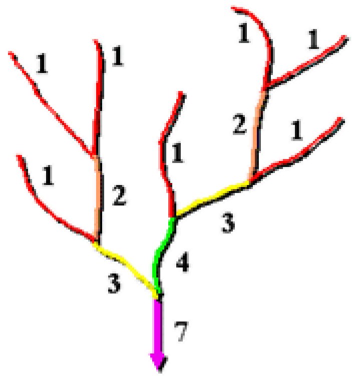
Figure 26: Stream Links

4.5.5.2 Stream Order

Stream order is defined as the process of assigning numeric value to the streams network the purpose of this method is to classify and identify the type of streams according to the numbers of attributes, first order stream is describing by overland of water flow, with no upstream concentrated flow, and there is no effective source of pollution problems usually occurred. Stream order tool was used to create and assign the order for the stream network, this method was proposed by the scientists Strahler (1957), Shreve (1967). Both methods are classifying the upstream segments or the exterior links and assigned them as order 1.



Strahler Ordering method



Shreve Ordering method

Figure27: methods of stream principal

<u>Strahler method</u> is the most widely used one, this method only increases the order at the intersection of the same one, the inter section of two stream having the first order link will create second order link, intersection of two second order will give a third order links, and so on. The intersection of two different links orders, however, will not result in an increase in order, that's means the intersection of first order with the second order stream will not create a third order link and will retrain the order of the highest order link.
<u>Shreve method</u> accounts all external stream link, dealing with them as Strahler method by assigning then in order 1, regarding the interior links, in Shreve method the order is additive, the intersection of two first order links give second order, the intersection of first order with the second order gives third order and the intersection of second order with third order gives fifth order.(Ogden, et al ,2001).

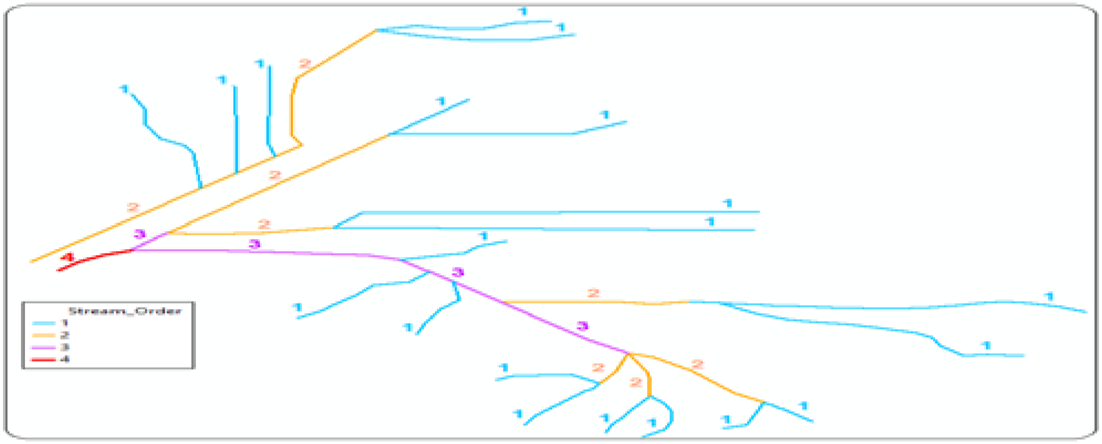


Figure28 : stream order

Table 11: Stream order and length according to Strahler classification.

Stream Order	Count of Segments	Length in (M)
1	48	36765
2	23	15582
3	4	5825
4	1	790

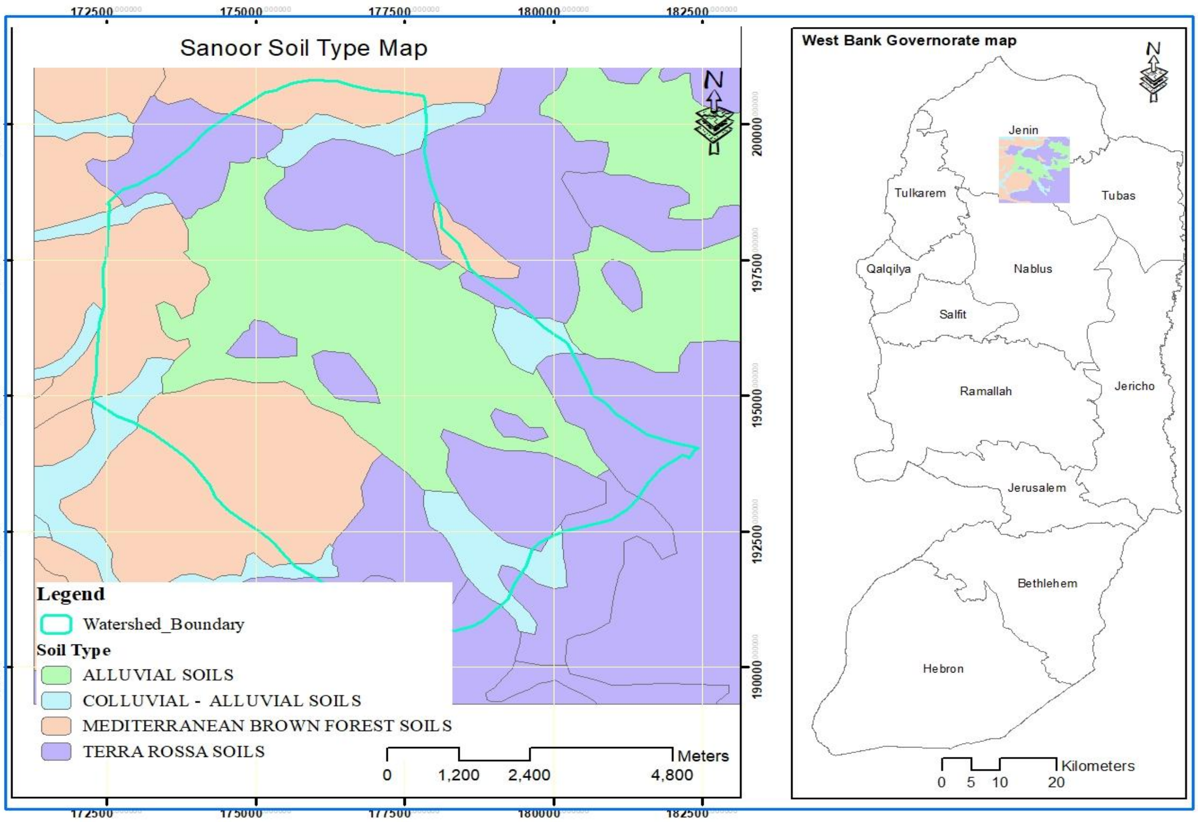


Figure29: Sanour Soil type**.**

4.6 Hydrological Soil Group (HSGs):

Soils were originally assigned to hydrologic soil groups based on measured rainfall, runoff, and infiltrometer data (Musgrave 1955). Soils infiltration rate is varying widely and affected by the permeability of the subsurface as well as the surface intake rates. Factors that affect the minimum infiltration rate for a specific surface are mainly; the soil type, soil texture, structure, degree of swelling, degree of water Saturation and soil depth. Soil texture, which describes the percentage of silt, sand and clay minerals that performing any soil type, SHG's are defined according to SCS standards of United State Department of Agriculture, USDA, according to these conditions Soils were classified into four main hydrological group. Table12 and Figure30

Table12: Soil Hydrological Group (NRCS, USDA, 1974)

Hydrologic Soil (HSG)	Soil textures	Runoff potential	Water transmission	Final infiltration (mm)
Group A	Deep, well drained sands and gravels	Low	High rate	> 7.5
Group B	Moderately deep, well drained with Moderate	Moderate	Moderate rate	3.8–7.5
Group C	Clay loams, shallow sandy loam, soils with moderate to fine textures	Moderate	Moderate rate	1.3–3.8
Group C	Clay soils that swell significantly when wet	High	Low rate	< 1.3

For identifying the percentage of sand, silt and clay in the sample, the soil texture triangle below illustrates the process of identifying the soil type. Soil texture classification is determined by the intersection of the three lines of the triangle. For example, if your sample has 50% clay, 30% silt, and 20% sand, then your sample is "clay."

- ❖ Clay is a very fine particle. When it is dry it is very hard, water cannot flow through. .
- ❖ Sand provides soil with air spaces and pathways for water to flow
- ❖ Silt is a light particle that erodes easily, but makes for good farm land.
- ❖ Loam is a "perfect soil" that is an even mix of all three soil separates.

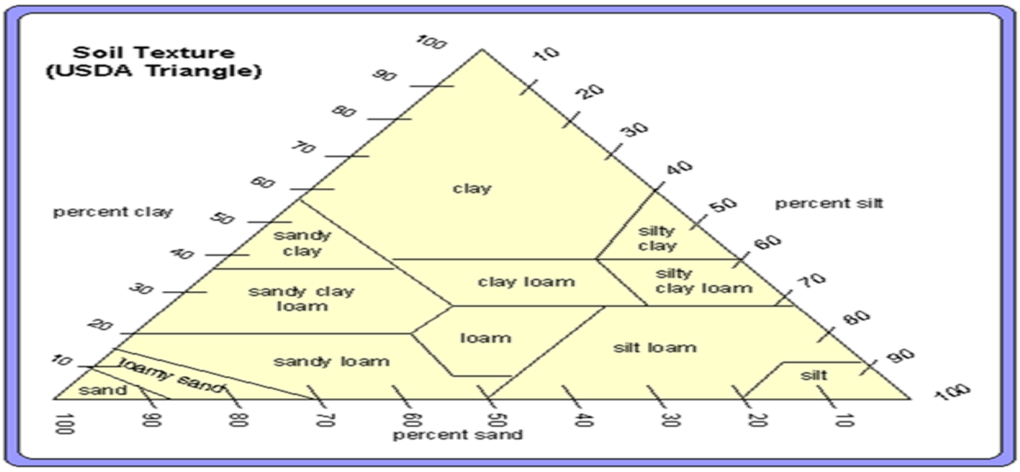


Figure30: Soil Texture Triangle, USDA soil texture classification

4.7 Soil Conservation Services (SCS) Method:

Runoff flow has two main elements: First is the base flow which is originated from groundwater, and the second one is surface runoff, which is the accumulation of rainfall that drains to the stream. The basin characteristics elements which affects the base flow and the surface runoff include soil properties geology formations, land cover cover, precipitation, drainage area and antecedent moisture condition (Bouwer, 1986; Zech et al., 1994; Bellal et al., 1996).

Soil Curve Number Method (SCS)is a simply, widely and effective method for determining the runoff amount from intensive rainfall event over a particular area, although the method was designed for a single storm event, it can be scaled to find the average annual runoff values. The main inputs for this method are the rainfall data and runoff coefficient (CN). The curve number is mainly based on the properties of hydrological soil group (HSG's) and surface land cover.

SCS-CN method was developed in (1954) by United State Department of Agriculture-Natural resources conservation services (USDA-SCS), which is defined by the national engineering handbook (NEH4 SCS,1985) Section of hydrology. Subsequent revisions followed in 1956, 1964, 1965, 1971, 1972, 1985, and 1993 (Ponce and Hawkins 1996). In 1994.

Soils Conservation Services –Curve number (SCS-CN,1972) is the approach that was applied for estimating the approximately amount of runoff over Sanour watershed. This method is focusing on the important properties of the watershed, specifically soil permeability, land use and the antecedent soil moisture conditions, these method was recognized with the name of Natural Resources Conservation Services(NRCS).

Curve Number (CN) is mainly based on the properties of hydrological soil group (HSG's) and land cover surface, ranges between 0-100, The low value of curve number means low runoff and high infiltration rate (dry soil), while the high value of curve number means high runoff and low infiltration rate (urban areas), using GIS tools makes the process of determining the CN is so easy through the intersection of the soil with land cover shape files

The following equation below illustrated the calculation mechanism for all variables related to the SCS-CN method including initial losses (Ia) (evaporation, evapotranspiration, water intercepted by vegetation, water retained in surface depression and infiltration), S = potential maximum retention or infiltration, and λ = initial abstraction ratio or coefficient and accumulative curve number sub-areas with different soil types and land covers.

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$ (Equation 1)

For P > 0.2 S; otherwise Q = 0

$$Ia = 0.2\,S$$ (Equation 2)

Where Q = accumulated runoff volume (inches)
P = accumulated precipitation (inches)
S = maximum soil water retention
Ia is the initial loss (mm)

$$Fa = \frac{S\,(P - Ia)}{(P - Ia) + S}$$ Fa: infiltration (Equation 3)

$$S = \left\{\left(\frac{1000}{CN}\right) - 10\right\}$$ (when Q, P, S are in inches) (Equation 4)

$$S = \frac{25400}{CN} - 254$$ (*S* is in mm) (Equation 5)

$$CN_{aw} = \frac{\sum_{i=1}^{n}(CN_i * A_i)}{\sum_{i=1}^{n} A_i}$$ (Equation 6)

Where: CN_{aw} = the area-weighted curve number for the drainage basin;
CN_I = the curve number for each land use-soil group polygon;
A_i = the area for each land use-soil group polygon;
n = the number of land use-soil polygons in each drainage basin.

Antecedent moisture condition equations

$$\textbf{CN I dry} = \frac{4.2 \times CN}{10 - 0.058 \times CN}$$ (Equation 7)

$$\textbf{CN III wet} = \frac{23 \times CN}{10 - 0.058 \times CN}$$ (Equation 8)

Where CN is the runoff curve number under (AMC II) normal conditions,
CN dry is the equivalent runoff curve number under (AMC I) dry conditions,
and CN wet is the equivalent runoff curve number under (AMC III) wet conditions

Tables13 below identifying the value of curve number for antecedent soil moisture condition AMCII (average moisture condition) and the adjustment process to calculate the AMCI under dry condition and AMCIII Under the wet condition.

Table 13 :Adjusments to select curve number for soil moisture conditions

Curve Number (AMC II)	Factors to Convert Curve Number for AMC II to AMC I or III	
	AMC I (dry)	AMC III (wet)
10	0.40	2.22
20	0.45	1.85
30	0.50	1.67
40	0.55	1.50
50	0.62	1.40
60	0.67	1.30
70	0.73	1.21
80	0.79	1.14
90	0.87	1.07
100	1.00	1.00

Source: Ward, Andy D.; Trimble, Stanley W. (2004).

4.8 Field Works:

4.8.1 Construction of ponds

In 2015, the Ministry of Agriculture carried out a water harvesting project in the Sanour plain area and established 20 agricultural ponds to reduce the flood of the land in the plain of Sanour.

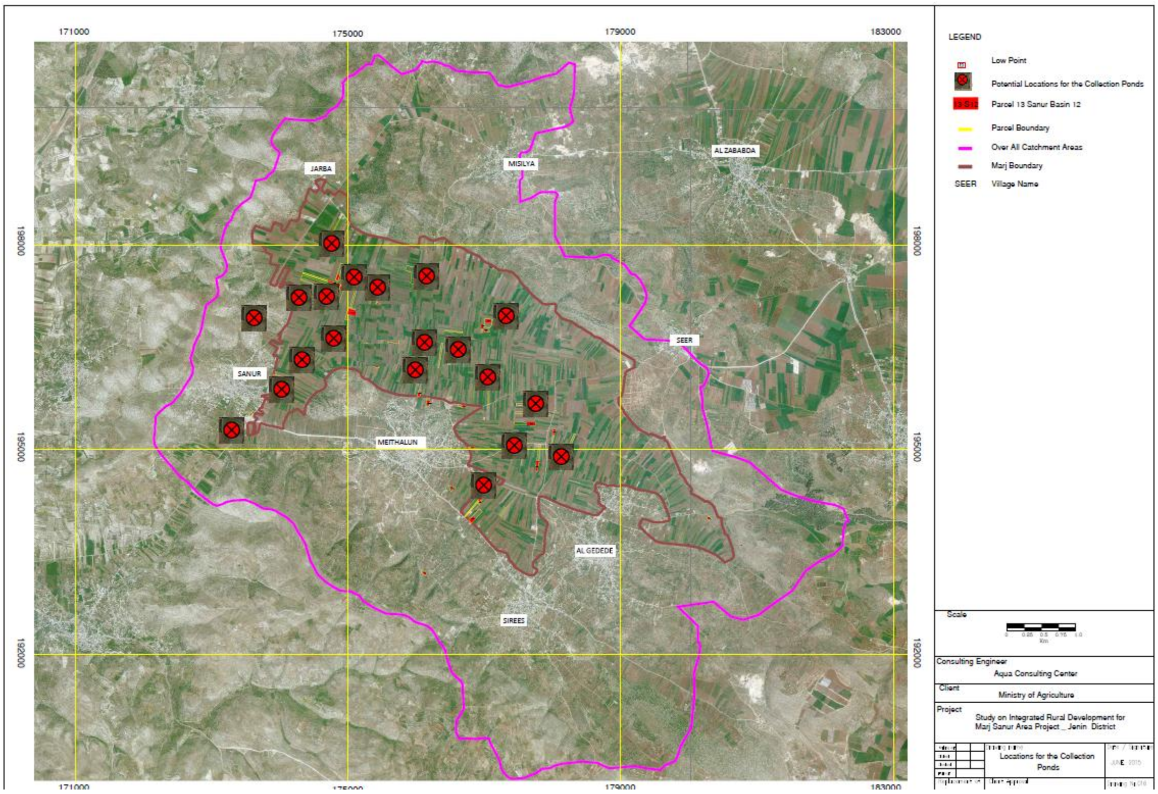


Figure31: pond location in Sanour plain.

Table 14: lists the names and locations of ponds and the engineering design size of each pond

number	Ponds name	Name of sub-basin	Coordinate (x)	Coordinate (y)	Volume design
1	Aisha hosen	Sanour plain	175402.23	196868.93	10650
2	Adnan kmail	Sanour plain	175396.358	196778.36	5508
3	Bilal rabaia	Southern slopes (Maithaloon)	175977.155	197931.007	4500
4	Mohamad hoseen	South-East(Alnasrani,Seres)	174393.192	197312.962	4125
5	Adnan nerat	Southern slopes (Maithaloon)	175336.526	1976355.501	4350
6	Jamal wild ali	Sanour plain	174130.897	196025.465	5143
7	Foad thiab	Southern slopes (Maithaloon)	175623.107	196628.161	9402
8	Ahmad nerat	Southern slopes (Maithaloon)	174211.514	195682.321	1233
9	Abdelsalam nerat	Southern slopes (Maithaloon)	175475.299	196898.561	1689
10	Kamel kmail	Sanour plain	175977.150	197931.007	15800
11	Yaesh danof	Sanour plain	175677	19831	2493
12	Riyad ayasi	Sanour plain	174389.380	196559.324	5166
13	Mahmod ayasi	Sanour plain	175475.414	197128.503	4620
14	Marof rabaya	Southern slopes (Maithaloon)	177007.320	194550.659	999
15	Ahma nerat	Southern slopes (Maithaloon)	176881.259	194491.699	1590
16	Osama nerat	Southern slopes (Maithaloon)	176532.741	194446.883	322
17	Mohamad abd elghafor	Southern slopes (Maithaloon)	176646.072	196582.61	7123
18	Jihad wild ali	Sanour plain	175413.785	197193.455	8945
19	Hamdan Sali7	Misslya-almilk	177601.355	196860.463	5483
20	Abd eljabar ayasi	Sanour plain	175132.149	196419.005	5346

4.8.2 Sites visits

Rainfall event of 16/2/2018 (468 mm)

On the 16/2/2018 the amount of precipitation was 486 mm and the water volume in the ponds and annexes was calculated in Table 15. There is an indicator in each pond divided from 1 meter to 4 meters in order to know the water level in each pond. The sample of rain water in ponds had been taken for required test in the lab.

Table 15 : Actual volume water collected

Number	Ponds name	Parcel number	Block number	Volume collected	Percentage collected %
1	Aisha hosen	S 13	45	4570.833	42
2	Adnan kmail	S 13	51	1930.667	35
3	Bilal rabaia	Ms 11	31	1623.333	36
4	Mohamad hoseen	S 12	20+21+22	3066.667	74
5	Adnan nerat	J4	24+25	3450	79
6	Jamal wild ali	S6	68	2606.25	50
7	Foad thiab	M4	39	5627.25	59
8	Ahmad nerat	Sr5	133	1233	100
9	Abdelsalam nerat	S13	80	1623	96
10	Kamel kmail	Ms11	67	2020	12
11	Yaesh danof	M3	79+80	2493	100
12	Riyad ayasi	S6	32	1168	46
13	Mahmod ayasi	S13	41	2880	62
14	Marof rabaya	M11	64	975	97
15	Ahma nerat	M11	77	1232	77
16	Osama nerat	M11	119	322	100
17	Mohamad abd elghafor	M3	91	5782.5	81
18	Jihad wild ali	S13	21	3705	41
19	Hamdan Sali7	Ser 17	50+51	3100	56
20	Abd eljabar ayasi	S7	7+8+9	3217.5	60

16/2/2018

Sampiling location in ponds is provided:

1- S6 , 32
2- S7, 7.8.9
3- S13, 45
4- S13,51
5- S13,80

The project was visited on 19/2/2018. It was observed that the water level decreased 4 cm. The project was visited on 23/2 2018 It was noticed that the water level was decreased 2 cm.

Rainfall event of 02/03/2018 (468 mm)

On 2/3/2018, the rainfall rate was 468 mm and the water volume in the ponds in Table 16.

Visit the project on 9/3/2018 and the water level in the ponds decreased by 6 cm.

Table 16: actual water volume collected

Number	Ponds name	Parcel number	Block number	Volume collected	Percentage collected %
1	Aisha hosen	S 13	45	3100	29
2	Adnan kmail	S 13	51	1620	29
3	Bilal rabaia	Ms 11	31	1410	31
4	Mohamad hoseen	S 12	20+21+22	2720	65
5	Adnan nerat	J4	24+25	2720	62
6	Jamal wild ali	S6	68	2310	44
7	Foad thiab	M4	39	5300	56
8	Ahmad nerat	Sr5	133	1233	100
9	Abdelsalam nerat	S13	80	1370	84
10	Kamel kmail	Ms11	67	1870	11
11	Yaesh danof	M3	79+80	2330	93
12	Riyad ayasi	S6	32	920	17
13	Mahmod ayasi	S13	41	2550	55
14	Marof rabaya	M11	64	640	64

15	Ahma nerat	M11	77	940	59
16	Osama nerat	M11	119	322	100
17	Mohamad abd elghafor	M3	91	5210	73
18	Jihad wild ali	S13	21	3200	35
19	Hamdan Sali7	Ser 17	50+51	2820	51
20	Abd eljabar ayasi	S7	7+8+9	2950	55

25-26/4/2018 Rainfall 516 mm

The site was visited on 27/4/2018. The volume of water in the ponds and annexes was measured in the following table.

Table 17: actual water volume collected

Number	Ponds name	Parcel number	Block number	Volume collected	Percentage collected %
1	Aisha hosen	S 13	45	10650	100
2	Adnan kmail	S 13	51	5508	100
3	Bilal rabaia	Ms 11	31	4500	100
4	Mohamad hoseen	S 12	20+21+22	4125	100
5	Adnan nerat	J4	24+25	4350	100
6	Jamal wild ali	S6	68	5143	100
7	Foad thiab	M4	39	9402	100
8	Ahmad nerat	Sr5	133	1233	100
9	Abdelsalam nerat	S13	80	1623	100
10	Kamel kmail	Ms11	67	15800	100
11	Yaesh danof	M3	79+80	2493	100
12	Riyad ayasi	S6	32	5166	100
13	Mahmod ayasi	S13	41	4620	100
14	Marof rabaya	M11	64	999	100
15	Ahma nerat	M11	77	1590	100

16	Osama nerat	M11	119	322	100
17	Mohamad abd elghafor	M3	91	7123	100
18	Jihad wild ali	S13	21	8945	100
19	Hamdan Sali7	Ser 17	50+51	5483	100
20	Abd eljabar ayasi	S7	7+8+9	5346	100

Attached pictures during the visit to the place of the Ministry of Agriculture project and taking water samples from the ponds and measuring the volume of water in the ponds.

Figure 32: suggestion construction pond was built in Sanour plain 2015

Chapter Five

Results:

5.1Division Sanour plain basin:

The geographic information system (GIS) and the digital elevation model are used to determine the Sub-basin boundaries, and the related SCS-CN is used to determine the surface runoff taking can use and soil classification, were slope and rainfall intensity to estimate the runoff. Non-executing areas (residential areas) were also estimated in each sub-basin.Based on this method, and guided by the tables of the Soil Conservation Department of the US Department of Agriculture (SCS), the study area classified into (SCS CN) for each sub-basin was estimated as in the table below Soulis, K. X., & Valiantzas, J. D. (2012).

As a result of DEM analysis using ARCMAP 10.2 software, the topographic map is developed for the basin, the basin is divided into 40 sub-basins that have been numbered and named for differentiation as figure 36 shows. The methodology describe in paragraph is used to definition sub-basin where 8 individual main sub catchment areas .Each sub catchment contain small sub basins Figure 33 illustrate The main sub catchment ,and small sub basin defined information about each sub catchment show in table 18.

Table18: Land use in the resulted sub catchments (area in donum):

Number	Name of sub-catchment	Land				Total Area	SCS CN
		Forest	Built up areas	Olives	Crop Field		
1	South-West (Alsarar) - Sanour	0	3,070	4,220	382	7,639	74.0
2	Misslya-almilk	317	832	4,560	841	6,489	68.5
3	Western slopes (north of Sanur)	351	0	980	0	1,319	66.8
4	Northern slope(South mislay,Seer)	682	61	5,522	464	6,713	65.2
5	North-East (FIFA)	655	0	1,999	201	2,848	67.3
6	South-East (Alnasrani,Seres	1350	1,971	8,511	485	12,302	69.1
7	Southern slopes (Maithaloon)	225	639	3,671	0	4,532	66.8
8	Sanour plain	301	0	978	14,591	15,860	77.1
	Total basin	3,881	6,573	30,441	16,963	57,701	71.1

- **One donum =1000 m^2**

The study area is divided into eight sub catchment with respect vegetation diversity for each area in terms of Built up areas and existence of forests, olive trees, and field crop. Whereas each area was measured, it being noted that Southern slopes (Maithaloon) was the smallest area and Sanour plain was the largest area. After computing the Scs for eight sub catchment areas , it's been observed that the maximum value of Scs was found on sanour plain , while the minimum value of Scs wsa found on Northern slope (South mislay,Seer) , the total value for each was 71.1

Table19: Calculated soil curve number Adjustment and Show curve number hydrological Soil group**.**

number	Name of sub-basin	SCS CN Calculated	**SCS-CN Adjustment**	**Curve number hydrological soil group**
1	South-West (Alsarar) - Sanour	74.0	**75**	**B**
2	Misslya-almilk	68.5	**70**	**C+B**
3	Western slopes (north of Sanur)	66.8	**70**	**C+B**
4	Northern slope(South mislay,Seer)	65.2	**65**	**A+C**
5	North-East (FIFA)	67.3	**70**	**B**
6	South-East(Alnasrani,Seres)	69.1	**70**	**B+C**
7	Southern slopes (Maithaloon)	66.8	**65**	**A**
8	Sanour plain	77.1	**85**	**D**
	Total basin	71.1	**71.25**	

- We make adjustment SCS –CN when the study area is wet
- Description and Curve Numbers table

The value of curve number for dry soil is calculated , then SCS-CN Adjustment is carried out according to the nature of study area.

Soil is classified according to infiltration rate to four groups (a,b,c,d) on the basis of Curve number hydrological soil group , taking into consideration the existence of areas diversity in terms of the overlapping in nature land . There are areas where have red soil and residential area, and areas have forests and red soil, and so on. And because that, it's been observed that the maximum value of SCS-CN was been in Sanour plain and the minimum values were been in mislaya, Seer and Maithaloon.

Table20: Area of sub basin and annual runoff.

Number of basin	Sub basin name	Area of Sub basin /dunom	Annual Runoff/ 1000 M^3
1	South-West (Alsarar) - Sanour	**A26=7638.5**	**1261**
2	Misslya-almilk	**A4+A5+A6+A7+A8+A9=6224.5**	**863**
3	Western slopes (north of Sanur)	**A10+A11+A28+A27 =1318,7**	**172**
4	Northern slope(South Mislay,Seer)	**A1+A2+A3+A12+A13+A30+A31 +A32+A34+A35=7457.4**	**813**
5	North-East (FIFA)	**A14+A15=2847.8**	**372**
6	South-East(Alnasrani,Seres	**A16+A17+A18+A19+A20+A21 +A22+A33=12301,2**	**1656**
7	Southern slopes (Maithaloon)	**A23+A24+A25=4531.9**	**567**
8	Sanour plain	**A29+A36+A37+A38+A39+A40=161 23.3**	**3032**
	Total basin	**58443.3**	**8745**

The study area was divided in terms of surface area with respect for the property for easy calculations and the distribution of suitable places for water harvesting techniques , having regard to landownership , it's been observed that sanour plain covers the largest area of 16123.3 dounom and the Annual Runoff is 3032000 cubic meters , while Maithaloon covers the smallest area , with an Annual Runoff of 805000 cubic meters .The total basin of Annual Runoff is 8745000 cubic meters , where it flow into the sanour plain .

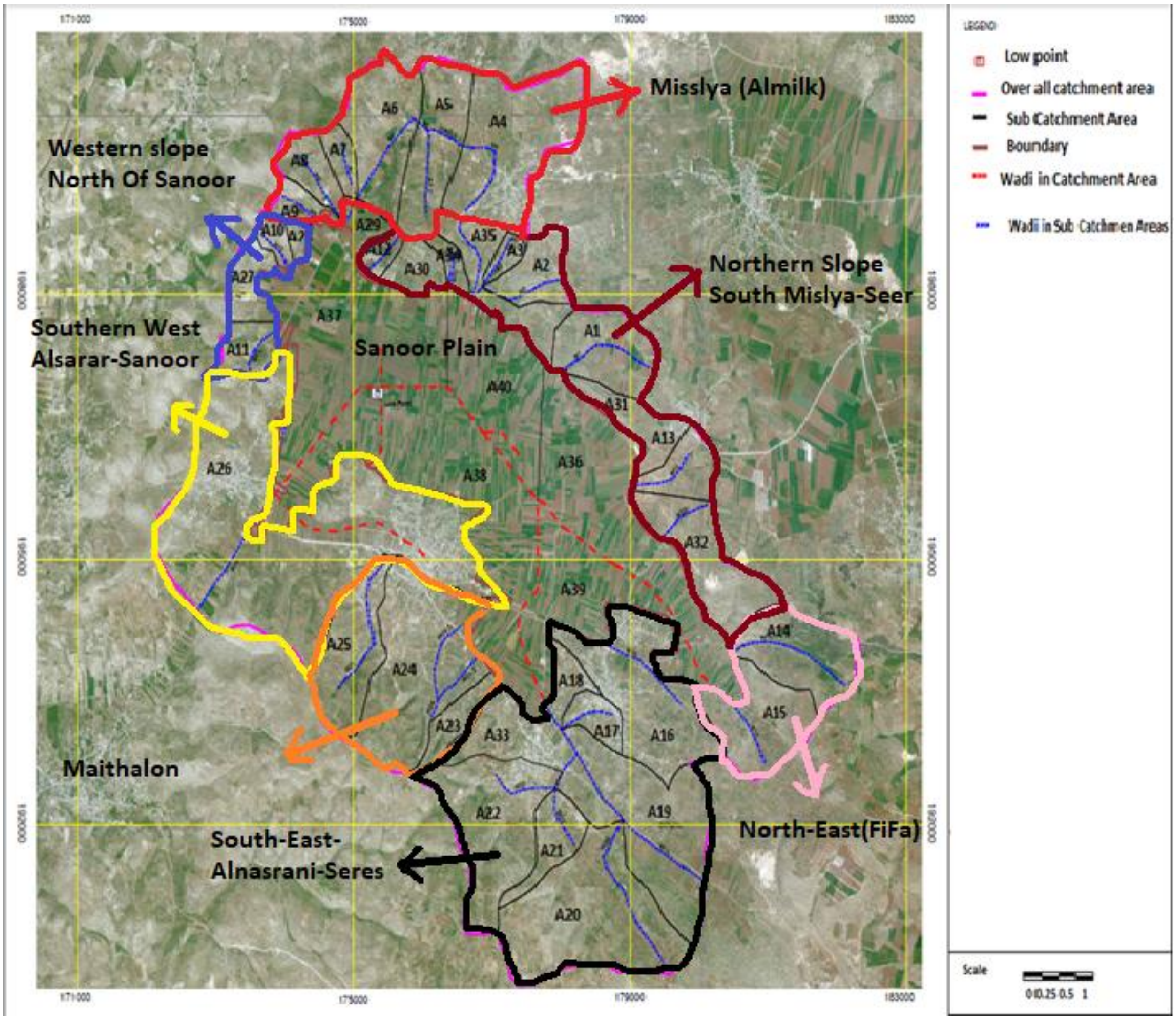


Figure33: 8basin, and 40 small catchment area from A1-A40).

The catchment area divided into 8 sub catchment according to figure 36

1- Direction of slope
2- Land use
3- Soil type
4- Rainfall value
5- Basin area

The 8 sub catchment are sub-divided into 40 small sub basins area based on stream direction and possible surface water collection, where Sc-CN method is applied. Depending on the result of this division 40 small catchment area are identified.

Table 25 summarized the total area of each sub basin and the SC-CNs range between 65 and 77.which indicate the Curve number hydrological soil group (clay)

Based on the hydrological study and using the daily rainfall for the periods (1953/1954) and (2018/2019), the monthly runoff rates obtained from each valley were estimated and the results summarized in the following tables:

5.2-Monthly runoff depth:

The monthly runoff was estimated in millimeters and the monthly runoff rate was calculated for each sub-basin. It was noted that the runoff rate reached about 10 mm during the month of January 10% of the monthly rainfall. The annual runoff is about 40 mm, 6.5% of the annual rainfall.

5.3-Annual and monthly runoff volumes:

The calculations was used in 1991-1992 was exception to estimate the monthly and annual runoff rate Table 24, the standard deviation table 23 and the maximum values for monthly runoff table 24 the exception was that the rains of 1991/92 were exceptional and extreme.

Figure 35 shows the large variation in annual runoff amounts during the period from 1954/1953 to 2018/2019. The annual runoff for the year 1992/1991 was estimated at 15 million cubic meters. If this year is excluded, The annual runoff ranged from about zero to 8 million cubic meters per year. At a rate of about 2.3 million cubic meters, the standard deviation of annual runoff was around 2.1 million cubic meters, indicating a very large variation in the runoff from year to year.

Table 23 indicates that the highest monthly runoff rate was during January about 0.9 million cubic meters, while the highest monthly runoff during January was about 7 million cubic meters, which indicates that the runoff could drop to one month (December, January and February). At the same time, drought can occur during the rest of the year, so water storage will be of great benefit to agricultural development in the region.

Table 21: Monthly and annual runoff volumes per thousand cubic meters of sub-basins

Number	Name of Sub-basin	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Annual
1	**Southern west**	0.0	0.0	38	116	138	71	27	3	3	396
2	**Mislya**	0.0	0.0	25	75	91	42	14	2	0	249
3	**Western slope**	0.0	0.0	6	14	20	13	5	0	0	58
4	**Northern Slope**	0.0	0.0	21	77	78	47	6	0	0	229
5	**Northern east**	0.0	0.0	14	35	41	23	9	1	0	123
6	**Southern East**	0.0	0.0	48	136	160	77	32	2	2	475
7	**Southern Slope**	0.0	0.0	18	55	62	31	8	0	0	174
8	**Sanour plain**	0.0	3	85	271	341	169	66	6	5	946
	Total	0.0	3	255	779	931	473	167	14	10	2650

The runoff volumes should be calculated daily, monthly and annually to closely design water harvesting techniques and determine the type and capacity of each technique. In table21, the runoff volume for the study area has been calculated monthly and yearly. It has been noticed that January is the most common month on which runoff has happened and in sanour plain of 341000 cubic meters while May is the month on which the less volume of runoff has happened, and there is no runoff in September.

Table 22: Standard deviation of monthly runoff in thousand cubic meters of sub-basins

Number	Name of Sub-basin	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Annual
1	Southern west	0.0	5	94	214	232	147	47	16	8	361
2	Mislya	0.0	3	67	152	172	107	36	7	5	221
3	Western slope	0.0	0	16	36	37	23	8	2	0	49
4	Northern Slope	0.0	4	67	147	167	97	29	5	3	201
5	Northern east	0.0	0	33	74	71	47	13	7	4	95
6	Southern East	0.0	5	129	281	313	207	52	13	8	431
7	Southern Slope	0.0	2	51	101	104	97	19	5	5	148
8	Sanour plain	0.0	12	224	494	523	347	117	39	27	721
	Total	0.0	31	681	1499	1619	1072	321	94	60	2227

Standard deviation is a measure of the deviation of data set from arithmetic mean. It is a key risk indicator in which the analysts used to avoid problems in designing water harvesting. The difference in standard deviation value in runoff of the study area has been found. the highest value of standard derivation is 7210000 cubic meter in sanour plain annually while in January, the highest value of standard derivation is 523000 cubic meter in sanour plain .

Table 23: Maximum monthly and annual runoff volumes per thousand cubic meters of sub-basins:

Number	Name of Sub-basin	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Annual
1	Southern west	0.0	29	523	841	1051	816	197	81	61	1261
2	Mislya	0.0	15	398	597	762	594	131	46	36	863
3	Western slope	0.0	5	81	118	154	116	31	9	8	172
4	Northern Slope	0.0	11	379	544	746	552	117	31	19	813
5	Northern east	0.0	6	172	261	331	253	61	17	13	372
6	Southern East	0.0	25	754	1138	1452	1146	251	79	52	1656
7	Southern Slope	0.0	9	271	394	518	398	90	25	16	576
8	Sanour plain	0.0	71	1156	1944	2447	1845	472	236	164	3032
	Total	0.0	171	3734	5837	7461	5720	1350	524	369	8745

The maximum annual runoff volumes has been calculated and distributed over the months. The Maximum runoff volume formed in November to February, and January, on which the value of runoff is higher than the others particularly in Sanour plain and south-western side of sanour plain.

Table 24: Annual runoff volumes of sub-basins per thousand cubic meters for the year 1992/1991:

Number	Name of Sub-basin	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Annual
1	Southern west	0.0	0	93	585	414	1015	0	0	0	2107
2	Mislya	0.0	0	49	384	280	693	0	0	0	1405
3	Western slope	0.0	0	8	72	53	131	0	0	0	264
4	Northern Slope	0.0	0	36	336	252	625	0	0	0	1249
5	Northern east	0.0	0	19	158	117	289	0	0	0	583
6	Southern East	0.0	0	98	747	542	1344	0	0	0	2731
7	Southern Slope	0.0	0	29	247	182	452	0	0	0	910
8	Sanour plain	0.0	0	247	1399	977	2373	0	0	0	4996
	Total	0.0	0	580	3927	2816	6923	0	0	0	14245

1991\1992 is indicated in this study because it is an exceptional year where the rainfall amount reached 1200mm. it is important to take this year into account to mainstream the process of selection of water harvesting sites and its capacity to mitigate the risk of drowning . It has been noticed that February ,on which the value of runoff is higher than the others by 6923000 cubic meter . in 1991 , the total runoff was about 14,245,000 cubic meter .(MOA-SP ,2015)

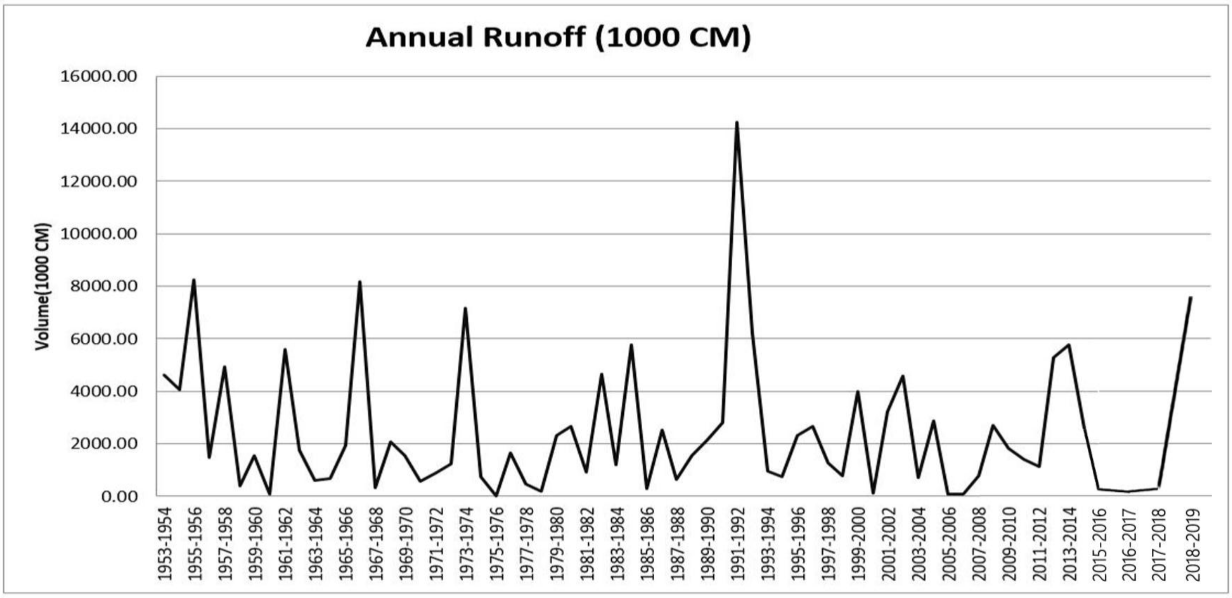


Figure 34: Annual runoff in the Sanour plain basin in thousand cubic meters during the period from 1953/1954 to 2018/2019

Runoff volume was been calculated from 1953 to 2019. 1991 was the year where there has been the grates runoff by 14000000 cubic meter, followed by 1957 and 1966 by about 8000000 cubic meter, then 1972 by about 7600000 cubic meter, and 2013 by about 600000 cubic meter and 2019 by about 8000000 cubic meter

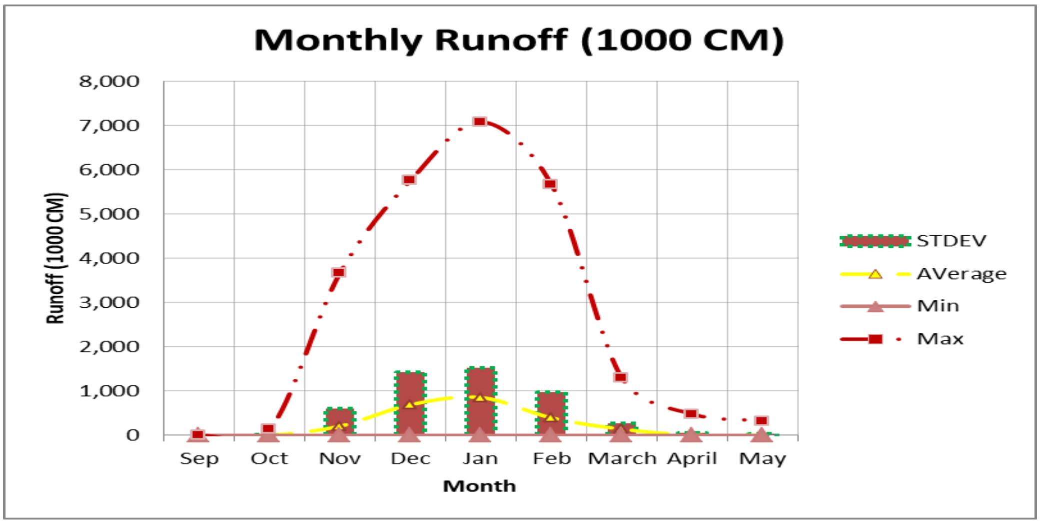


Figure 35: Average, minimum and upper values and standard deviation of monthly runoff per thousand cubic meters of Sanour plain. (1953 – 2019)

This chart shows standard deviations, average, and minimum and upper values of runoff occurring at a month. It has been noticed that the highest value happened in January by about 2000000 cubic meter and runoff is about 16000000 cubic meter, the best runoff value reached 7000000 cubic meter and the less value was in September and May.

Table 25: Average, median, standard deviation, and maximum and minimum monthly and annual runoffs of the grass basin in thousand cubic meters

Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Annual
Average	0.0	4	211	699	863	401	147	12	9	2346
Median	0.0	0	0	18	251	16	0	0	0	1611
standard deviation	0.0	21	605	1431	1523	984	271	67	46	2113
Minimum value	0.0	0	0	0	0	0	0	0	0	26
Maximum value	0.0	134	3673	5761	7088	5674	1293	482	326	8241
1991-1992	0.0	0	580	3927	2816	6923	0	0	0	14245

In this table , it has been used statistical analysis in terms of standard deviations , average , arithmetic mean and minimum and upper values of runoff in the study area in 1991 \1992 . Whereas the average value is 2346000 cubic meter, arithmetic mean from 1954 to 2019 is about 1611000 cubic meter , the minimum value of runoff is 26000 cubic meter , the upper value of runoff is about 82410000 cubic meter and the total value of runoff is about 14245000 cubic meter in 1991 .

5.4-Maximum daily runoff:

After calculating the daily runoff values, The day that have the maximum runoff during each month of the year for the examined period (66 years). The absolute maximum monthly runoff is shown in table 26.

Table 27 indicates that the maximum daily maximum runoff values in Sanour plain amount to about 0.5 million cubic meters, while the maximum daily runoff is about 6.6 million cubic meters. This indicates the large variation in the runoff and therefore the need to think about the impact of such runoff on the structures that can be built, it is not economically feasible to build facilities to store such large quantities.

Table 26: Average daily maximum runoff of sub-basins per thousand cubic meters

Number	Name of Sub-basin	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	Southern west	0.0	0.5	26.3	63.9	79.5	44.6	20.1	1.9	0.9
2	Mislya	0.0	0.4	17.2	43.0	52.3	29.3	11.3	0.8	0.4
3	Western slope	0.0	0.0	3.8	8.7	10.4	6.2	2.3	0.3	0.1
4	Northern Slope	0.0	0.2	15.1	38.6	46.1	24.9	9.5	0.6	0.4
5	Northern east	0.0	0.3	7.2	18.2	22.4	12.2	4.3	0.5	0.3
6	Southern East	0.0	0.4	32.9	83.4	102.1	55.8	21.4	1.8	0.8
7	Southern Slope	0.0	0.2	11.9	27.9	34.2	18.3	7.6	0.4	0.3
8	Sanour plain	0.0	1.4	63.4	150.2	191.1	107.1	48.5	2.9	2.8
	Total	0.0	3.4	177.8	433.9	538.1	298.4	125	9.2	6

Daily quantity of rainfall is used and distributed over months and the rate has been taken for precision work and design, risk mitigation during water runoff, the accurate process of selection and capacity of water harvesting sites. it's been observed that January ,on which the value of runoff is highest by about 531000 cubic meter and followed by December by about 427000 cubic meter . There is no runoff in September.

Table 27: Upper limits of daily maximum runoff of sub-basins per thousand cubic meters

Number	Name of Sub-basin	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
1	Southern west	0.0	23.8	518.2	498.2	918.1	483.3	185.0	52.9	36.2
2	Mislya	0.0	11.6	391.1	373.8	720.4	363.1	126.2	31.3	18.3
3	Western slope	0.0	1.9	77.4	73.4	144.1	72.2	24.9	5.8	4.0
4	Northern Slope	0.0	7.2	372.4	355.1	703.9	344.3	113.2	23.2	13.9
5	Northern east	0.0	4.4	167.4	160.1	311.3	155.2	54.2	12.8	7.1
6	Southern East	0.0	22.1	749.1	716.4	1376.5	696.3	243.5	59.7	37.4
7	Southern Slope	0.0	6.9	262.9	251.6	490.8	243.2	83.4	19.6	13.1
8	Sanour plain	0.0	63.1	1143.2	1099.3	1985.3	1068.6	427.5	133.1	92.1
	Total	0.0	141	3681.7	3527.9	6650.4	3426.2	1257.9	338.4	222.1

When designing water harvesting plants, it should be take into account upper limits of runoff in order to avoid the flaws in designing water harvesting plants and determine the size and capacity of water harvesting technique. In January, there has been an upper limit of runoff by about 6650000 cubic meter, followed by November by about 368100 cubic meter, then December by about 3527000 cubic meter. The most area where surface runoff is in area of sanour plain and the least area is northwest of sanour plain.

4-) Probabilistic distribution of runoff in the Sanour plain: Due to estimates of runoff in the Sanour plain for 66 years, these estimates were used to study the probability distribution of runoff in the Sanour plain. The probability distribution obtained from the 66-year period was compared with theoretical models of probability The most suitable probability distribution for runoff values was to include normal distribution, lognormal distribution and Gumball distribution using these probabilistic distributions, and then to estimate the maximum and frequency values once (2, 5, 10, 25, 50, 100 years) and displaying the results in the table (No. 28).

Table 28: Maximum and Minimum Annual Runoff**:**

Year	**Dry year**				**Wet year**			
Intensity	**Empirical**	**Normal**	**Lognormal**	**Gumbel**	**Empirical**	**Normal**	**Lognormal**	**Gumbel**
2	1,613	2,511	1,401	2,083	1,613	2,508	1,397	2,082
5	621	334	481	386	4,328	4,677	4,088	4,363
10	132	0	277	0	5,781	5,811	7,162	5,872
25	58	0	153	0	7,672	7,022	13,121	7,778
50	31	0	105	0	8,246	7,804	19,171	9,197
100	-	0	74	0	-	8,506	27,134	10,599

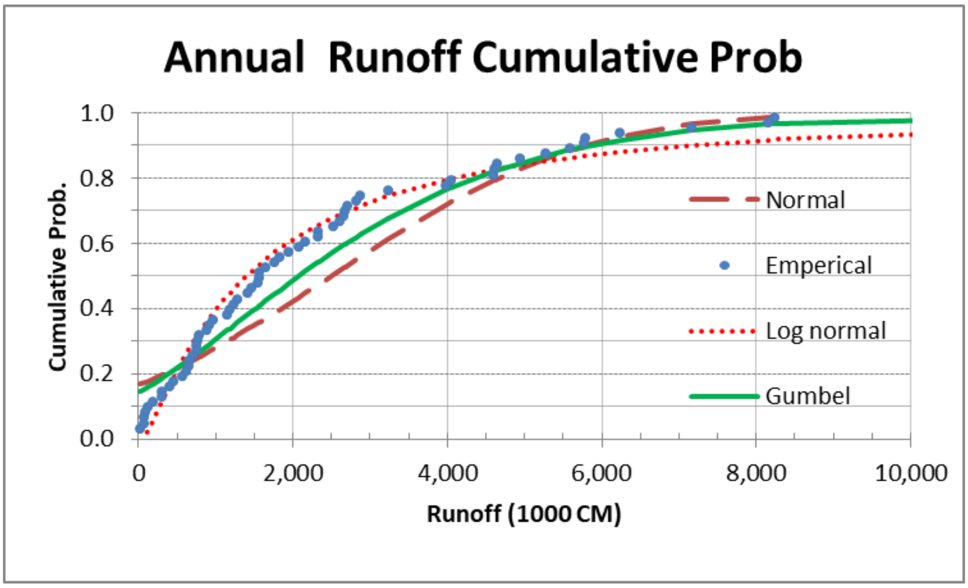


Figure 36: Probabilistic distribution of annual turf runoff per thousand cubic meters

Based on the figure 36, it is noted that the average annual runoff in the Sanour plain are 2.5 million cubic meters and 2.3 if excluded from 1991/92, the probability of such a value being less than 50%. Therefore, if we are to design a group the ponds can be filled at least once every two years (50%). The size of these ponds should not exceed 1.4 million cubic meters according to the lognormal distribution of the runoff in the Sanour plain 1.6 million cubic meters. From the observation of the minimum values of runoff in Table 28, we will notice that a runoff of no more than 0.477 million cubic meters is expected once every five years and we will receive a runoff of less than 0.27 million cubic meters once every 10 years.

Table29: Suggestion selected water harvesting pond in Sanour plain**:**

Pond number	x	y	Name of sub basin	ponds Volume (m^3)
1	175442.402	198193.150	Misslya-almilk	852000
2	175105.335	198109.851		
3	174915.903	198285.290		
4	175362.959	198009.028		
5	175953.174	197886.006		
6	174787.425	197851.488	Western slopes (north of Sanour)	165000
7	174999.610	197635.861		
8	175296.119	197600.324		
9	175964.201	197500.222		
10	174688.505	197555.295		
11	174916.754	197387.133		
12	174791.179	197283.582		
13	175361.070	197173.721	Sanour plain	301800
14	175434.912	197136.586		
15	174339.243	197263.259	South-West (Alsarar) - Sanour	600000
16	174737.372	197106.097		
17	174548.848	197052.625		
18	174734.659	196973.950		
19	175015.537	196861.818		
20	175272.897	196873.708	Sanour plain	301800
21	175445.089	196891.606		
22	175378.537	196749.943		
23	175548.396	196635.227		
24	174360.586	196717.244	South-West (Alsarar) - Sanour	600000
25	174637.431	196733.411		
26	174341.172	196484.618		
27	174311.154	196371.417		
28	175103.913	196347.291	Sanour plain	301800
29	174082.867	196024.983	South-East(Alnasrani,Seres)	164100
30	173969.730	195779.901		
31	176458.139	197051.522	Southern slopes (Maithaloon)	400000
32	176209.124	196521.884		
33	176629.131	196569.399		
34	177555.332	196806.166	Northern slope(South mislay,Seer)	100000
35	177744.126	196720.349		
36	176514.055	194450.139		
37	176987.111	194535.790		
38	176857.173	194497.603		
39	176741.054	194279.257		
40	176943.095	194108.845		

In table29, it has been proposed to establish 40 water harvesting ponds in the area study to mitigate from sinking land. it was suggested to establish 5 ponds in misslya-almilk where the total volume of ponds is about 852000 cubic meters , 6 water harvesting ponds in western slops (north of sanour) , with about 156000 cubic meters , 7 ponds in sanour plain , with about 301800 cubic meters , 9 ponds in south-west (alsarar)-sanour , with about 600000 cubic meters , 2 ponds in south east (Alnasrani , seres) , with about 164100 cubic meters , 3 ponds in southers slopes (Maithaloon) , with about 400000 cubic meters , 6 water harvesting ponds in northen slopes , with about 100000 cubic meters and the total open ponds is 40 and the volume of water harvesting ponds is 2943900 cubic meters .

Table30: Suggestion selected artificial recharge well in Sanour plain

Artificial recharge no	**Name of sub-catchment**	**x**	**y**
1	South-West (Alsarar) - Sanour	174372.706	197232.706
2		174742.506	196240517
3		175179.069	196187.6
4	Southern slopes (Maithaloon)	175814.071	195817.83
5		176634.281	195737.807
6		177097.302	195803.953
7	Northern slope(South mislay,Seer)	175271.647	197854.478
8		175575.945	197722.186
9		176131.571	197457.602
10		176607.822	197378.227

In table33, it has been proposed to establish 10 Artificial recharge wells to mitigate from sinking land, taking into consideration the selection of appropriate place of these wells in terms of pond fullness that close to these wells. The place of artificial recharges has been chosen to be in the most lowest places in sanour plain . These wells were distributed to the regions as follows: (Alsarar) – Sanour, Southern slopes (Maithaloon) and Northern slope (South mislay,Seer) . It is estimated that all artificial recharge wells fill up with water approximately 333000 cubic meters to replenish groundwater

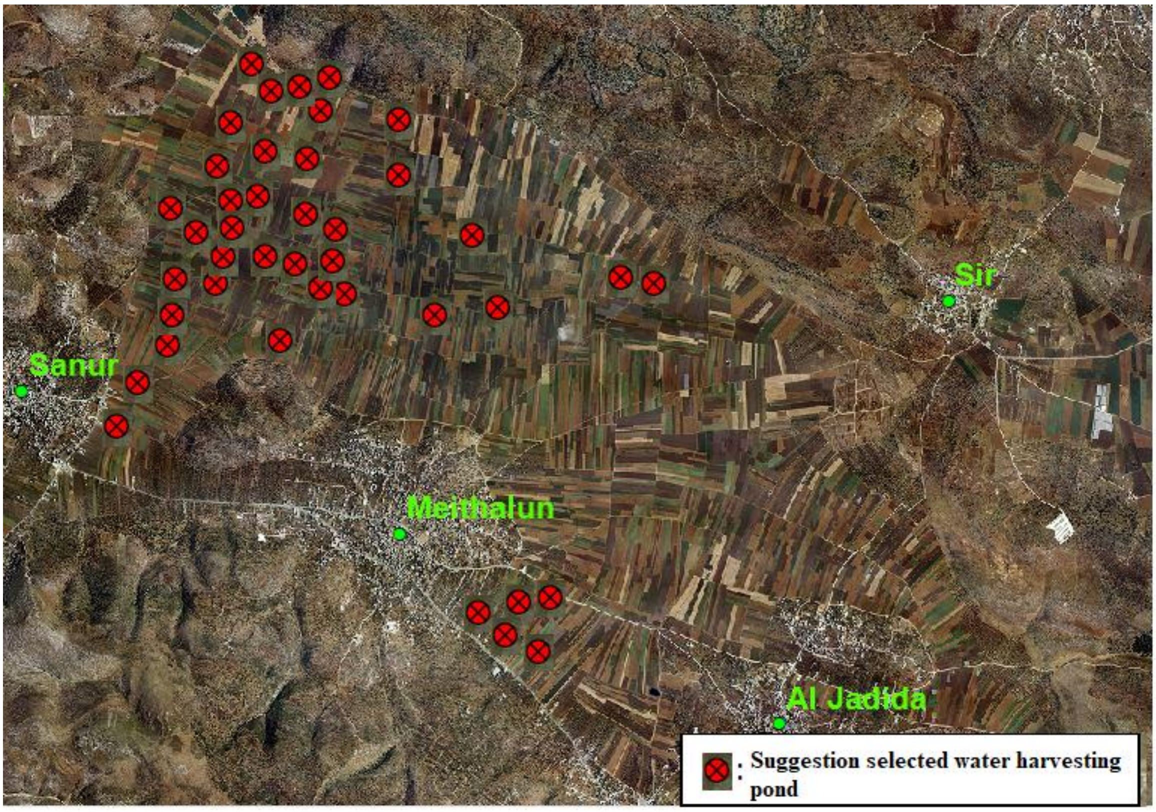


Figure:37 Suggestion selected water harvesting ponds

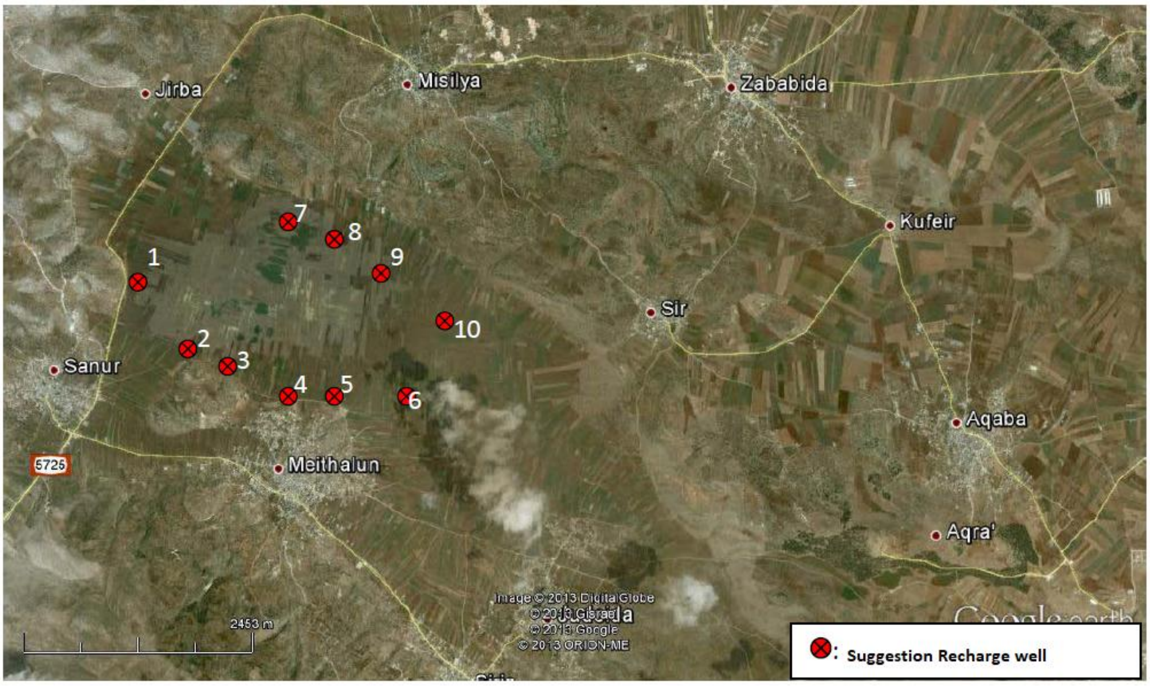


Figure38: Suggestion Recharge well

Table31: Number of construction ponds comparing with moa implemented ponds

Number	Name of sub-catchment	Total Area	Annual Runoff/ 1000 M^3	Volume ponds(m^3)	Ponds number	Implemented ponds Moa project	Volume ponds(m^3)
1	South-West (Alsarar) - Sanour	7,639	**1261**	600000	9	0	0
2	Misslya-almilk	6,489	**863**	852000	5	1	5483
3	Western slopes (north of Sanur)	1,319	**172**	165000	6	0	0
4	Northern slope(South mislay,Seer)	6,713	**813**	100000	6	0	0
5	North-East (FIFA)	2,848	**372**	361000	3	0	0
6	South-East(Alnasrani,Seres	12,302	**1656**	164100	2	1	4125
7	Southern slopes (Maithaloon)	4,532	**576**	400000	2	9	31217
8	Sanour plain	15,860	**3032**	301800	7	9	63671
	Total basin	57,701	**8745**	2943900	40	20	104496

Table31 show a summary of comparison of Pond Project for Ministry of Agriculture and the findings of the Master's thesis have been drawn up . It was noticed the following-:

1.The study area has been divided into eight parts disaggregated by name of sub-catchment , total area , ponds volume and ponds number in each area .

2.The total area of South-West (Alsarar) – Sanour is 7639 dunums , and the runoff is1261000 cubic meters . in my master's thesis , it has been suggested to establish 9 ponds , with 600000 cubic meters while Ministry of agriculture project has not established a pond

3.The total area of Misslya-almilk is 6489 dunums , and the runoff is 863000 cubic meter . in my master's thesis , it has been suggested to establish 5 ponds , with 852000 cubic meters while Ministry of agriculture project has not established a pond , with a volume of 5483 cubic meters .

4.The total area of Western slopes (north of Sanur) is 1319 dunums , and the runoff is172000 cubic meters . in my master's thesis , it has been suggested to establish 6 ponds , with 165000 cubic meters while Ministry of agriculture project has not established a pond

5.The total area of Northern slope(South mislay,Seer) is 6713 dunums , and the runoff is813000 cubic meters . in my master's thesis , it has been suggested to establish 6 ponds , with 100000 cubic meters while Ministry of agriculture project has not established a pond

6.The total area of North-East (FIFA) is 2848 dunums , and the runoff is372000 cubic meters . in my master's thesis , it has been suggested to establish 3 ponds , with 372000 cubic meters while Ministry of agriculture project has not established a pond.

7.The total area of South-East(Alnasrani,Seres) is 123032 dunums , and the runoff is165600 cubic meters . in my master's thesis , it has been suggested to establish 2 ponds , with 400000 cubic meters while Ministry of agriculture project has established 9 pond , with a volume of 5483 cubic meters .

8.The total area of Sanour Plain is 15860 dunums , and the runoff is1301800 cubic meters . in my master's thesis , it has been suggested to establish 7 ponds , with 303200 cubic meters while Ministry of agriculture project has established 9 pond , with a volume of 63671 cubic meters .

9. A total of 20 ponds have been implemented by Ministry of Agriculture , with a total volume of 104496 cubic meters . in my master's thesis , it has been suggested to establish 40 ponds , with 2943900 cubic meters .

Chapter Six

Conclusion & Recommendations

6.1. Conclusion:

1- Historical rain fall data should be used with limitation, the insufficient rain fall – runoff records has made the verification and validation process very difficult for the proposed approach to generally arid and semi-arid watershed, especially that the SCC-CN method was developed for humid areas which there climatic condition of are quite differ from the Palestinian arid and semi-arid zone .

2- Water harvesting technique is a very important management for increasing fresh water quantities from surface runoff, medium scale water harvesting is one of the powerful constructions and suitable techniques could be applied within the study area for more water availability to enhance the life conditions regarding the agricultural sector, livestock and human practices, on the other hand supplementary irrigation can be applied within the climatic regime of the area to increase the yield and productivity, quality of the crop and finally enhancing the farmer economic condition

3- There is a lack in the accurate and reliable meteorological data in the west bank, which is important for water resources management and engineering design that is mainly depend on hydrological analysis. Therefore, there is a need to install all more automatic and manual instruments for measuring precipitation, rainfall, intensity, runoff, infiltration in addition to all other meteorological parameters (evaporation, evapotranspiration, temperature, humidity etc.….).

4- Surface Runoff doesn't occur immediately, certain amount of rainfall must first satisfy interception, depression storage, and initial infiltration. This part of precipitation is referred to as initial abstraction, ***Ia***. Surface runoff will only occur when the rate of precipitation exceeds the rate of water infiltration into the soil. Runoff in arid and semi-arid occurs when rainfall exceeds 50 mm in one day or 70 mm in two consecutive days or when the total rainfall exceeds 200mm. Based on the considerations of different studies in the eastern slopes, After initial abstraction is satisfied, runoff occurs and the difference between rainfall depth, *P*, and runoff volume, *Q*, is the loss due to the infiltration.

5- The characteristics of a watershed that affect the base flow and runoff include, geology, soil type, vegetation cover, mean precipitation, drainage area and antecedent moisture condition Runoff flow is composed of two main elements: base flow, which has its origin in ground water, and surface runoff, which is the accumulation of rainfall that drains to the stream.

6- One of the major difficulties during this study was the lack or real surface runoff volumes. Unfortunately, most of Palestine basins are not equipped with surface water gauges to measure the surface runoff volumes during the rainy seasons.

7- The storm runoff analysis indicates that only precipitation events exceeding 50 mm within a 24-hour period (one day) or 70 mm in two consecutive days would generate runoff. The total precipitation volume within the Catchment area was approximately 50.320.000m3/year, while only about 10% approximately of the total precipitation volume became runoff. Therefore, the expected (Calculated) runoff volume is about 2.5mm3.

8- Small and medium scale water harvesting is one of the powerful methods and suitable techniques that can be applied within the study area for increasing the water availability to enhance the life conditions in regard to agricultural sector and live stock and human practices, on the other hand supplementary irrigation can be applied within the climatic regime of the area which will be reflected positively on the productivity, quality of the crop and finally on the farmer income.

6.2 Recommendation:

1. Conducting detailed studies of water drainage caused by flooding at the drainage basin.

2. wadis must be cleaned up from debris in addition to the need to remove barriers in the water flow.

3. Adopting an effective and early warning system for flood forecasting.

4. Cooperation between the Ministry of Agriculture and the palestinian Water Authority for the establishment of water harvesting projects to reduce the risk of flooding and use this project for agriculture.

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Appendices

Appendix 1: Description and curve numbers

Land Use Description on Input Screen	Description and Curve Numbers from TR-55					
	Cover Description		Curve Number for Hydrologic Soil Group			
	Cover Type and Hydrologic Condition	% Impervious Areas	A	B	C	D
Agricultural	Row Crops - Straight Rows + Crop Residue Cover- Good Condition [(1)]		64	75	82	85
Commercial	Urban Districts: Commercial and Business	85	89	92	94	95
Forest	Woods[(2)] - Good Condition		30	55	70	77
Grass/Pasture	Pasture, Grassland, or Range[(3)] - Good Condition		39	61	74	80
High Density Residential	Residential districts by average lot size: 1/8 acre or less	65	77	85	90	92
Industrial	Urban district: Industrial	72	81	88	91	93
Low Density Residential	Residential districts by average lot size: 1/2 acre lot	25	54	70	80	85
Open Spaces	Open Space (lawns, parks, golf courses, cemeteries, etc.)[(4)] Fair Condition (grass cover 50% to 70%)		49	69	79	84
Parking and Paved Spaces	Impervious areas: Paved parking lots, roofs, drives ways, etc. (excluding right-of-way)	100	98	98	98	98
Residential 1/8 acre	Residential districts by average lot size: 1/8 acre or less	65	77	85	90	92
Residential 1/4 acre	Residential districts by average lot size: 1/4 acre	38	61	75	83	87
Residential 1/3 acre	Residential districts by average lot size: 1/3 acre	30	57	72	81	86
Residential 1/2 acre	Residential districts by average lot size: 1/2 acre	25	54	70	80	85
Residential 1 acre	Residential districts by average lot size: 1 acre	20	51	68	79	84
Residential 2 acres	Residential districts by average lot size: 2 acre	12	46	65	77	82
Water/ Wetlands		0	0	0	0	0

Residential 1 acre	Residential districts by average lot size: 1 acre	20	51	68	79	84
Residential 2 acres	Residential districts by average lot size: 2 acre	12	46	65	77	82
Water/ Wetlands		0	0	0	0	0

معايير اختيار تقنيات الحصاد المائي في منطقة صانور –جنين

إعداد: رائد يوسف محمد ابوالرب

المشرف: د. عامر مرعي

الملخص:

تم في هذه الدراسة تقدير كميات مياه الفيضان في حوض صانور حيث تبلغ مساحة الحوض (16 كم^2) حيث يقع في الجزء الشمالي من الضفة الغربية. يتم غرق حوالي 60 ٪ من الاراضي الزراعية بسبب فيضان مياه الامطار خلال فصل الشتاء ،مما يتسبب في تقييد استخدام الأراضي. الهدف من هذا البحث هو اختيار مواقع التجميع المثلى لجمع مياه الامطار السطحية بالإضافة إلى تحديد اماكن آبار الحقن الصناعي. المنهجية المستخدمة في هذا البحث هي مزيج من استعمالات الاراضي في الفترة 1953 و2019 بناء على بيانات حفظ التربة واستخدام عدد منحنى التربة واستخدام تقنية نظم المعلومات الجغرافية، حيث يتراوح حجم مياه الفيضان ما بين 0.0 في السنة الجافة و 15 مليون متر مكعب في عام 1992/1991 بمعدل حوالي 2.5 مليون متر مكعب سنويا ،وفقا لهذه الدراسة تم اختيار 40 موقع لانشاء برك ترابية زراعية من احواض التجميع لتخزين حوالي 3 ملايين متر مكعب ، وتم تحديد اماكن انشاء 10 ابار حقن صناعي بسعة اجمالية تبلغ 0.33 مليون متر مكعب لتغذية نظام المياه الجوفية. وعليه يبلغ الحجم الكلي السنوي لتخزين المياه حوالي 3.33 مليون متر مكعب واستخدامه في تحسين القطاع الزراعي وتجنب حدوث الفيضان في حوض صانور.