Rain Water Harvesting System for Addressing Water Scarcity Challenges

By:

Isra Awad **Majd Jamal**

Supervisor:

Dr. Samah Jabari

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ABSTRACT

Rain Water Harvesting System for Addressing Water Scarcity Challenges

Project Team

Israa Awad Majd Jamal

Project Supervisor:

Dr. Samah Jabari

This research aims to discuss the rainwater harvesting system as a useful tool to decrease the challenge of the water scarcity in arid and semi-arid areas. The methodology based on making a broad literature review about this subject along global and local level, then the study focuses on the Palestinian territory specially the southern part of west bank , which is facing a chronic water shortage problem. The result of this research show that the problem of water scarcity generally afflicts the world, especially Palestine, especially the southern part of the West Bank, several projects were conducted in the West Bank, but none were completed or succeed. The study was focusing on two projects (Beit Al-Rush Al-Foka and Bani Neim Dams), the choices of places were correct along to their topography and morphology characteristics. These projects were facing many problems relating to design and implementation , and so many studies and research related to the water harvesting should be conducted in order to reach a good and useful solution regarding the water scarcity challenges

إهداء

بدأنا بأكثر من يد وقاسينا أكثر من هم وعانينا الكثير من الصعوبات وها نحن اليوم والحمد لله نطوي سهر الليالي وتعب الأيام وخلاصة مشوارنا بين دفتي هذا العمل المتواضع.

إلى منارة العلم والإمام المصطفي إلى الأمي الذي علم المتعلمين إلى سيد الخلق إلى رسولنا الكريم سيدنا محمد ﷺ.

إلى الينبوع الذي لا يمل العطاء الي من حاكت سعادتي بخيوط منسوجة من قلبها إلى والدتي العزيزة.

إلى من سعى وشقي لأنعم بالراحة والهناء الذي لم يبخل بشيء من أجل دفعي في طريق النجاح إلى الذي علمني أن ارتقي سلم الحياة بحكمة وصبر إلى والدي العزيز.

إلى من حبهم يجري في عروقي ويلهج بذكراهم فؤادي إلى أخواتي وأخواني إلى من سرنا سوياً ونحن نشق الطريق معاً نحو النجاح والإبداع إلى من تكاتفنا يداً بيد ونحن نقطف زهرة العلم إلى اصدقائي وزملائي.

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Work Team

TABLE OF CONTENT

CHAPTER 1: INTRODUCTOIN

CHAPTER 2: LITERATURE REVIEW

LISTS OF TABLS

LISTS OF FIGURES

FIGURE#　　DISCRIPTION　　PAGE

CHAPTER ONE

INTRODUCTION

1.1 General:

Rainwater harvesting is a technology used to collect, convey and store rainwater for later use from relatively clean surfaces such as a roof, land surface or rock catchment. It is a simple technique of catching and holding rainwater where its falls. Either, we can store it in tanks for further use or we can use it to recharge groundwater depending upon the situation. RWH system provides sources of soft; high-quality water reduces dependence on well and other sources and in many contexts are cost effective. The system is economically cheaper in construction compared to other sources, such as well, canal, dam, diversion (j. Gurav, 2013)

The rainwater harvesting system is one of the best methods practiced and followed to support the conservation of water. Today, scarcity of good quality water has become a significant cause of concern. However, rainwater, which is pure and of good quality, can be used for irrigation, washing, cleaning, bathing, cooking and for other livestock requirements. It is one of the simplest and oldest methods of self-supply of water for households, having been used in South Asia and other countries for many thousands of years (A. Kinkade, K. Levario, I. Heather, 2007). Installations can be designed for different scales including households, neighborhoods and communities and can be designed to serve institutions such as schools, hospitals and other public facilities.

Rainwater harvesting differs from storm water harvesting as the runoff is typically collected from roofs and other surfaces for storage and subsequent reuse. Its uses include watering gardens, livestock irrigation, domestic use with proper treatment, and domestic heating. The harvested water can also be committed to longer-term storage or groundwater recharge (K. Levario, 2007)

Rainwater harvesting in its simplest shape stores the rainwater in underground tanks after passing it through intricate filtration systems. This system is usually easy to install and is mostly used for domestic purposes. The water gets to the tank with the help of both gravity and often a pump, and is then redistributed from the tank to your desired appliances via another pump. If that pump is inside the tank, the system is called a “Submersible direct pumped rainwater harvesting system” and if the appliances and “sucks” water out of the tank locate the pump, it is a “Suction direct pumped rainwater harvesting system.”

1.2 Water scarcity overview

Safe potable water should be available to every human being, now and in the future (Serageldin et al. 2000; David et al. 2010). As water is essential for life its deterioration or lack affects every living being. As the population of the world increases, demand on water also significantly increases. Unfortunately, water resources are not uniformly distributed and are generally scarce (El-Fadel et al. 2000).

About 880 million people still lack access to improved drinking water sources (WHO amp; UNICEF 2008), which affects their social and their health. Urgent attention needs to be given to the sustainable supply of water, especially in remote rural areas, the Millennium Development global target of halving the number of people without access to water and sanitation was to be achieved by 2015, but the goal remains to be un full-filled so the initiative has been extended until 2025to reach of 30 million people. (United Nations Development Program (UNDP) 2000).

Water management in cities is crucial since their present water usage is far from being sustainable (Sazakli et al., 2007), the main problems related to it being water shortage, stream degradation and flooding. Pressure on water resources is increasing, with growing demand and limited water sources (Fletcher et al., 2008; EEA, 2009). This increasing demand reduces fresh water reservoirs. Rainwater harvesting (RWH) is presented as a sustainable strategy to be included in urban water cycle management. It presents many benefits. it may reduce a city’s external water demand, alleviate water stress on the area, reduce non-point source pollutant loads, reduce treatable urban runoff volume, prevent flooding and help to alleviate climate change (Eroksuz and Rahman, 2010; Kim et al., 2005; RiverSides, 2009; van Room, 2007; Villarreal and Dixon, 2005; Zhu et al., 2004).

In arid and semi-arid environments, where there are no rivers, or lakes, rainfall is considered one of the most important natural resources, and the rainwater harvesting become the technique suitable to support water resources (Al-Salaymeh et al., 2011).

According to (Pandey et al. (2013)), rainwater harvesting in on-farm reservoirs (OFR) and the subsequent use of stored water for irrigation can potentially increase the benefits of rain fed agriculture.

1.3 Problem Definition:

Water scarcity is a global problem and an intractable challenge facing several regions of the world, including the West Bank, due to several reasons, including climate change, increasing population and weak infrastructure, and when talking about the West Bank specifically, there are other problems, which are political problems such as the occupation authorities' control of water sources , Therefore, water harvesting is a cheap solution to reduce the challenge of water scarcity in arid and semi-arid areas, so that it will provide a source of water to meet a large part of the need for it when it is interrupted or unavailable, thus solving a big problem for farmers and city dwellers and reducing the burden on municipalities.

1.4 Project Objectives

The research aims to discuss RWH as a cheap solution to address the challenge of water scarcity in West Bank.

As well, the research has

1. Conduct a broad literature review on this topic at the global and local level.
2. Study of RWH in Palestine, specifically in the southern part of West Bank.
3. Make a field visit, collect data and aerial maps.
4. Discuss the best solution for the water scarcity problem.

1.5 Phases of Project

The project consists of five phases, which are designed to be completed in accordance with time schedule shown below. The description of each of the four phases of the project and tasks involved are listed below:

Table 1.1 Phases of the project with their expected duration

Title	Duration "year 2023"								
	Jan	Feb	March	April	May	Sep	Oct	Nov	Dec
Literature Review									
Field Work									
Data Collection									
Discussion									
Writing the Report									

1.5.1 First phase: Literature Review:

During this phase, the literature be reviewed at the global and local level, and water harvesting defined based on several writers.

1.5.2 Second phase: Fieldwork

Numerous field visits to assess rainwater harvesting in the southern West Bank the aim of these visits was to assess the selected sites in coordination with local stakeholders and to collect data from experience in relation to the proposed intervention chosen. Visits were made to:

a) The Palestinian Water Authority in Ramallah
b) Visit the Ministry of Agriculture
c) RWH projects in the West Bank.

1.5.3 Third phase: Data collection:

During this phase, available data and information were collected from different sources.

Moreover, many site visits were done. This phase includes the following activates:

1 .Collecting data on what has been achieved in RWH in Palestine.

2 .Read and summarize international and local research based on its references

3. Collecting data, details, maps and figures.

1.5.4 Fourth phase: Dissection

At this stage, two areas were selected for the study, namely the town of Bani neim and the village of Beit Al-Rosh Al-Fawqa, as they are two areas in which water harvesting projects have been established, namely two dams implemented by the Palestinian Water Authority, and they were explained in detail and the reasons for the failure of the two dams were presented.

1.5.5 Fifth phase: Writing the report

During this phase, the final report has been written, and the Final report submitted to the department of Civil Engineering at Palestine Polytechnic University.

1.6 Organization of the study

The report consists of several chapters :the first chapter, titled “Introduction”, introduces the basic concept related to rainwater harvesting like collect, convey and store rainwater for later use from relatively clean surfaces such as a roof, land surface or rock catchment. The second chapter is titled “Literature Review”, in this chapter we review the literature on Rain Water Harvesting on a global and local scale. The third chapter is titled “Rain Water Harvesting in Palestine”, in this chapter we review the water harvesting in Palestine, and study the methods used in it, based on the information we get from the field work. The fourth chapter is titled "Dissection" In this chapter, the areas of Bani neim and Beit Al-Rosh Al-Fawqa were presented in detail, where they were selected for study, and then the dams built in them were presented. The fifth chapter is titled "Conclusions and Recommendation" In this chapter, we presented the results of the research that we reached after the study, in addition to our recommendations in this regard.

CHABTER 2

LITERATURE REVIEW

2.1. General

Rainwater harvesting in its broad sense defined as the "collection of runoffs for its productive use" (Critchley and Siegert, 1991). More specifically, in crop production, water harvesting is essentially a spatial intervention designed to change the location, where water is applied to augment evapotranspiration that occurs naturally in relevant areas where the rainfall is reasonably distributed in time, but inadequate to balance potential evapotranspiration of crops (Oweis et al., 1999).

Reported that more precisely water harvesting can be defined as the process of concentrating rainfall as runoff from a larger catchment area to be used in a smaller target area. This process may occur naturally or artificially and the collected water is either directly applied to an adjacent agricultural field or stored in some type of (on-farm) storage facility for domestic use an as supplemental irrigation of crops. For landscape use, water harvesting is defined as the capture diversion, and storage of rainwater for plant irrigation and other uses (Waterfall, 2006). Examples of landscapes are parks, schools, commercial sites, parking lots apartment complexes and small-scale residential landscapes.

Rain Water harvesting for dry land agriculture is a traditional water management to ease future water scarcity in many arid regions of the world (Prinz and Singh, 2000). It is an ancient art practiced in the past in many parts of North America, North Africa, China and India (Oweis et al., 1999) and can be defined as the process of intercepting storm water from a surface such as a roof, parking area, or land surface and putting it to beneficial use (Philips, 2005).

Therefore, the rainwater harvesting is a general term used for all the different techniques to collect runoff or flood water for storage in the soil profiles or in tanks that can be used for the production of crops, trees or fodder. In addition, it can be a collection of runoff water for human and livestock consumption.

Although the term water harvesting is used in different ways, the following are among its characteristics (Oweis et al., 1999):

1. It is practiced in arid and semiarid regions, where surface runoff often has an intermittent character.

2. It is based on the utilization of runoff and requires a runoff producing area and a runoff receiving area.

3. Because of the intermittent nature of runoff events, storage is an integral part of water harvesting system

2.2. Historical perspectives:

2.2.1. Historical perspectives all over the world

Nasr (1999) have mentioned that the first water harvesting system in history was built in the Middle East and North Africa (MENA) region and signs of early water harvesting structures are believed to have been constructed over 9000 years ago in the Edom mountains in southern Jordan.

In the Negev desert of Palestine, water-harvesting systems dating back 4000 years or more have been discovered (Evanari et al., 1971). These schemes involved the clearing of hillsides from vegetation to increase runoff, which was then directed to field on the plains.

The remains of dams, reservoirs and other enduring, ancient water storage and delivery structures, coupled with its unique, spectacular mountain terraces confirm that historically Yemen's inhabitants have used a wide variety of water harvesting systems throughout the country's various agro-ecological zones. The historic Marib dam is central to the Yemen identity (Ghalib and Bamatraf, 2004).

Ghalib and Bamatraf (2004) have also shown that archeological missions at different sites have excavated the ruins of several flood-control systems. The structures served as flood breakers, sediment traps and water stores. The most spectacular and famous parts of these systems are the tanks known as Saharij.

In Baluuchistan, Pakistan, two runoff-farming techniques were applied in ancient times: the Khuskaba and the Sailaba system (Oosterbaan, 1983). The first one employs bunds being built across the slope of the land to increase infiltration, while the later one utilizes flood in natural watercourses that are captured by earthen bunds.

In west Rajastan, India, large bunds were constructed as early as the 15th century to accumulate runoff. These "Khadin" creates a reservoir, which can be emptied at the end of the monsoon season to cultivate wheat and chickpeas with the remaining retained moisture

(Kolarkar et al., 1983). A similar system called "Ahar" was developed in the state of Bahar (UNEP, 1983). Furthermore, a system known as "haveli" is practiced in areas with black cotton soil in central India. According to this system, fields are embanked on four sides to retain water in the field until the beginning of October and a few days before sowing Rabi (winter) crop; the excess water is drained off.

Wesemael et al. (1998) showed that runoff was collected and stored in underground cisterns or aljibes in the semiarid part of Spain. The catchment area included rocky slopes, dirt roads and gentle slopes with crusted surfaces. Eugene and Dutt, (1980) indicated that water harvesting systems have been used in the south western United States for domestic, animal, field crops and deciduous trees and vine crops. Fink et al.

(1979) pointed out that research program on water harvesting was established at the U.S. Water Conservation Laboratory in Phoenix, Arizona in 1959 to commence laboratory and field studies.

Evenari and Koller, (1956) pointed out that the Nabatean people (200 B.C. to 630 A.D.) have practiced the ancient runoff farming in the Negev desert in Palestine through leaving steep lands bare to encourage runoff during the brief, intense rain storm characteristic of the region. Records showed that a variety of crops were grown including barley, wheat, legumes, grapes, figs and dates in the drainage bottomlands below the catchment.

The importance of rainwater in Libya as a resource is reflected in the fact the total precipitation above 100 mm isohyte in northern Libya exceeds 30 billion m3/yr. Out of this amount, less than 3% is efficiently used (Alghariani, 1987). This valuable resource was more used in ancient times, as revealed by historical and archeological studies (Goodchild, 1952). Alghariani (2004) has shown that water harvestings in Libya are classified into two basic categories:

1) Systems based on harvesting the floodwater of wadis, gullies and channel flow.

2) Systems based on harvesting rainwater of local origin through runoff collection from rooftops and overland flow.

Among the well-known water harvesting systems in use in Morocco's arid and semiarid area are matfia (cistern), which was introduced into the country by the Portuguese in the 16th century, when they colonized cities on the coast of the Atlantic Ocean, and the rhettara (qanat), an underground water- harvesting system developed during the period of almohad (AD 1147 -1269).

Mechlia and Quessar (2004) have reported that the various water-harvesting techniques (which are used on approximately one million hectares within Tunisia) are considered an integral part of the country's national heritage. Furthermore, they have shown that the water harvesting techniques includes:

1) Runoff harvesting that makes use of runoff as collector, thus eliminating the need for storage-included among such systems are the related micro-catchment techniques called, meskat and Jessour.

2) Floodwater harvesting and spreading or spate irrigation using diversion dykes (mgoud)

3) Runoff water collection and storage in reservoirs of variable capacities.

At present, 500 hill lakes are in operation out of a planned 1000 lakes, with an estimated overall capacity of 500 million m3 (Alouani, 1997).

In Syria, many water structures and constructions are found in Damascus, at Hama, on the banks of Orontes and in many other parts of Syria. This development was associated with the Abbasid Caliphate (AD 750- 1258) (Soumi and Abdel Aal, 2004). Moreover, it was shown that the indigenous water harvesting systems are comprised of Abar Rommani, Birak and Khazzanat, Qanawat Romani, Nawair etc.

Ghaleb and Bamatraf (2004) have reported that the historic Marib dam, associated with pre-Islamic Yemeni civilization, is central to the Yemeni identity. The dam was built on a 400 –m wide gorge that catches the runoff from the 10 000-km2 watershed of Wadi Saba. Water was diverted through the north and south sluices to irrigate two gardens: north (Shamal) and south (Yamin), mentioned in the Holy Koran. The dam and its hydraulic and irrigation structures collapsed around the year 610 AD. In addition, the ruins of several flood- control systems, which served as flood-breakers, sediment traps and water stores, the most spectacular and famous parts of these systems are the tanks known as saharij, which were built to supply water to the coastal city of Aden in ancient time. Furthermore, Ghaleb and Bamatraf (2004) have shown that the indigenous water harvesting systems includes terraces, Kuruf and Birak (Roofless fabricated cisterns; Siqayat (roofed tanks); Saharij (9 elevated

Tanks); Niqab (roofed cistern) and Mawajel (Sud or dam). In Egypt, water harvesting systems are confined to the north coastal and the northeastern coastal zone to serve rangeland and cereals crops (Salem, 2004). The stems include dikes; contour furrowing, soil ripping or chiseling, small-catchment water harvesting, inter-sand-dune farms, summer crop farms, Roman-style cisterns, reinforced concrete tanks and groundwater harvesting. The latter comprises open galleries, Mawasi system and Qanats.

In Jordan, there are indications of early water harvesting structures being constructed in sites more than 4000 years old. Pools, hafair (earthen tanks dug into the ground), and cisterns have been found in most ruins and archeological sites in the country (Fardous, 2004). In addition, Fardous (2004) pointed out that water was delivered to Petra (capital of Nabatean). This water was channeled and piped to the city during winter in cisterns and excavated rock reservoirs Furthermore, Fardous (2004) has reported that different water harvesting techniques can be found in Jordan such as cisterns, water ponds and Hafair and water conservation works like earth banks, gradoni terraces, bench terracing, contour stone terracing stone and reinforced concrete structures, microchemists, and check dams.

2.3. Rain Water harvesting advantages and disadvantages:

"Rain Water harvesting advantages" Runoff farming has potential to increase the productivity of arable and grazing lands by increasing the yields and by reducing the risk of failure (Prinz and Malik, 2003). Prinz and Malik (2003) also, facilitate re or afforestation, fruit tree planting or an agroforestry. Furthermore, they have showed that unlike pumping water, water harvesting saves energy and maintenance costs and helps in decreasing the other valuable water source like ground water. Prinz (2000) has shown that Geographical Information Systems (GIS) can help in determination of areas suitable for water harvesting. Although it requires expertise for evaluating site suitability and in designing the system, it does not necessarily depend on high technology (Avenair and Nessler, 1986). The continued application of conventional breeding and the recent developments in non-conventional breeding offer considerable potential for improving cereals yield growth in rainfed environment (Rose grant et al., 2002).

"Rain Water harvesting disadvantages" Although runoff farming methods can increase the water availability, the climatic risk exists in years with extremely low rainfall, it cannot compensate for water shortage (Prinz and Malik, 2003). In addition, Prinz and Malik (2003) have reported the following drawbacks for such system: Successful water harvesting projects depend on farmer experience and trial and error rather than on scientifically well-established techniques; agricultural extension services have often limited experience with it; possible conflict between upstream and downstream users and requires relatively large labor. Prinz (2000) noticed that it has possible harm to fauna and flora adapted to running waters and wetland. Runoff farming requires a relatively large watershed area, which concentrates its rainfall into a small catchment basin (Bean and Saubel, 1972). In addition, appropriate investments and policy reforms will be required to enhance the contribution of rainfed agriculture (Rose grant et al., 2002).

2.4. Rain Water harvesting components

(Oweis, 2004) has shown that the components of any water harvesting systems include:

1. Catchment area: it is part of the land that contributes some or all its share of rainwater to a target area outside its boundaries.

2. Storage facility: a place where runoff water is held from time to time. It is collected until use. Storage can be surface reservoirs, subsurface reservoirs, in the soil profile or in ground water aquifer.

3. Target area: it is the area where the harvested water is used. In agricultural production, the target is the plant or the animal, while in domestic use, it is the human being or the enterprise and its needs.

On the other hand, (Oweis et al., 1999) presented the following components:

a) Runoff producing catchment

b) delivery system

c) Runoff storage facility

d) Cultivated or cropped area.

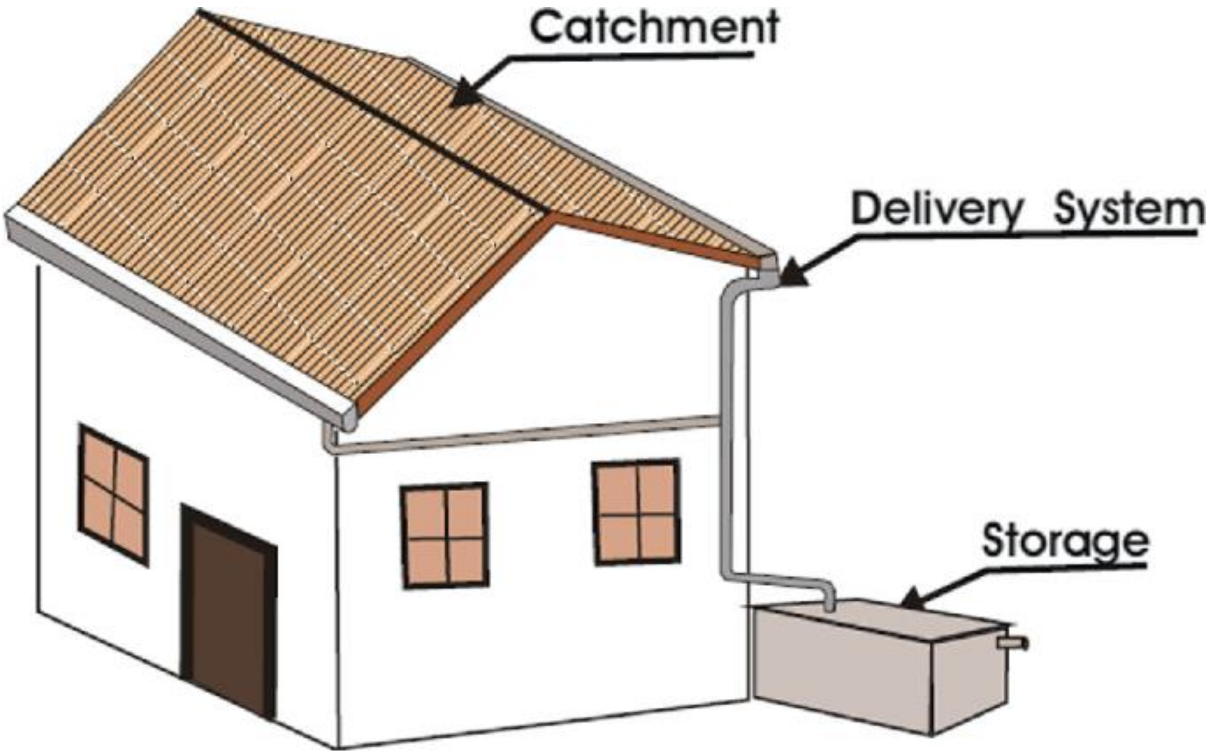

Figure 2.1: Rain Water harvesting components

They also stated that there is a general agreement that the first two components are found in all water harvesting systems. Furthermore, they clarified that the confusion starts with

Component (c) and this component raised three important questions:

1) Is the runoff water stored in a surface reservoir or directly in a soil profile?

2) Is the collected water applied to the cropped area immediately or later?

3) Are the cultural practices of the crop under supplemental irrigation the same as under irrigated conditions?

2.5. Types of water harvesting

Different authors have classified water-harvesting methods in various ways (Sulaiman, 2000). Pacey and Cullis (1986) classified rainwater-harvesting techniques into three broad categories: external catchment systems, and rooftop runoff collection. However, a brief description of water harvesting techniques along with subtypes is given below (Prinz and Singh, 2000)

1) Rainwater harvesting: this is defined as a method for inducing, collecting, storing, and conserving local surface runoff for agriculture in arid and semiarid regions (Boers and Ben-Asher, 1982). This in turn includes a) water collected from rooftops, courtyards and similar compacted or treated surfaces, used for domestic purposes and garden crops b) micro catchment water harvesting: is a method of collecting surface runoff from a small catchment area and storing it in the root zone of an adjacent infiltration basin. This type of harvesting is called runoff farming water harvesting which is characterized by (Oweis et al., 1999) the absence of surface storage; the collected runoff is directly applied to the cropped area and the agricultural practices are in accordance with the catchment characteristics c) micro catchments water harvesting or harvesting from external catchments: here runoff from hill-slope catchments is conveyed to the cropping area located at hill foot on flat terrain.

Floodwater harvesting or large catchment water harvesting or spate irrigation: it can be defined as the collection and storage of creek flow for irrigation use. It may be classified into: a) floodwater harvesting within streambed, the water flow is dammed and as a result, inundates the valley bottom of the flood plain. The water is forced to infiltrate the wetted area and can be used for agriculture or pasture improvement; b) floodwater diversion: the wadi water is forced to leave its natural course and conveyed to nearby cropping fields.

Groundwater harvesting: it is employed to cover traditional as well as unconventional ways of ground water extraction like Qanat systems, underground dams and special types of wells. For instance, qanats, which consist of a horizontal tunnel that taps underground water in an alluvial fan, brings it to the surface due to gravitational effect. It is widely used in Iran, Pakistan. Subsurface dams and sand storage dams are other examples of groundwater harvesting. By these methods, flow of ephemeral streams is obstructed in a riverbed and stored in the sediment below ground surface and can be used for aquifer recharge (Oweis et al., 2001) presented a simplified classification as show in Figure (2.1).

According to this classification water, harvesting is categorized into: 1) Micro catchment methods. This category can be further subdivided into rooftop systems and on farm systems. The common systems of the later one in West Asia and North Africa (WANA) are contour ridges, small pits, runoff strips, meskat, semicircular/ trapezoidal bunds, Negarim, interrow systems and contour bench terraces.

2) Macro catchments, which can be further subdivided into:

a) Wadi- bed systems like small farm reservoirs.

b) off-wadis systems like water spreading, large bunds, Tanks, cisterns and hillside conduits.

According to Nasr (1999), there are two basic types of runoff farming systems:

1) The direct water application system, where runoff is stored in the soil of the crop growing area

2) The supplemental water system, where collected water is stored offsite in some reservoirs and later used to irrigate a certain crop area.

According to Critchley and Siegert (1991) generally, two runoff farming water-harvesting groups are generally recognized: rainwater harvesting and floodwater harvesting. Rainwater harvesting can be further divided into micro catchment and macro catchment runoff farming types. Floodwater harvesting can also be divided into streambed and through diversion runoff farming types.

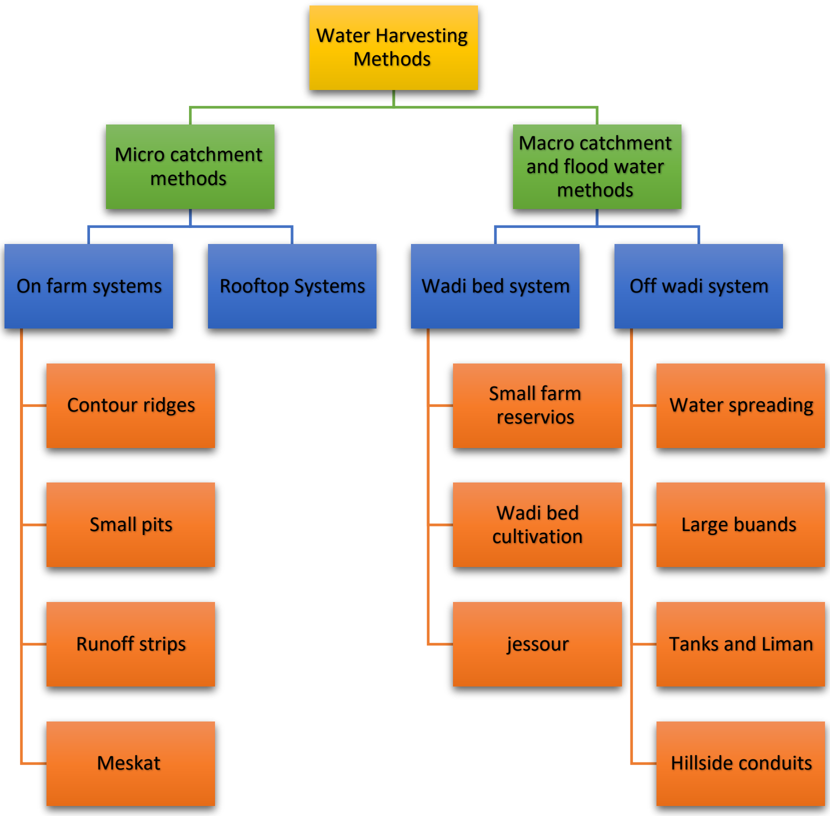

Figure 2.2: classification of RWH methods

2.6. Kinds of storage:

2.6.1. Above-ground water storage

Regarding kind of storage, (Prinz and Singh, 2000) have declared that when the collected rainfall is stored in the soil matrix, its application will be limited to the rain season. To allow cropping outside the rainy season, a number of storage media are employed, ranging from Ferro cement tanks of little m^3 content to large reservoirs, storing millions of m^3. (Agrawal and Narian, 1997) have reported that without tank systems, paddy cultivation in large parts of India is impossible.

2.6.2. Underground storage

As several disadvantages are connected with surface storage of water such as large evaporation losses, loss of storage caused by siltation, pollution problems and loss of agricultural land, underground storage may be an interesting alternative (Prinz and Singh, 2000). This storage can be done in near surface aquifers (e.g., in wadi beds) or in fabricated caves or underground constructions to store water (Cistern). Often the walls of these cisterns are plastered; their water losses by deep percolation or by evaporation can be minimal. In India, underground tanks with a plastered catchment can be found (Agarwal and Narain, 1997).

CHAPTER 3

PALESTINE AND WATER SCARCITY

3.1. General

3.1.1 Location & Area of Palestine:

Palestine is located on the eastern coast of the Mediterranean Sea between longitudes 34° 15° and 35° 40° east of Greenwich, and latitudes 29°30° and 23° 15° N. The Syrian Arab Republic and Jordan border it to the east, to the north by Lebanon and part of Syria, and to the south by Sinai and the Gulf of Aqaba. The area of Arab Palestine is about 27,009 square kilometers.

Figure 3.1: Palestine's map (WorldAtlas.com)

The West Banks a landlocked territory near the coast of the Mediterranean in Western Asia that forms the main bulk of the Palestinian territories, The area of the West Bank constitutes approximately 21% of the area of Mandatory Palestine, or about 5,860 km², and this area geographically includes the Nablus Mountains, the Jerusalem Mountains, the Hebron Mountains, and the western part of the Jordan Valley.

The estimated population of the West Bank is about 3.19 million according to the 2022 census of the Palestinian Central Bureau of Statistics.

The conditions and problems of water services in the West Bank, although their addresses are similar to those in other regions of the world, however, they differ in character and substance. This imbalance lies in the objectives of the Israeli authorities to control the entire Palestinian territory.

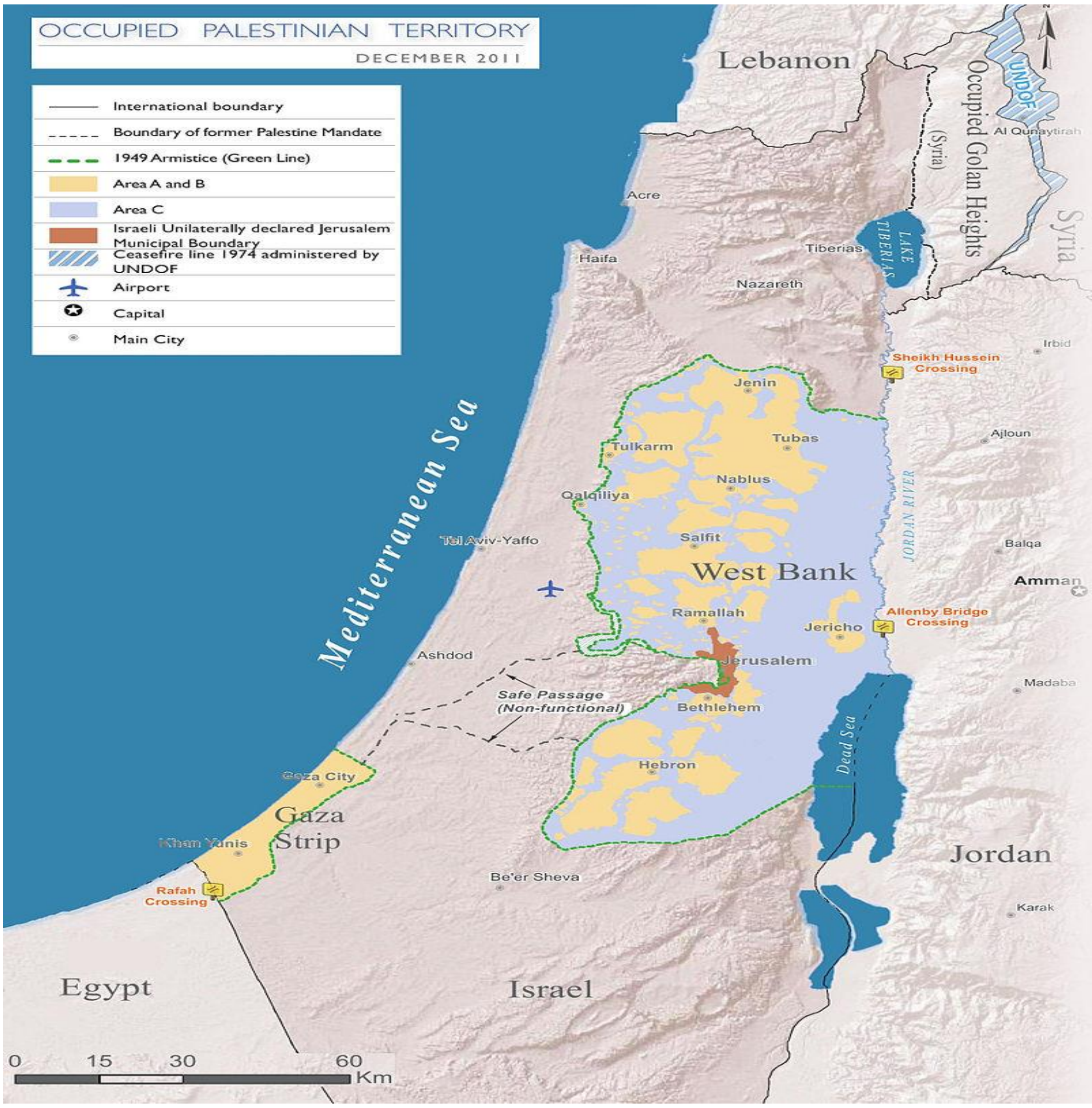

Figure 3.2: West Bank (Palestinian Central Bureau of Statistics, 2011)

3.1.2 Climate:

Palestine is dominated by three main climatic zones:

1 -Temperate rainy Mediterranean region:

This region is represented in the coastal plains and the western slopes of the highlands, and is characterized by its hot, dry climate in summer and mild rainy in winter, and the quantities of the airport range between 300-700 mm annually, which allows for diversified agriculture in this region.

2 -Semi-arid (semi-desert) region:

This region is located in the northern and central part of Wadi Arabia and the northern Negev, and is characterized by its hot climate in summer and semi-arid and warm in winter, and low rainfall ranging from 15-300 mm annually, which makes dependence on irrigation water in this region of great importance in agriculture.

3 -Arid (Saharan) Region:

This region prevails in the Negev desert, Wadi Araba, the Dead Sea, Jericho and the southern Jordan Valley. It is characterized by its hot, dry climate in summer, and warm in winter, and the amount of the airport falling on it ranges between 50-150 mm per year, which are semi-arid areas with few plant and water resources.

Due to the climatic, topographical and geographical conditions prevailing in Palestine, including the West Bank, water resources are scarce. This is why many experts and others warn of the consequences of severe conflicts in the future in the Middle East in general, and in Palestine in particular, over water resources (M. Naff,1989; B. Gowers, 1989; K. Joyce and L. Stoll, 1987; C. Dillman, 1989; M. Naff and C. Matson 1984;). The only surface water available is the Jordan River and its tributaries. According to numerous reports, Israel takes approximately one-third of its water consumption from the Jordan River. (A. El-Khatib 1989؛J. Gwyn 1984).

The land of Palestine contains three main aquifers: the coastal plain reservoir and the Jerusalem reservoir, which date back to the world, however period, and the Auja reservoir for central Palestine. Reservoirs run in a westerly direction. Rainfall is the origin of all water sources in Palestine, which lies between the low rainfall zone in the south and southeast and the high rainfall zone in the north. Average annual rainfall in the West Bank ranges from 500 mm to 700 mm (lindies and Blake 1939; Elazar 1982; M. Haddad 1990). All these

The capacity of runoff and water springs in the West Bank, according to many experts, ranges from 30 to 50 million cubic meters per year. The capacity of the West Bank springs was estimated at 75-115 million cubic meters in the West Bank (Elazar 1982; Asir 1986; Rabi and Tamimi 1989).

Before the Israeli occupation, there were 729 wells in the West Bank, from which groundwater was extracted for various consumption purposes, and now there are only 314 wells (of which 20 are intended for domestic purposes) operating with a production capacity set by the Israeli military authorities at 37.9 million cubic meters per year. The rest of the wells are idle due to drought caused by pumping wells dug by the military authorities on large works, or because they were abandoned, or for reasons and security claims resorted to by the Israeli authorities (Awartani 1981; Labadi 1989).

3.2. Water Distribution Networks

Until 1967, water distribution in the West Bank through pipes was limited to parts of cities and to a few villages. To date, the supply of water to all communities in the West Bank has not been completed. The current state of water distribution networks in the West Bank, especially in cities, is characterized by a lack of documented planning, neither for the present nor for the future. (The Water Crisis in the West Bank: Status and Treatment Trends).

The population in the West Bank can be divided into three main groups: urban residents, rural residents, and residents of Palestinian refugee camps. This division will facilitate exposure to water services, as it will follow the same division to homogeneity of these groups. Accordingly, the following paragraphs contain the conditions of water services for each group individually.

3.2.1 Cities:

There are eight main cities in the West Bank, home to about 410,000 people, or about 37% of the total population. The water distribution systems in the municipalities of these cities are dual in character: some are old, others relatively new.

Water consumption in these cities, excluding East Jerusalem, is estimated at 12.1 MCM per year. Some 44 percent of the consumption of these municipalities comes from sources controlled by the Israeli military authorities. This percentage does not include the amount of water extracted from wells leased by the military government to municipalities (such as Bir al-Badan and Bir al-Far'a in the Nablus governorate area).

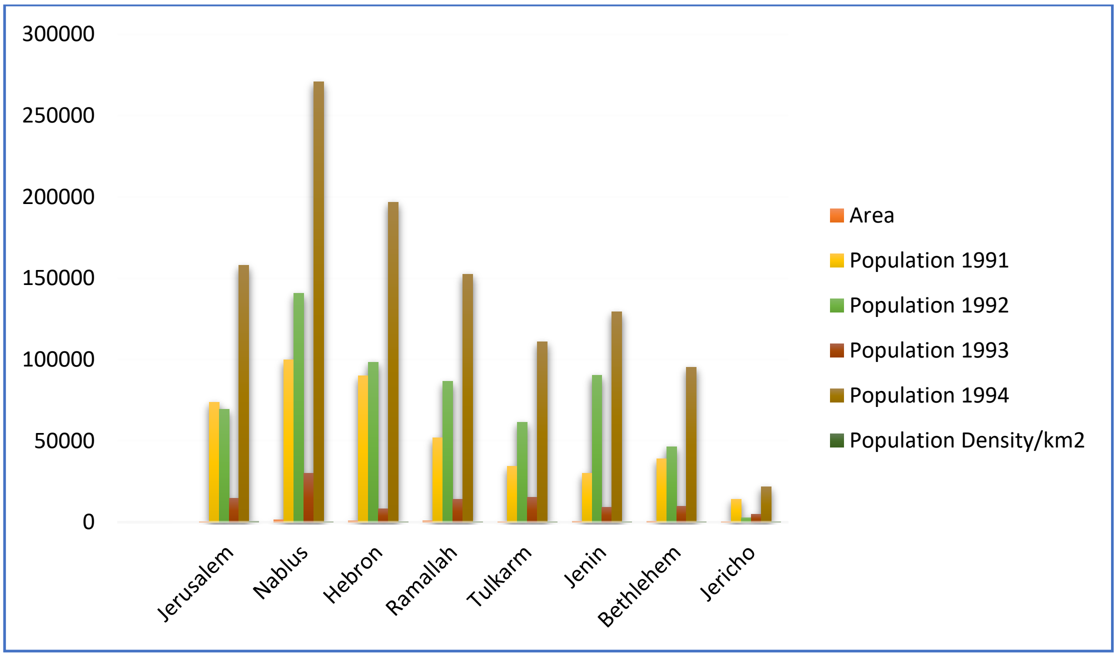

Figure 3.3: Area, population and density population of west bank governorates

The amount of water consumption in East Jerusalem was estimated at 2,677 million cubic meters per year, assuming that the average consumption of water by the Palestinian population in the city for domestic purposes is equal to the rate of consumption in the West Bank, i.e., an actual water consumption rate of 58.3 liters per capita per day, and the loss in the distribution network at a rate of 41.3%. The number of losses in water distribution networks in West Bank municipalities is the first major problem facing the management of these networks, ranging from 25% to 55%. This percentage is unacceptable, neither from an engineering point of view nor in terms of economic feasibility and cost to the citizen. The reasons for this high percentage, listed in order of importance, are due to inadequate water meters, thefts, the age of the network, poor network design (or random design if you will), and poor practical experience to operate these networks properly. The average per capita water consumption in municipalities per day ranges from 24 liters in Jericho to 91 liters in Tulkarm, or an overall average of 58.3 liters.

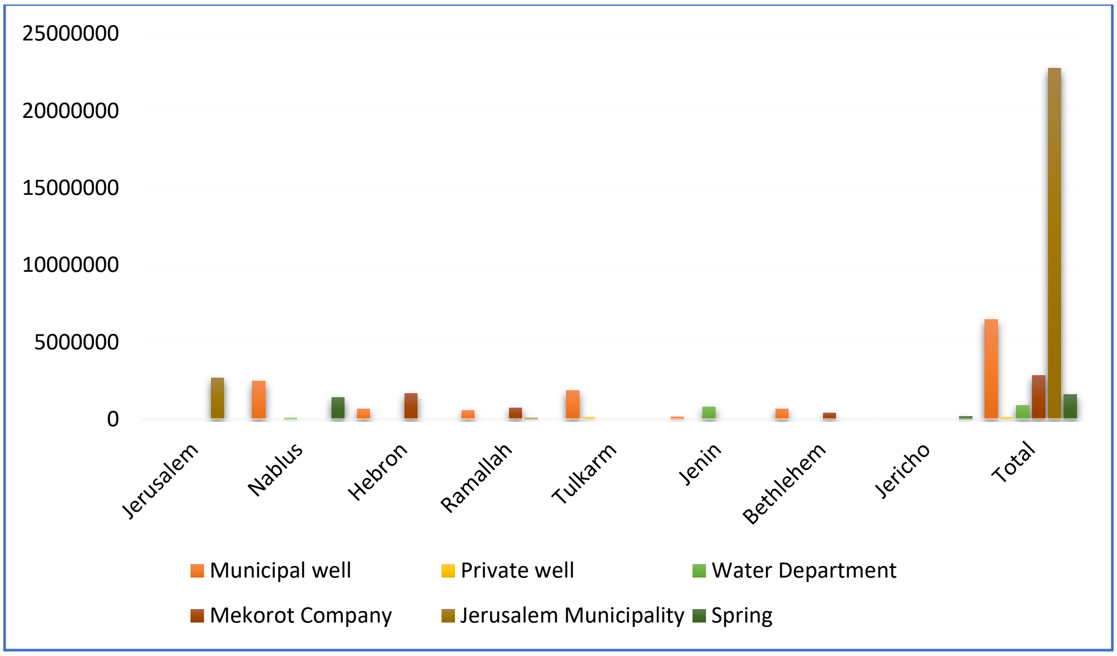

Figure 3.4: Total Water Consumption in major Municipalities in West Bank

3.2.2 Villages

There are more than 400 villages in the West Bank, many of which lack public services, including water. About 51% (179 out of 351 villages) of the villages, or 38% of their population, do not have water distribution networks. In addition, a few villages with a water distribution network provide service to all residents, and some of them reach less than 50%. It was found that the percentage of losses in water distribution networks in West Bank villages ranges between 8.95% and 16.7%, or an average of approximately 12%. Due to the recent installation of most distribution networks, the main cause of this loss is water meter reading, and/or incorrect consumer practice. Daily per capita water consumption in Palestinian villages in the West Bank ranges from 22.1 liters in the Nablus area to 41.1 liters in the Jerusalem area, or an overall.

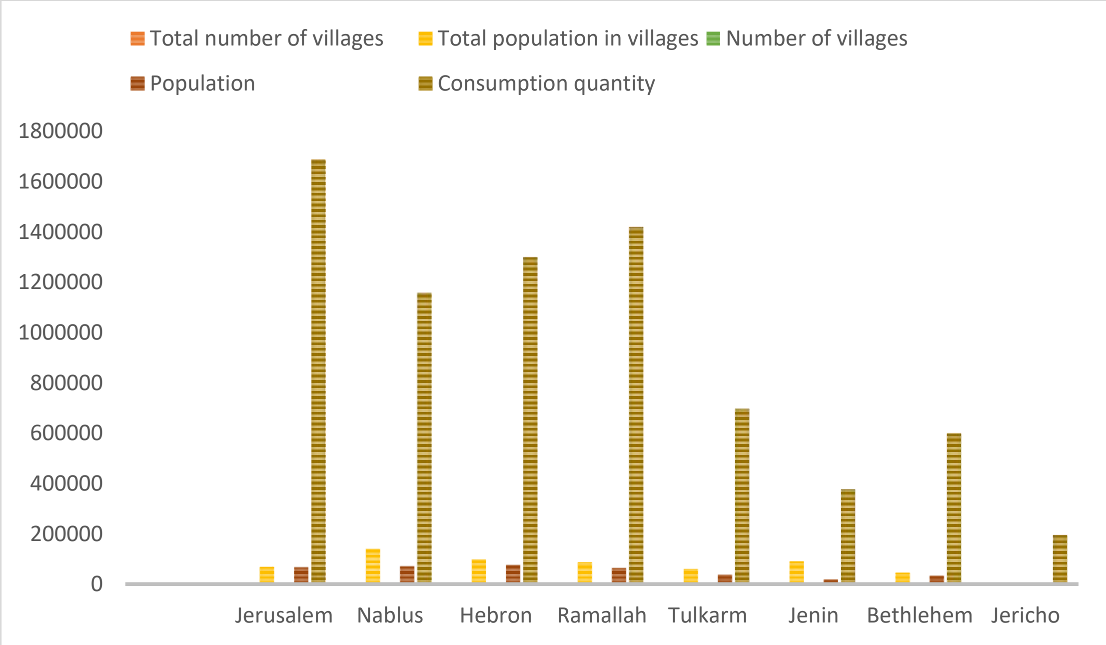

Figure 3.5: Villages with water services, number,population and total water consumption

Average of 32.9 liters. The consumption of water by villages (where there are water networks) for domestic purposes is about 6.59 million cubic meters per year. The Israeli authorities, through Mekorot Company and the Water Department, supply about 64% of this quantity. The amount of water consumption in villages without water distribution networks was estimated at 1,828 million cubic meters per year, assuming that the average daily water consumption of the population in these villages is equal to the lowest rate of consumption in villages with water networks, which is 22.1 liters per capita per day.

3.2.3 Palestinian Camps:

There are 20 camps in the West Bank for Palestinian refugees who came there because of their expulsion from their homes in 1948, following the establishment of the Jewish state in Palestine. These camps are home to about 106,000 people, and are geographically distributed throughout the West Bank. The management of Palestinian camps in the West Bank, including water services, has been placed in the hands of the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA).

Because most Palestinian camps are located near cities and/or major communities in the West Bank, over time the water services of these camps have been linked to the municipality adjacent to the camp. The average daily per capita water consumption in Palestinian camps in the West Bank ranges from 14.7 liters to 31.7 liters, or on average 26.25 liters.

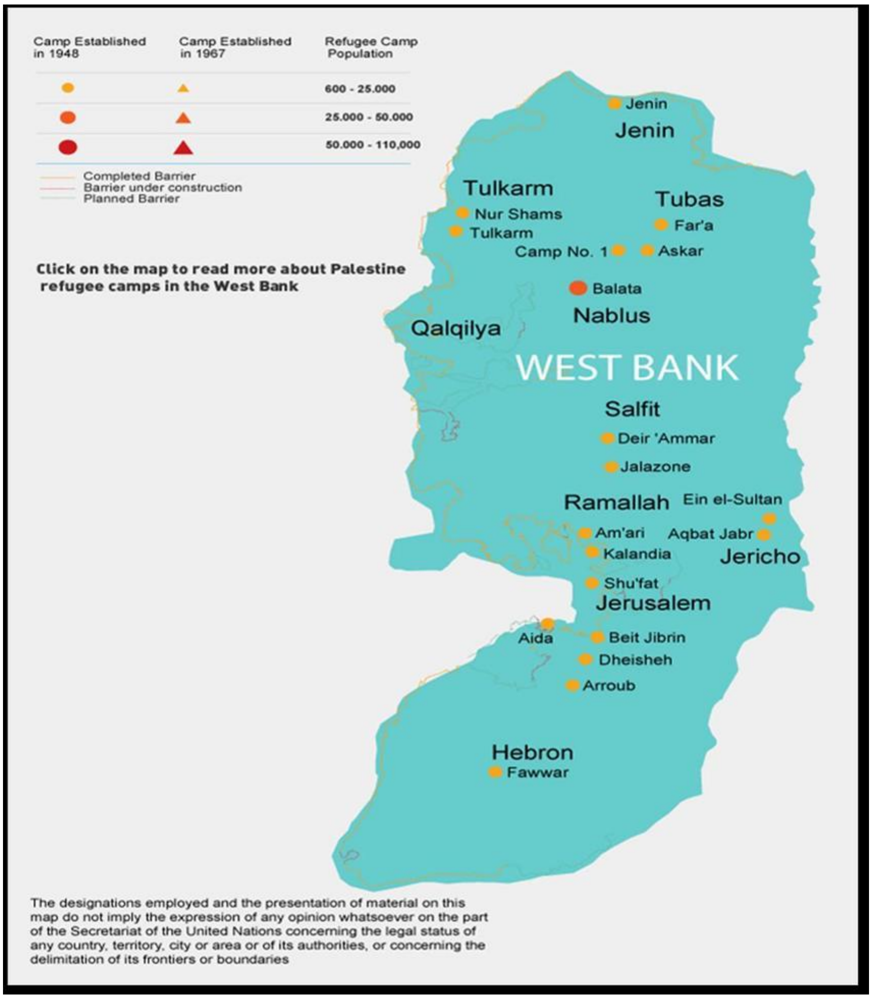

Figure 3.6: Map of Refugee Camps in the West Bank
(Palestinian Central Bureau of Statistics, 2011)

Summary of the present situation:

The average Palestinian per capita consumption of water was 84.2 liters per day. This rate reached 82.4 liters per day in the West Bank, and 86.6 liters in the Gaza Strip. If we take into account the high rate of water pollution in the Gaza Strip, and calculate the quantities of water suitable for human use, Of the available quantities, the per capita share of fresh water amounts to only 26.8 liters per day in the Gaza Strip.

If we look at the disparity between per capita shares between governorates, achieving justice in distribution among population centers is one of the main challenges facing the State of Palestine as a result of the political situation that prevents the development of an integrated water system at the national level. It is worth noting that the rate of Palestinian per capita water consumption is still less than the minimum recommended globally according to World Health Organization standards, which is 100 liters per day, as a result of Israeli control over more than 85% of Palestinian water sources.

CHAPTER FOUR

DISSECTION

4.1 General

Every day, the access of water to the vast majority of Palestinian cities and neighborhoods in the various governorates of the West Bank is cut off, facing a severe crisis in water scarcity and lack of nutrition to citizens' homes and agricultural lands, due to the arbitrary occupation measures and the control of many springs and fresh water springs. (Institute for Palestine Studies,2023).

So far, the occupation and its settler's control 21 main sources of water in the occupied West Bank, which feed thousands of these springs and springs, and Israel also controls the three aquifers in the West Bank, which provide more than 650 million cubic meters of water annually, while allowing Palestinians to benefit from 20% of these total quantities.

As a result of this control, residents of the occupied West Bank are forced to buy water from Israeli companies, most notably Mekorot, for use in drinking, irrigation of agricultural dunums, watering livestock, as well as various domestic uses. As a result, the suffering of Palestinian citizens in many areas of the occupied West Bank is exacerbated, which witnesses water cuts that last for days during the summer, forcing residents of these areas to buy water with high-cost tankers.

36% of West Bankers have access to water every day throughout the year, and about 70 Palestinian communities throughout the West Bank, home to more than 100,000 Palestinians, are completely unconnected to water networks

4.2 Forms of Water Harvesting in Palestine:

Based on field visits to the office of the Ministry of Agriculture and the Palestinian Water Authority and studying numerous researches, we have identified the following types:

Drilling wells: Farmers and residents of rural areas construct wells in order to collect rainwater and runoff for reuse in summer.

Rehabilitation of springs and surface water.

Establishment of mineral ponds: where mineral ponds of different sizes are established in which excess water is collected from the need of springs, examples of which are mineral ponds erected in Dora and Bitola, and it is worth noting that this idea is a project with a French rehabilitation.

Plastic ponds: They are the most widespread ponds among farmers, where a hole is dug in the ground and then the floor of the pit is covered with plastic tape of great thickness to prevent water leakage from the pond.

Exploitation of contour lines and lands with a high inclination, where rainwater is easily collected due to its high slope, and one of its advantages is its low cost, as a simple rehabilitation is done for the surface from which rainwater is collected, then a water barrier is established against the slope, and thus water is confined and collected

Rehabilitation of valleys: where the valleys are cut into levels to collect water, and one of its benefits is to reduce soil erosion and save water in it and thus obtain fertile land for seasonal agriculture such as vegetables and the land of the valley is divided by placing stone springs in the form of separations between the pieces.

Dams implemented by the Water Authority in West Bank:

Bani neim Dam: The dam was implemented 3 years ago; the water did not meet due to the low flow speed in the dam construction area.

Beit Al-Rosh Dam in the city of Dura: It was built 3 years ago, the dam failed because the dam was built on a crack, so the water escapes into the ground and the water is not collected on the surface of the earth.

Al-Auja Dam: The dam was established in 2012, and it is the first water dam in Palestine, but it did not work as planned, in addition to that, the water of the Auja spring was not pumped into the dam because of the fear of the owners of the spring that the state would control it.

Far'a Dam: The dam was established in 2013, but it turned into a health hazard, due to the access of sewage to the dam pond.

4.3 Beit Al-Rush Al-Foka and Bani neim Dams as study area

In this study, we chose these two dams for study and analysis, as they are located in the southern part of the West Bank, which suffers from the problem of chronic water scarcity. The choice of the places was correct, in addition to their topographical and morphological characteristics, but they faced problems related to design and implementation.

4.3.1 Beit Al-Rush Al-Foka Dam

Location

Beit Al-Rush Al-Foka is a Palestinian village, one of the villages of Dura in the Hebron Governorate. It is located to the southwest of the city of Hebron, 18 km away. It is bordered to the east by the city of Dura, to the west by Beit Marsam, to the south by Al-Burj village, and to the north by the separation wall.

The village of Beit al-Rush al-Fawqa is classified as a rural area. The village has been managed since 1996 by a village council. The council consists of Seven members. Among the services provided by the Council are: water services, electricity, solid waste management, and the construction and rehabilitation of schools, The village has a structural plan of 2,500 dunums.

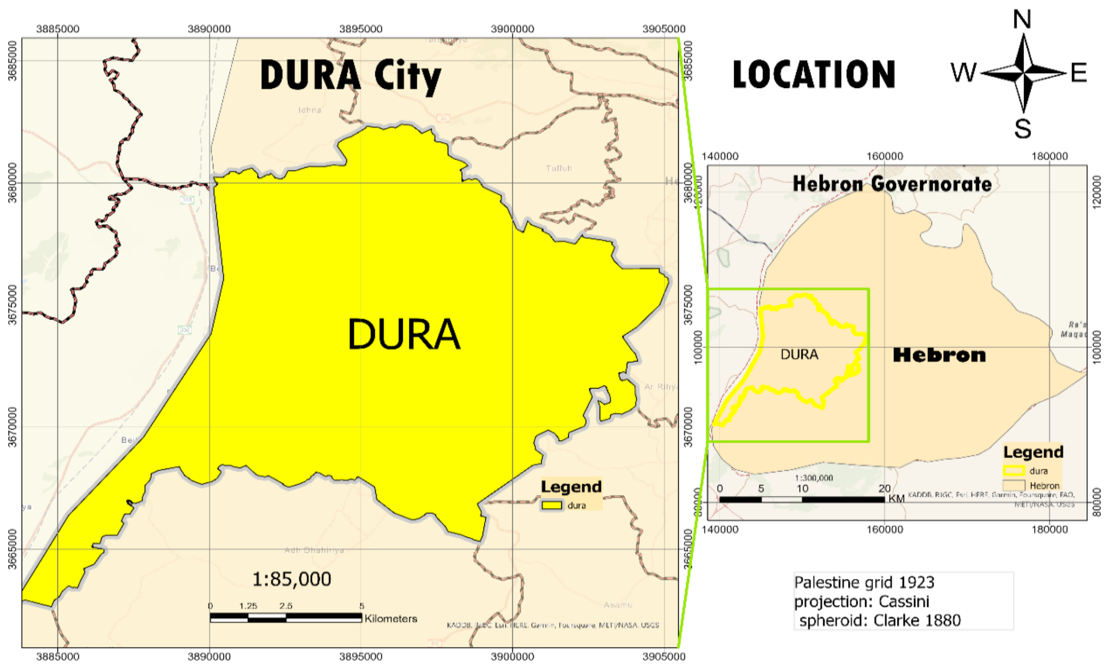

Figure 4.1: Dura City location

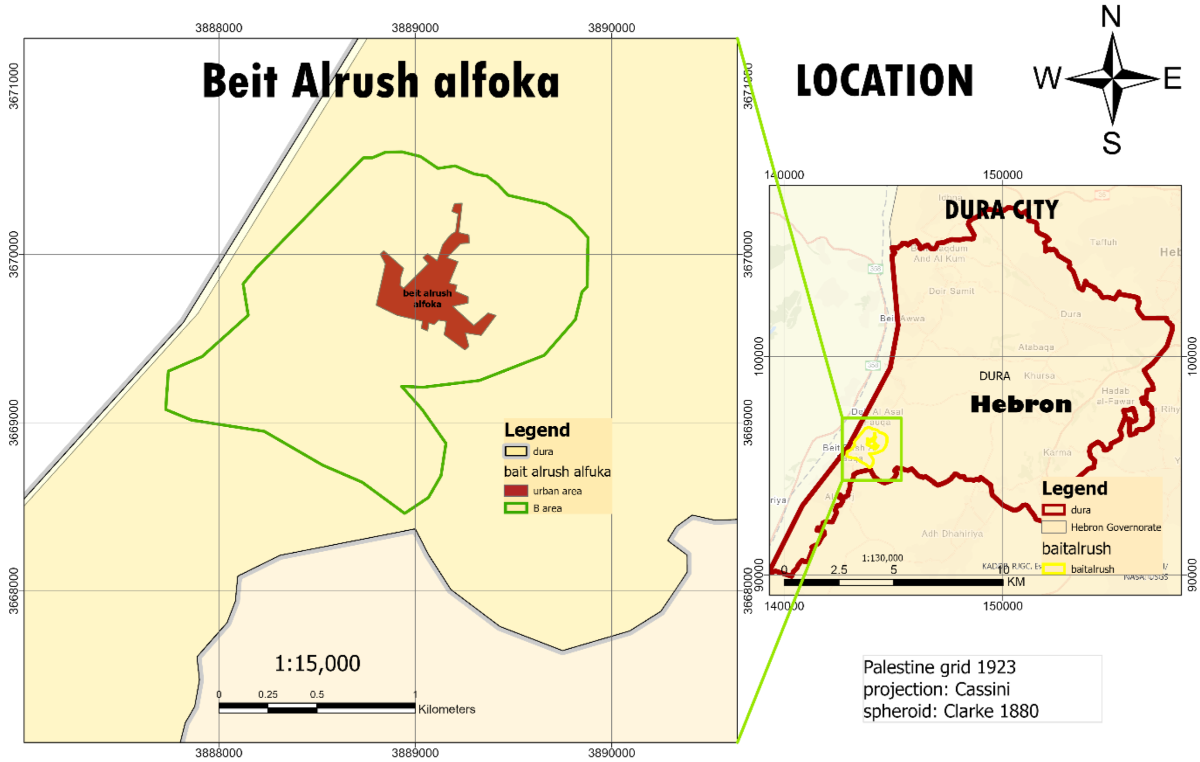

Figure 4.2: Beit Al-Rosh Al-Foka Village Location

Climate

The village of Beit al-Rush al-Fawqa is located at an altitude of 531 meters above sea level, and the average annual rainfall there is about 436 mm. The average temperature reaches 16 degrees Celsius, and the average relative humidity is about 61% (Geographic information unit-Areej).

The climate is affected by the climate of Palestine, which is characterized by being dry and hot in summer and mild and rainy in winter, and the climate of Dora, despite its smallness, varies according to the terrain and neighboring water bodies and distance from the desert, the winds that blow on Dura are the southwest winds that bring rain in addition to the eastern winds, which are cold and dry in winter.

Landforms

As for the terrain of the Hebron Heights, including the heights of the Dura Mountains, they slope steeply from the east towards the west towards the Mediterranean Sea, this decline led to the creation of valleys and plains due to erosion and erosion factors, but this erosion is slow due to the drought factor that characterizes the climate of this region.

Topography of Beit al-Rush/Dora area

Rain falls on Al-Khalbal-Dura mountain range, the high-altitude region where the water shed boundaries are steep from east to west, leading to a natural flow of this water westward through two main valleys, one of which flows from the Dura region through Wadi Hammad - Wadi Kafr Gul and the other valley, which Rainwater flows into it, coming from Al-Dhahiria Mountains area, which is Wadi Al-Kalb, which meet in the wide and main Unayzah Valley at the location of the proposed dam body with a length of 500 meters, based on which the location of the dam was determined along the end of Wadi Al-Unayzah. as shown in Figure 3 is a map showing the topography of Dura city and Beit al-Rush watershed area.

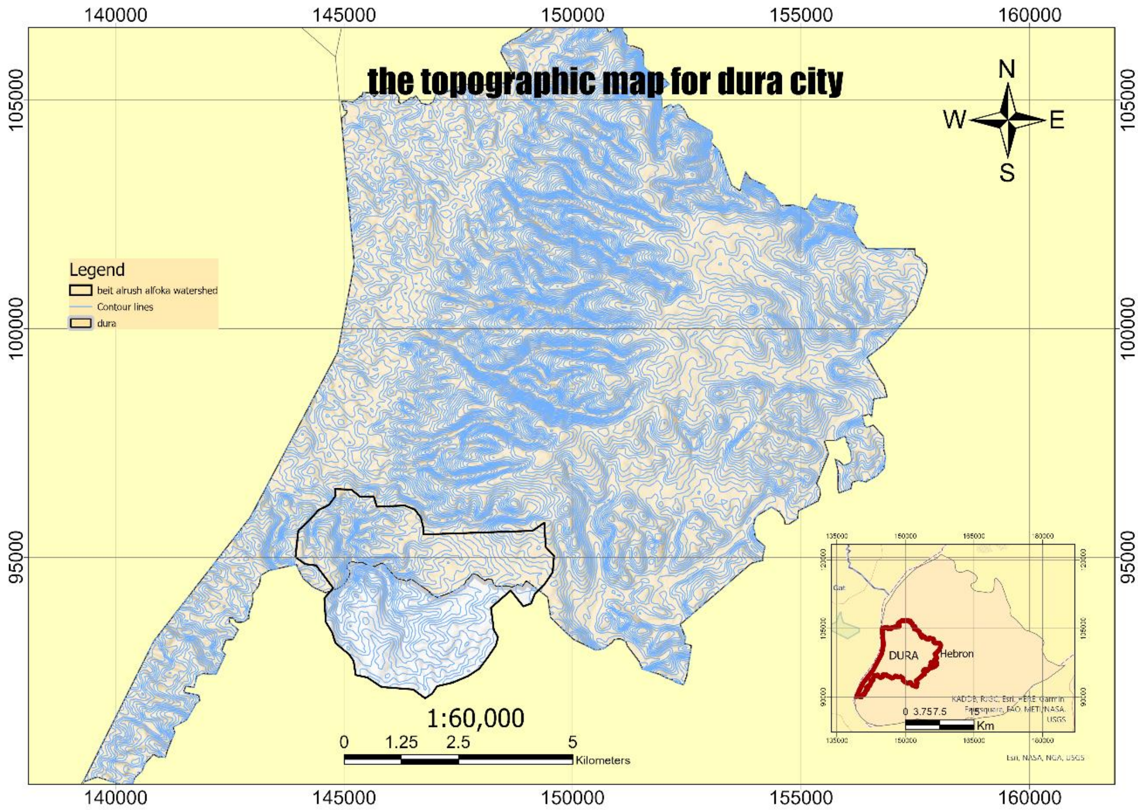

Figure 4.3: The Topographic Map for Dura City

Population

The population of the Dura region is approximately 100,000 people, according to the statistics of the Palestinian Population Census for the year 2011, and the population of the population centers of the villages of Beit al-Rush al-Tahta, al-Foka, and Deir al-Asal al-Foka is 6,000 people, according to the statistics of the Palestinian Population Census for the year 2011.

In the village of Beit Al-Rush Al-Fawqa in 2007, the following were: 44.1% in the age group under 15 years, 52.5% in the age group 15- 64 years, %2.5 Within the age group of 65 years and above. The data also showed that the percentage of males to females in the region is 113:100 That is, the percentage of males is 53% and the percentage of females is 47%.

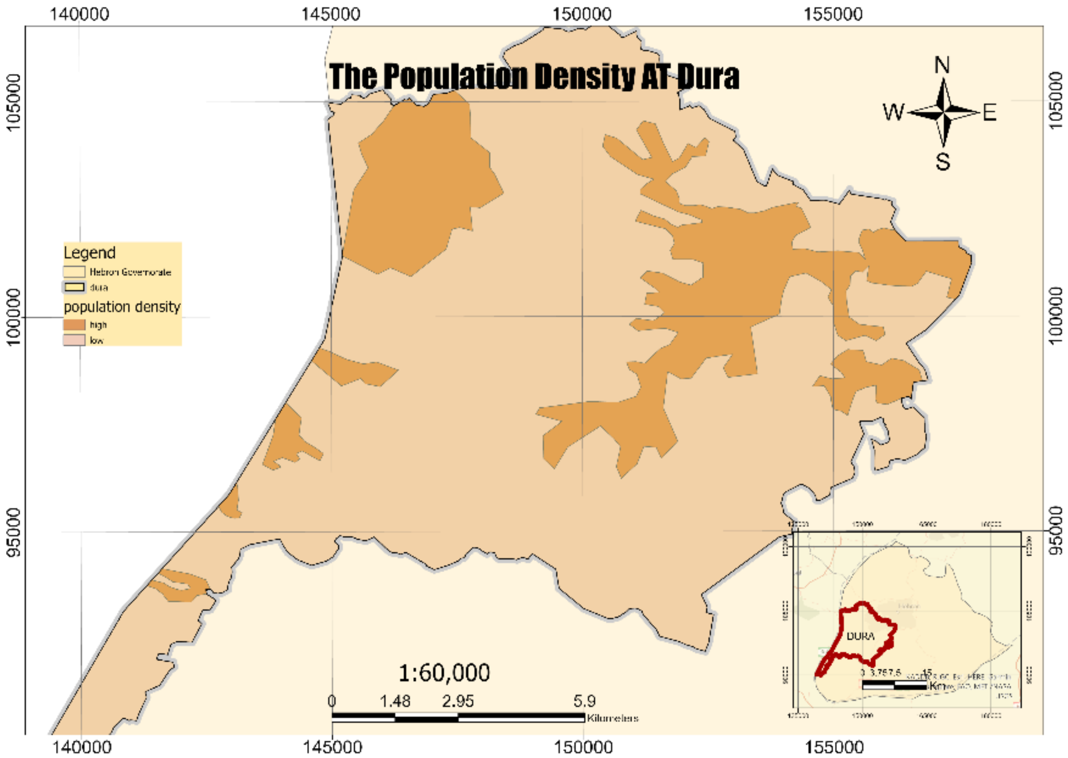

Figure 4.4: Population Density at Dura City

Economic Activities

In a statistic carried out by Areej, the following economic activity was shown

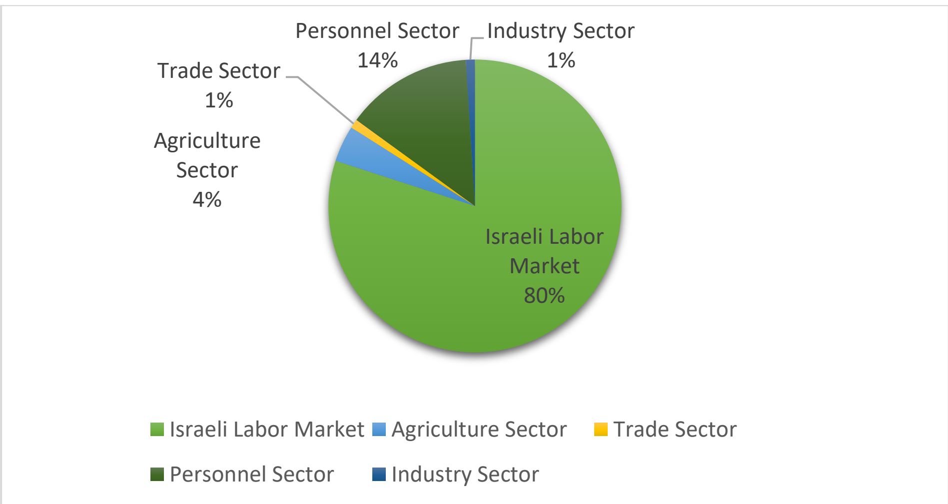

Figure 4.5: distribution of the Labor forceby economic activity in the villiage of Beit Al-Rosh Al-Fawqa

It is clear from the graph that the largest percentage of the labor force is employed in the Israeli labor market.

Rainfall

The amounts of rain falling annually during the past fifteen years on Dura and some of the countries of the neighboring Hebron Governorate. Dura is characterized by a high rate of rainfall compared to the rest of the areas of the Hebron Governorate. As shown in Table 4.1 and figure 4.7 shows the amounts of rain fall Annual survey of the city of Hebron from 1926 to 2015. (According to Palestinian Water Authority).

Table 4.1: Rainfall rates in some areas of Hebron Governorate (Palestinian Water Authority, 2015).

Year/ City	Yatta(mm /yr.)	Bani-neim(mm/yr.)	Hebron(mm/yr.)	Dura(mm/yr.)	Alsamou(mm/yr.)
2000-2001	537	426.5	569.5	610.4	385.5
2001-2002	437.9	464	674.8	492.6	386.5
2002-2003	524.5	572.4	721.6	654.3	516.5
2003-2004	340.5	344.5	465.9	374.7	308
2005-2006	261	278.7	414	347	223
2006-2007	391	403	544.8	407.2	303.5
2007-2008	229	271	329.3	316.1	196
2008-2009	252	267	409.2	362.1	185.3
2009-2010	430.5	366	430	510.6	263.5
2010-2011	218.8	266.6	367.9	316.3	174.2
2011-2012	218.8	266.6	367.9	316.3	174.2
2014-2015	324	445.5	493.2	478.6	333.5

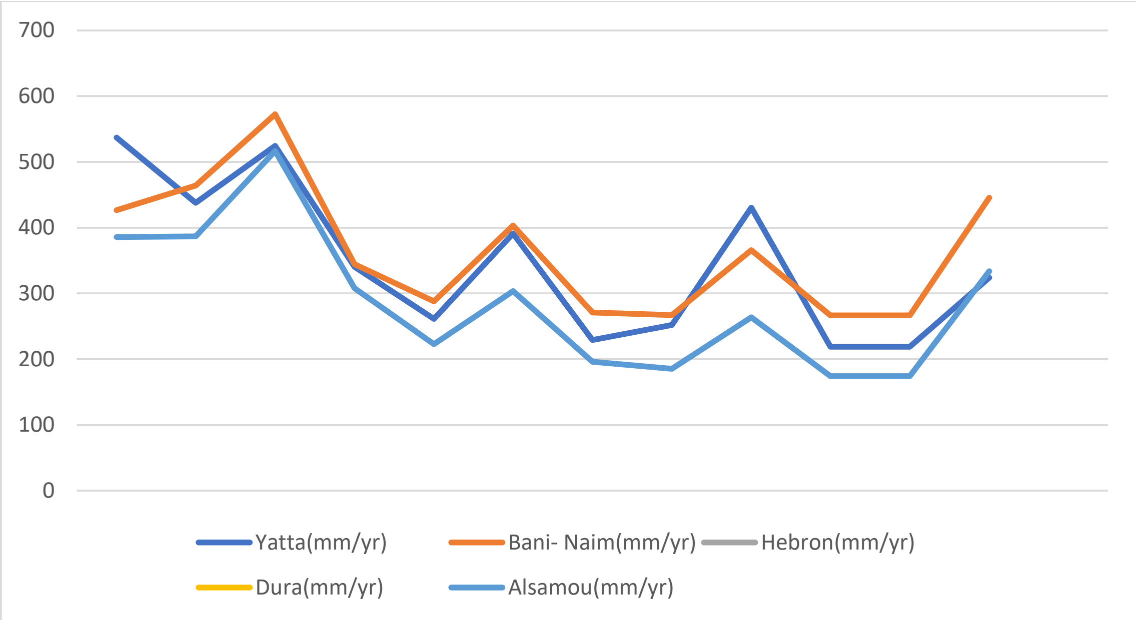

Figure 4.6: Rainfall amounts in some areas of Hebron Governorate from 2000-2015

It is clear from table 4.2 that the month of January has the highest rainfall rate in the region, followed by month of December and month of February. Because the weather depressions are concentrated in this month and the temperatures are at their lowest annual levels in these months.

Table 4.2: Rainfall rate at Dura station and its standard deviation. (, 2015).

	Sep. (mm)	Oct. (mm)	Nov. (mm)	Dec. (mm)	Jan. (mm)	Feb. (mm)	Mar. (mm)	Apr . (mm)	May (mm)
Average	0	12	32.07	102.44	123.83	111.98	28.23	17.68	6.34
Standard Deviation (SD)	0.00	11.28	47.07	61.20	64.61	43.60	25.62	21.86	16.09

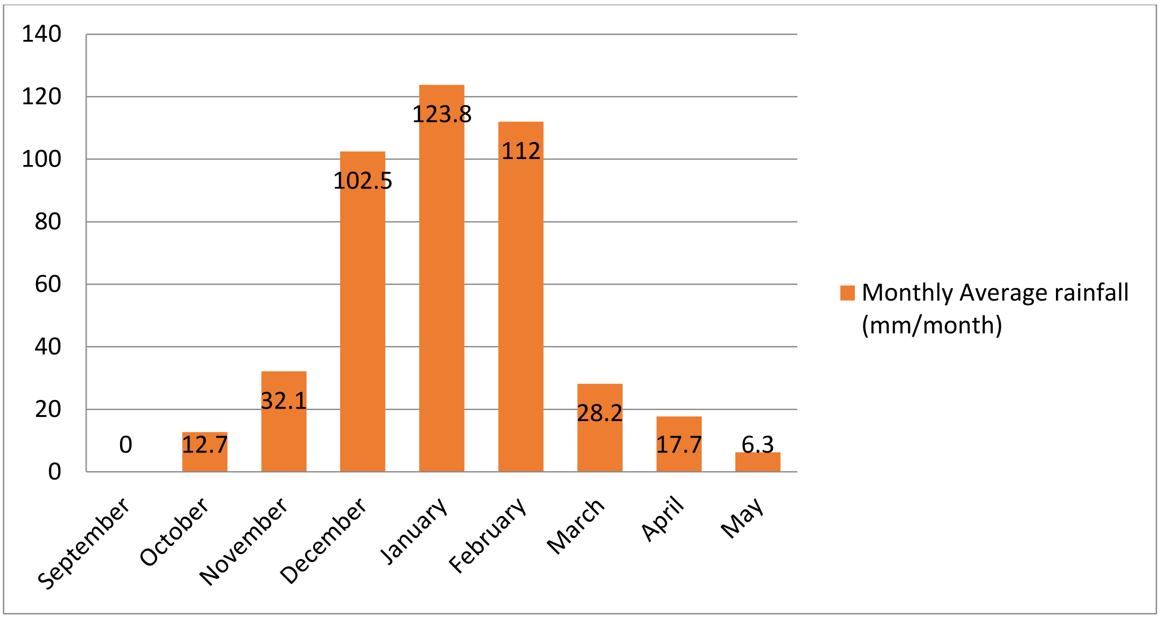

Figure 4.7: Average monthly rainfall in Dura City. (Palestinian Water Authority , 2015).

Table 4.3 and figure 4.9 indicate the frequency of the amount of rain falling on the Dura region, which indicates the number of rainy days and the determination of the amount of this rain. It is clear from this table that the incidence of floods is low due to the absence of repeated rainy days with high rainfall rates.

Table 4.3: Frequency of rainfall amounts. (Palestinian Water Authority,2015).

Rainfall (mm/month)	Frequency
5	32
50	19
100	9
150	6
200	4

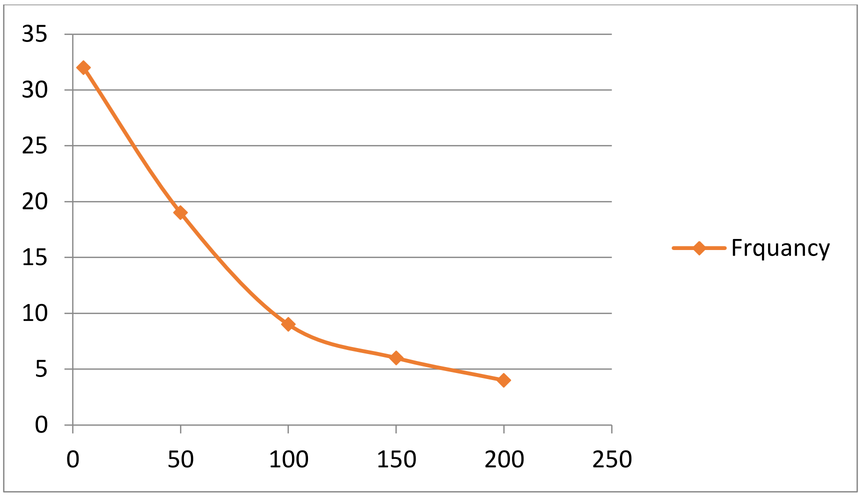

Figure 4.8 Frequency of rainfall amounts. (Palestinian meteorology , 2015).

The area of the Beit al-Rush basin reached 17 km2, and areal properties are considered one of the most important matters frequently used in hydrological models, and are used in calculating many important metrics such as drainage density. It is the entire area bounded by the water dividing line, and it is measured in several ways, including using a planometer on a contour map, or through aerial photographs or satellite visuals, or by the method of squares or any other surveying devices, or computer programs.

The following maps are prepared to analyze the effectiveness of building a dam in that area:

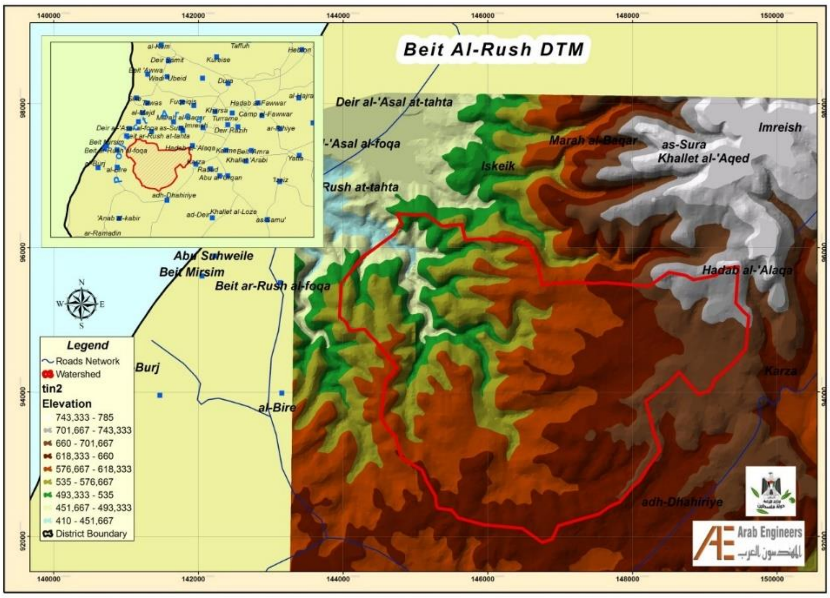

Figure 4.9 Beit Al-Rosh TIN. (Arab Engineers,2015).

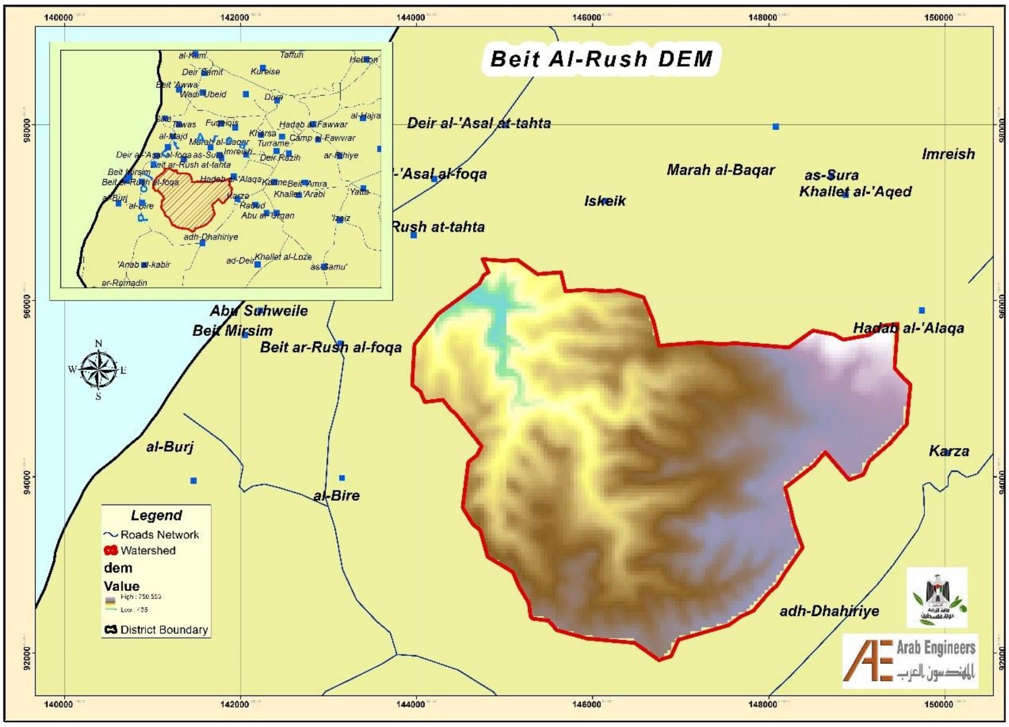

Figure 4.10: Beit Al-Rosh DEM. (Arab Engineers,2015).

The dam area was chosen at the lowest point as shown in the previous maps, so it is a good and correct choice.

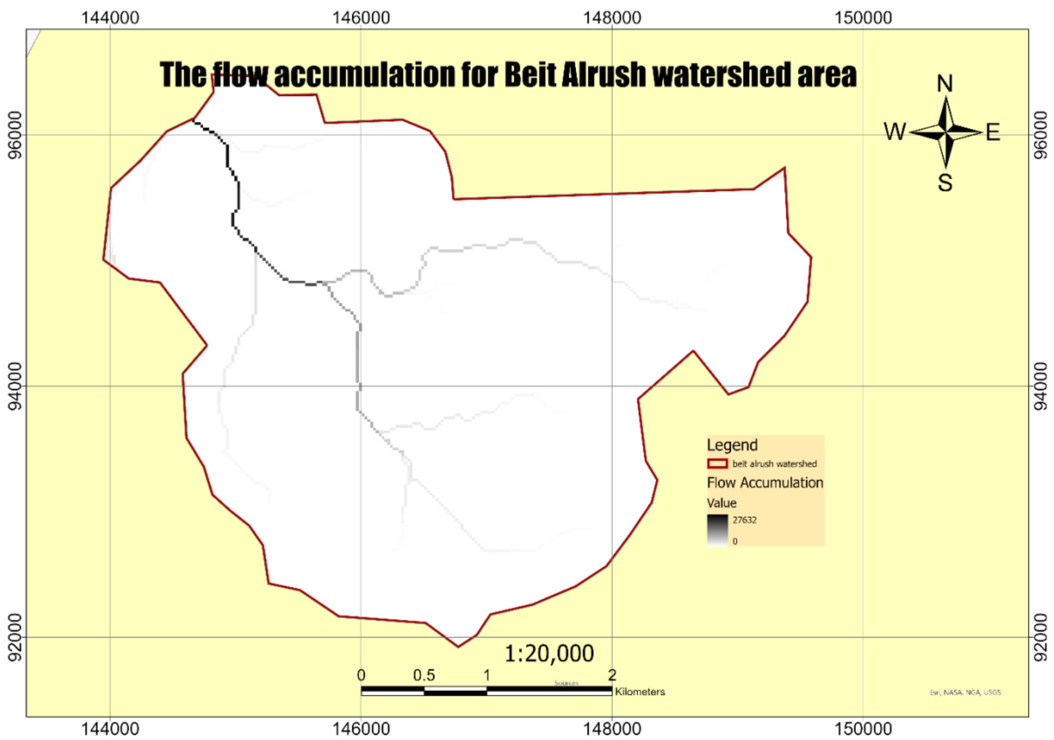

Figure 4.11: The flow accumulation for Beit Alrush watershed area

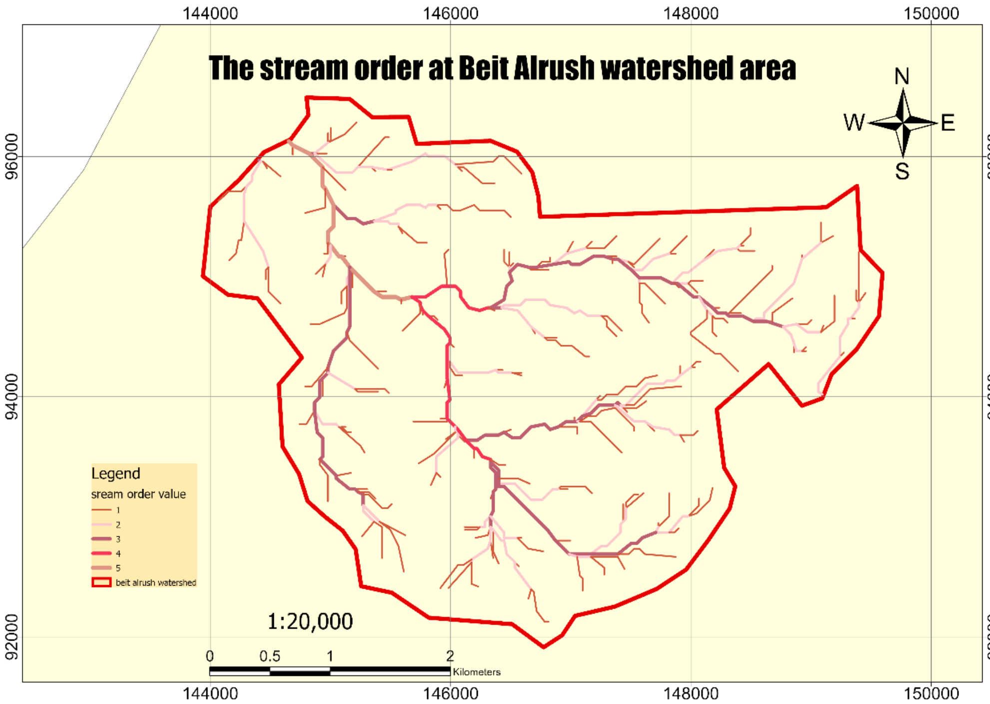

Figure 4.12: The stream order at Beit Al-Rosh watershed area

It is clear from the previous maps that the direction of water flow and collection is located in the dam area.

Land Use

Through the study of previous studies from ARIJ Center for Studies, the area of the village of Beit Al-Rosh Al-Fawqa is 3500 dunums, of which 154 dunums are residential lands and 2030 dunums are agricultural land, including: 1185 dunums of cultivated land, 8 dunums of forests, 860 dunums of open land and 500 dunums in need of reclamation.

There are 5 dunums of greenhouses in the village, most of which are used to grow cucumbers, while the fruit trees in the village there are 483 dunums planted with olive trees in addition to areas planted with other trees such as grapes and almonds.

As for field crops, there are 95 dunums of field crops grown with cereals, especially wheat and barley. As for livestock, 25% of the residents of Beit Al-Rosh village raise livestock such as sheep, chickens and bees. (Geographic information unit-Areej).

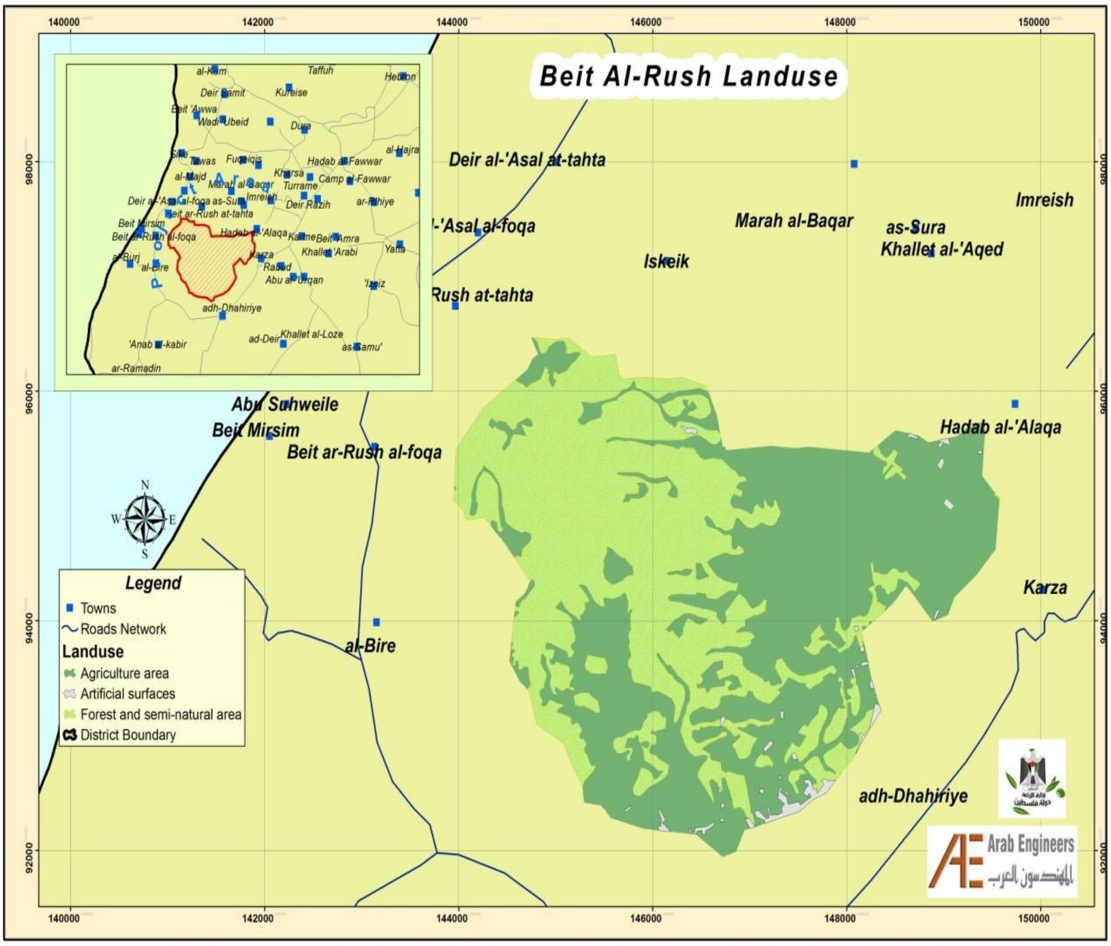

Figure 4.13: Beit Al-Rosh Landuse (Arab Engineers, 2015)

As the use of land in the project area is one of the important factors affecting the runoff resulting from rain, in urban areas the runoff is large compared to agricultural areas with red soil. The percentage of surface runoff varies based on the quality and density of vegetation and land use.

The soil was divided into four hydrological groups and this classification depends on the composition of the soil and the percentage of moisture as these and other factors affect the value of water penetration in the soil as the group A penetrates water in high proportions as a result of its formation of loose soil and soil D is a cohesive soil and water does not penetrate in high proportions.

Table 4.4 : Types of soil, characteristics and specifications of each of these types (Palestinian Water Authority, 2015).

Hydrologic Soil Group	Soil Group Characteristics
A	Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well to excessively-drained sands or gravels. These soils have a high rate of water transmission.
B	Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately deep to deep, moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
C	Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.
D (K)	Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high-water table, soils with a clay pan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

Table 4.5: Areas and types of soil and the characteristics and specifications of each of these types (Palestinian Water Authority, 2015).

Soil group	Area (m^2)	Percentage of Area %
A	7200491.16	**47.7%**
C	7892506.5	**52.29%**
SUM	**15092997.66**	**100**

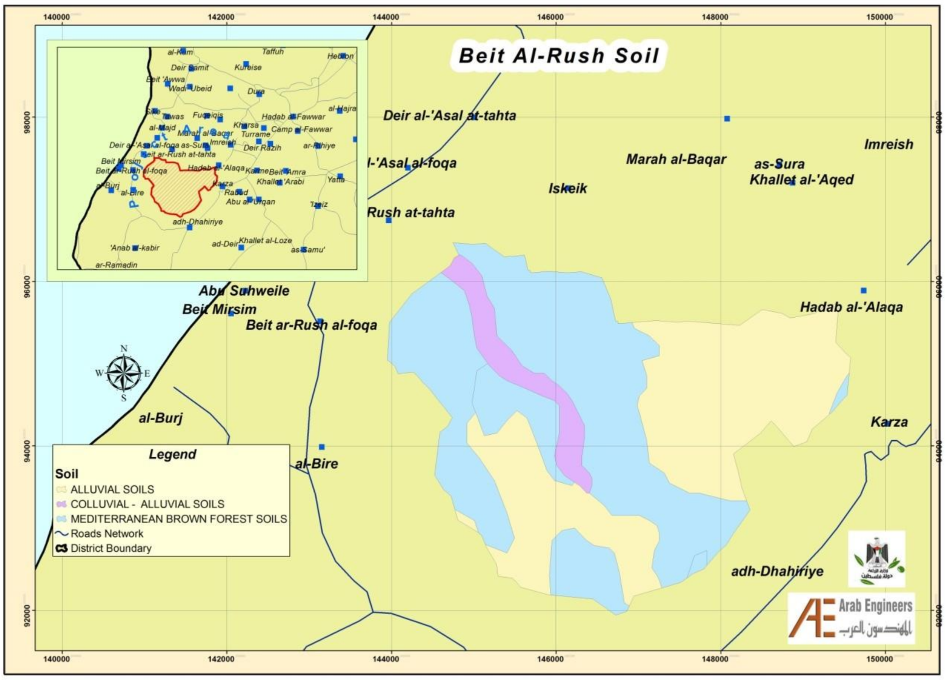

Figure 4.14: Types of soil in the Beit Al-Rosh basin area (Arab Engineers, 2015).

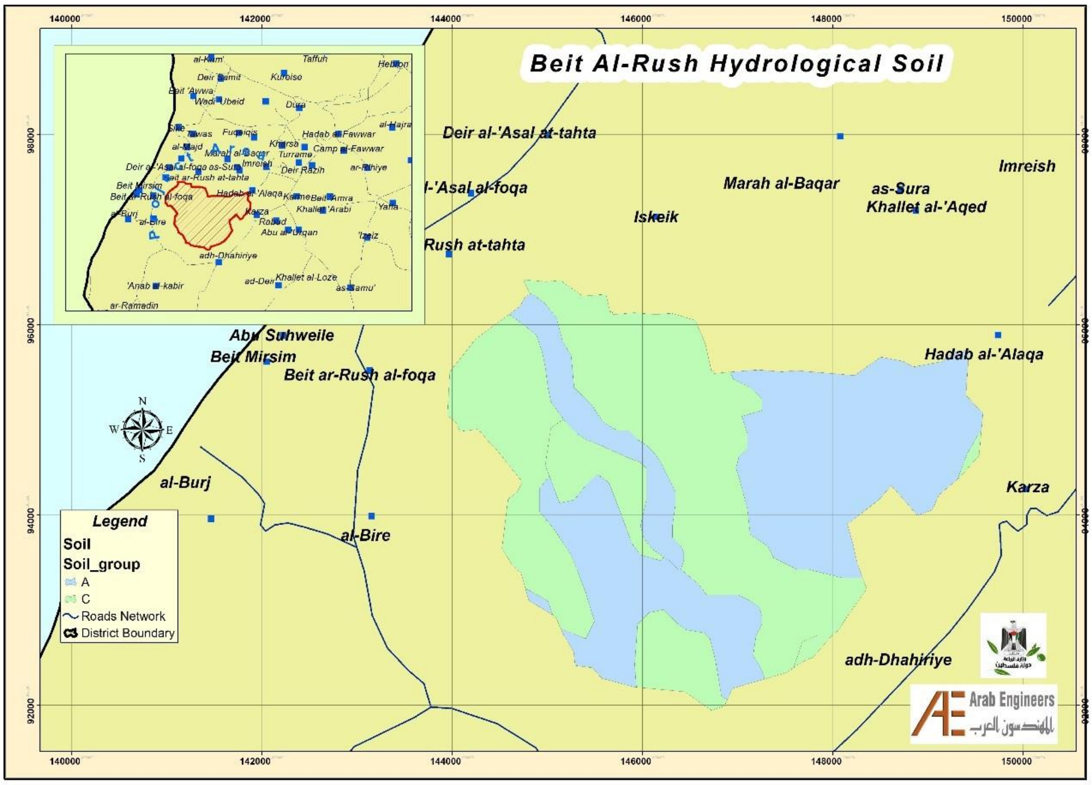

Figure 4.15: Types of Hydrologic Soil Group in the Beit Al-rosh Basin Area (Arab Engineers, 2015).

Water sector

Water is provided to the population through rainwater collection wells, The water network is old and in need of maintenance and restoration, and the water that reaches homes is weak and does not meet the needs of citizens.

Since the main source of water is rainwater, there was a need to develop the use of water harvesting of rainwater through the construction of ponds and the construction of the Beit Al-Rosh Al-Fawqa Dam.

Beit Rosh Dam

The Palestinian Ministry of Agriculture completed the construction of the Beit al-Rush al-Fawqa Dam, with funding from the Arab Authority for Agricultural Investment and Development, managed by the Islamic Development Bank "Al-Aqsa Fund," but to this day it is without any water.

The dam can accommodate about 220,000 cubic meters of rainwater, according to data from the Palestinian Ministry of Agriculture, but the water quickly evaporates and is swallowed by the ground as a result of cracks in the ground, even though it is the largest dam in Palestine, and it is a strategic water harvesting project, but citizens were shocked in 2020 by the loss of about half a million cup of water.

Table 4.6: Dam Loocation Coordinates (Palestinian Water Authority, 2015).

X	Y
144616	**96126**

According to Beit al-Rush al-Fawqa Village Council, citizens of the town, with an area of 50 dunams, which is fertile and abundant with rain, donated the land and the residents of the areas adjacent to the dam depend on agriculture and the dam serves 1,000 dunams of surrounding land.

Village Council are in the process of repairing the dam, and have contacted the competent authorities to follow up on the matter, noting that experts from the Palestinian An-Najah University will work to repair the dam, in addition to creating agricultural ponds to serve citizens who work in agricultural wealth.

According to the Ministry of Agriculture in January 2020, rainfall during the last depression amounted to 38 mm, with a rain intensity that reached a peak of 4 mm/hour, which led to torrents flowing from the harvest area and into the water pooling in the dam lake. The water column from the deepest point in the dam lake reached about 1.5 m, and the volume of water was estimated according to the implementation plans at about 1000 m3.

The dam's capacity was 180,000 cubic meters, and its construction cost amounted to about 650,000 dollars.

Activist in the southern Hebron countryside, Iyad Rajoub, describes the scene: “During times of heavy rainfall, the dam fills with water, but it quickly dries up after about two weeks (..) There is no floor for the dam to prevent leakage. They put a load of about 200 truckloads of stones and dirt on its floor, but it is It was not enough to retain water, The project may succeed if maintenance operations are carried out and the causes of leakage are detected and treated.

Results and Dissection

Looking at what was presented earlier, it is clear that the village of Beit Al-Rosh Al-Fawqa is considered a fertile agricultural area, so its choice to establish the dam was a correct choice, but it needed to do more geological studies before the dam was built, in order to ensure that the dam floor does not suffer from any crack to preserve the collected rainwater.

As for the current situation of the dam, the best option is to repair the dam to take advantage of the upcoming rainy seasons, in addition to encouraging farmers to reclaim agricultural land near the dam, and using tankers to transport water from the dam to agricultural lands far from it.

When taking into account the situation of the West Bank in terms of water scarcity, focusing on rainwater harvesting projects is the best solution for the future of these areas.

4.3.2 Bani neim Dam

Location

The city of Bani neim is located about 7 km east of the city of Hebron. The city is located above a high area of the Hebron Mountains and at an altitude of 970 meters above sea level, which represents the eastern edge of the heights of the Hebron Mountains.

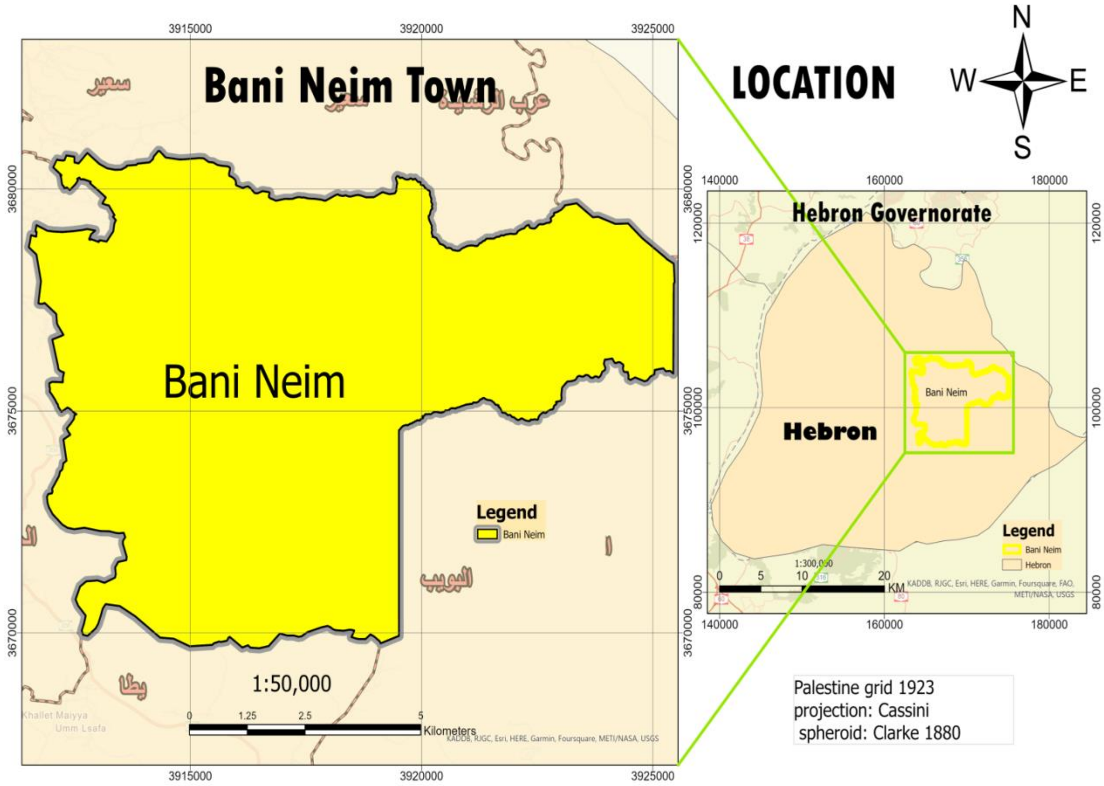

Figure 4.16: Bani neim Town Location

Climate

The town of Beni neim is located at an altitude of 970 meters above sea level, and the average annual rainfall there is about 475.5 mm. The average temperature reaches 17 degrees Celsius, and the average relative humidity is about 60% (Geographic Information Unit-ARIJ).

Bani neim region enjoys a moderate climate in the summer and a cold climate in the winter, like the Hebron region, as the prevailing climate in the region is the Mediterranean climate and the southwestern winds carrying rain, in addition to the eastern winds that are cold and dry in the winter.

Table 4.7: shows the average temperatures during the months of the year in the town of Bani neim(Palestinian meteorology)

month	Sep. (C^o)	Oct. (C^o)	Nov. (C^o)	Dec. (C^o)	Jan. (C^o)	Feb. (C^o)	Mar. (C^o)	Apr .(C^o)	May (C^o)
Average Temperature	26 -15.9	-14 23.2	-9.9 17.5	-5.6 12.1	4- 10.2	4.7- 11.5	6.5- 14.6	9.9- 19.6	13.2- 23.6

Land use

The area of the city of Bani neim is 207 square kilometers, which is equivalent to 15.35% of the area of the Hebron Governorate. The city of Bani neim is considered the second largest town in terms of area in the Hebron Governorate.

The percentage of arable land is estimated at 11.3%, and it is increasing due to land reclamation operations by citizens in the town of Bani neim.

The percentage of lands used for pastures is 81%, and these lands are located in the eastern region of the city and are called the Al-Misfra area.

Land use is an important factor in surface runoff resulting from rain. The following maps and information were obtained based on previous studies by the ARIJ Center and the Geographic Information Systems Programmed. In urban areas, surface runoff is large compared to agricultural areas with red soil. The rate of runoff varies based on the quality and density of vegetation and land use.

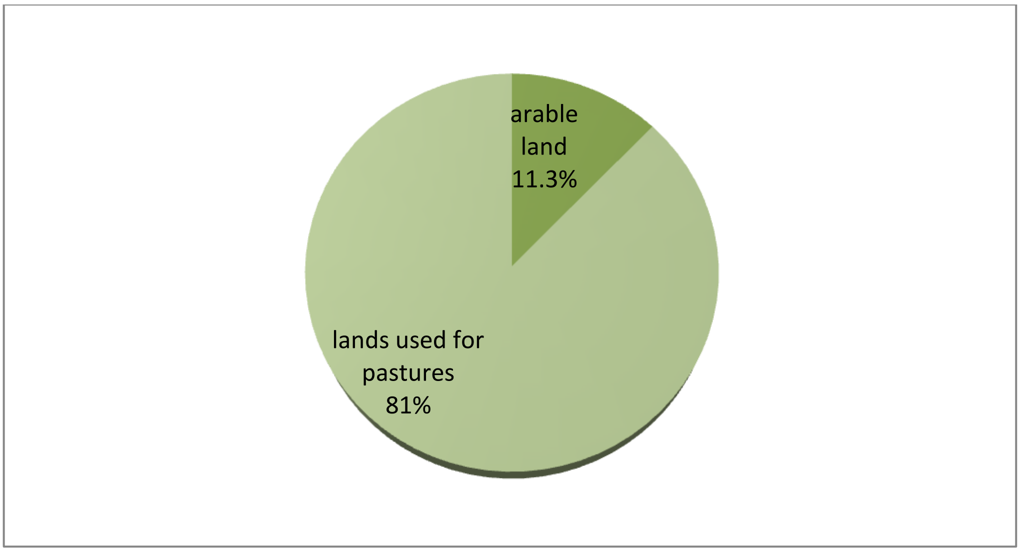

Figure 4.17: Percentage of Bani neim lands in terms of arable land and pasture land

Table 4.8: Types of land uses in the Bani neim Basin (Palestinian Water Authority,2015)

Land Use	Area (m^2)	مPercentage of Area %
Agricultural area	13368558.67	**41.4%**
Artificial Surfaces	1197651.9	**3.71%**
Forest and semi-natural area	17655219.9	**54.79%**
SUM	**32221430.47**	**100**

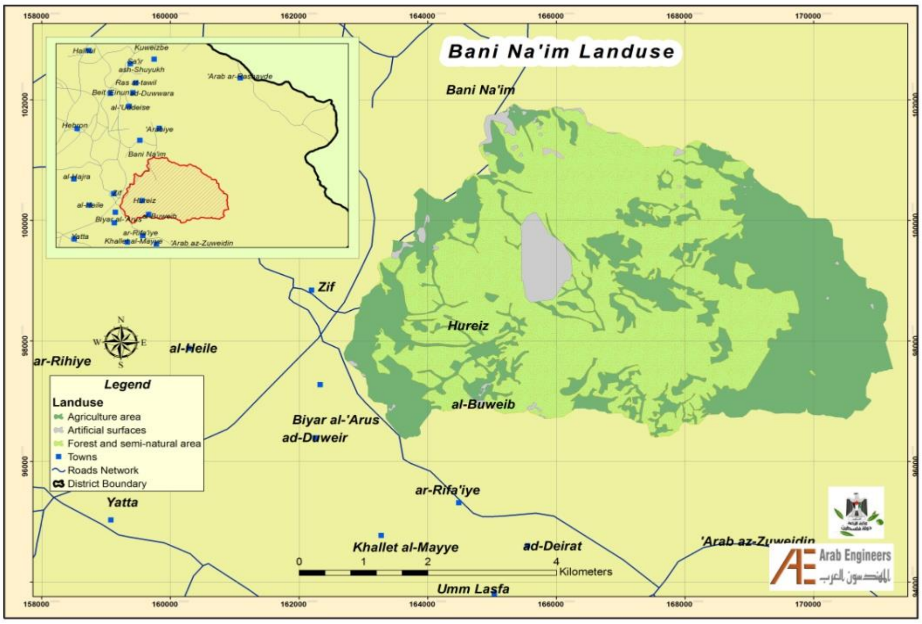

Figure 4.18: Land uses in the Bani neim watershed area. (Arab Engineers,2015)

Table 4.9: shows the areas of each soil group and the percentages of these areas (Palestinian Water Authority, 2015)

Soil group	Area (m^2)	Percentage of Area %
A	4938940.6	**15.35**
B	5242589	**16.25**
C	22039900.8	**68.3**
SUM	**32221430.4**	**99.9**

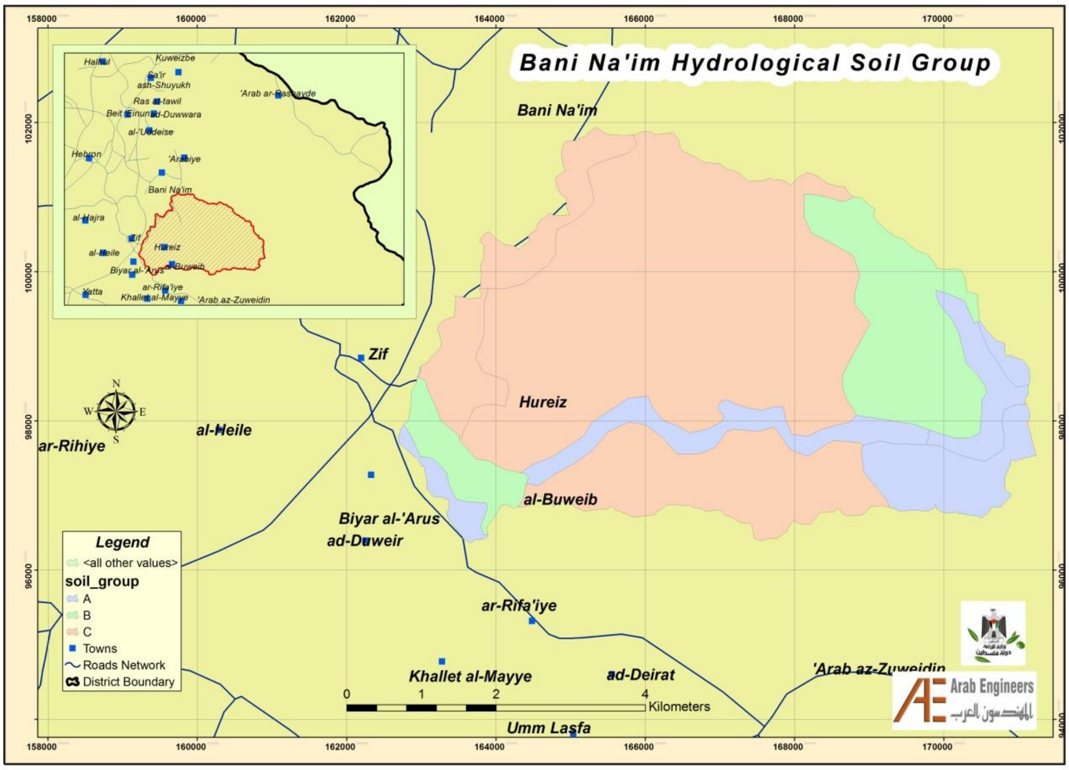

Figure 4.19: Types of Hydrologic Soil Group in the Bani neim Watershed Area (Arab Engineers,2015)

Landforms

As for the terrain of the city of Bani neim, it consists of mountains of varying levels, with the mountains of Hebron and Halhul to the west, and a clear slope towards the east, towards the Dead Sea. Altitudes in the Bani neim Basin area range between 415-980 meters above sea level. This slope led to the emergence of valleys and plains due to erosion and erosion, but this erosion is slow due to the drought factor that characterizes the climate of this region.

Topography of Bani neim Town

The Hebron Heights, including the heights of the Bani neim and Halhul area, constitute the water dividing line between the drainage that heads west towards the Mediterranean Sea and the drainage that heads east towards the Dead Sea, which permeates the lands of the city of Bani neim, forming a number of dry valleys that form integrated river basins from source to mouth. Most of them are located within the lands of Bani neim, where their level starts from 970 meters above sea level to 392 meters below sea level, meaning the difference between the source and the downstream level is 1362 meters. The length of these valleys is about 23 horizontal kilometers, which is the horizontal distance between the city of Bani neim and the Dead Sea. These valleys are: -Wadi Al-Ghar, Wadi Saif, Wadi Al-Jarfan, Wadi Al-Mantar, Wadi Amer, Wadi Al-Waar, and Wadi Al-Mu'azza.

This area is considered one of the largest water basins in Palestine, and there are artesian wells and collection wells in the area.

As shown in Figure 4.21 a map showing the topography of Bani neim Town and bani neim watershed area

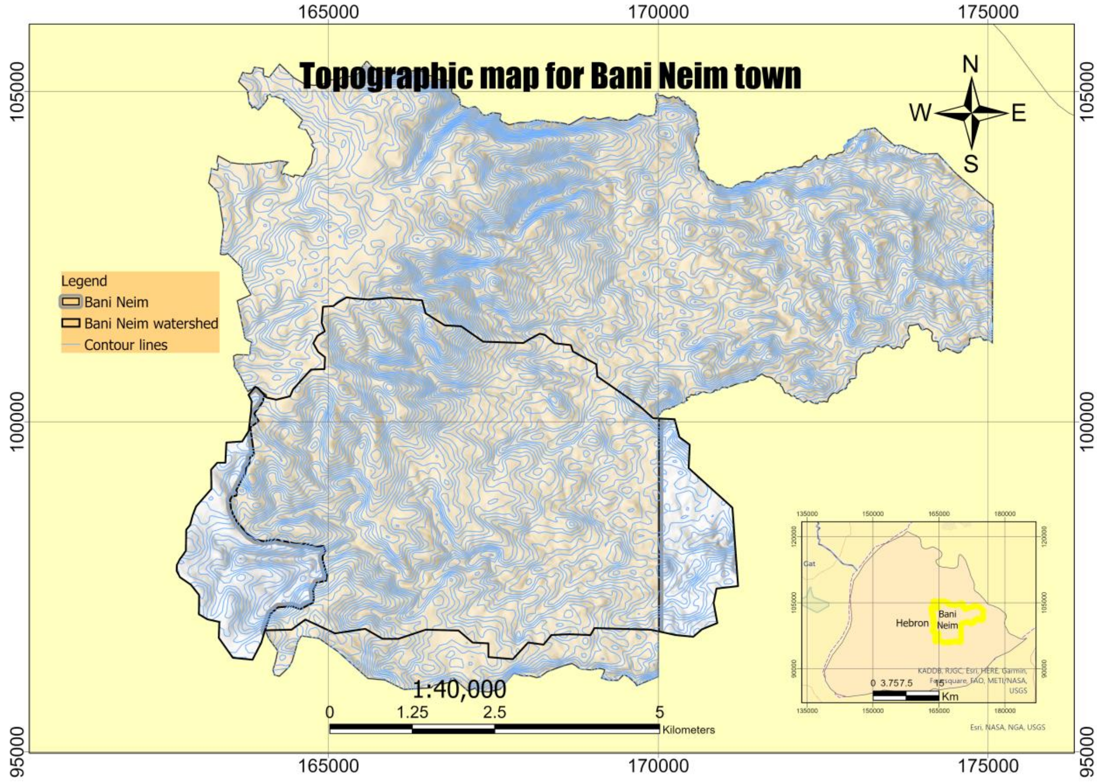

Figure 4.20: Topographic map for Bani neim Town

Population

The population of the town of Bani neim is 20,301 people, according to the number of Palestinian residents who were censused in 2007. The population of the town of Bani neim constitutes 3.67% of the total population of Hebron Governorate, and the population of the town of Bani neim is estimated at 26 thousand people according to estimates in 2010.

The population of the city of Bani neim in 1922 was about 1,179 people, and their number increased in 1931 to about 1,646 people who lived in 320 houses. In 1945, their number reached 2,160 people, and in the 1961 census their number reached 3,392 people. Their number in 1980 was estimated at more than 7,000 people, and rose to 7,600 people in 1987 AD until it reached more than 20,000 people in 2007, and in 2010 it reached 26 thousand people.

It is worth noting that the population of Bani neim constitutes 3.67% of the total population of Hebron Governorate.

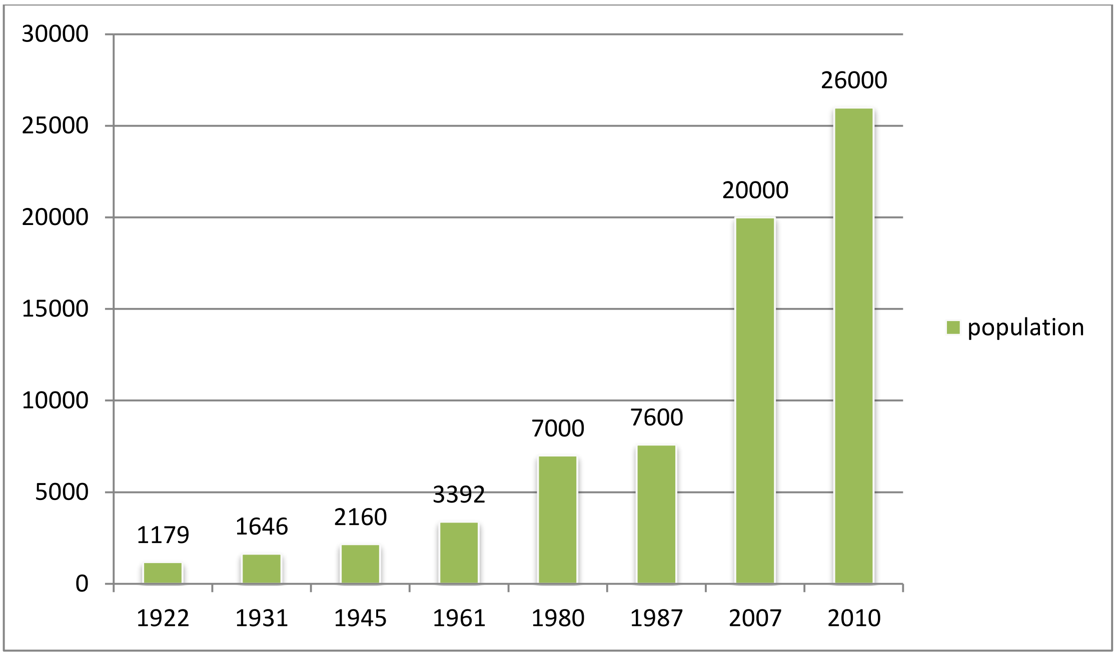

Figure 4.21: population of Bani neim **(Palestinian Central Bureau of Statistics, 2009,)**

The Palestinian population census conducted in 2007 showed that the population of Bani neim reached 20,301 people, including 20,084 people, they live in the town of Bani neim, and 217 people live in Misfra Bani neim.

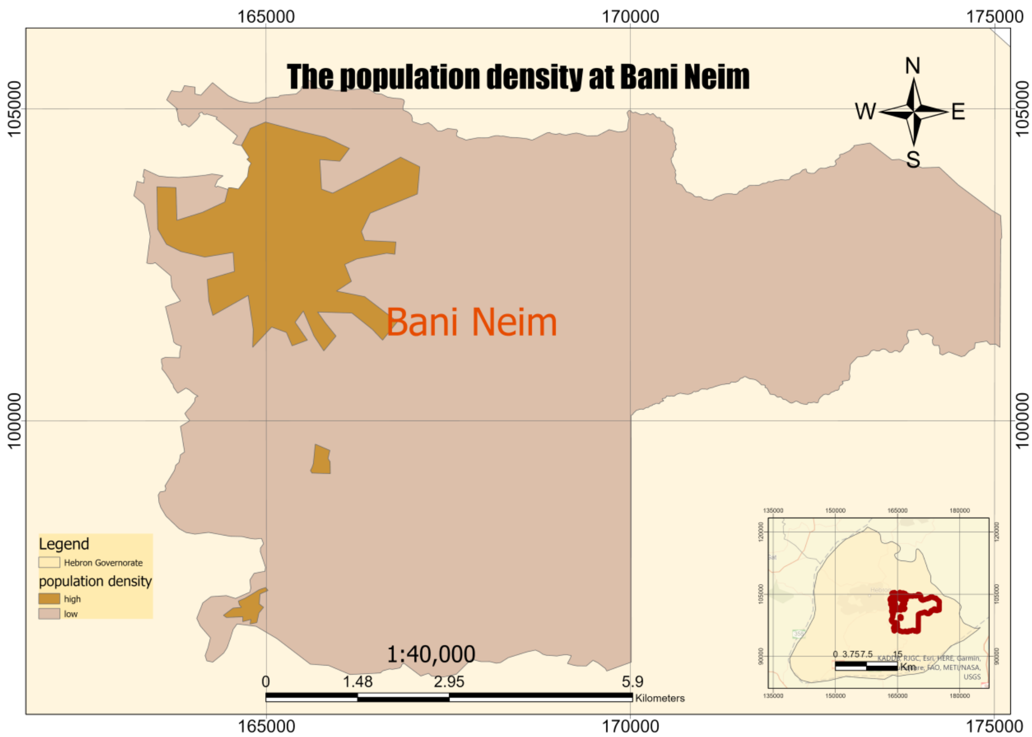

Figure 4.22 population density at Bani neim

Economic Activities

In a statistic carried out by Areej, the following economic activity was shown

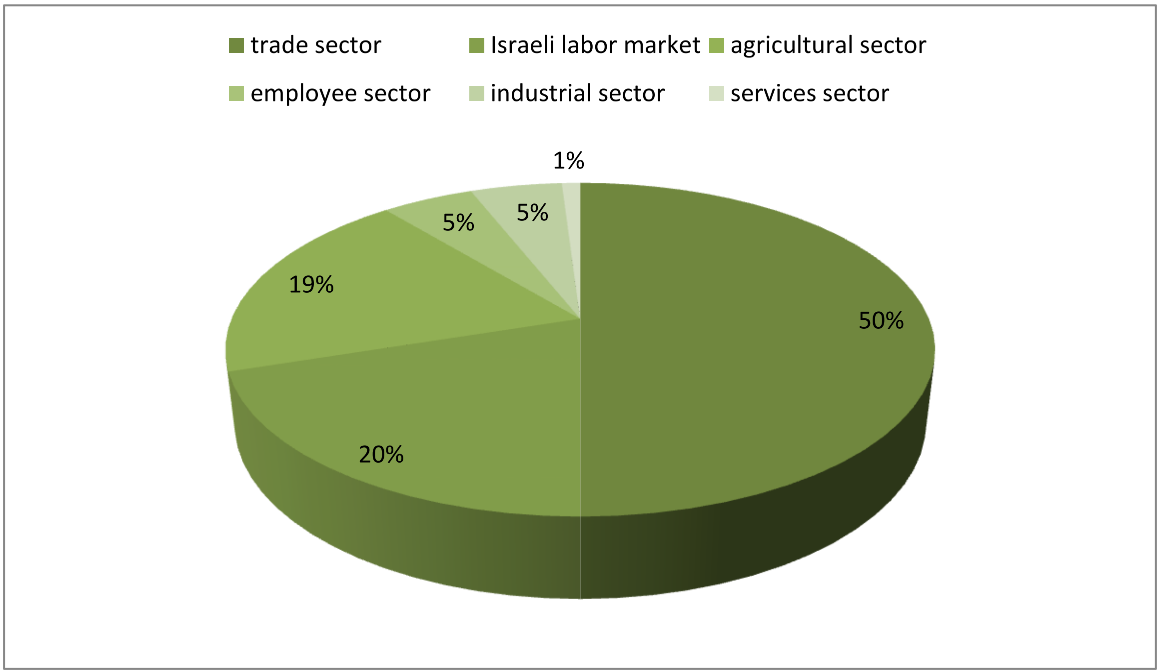

Figure 4.23 distribution of the labor force by economic activity in Bani neim Town

According to the previous graph, the percentage of employees in the agricultural sector in the town of Bani neim constitutes 19% of the total workforce in the town, which is a large percentage, and this gives a perception about the town's need for rainwater harvesting projects in addition to agricultural reclamation projects.

Rainfall

Table 4.1 previously presented, shows rainfall rates in some areas of Hebron Governorate, including the town of Bani neim.

Table 4.10 Rainfall rate at Dura station and its standard deviation. (Palestinian Water Authority ,2015)

	Sep. (mm)	Oct. (mm)	Nov. (mm)	Dec. (mm)	Jan. (mm)	Feb. (mm)	Mar. (mm)	Apr . (mm)	May (mm)
Average	0.17	6.1	21.71	81.37	103.88	94.48	31.42	16.75	4.33
Standard Deviation (SD)	0.58	5.66	29.99	61.20	58.60	33.08	30.16	23.95	12.85

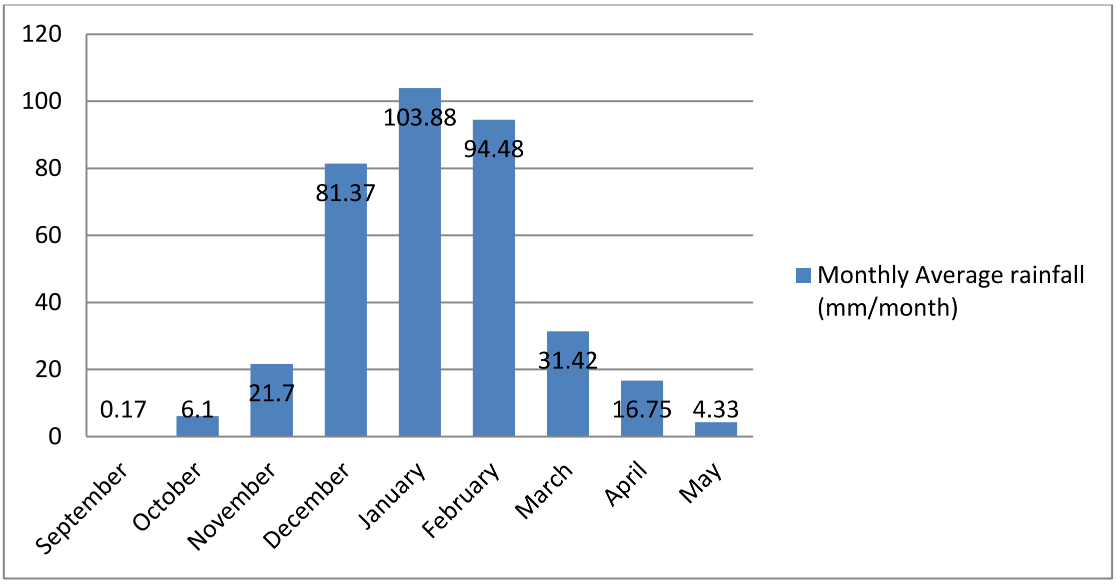

Figure 4.24: Average monthly rainfall in bani neim town. (Palestinian Water Authority, 2015)

Table 4.11and Figure 4.26 indicate the frequency of the amount of rain falling on the bani neim region, which indicates the number of rainy days and the determination of the amount of this rain. It is clear from this table that the incidence of floods is low due to the absence of repeated rainy days with high rainfall rates.

Table 4.11: Frequency of rainfall amounts. (Palestinian Water Authority, 2015)

Rainfall (mm/month)	Frequency
5	30
50	19
100	7
150	6
200	2

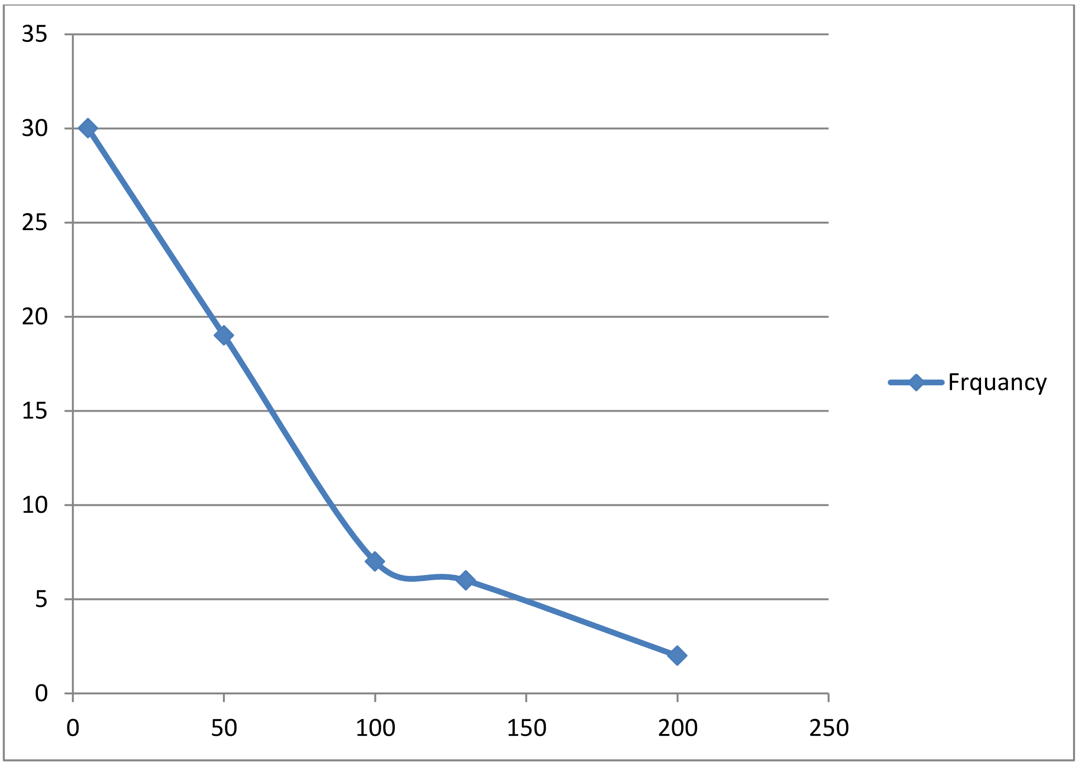

Figure 4.25: Frequency of rainfall amounts. (Palestinian Water Authority,2015)

The area of the Bani neim basin reached 32.22 km2, and areal properties are considered one of the most important things often used in hydrological models, and are used in calculating many important metrics such as drainage density. It is the entire area bounded by the water dividing line, and it is measured in several ways, including using a planometer on a contour map, or through aerial photographs or satellite visuals, or by the method of squares or any other surveying devices, or computer programs.

The following maps are prepared to analyze the effectiveness of building a dam in that area:

A digital model showing the digital elevations of the Beni neim watershed area, which ranges approximately from 400 m to 950 m above sea level. This model was obtained through geographic information systems and based on the irregular triangle network called TIN.

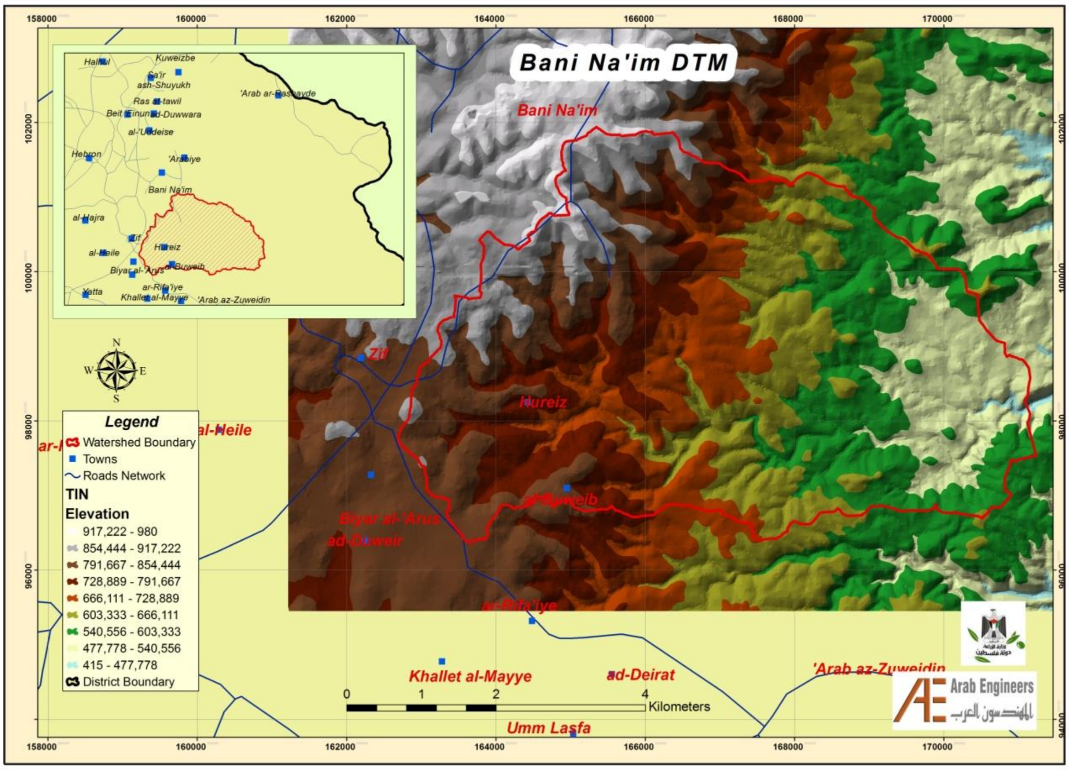

Figure 4.26: Bani Neim TIN. (Arab Engineers,2015).

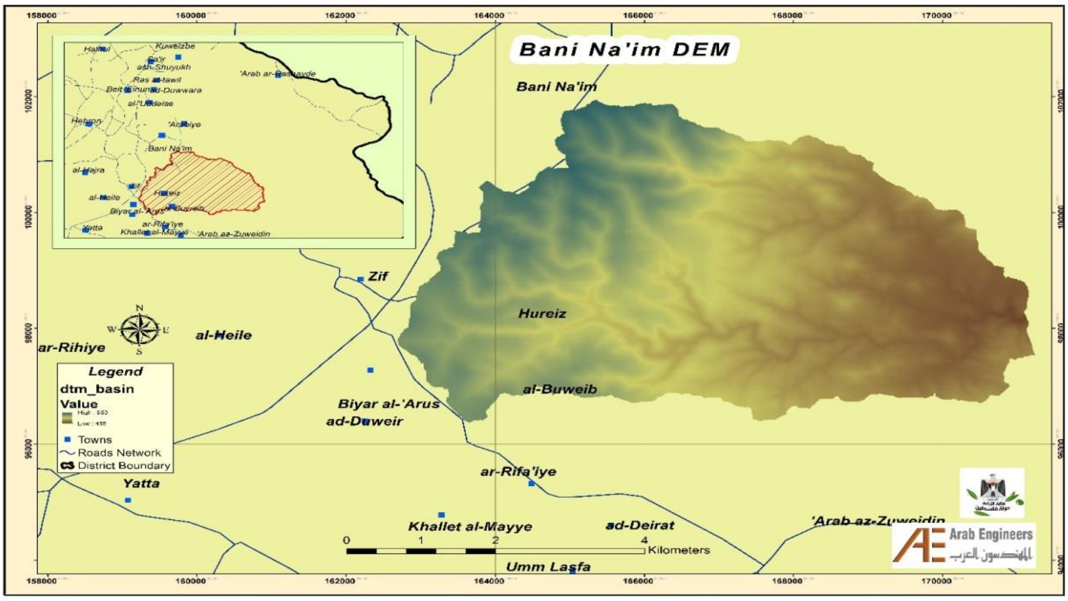

Figure 4.27: Bani Neim DEM. (Arab Engineers,2015).

The dam area was chosen at the lowest point as shown in the previous maps, so it is a good and correct choice.

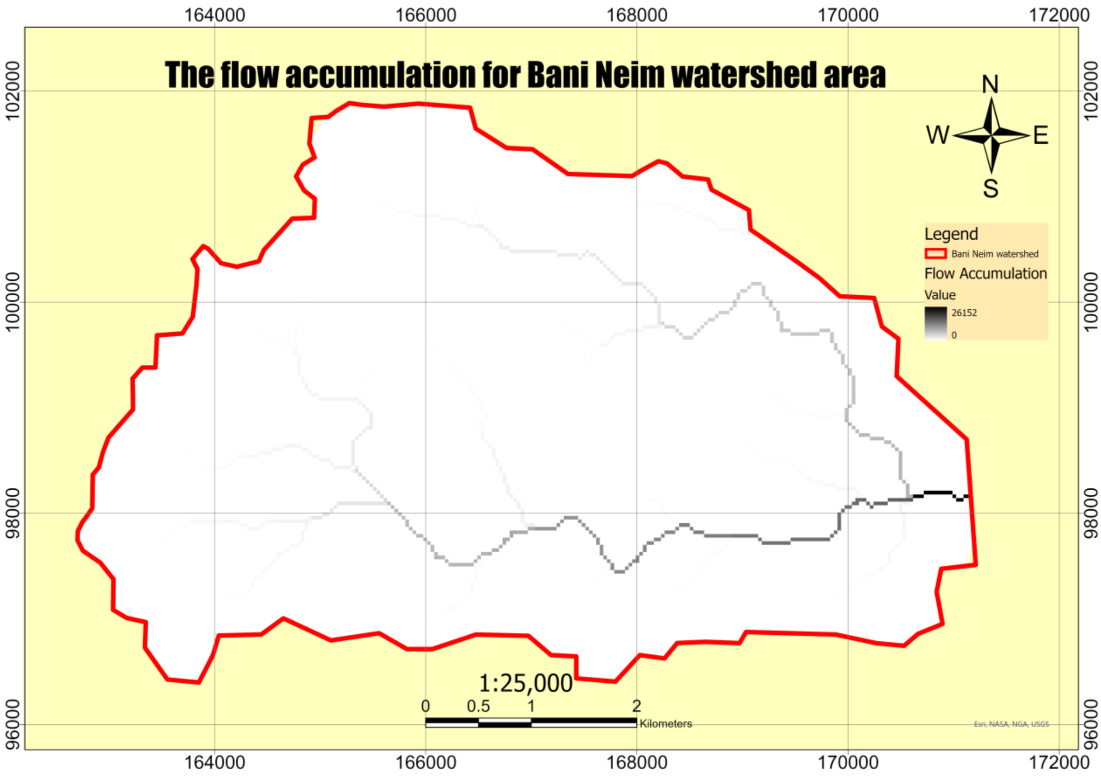

Figure 4.28: The flow accumulation for bani neim watershed area

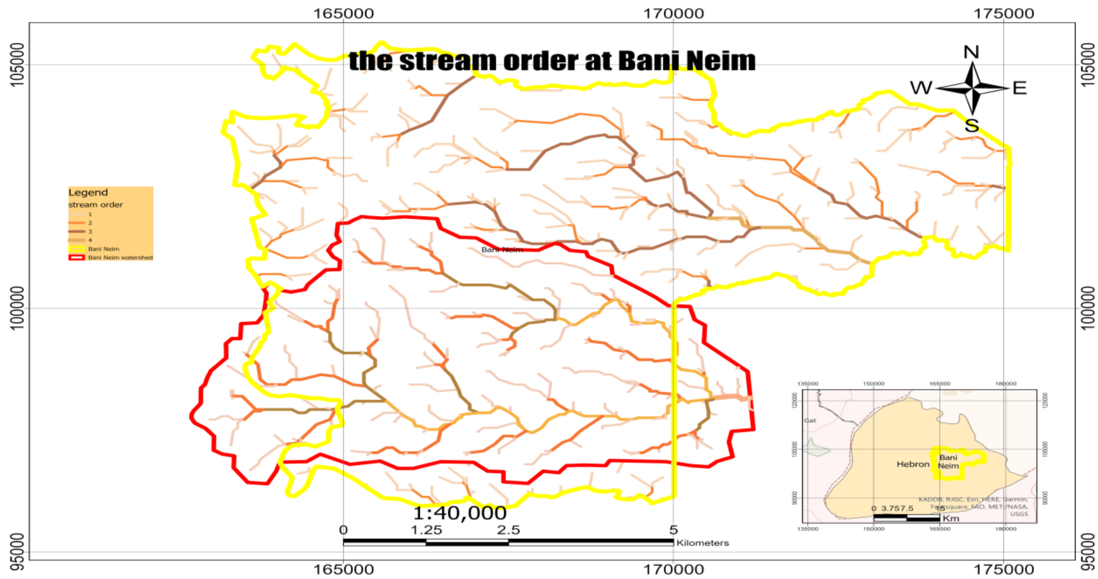

Figure 4.29: The stream order at bani neim town

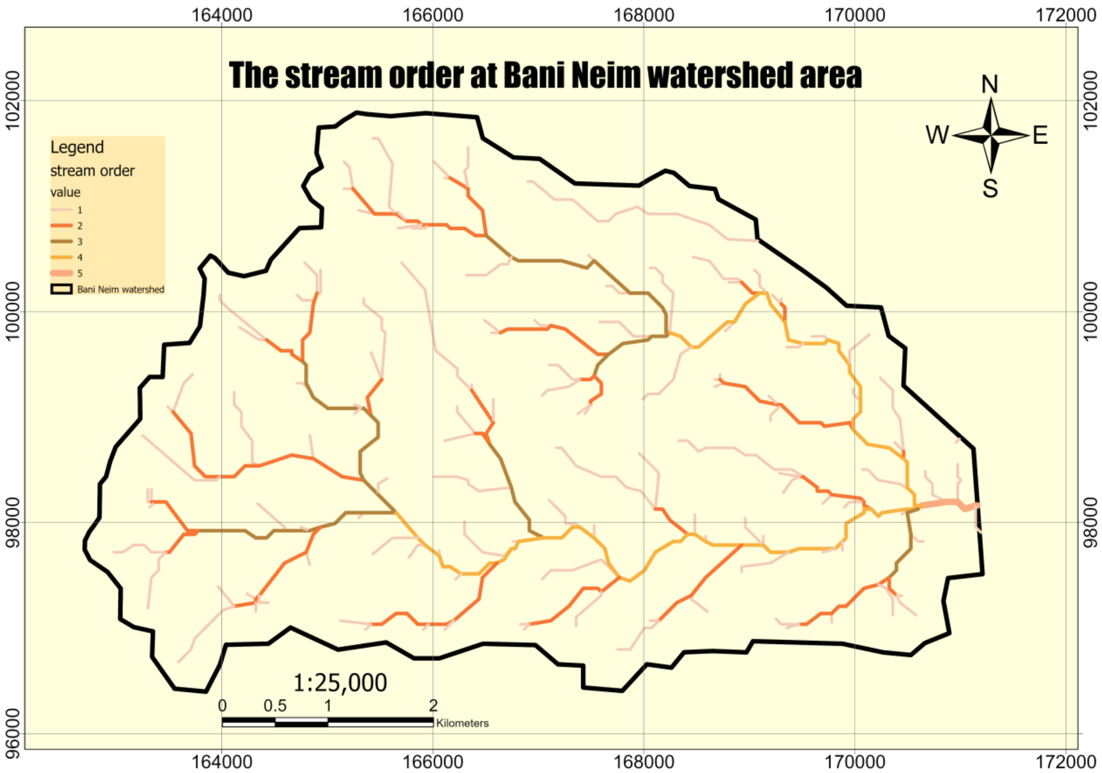

Figure 4.30: The stream order at bani neim watershed area

It is clear from the previous maps that the direction of water flow and collection is located in the dam area.

The slope of the land

the greater the slope, the greater the behavior, and vice versa, the lower the slope, the less Drainage, as the steep slope prevents water from seeping into the soil and quickly reaching the valley exit While the flat land facilitates water leakage into the soil, thus increasing water losses and reducing surface runoff.

The slope in the study area ranges between 0-40%, with an average rate of 12%, as shown in the figure, which is a map showing the slope in the Bani neim basin area.

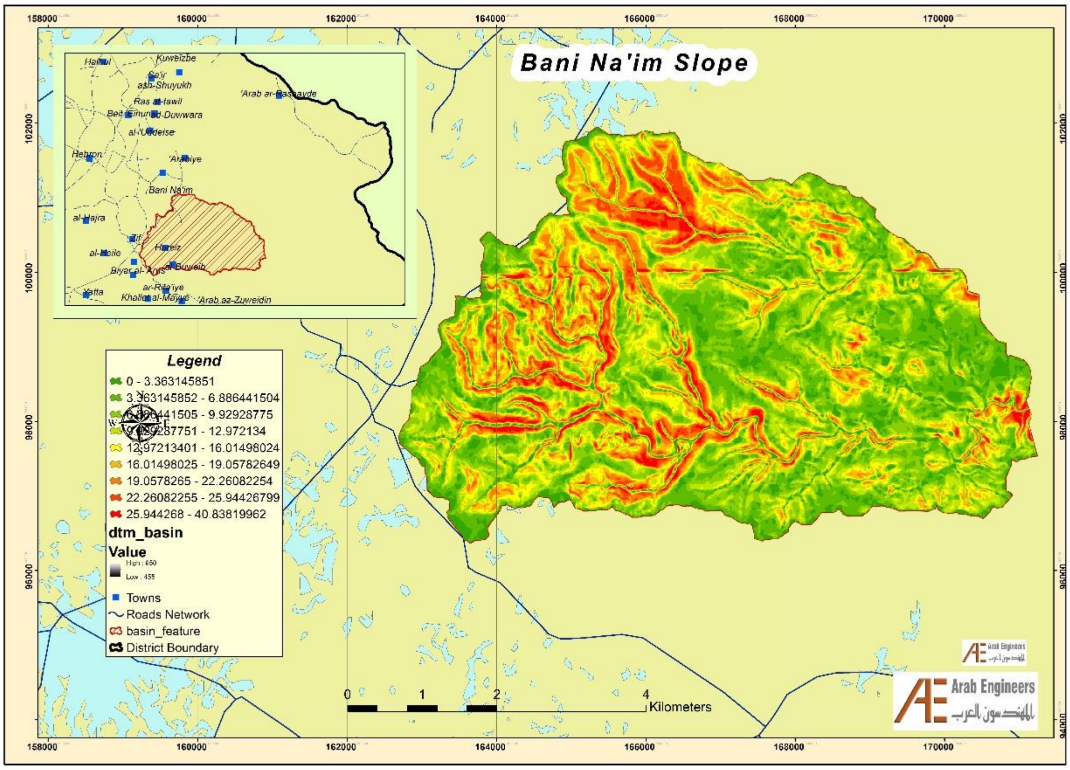

Figure 4.31: Bani Neim Slope. (Palestinian Water Authority,2015).

Bani neim Dam

Managed by the Islamic Development Bank, and funded by the Arab Investment Authority and the European Union, the Bani neim Dam was constructed. The dam site is approximately 8 km southeast of the city of Bani neim in the area called Jub al-Nashl. It rises approximately 450 meters above sea level to the valley stream, and the area of this basin is approximately 32.22 km2.

***Table 4.12*:** **Bani neim Dam location coordinates**

X	Y
172912	**98149,82**

The Ministry opened the Bani neim Dam in the same period as the opening of the Beit Al-Rush Dam, and water began to accumulate in it, but it soon dried up. Note that its capacity reaches about 180 thousand cubic meters, and the cost of its construction amounted to about 600 thousand dollars.

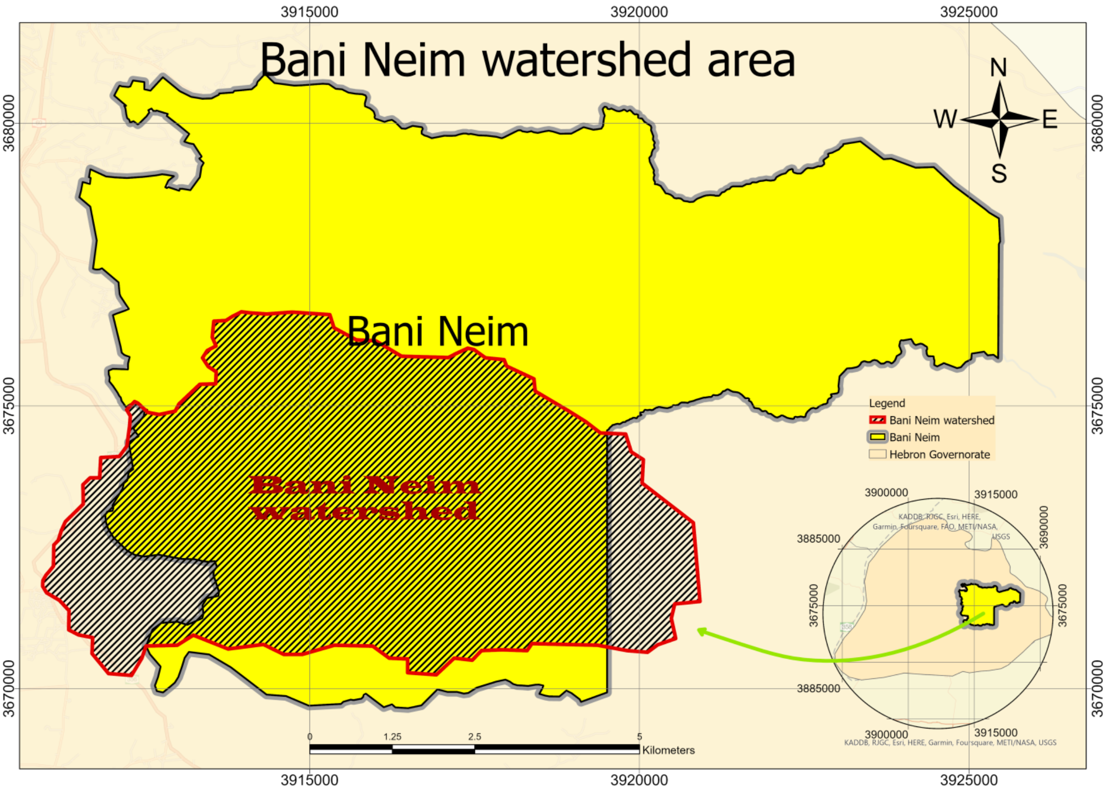

Figure 4.32: Bani neim Watershed Area

The dam area can be divided into several areas based on the amount of rain falling in each area. From Figure 4.34 it is clear that the dam area is located in 3 rainwater divisions, namely (300-350 mm, 350-400 mm, 400-450 mm). This was approved in the rain calculations on the rain stations of the Meteorological Department , we relied on rain information for two stations in Bani neim, which is 4 km away from the dam area, and Yatta station, which is approximately 4 km away

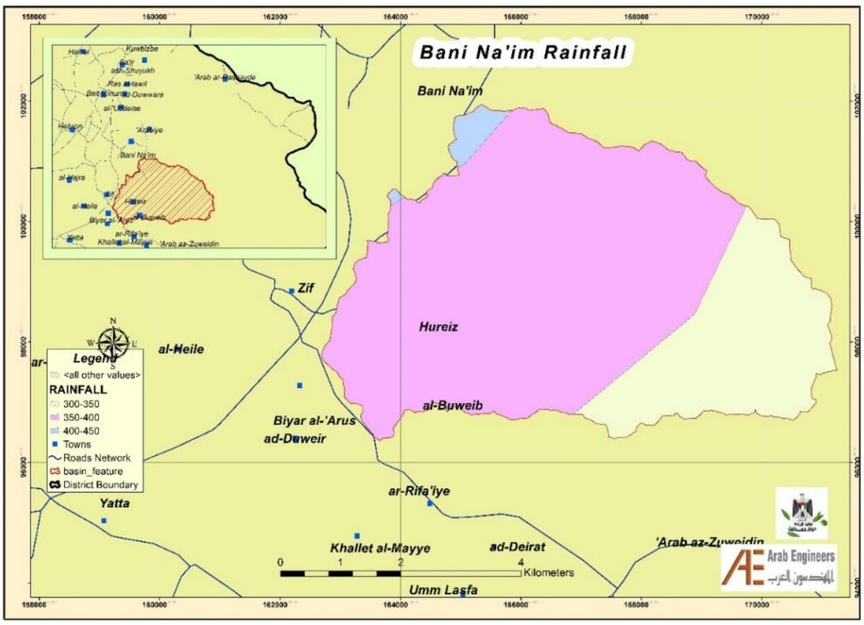

Figure 4.33: Rainfall rates in the Bani neim Watershed area (Arab Engineers,2015)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

5.1 conclusions

It is clear from the study that we conducted, that many areas in the world suffer from water scarcity, including the West Bank, specifically the southern part of it, more than 620,000 Palestinians in vulnerable communities in the West Bank are either not connected to piped water services or have insufficient access to water, often arriving through unsafe sources or water trucks. This lack of access to basic water and sanitation services affects their daily lives and directly affects their personal hygiene and health. In addition, families that rely primarily on agriculture and grazing as a source of income suffer from a lack of water necessary to maintain their livelihoods.

and we monitored the conduct of many projects to try to solve the problem, but The projects under development due to the lack of sufficient experience in this field, so we relied on conducting the study on the areas of Beit Al-Rosh Al-Foka and Bani neim, because there are two huge projects for harvesting rainwater, namely the two dams built in them, In addition to the large percentage of agricultural land in them.

The Water harvesting is an effective and cheap solution to address water scarcity.

5.2 Recommendations

1- To do more research regarding rainwater harvesting.
2- Working to enhance regional, international and local cooperation in the fields of scientific research, technical development and exchange of experiences to develop water resources and manage them in an integrated manner, including finding technologies with low operating and maintenance costs and high efficiency in various fields.
3- Raising awareness among the local community and the farmer sector of the need to implement rainwater harvesting projects and rely on it as an alternative to the water that reaches them from the water network.
4- Repair of dams built by the Palestinian Water Authority by bringing experts in similar projects.
5- Conducting the necessary geological research before implementing any project to avoid economic losses and achieve the benefit of the project to be established.
6- Protecting water sources from pollution and depletion.
7- Promoting the concept of treating domestic gray water and improving its use, especially in rural areas, and using the treated water directly for irrigation purposes.
8- We need technicians and engineers trained to establish water harvesting projects.

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