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Impacts of Using Treated Wastewater on Rainfed Agriculture in the Jenin Governorate

M.Sc. Thesis

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Impacts of Using Treated Wastewater on Rainfed Agriculture in the Jenin Governorate

تأثير استخدام المياه العادمة المعالجة على الزراعة البعلية في محافظة جنين

Submitted by

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This thesis was prepared under the main supervision of Dr. Maher Abu-Madi and has been approved by all members of the examination committee**.**

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Dedication

To my dear parents, my lovely husband, brothers, sister, for their support, and for my coming baby

الملخص:

هناك العديد من الدراسات والأبحاث التي أجريت في جميع انحاء العالم لمعرفة تأثير استخدام المياه المعالجة في الري التكميلي للمزروعات البعلية. هذا البحث يهدف لدراسة وتقييم تأثير استخدام المياه المعالجة لري المزروعات البعلية.

تم اختيار محافظة جنين لامتلاكها أكبر مساحة زراعية في الضفة الغربية حيث الغالبية من اهلها يعملون في مجال الزراعة وتساهم في ما يقرب 16.2% من الانتاج الزراعي في السوق الفلسطيني.

في هذا البحث تم تقدير كميات المياه للأعوام 2015، 2020، 2025 وهذه الكميات تزداد مع السنين نتيجة للنمو السكاني بنسة 2.3%.

حاليا يتم معالجة المياه في كل من مدينة جنين وقرية عنزة حيث يتم معالجة 1309744م ^{3}/سنة وبهذه الكمية نستطيع ري 2911 دونم /سنة، في عام 2020 كمية المياه المعالجة ستصل الى 2714768م^3/سنة حيث سيتم ري ما يقرب 6033 دونم/سنة، في عام 2025 كمية المياه العادمة المعالجة ستصل لما يقرب 3302819 م^3/سنة حيث سيتم ري 7340 دونم/سنة .

المزروعات التي تم اختيارها في هذا البحث كانت في الاعتماد على التعاليم الاسلامية و المواصفة الفلسطينية و مواصفة الصحة العالمية و مواصفة منظمة الغذاء والمزروعات. المزروعات هي العنب، اللوزيات، الزيتون، الشعير، المشمش، البرسيم .

المياه العادمة المعالجة الخارجة من محطة معالجة جنين لا تتناسب مع الجودة الموصى بها في المواصفات العالمية ولذلك ليتم استخدامها يجب تعريضها للمرحلة الثالثة للمعالجة اما في استخدام الكلور او الأشعة فوق البنفسجية، ولكن المياه الخارجة من محطة المعالجة في عنزة تتوافق مع المواصفات العالمية ويتم استخدامها في ري اشجار الزيتون في القرية.

يوجد في قرية عنزة خزان مياه سعته 500 م^3/يوم، وفي مدينة جنين خزان مياه سعته 3000 م^3/يوم وذلك لتخزين المياه العادمة المعالجة ومن ثم اعادة توزيعها باستخدام انابيب بنفسجية في المدينة والقرية.

العديد من المنظمات العالمية والأهلية تقوم بتمويل مشاريع تستخدم المياه العادمة المعالجة في الري وتعمل على رفع وعي المزارعين بأهمية استخدام المياه العادمة المعالجة في الزراعة.

Abstract:

Studies and researches have been conducted all over the world in order to assess the impact of using treated wastewater for supplementary irrigation for rainfed agriculture. This thesis aims to assess the impacts of using treated wastewater on rainfed agriculture.

Jenin has been chosen as the study site, since it is one of largest agricultural area in West Bank. Contributes with about 16.2% of the agricultural production in the Palestinian market.

An analysis was done to estimate the quantity and the quality of treated wastewater and its effect on rainfed agricultural areas, and production.

The quantities of treated wastewater were estimated for years 2015, 2020, and 2025. During these years, the quantity of wastewater will increase in Jenin governorate due to population growth rate of 2.3%.

The current amount of treated wastewater in Jenin and Anza wastewater treatment plants is 1,309,744 m^3/y and it can irrigate (2911 Dunum/y). In 2020, the quantity will be 2,714,768 m^3/y which can irrigate an average of (6,033 Dunum/y). In 2025, the quantity of treated wastewater will be 3,302,819 m^3/y and it can irrigate an average of 7,340 Dunum/y.

The crops chosen for this research are in accordance with the guidelines of Palestine, FAO, and WHO, for reuse of treated wastewater.

The quality of treated wastewater that exits in the Jenin wastewater treatment plant is not in conformity with FAO and Palestinian guidelines. Accordingly, in order to use it, the wastewater needs tertiary treatment using chlorine or UV radiations, but the treated wastewater from Anza wastewater treatment plant can be used without extra treatment because they use chlorine for disinfection and it is used for irrigating olive trees in Anza town.

The quantity of treated wastewater increases by a factor of 1.6 and so the areas to be irrigated with water will also increase. The treated wastewater in Anza goes to a reservoir which has a capacity of 500 m^3 and the capacity of the reservoir is 3,000 m^3 in Jenin.

Reclaimed wastewater can play a significant role in mitigating the prevailing water shortage in Palestine, and specifically for supplementary irrigation of rainfed crops to fill in the gap between crop water requirement and rainfall precipitation.

Acknowledgment

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My thanks also to the Palestinian Ministry of Agriculture, Palestinian Water Authority, center and the National Palestinian Research Center for providing the data and references required.
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Finally, I want to acknowledge my wonderful family, friends and colleagues, for their encouragement. And thank you to all those whom I did not specifically mention by name.

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List of Abbreviations and Symbols

ANERA	: American Near East Refugee Aid
ARIJ	: Applied Research Institute – Jerusalem
BOD	: Biochemical Oxygen Demand
Ca	: Calcium
CFU	: Colony Forming Unit
Cl	: Chloride
COD	: Chemical Oxygen Demand
DO	: Dissolved Oxygen
Ec	: Salinity
F.C	: Fecal Coliform
FAO	: Food and Agricultural Organization
FAU	: Formazin Attenuation Units
IR	: Irrigation Requirements
JICA	: Japan International Cooperation Agency
Mg	: Magnesium
MoA	: Ministry of Agriculture
Na	: Sodium
NARC	: National Agriculture Research Center- Palestine
NH_3	: Ammonia
NO_3	: Nitrate
PCBS	: Palestinian Central Bureau of Statistics
PO_4	: Phosphate
PPM	: Part Per Million
PWA	: Palestinian Water Authority
SAR	: Sodium Adsorption Ratio
T.C	: Total Colliform
TDS	: Total Dissolved Solid
TKN	: Total Kjeldahl Nitrogen
TSS	: Total Suspended Solid
WHO	: World Health Organization
WWTP	: Wastewater Treatment Plant

Chapter One: Introduction

1.1 Background

Water need for food production and irrigation is the greatest stress on fresh water. The daily requirements for drinking water is 2-4 liter per person, but the requirements for daily food production range from 2,000 to 5,000 liters. In Asia and Africa, about 85-90% of fresh water is used for agriculture to produce about one billion tons of cereals and 200 million tons of meat. Rainfed and irrigated agriculture is expected to increase to 19% by the year 2050 (WHO, 2013).

In developing countries, the population growth, the urbanization, and climate change will cause high stress on fresh water. Therefore, the untreated or partially treated water is used for food production in these countries is about 10% of the world's population. This depends on type of water for food production (Idais, 2013).

1.1.1 Water and Wastewater in Palestine

In the West Bank, there is a critical lack of sanitation. The domestic sewage flow on the surface of ground to cesspits or septic tanks, and small number of villages collect their sewage in sewerage networks (Mizyed, 2008).

The wastewater characteristics in most West Bank cities are found that the chemical oxygen demand (COD) of 1,000-3,000 mg/L, the biochemical oxygen demand (BOD) of 500-1,000 mg/L, and the total nitrogen (N) of 70-280 mg/L which is higher than the strength of wastewater in the USA with COD of 800 mg/L, BOD of 350 mg/L, and the total N of 70 mg/L (Mizyed, 2008).

Proper treatment of wastewater face great challenges due to limited fund, lack of infrastructure, depressed economy and Israel occupation. However; there are some treatment plants for reusing wastewater. In some Governorates of West Bank such as Al-Bireh wastewater treatment plant where the treated wastewater is used to irrigate olive trees, fruit trees, date palms, flowers, grape stocks, ornamental plants, and green house grown egg plants. In Birzeit University, the effluent is used for restricted irrigation (landscape irrigation). Al-Quds University has been using effluent from the activated sludge system to irrigate chick peas from Ein Sinya pilot plant (Mizyed, 2008).

An earlier study shows that approximately 75% of farmers in rural West Bank villages oppose using treated wastewater for agricultural irrigation, because they are afraid of the risks on soil, farmers and crops. And they say that this manner is in contrast to local cultural irrigation (Mizyed, 2008).

1.1.2 Rainfed agriculture in Palestine

The total area of Palestine covers 6,023,510 Dunums, distributed between West Bank (5,660,820 Dunums, forming 94% of the total area of Palestine) and the Gaza Strip (362,690 Dunums, forming 6% of the total area). In 2005, the Palestinian population was 3,762,005 people, 63% live in West Bank and 37% live in the Gaza Strip. The total area of agricultural land currently used by Palestinians covers 30.5% (1,833,350 Dunums) of the Palestinian land area and 54.4% of the total suitable lands for cultivation Rainfed agriculture is practiced in 87.0% of the total cultivated area. While only 13.0% is irrigated agriculture. In addition to the limited land fertility, just 45% of owned lands are presently cultivated, 11.9% is arable but uncultivated, 8.5% is suitable for reclamation, 5.5% is unsuitable for reclamation, 0.4% is being used as grazing land, while 17.2% includes urban areas used for construction. 11.5% of owned land has been confiscated by Israel for the purposes of building new settlements, constructing bypass roads and building the separation wall (Azahar, 2007).

Jenin is the largest agricultural area in West Bank with area of that produces about 16.2% of the total Palestinian agricultural production, mainly rainfed agriculture (Abu-Madi, 2015).

Figure (1.1): Location map of the West Bank and the Gaza Strip (east, 2007)

1.2 Research Problem and Questions

Jenin has the largest agricultural area in West Bank but the quantity of water allocated for irrigation is very small. Therefore, in summer farmers depend on purchased water or digging wells that cost ample amount of money. While in winter they depend on rainfall. This thesis investigates the possibilities of using a non-conventional source of water which is treated wastewater for supplementary irrigation of rainfed agricultural lands in Jenin by answering the questions below.

1. What are the quantities of treated wastewater that could be used and how much agricultural areas could be irrigated using this type of water?
2. What types of crops are suitable for irrigation with treated wastewater?

1.3 Research Goal and Objectives

The main research goal of this thesis is to assess is to the applicability and potential use of treated wastewater for irrigation of rainfed crops in the Jenin Governorate. The specific objectives are:

- To assess the quantity and the quality of the treated wastewater that goes from the wastewater treatment plants in the Jenin Governorate and how much could be used for irrigation.
- To identify the crop types that is suitable for irrigation with treated wastewater in the Jenin Governorate.

1.4 Thesis Outline

This thesis report contains six chapters: Chapter One presents an introduction. Chapter Two includes the literature review. Chapter Three describes the study area. Chapter Four presents the methodology adopted in the study. In Chapter Five, results are discussed based on the outcomes. The last chapter summarizes the conclusions and recommendations.

Chapter Two: Literature Review

2.1 Wastewater Reuse

The term reuse means that the users don't take their water from a conventional resources such as (rivers, springs, ground water, and wells), but they get the water from water source that have already been used in municipal, industrial, commercial purposes (Idais, 2013).

2.2 Wastewater Reuse Policies, Regulations and Practices

Wastewater reuse is an alternative water resource for food production and sustainable development but a few countries such as (Israel, Cyprus, Jordan, Tunisia, United State, Germany and, Netherlands) include treated wastewater in their water resources. Wastewater reuse depends on socio-economic, institutional, and technological condition. (Kamizoulis, 2003)

Differences between countries occur in their environmental and public health policies. They also occur in existing wastewater collection, treatment, and disposal facilities, human capacities, equipment, material, financial resources and, treatment level. The reuse of wastewater depends on producing an effluent that complies with the discharge requirement (Kamizoulis, 2003).

In many cases raw or in sufficiently treated wastewater is applied, in other cases wastewater treatment plants may not functioning or overloaded and the effluent from these plant are not suitable for reuse applications, which leads to health risks, environmental impacts, and water related disease (Kamizoulis, 2003).

When the treated wastewater is suitable for reuse it should not present any risk for human health (Kamizoulis, 2003).

There is not a common regulation of wastewater reuse in the world due to various climatic, geological and geographical conditions, water resources, type of crops and soils, economic and social aspects, and country /state policies towards using wastewater influents for irrigation purposes. Some countries and organizations have already established reuse standards such as United States Environmental Protection Agency (USEPA), WHO, FAO, France, Italy. Most of the developing countries have adopted their own standards from the leading standards set by either FAO, or WHO, etc. (EPA, 2004).

WHO guidelines to ensure human health and to protect environments, WHO developed guidelines for wastewater reuse in agriculture and aquaculture since 1973. After a thorough review of epidemiological studies and other information, the guidelines were updated in 1989. The most recent revision took place in 2006. These guidelines have been very useful, and many countries have adopted them in their wastewater and excreta use practices. The main features of WHO guidelines for wastewater reuse in agriculture are as follows:

• Wastewater is considered as a resource to be used safely;

• The aim of the guidelines is to protect against excess infection in exposed populations (consumers, farm workers, populations living near irrigated fields);

• Fecal coliforms and intestinal nematode eggs are used as pathogen indicators;

• Measures comprising good reuse management practice are proposed alongside wastewater quality and treatment goals; restrictions on crops to be irrigated with wastewater; selection of irrigation methods providing increased health protection, and observation of good personal hygiene (including the use of protective clothing) (WHO, 1989); The feasibility of achieving the guidelines is considered alongside desirable standards of health protection, WHO guidelines are presented in Annexes.

2.2.1 Quality of treated wastewater according to WHO

1-High treated water quality (A) 20 mg/l TSS, not more then 200/100 ML fecal coliform (Vertex Development Company, 2014).

2-good treated water quality (B) 20 mg/l BOD, 30 mg/l TSS, not more then 100/100 ml fecal coliform (Vertex Development Company, 2014).

3- Medium treated water quality (C) 30 mg/l BOD, 50 mg/l TSS, not more not more than 1,000/100 ml fecal coliform (Vertex Development Company, 2014).

4-Low treated water quality (D) 60 mg/l BOD, 90 mg/l TSS, not more not more than 1,000/100 ml fecal coliform (Vertex Development Company, 2014).

2.2.2 Countries with Wastewater Reuse Regulations and Policies

Spain: In 1985, the Government indicated water reuse as a possibility, but no specific regulation followed. Adraft legislation has been issued in 1999, with a set of standard for 14 possible applications of treated water. (Bixio, et al., 2005)

France: (Art. 24 décret 94/469 3 1994 Circulaire DGS/SD1.D./91/n°51). Both refer as water reuse for agricultural purposes. Essentially follow the WHO standards, with the addition of restrictions for irrigation techniques and set-back distances between irrigation sites and residential areas and roadways (Bixio, et al., 2005).

Israel: about 92% of wastewater is collected and treated in Israel, 42% for irrigation purpose, but the treated wastewater approved by national, regional, local authorities, and treated wastewater must meet the criteria of water quality that set by the ministry of health. Cost benefit analysis indicate that treated wastewater reuse has a very low cost, the water crisis, and the low cost of reuse, are the main driving forces of high percentage for reuse. (Kamizoulis, 2003) wetlands are the most prevalent way for treating wastewater, they are non energy intensive, lower maintainance cost, and aesthetic option.Farmers don't accept use treated toilet water for irrigation they only use treated grey water for food irrigation. (Green Business, 2010). It is forecasted that in the near future, reclaimed effluents from various treatment schemes will form 80% of all irrigation water used in the previous mentioned valley, due to the increase in raw sewage production combined with a decrease in the amount of freshwater allocated for irrigation (due to freshwater shortages) (Friedler, 1999).

Tunisia: there are a restricted regulations for reuse that protect workers, residential areas, and consumers from contamination. In Tunisia, the farmers pay for using treated wastewater for irrigate their fields (Kamizoulis, 2003).

Turkey: in Turkey the use of wastewater in agriculture irrigations is attractive approach because it enhances the agricultural productivity, but it requires public protection, appropriate wastewater treatment technology, public acceptance and participation.

The sustainability of irrigation faces great restrictions:

- ✓ On soil, water, and energy resources
- ✓ Changes in economic conditions
- ✓ Growing environmental consciousness
- ✓ In effective decisions in irrigation system management

Wastewater should be treated in effective manner to have appropriate concentrations of (COD, BOD, N, P, K, Salinity, Trace elements, Boron) the increase concentration of Boron lead to a sharp decrease in the agricultural productivity, the guidelines and regulations are used in addition to technical constrains on wastewater reuse for agriculture regarding to classifications of waters, the maximum allowable heavy metals and toxic elements concentrations, and the mass limits of application of these pollutants in agricultural areas (G. Kamizoulis, 2003).

United States: the treated wastewater is used in agricultural irrigation. It varies from grazing pastures to food crops that eaten raw but in some state it is prohibited for using treated wastewater for crops that eaten raw, chemical composition of treated wastewater has that met standard because wastewater has secondary or tertiary treatment.

The guidelines put regulatory controls on health protections, irrigation method crops type, and the distribution area management and operation (Council, 2011).

Jordan: Jordan has water shortage, so it cannot comply with needs of various sectors. The agricultural sector takes up about 73%of the total water consumption, the domestic need about 22% of total water consumption, and only 5% of the total water demand is needed by the industrial sector.

There are twenty treatment plants present in Jordan; they are using different types of treatment, which are waste stabilization ponds, biological filters, activated sludge, and aerated lagoons.

Wastewater in Jordan is classified as strong wastewater that has BOD, COD, and TSS concentrations higher than international figures. Treatment plants are designed to receive lower concentrations of BOD, COD and TSS than that are presented in wastewater, so this cause ineffectiveness in their performance.

Effluent from treatment plants is used to recharge the Al-Zarqa River, and ground water, and to irrigate fruits trees and food crops (Al-Zboon, et al., 2008).

United Arab Emirates: It is one of the most water-poor states in the world, but its wastewater recycling program has enabled it to expand its green spaces and to conserve valuable groundwater supplies. The recycled wastewater is used for landscape and horticulture irrigation. To protect public health Sharjah established conditions and regulations for the safe use of recycled wastewater for irrigation (Cooper. 2001).

Mexico City: The study describes and illustrates the problems related to wastewater treatment in mega-cities of the developing world. here reuse in agriculture is used as a possibility to get rid of the wastewater without treatment. The high content of organic matter and plant nutrients in the water has improved the physical and chemical conditions of the soils. Soil organic matter increased and so did the crop harvest: the crop yield increased by 94 – 150 %. The irrigated area receives over 80kg/ha of nitrogen per year. Nevertheless a high prevalence of enteric and parasitic diseases among more than 100,000 workers had to be noticed (Hareman and Murcott, 1999).

Belgium: In the case of Belgium reuse has been implemented because of water quality issues (water scarcity isn't a problem there). A food processing industry, which freezes locally grown garden market products, has recycled all its wastewater by irrigating 550 ha of crops located around the factory. By adopting this solution, the processing plant was able to avoid paying a tax. Here the soil is only used as purification facility for the industrial effluent which consists of wastewater from washing and processing the vegetable and cleaning the building. Additionally it is worth to mention that since the early stages of the project adaptations and technical adjustments in the industrial process have been made, such as minimizing the volume of process water or changing the method of vegetable processing (e.g. peeling with steam instead of soda). (Guillaume and Xanthoulis, 1996)

2.3 Possibilities of Reuse

Two major types of reuse have been developed and practiced throughout the world:

- **Potable uses:** after high level of treatment the treated wastewater use as drinking water indirectly by passing through the natural environment. (Nicole Kretschmer, 2002)
- **Non-potable uses**: for agricultural irrigation, recharge aquifer, forest, aquaculture (Nicole Kretschmer, 2002).
- **Industrial uses**: wastewater reuse in industry depends on types of industries, industries that need a large volume of water have a greater potential for industrial reuse. Effluent use for cooling, washing floors and heating (Takashi Asano, 2009).
- **Agricultural uses:** Wastewater is not conventional resource of water for agriculture irrigation in order to reduce the gap of the growing needs for water. The degree of wastewater treatment required for crop irrigation depends on the nature of crops, local conditions, and regulatory requirements. Wastewater treatment cost studies show that marginal costs are very high at higher levels of treatment (Schleich et al., 1996).
- The treated wastewater increase agriculture productivity because it has the nutrients required for crop yield. It requires appropriate technology, the acceptance of public, the reliability of treatment, health protection, financial and economic support. But the mismanagement of treating wastewater leads to health and environmental problems. In Middle East and North Africa there are enormous efforts for using the treated wastewater because of:
- The quantity of wastewater produced is large and they have high number of treatment plants.
- Nutrient concentrations in wastewater are high so reduce the use of fertilizer.
- Reduce the environmental and health risks.
- The wastewater used for irrigation is cheaper than fresh water used (Idais, 2013).

2.4 Impacts of Wastewater Reuse

2.4.1 Positive impacts

- When it is discharged to surface water, this reduces the possibility of eutrophication because of high N, P concentrations
- Saving the groundwater resources from salinity and depletion of water level

- High crop productivity and use as fertilizer for soil. (Nicole Kretschmer, 2002)
- Reuse of treated wastewater can also decrease vulnerability to extreme climatic events while seasonal demand peaks due to the ongoing drought.
- Use of treated wastewater for irrigation would reduce the degradation of groundwater quality, enhance aquifer recovery, and reduce sea water intrusion. Irrigation with treated wastewater is considered as an environmentally sound (Al-Juaidi, 2009).
- it enhances agricultural productivity: it provides water and nutrients, and improves crop yield (Rusan et al., 2007).

2.4.2 Negative impacts

- Effects on soil

The treated wastewater reuse may cause Salinization, alkalinity and reduced soil permeability, accumulation of potentially toxic elements and accumulation of nutrients (Nicole Kretschmer, 2002).

- Effects on groundwater

The effects on groundwater under certain conditions are more important than effects on soil. Pollution of groundwater with constituents present in wastewater is possible (Nicole Kretschmer, 2002).

- Effects on surface water bodies

Cause eutrophication because of high nitrogen concentrations this will lead to clog the pressurized irrigation system, and cause oxygen depletion this will cause anoxic condition that lead fish to die (Nicole Kretschmer, 2002).

- Effects on crops – phyto toxicity problem

Reclaimed wastewater contain N,P,K that required for crop to grow up, but if high concentrations of N, P specially N can cause reduction in quantity and quality of crop because it simulates the growth crop.

The quantity of N, P in wastewater can be managed by using high and appropriate technology for treating wastewater (Abu.Mahdi, 2004).

2.5 Water Situation in Palestine

West Bank is an agricultural area with limited water resources ; its population around 2.5 million, and the consumption of water about 65L/C/day which is less than the level recommended by WHO that is 150 L/C/day (Mizyed, 2008).

In 1967 Israel occupied more than 85% of water resources (surface water and ground water) and leaves less than 15% of water resources for Palestinians (PWA, 2012).

Four aquifer basin produce water in Palestine and Israel: the North Eastern aquifer basin, the Western Aquifer Basin, and the Eastern Aquifer Basin for the West Bank and the Coastal Aquifer Basin for the Gaza strip (PWA, 2012).

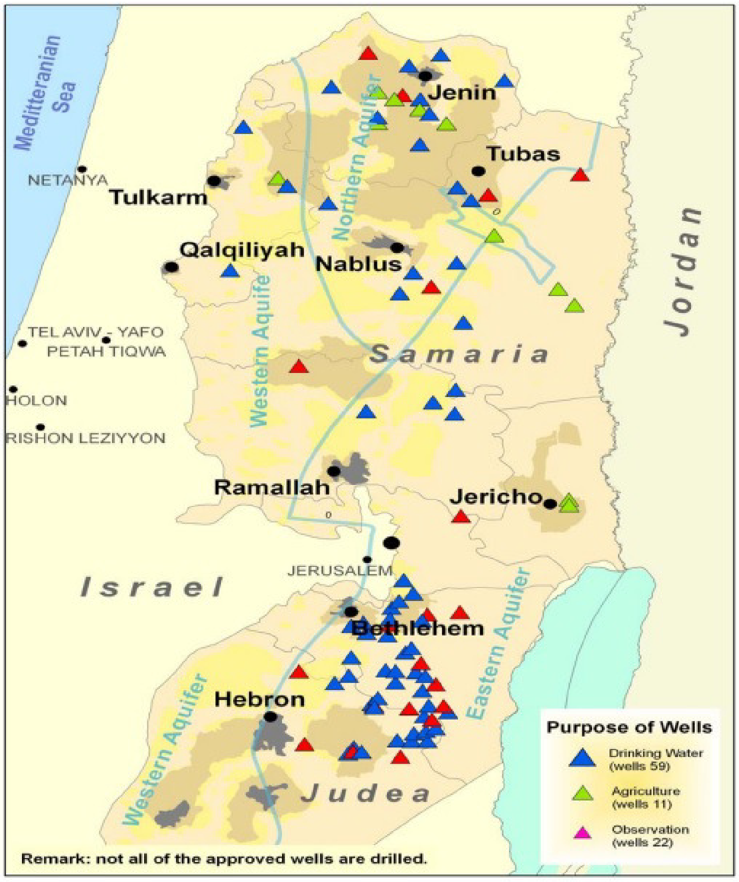

Figure (2.1): A map of the three Mountain Aquifer basins and their average water potential as defined in the Interim Agreement

The ground water is the main water supply in Palestine that provides about 90% of water supply, most of ground water use is for domestic water supply that limits the available resources for agricultural irrigation and industry (PWA, 2012).

About 88% of houses connected with water networks and only 45% of them connected with sewerage networks and the other get of their wastewater in cesspits or discharge it directly to environment. About 70% of water use for agricultural irrigation, the irrigated agriculture represent about 37% of total agricultural production, and the rainfed agriculture represent about 24% of total agricultural production (PWA, 2012).

2.5.1 The non-conventional water resources

- ✓ Purchased water: in west bank they depend heavily on the purchased water from Mekorot, about 53 MCM of water imported from it (49 MCM for Domestic usage, and 4 MCM of agricultural usage).
- ✓ Desalinated water: desalinated water is not implemented in West Bank, in Gaza Strip is implemented and produce around 2-3 MCM/y for drinking.
- ✓ Treated wastewater: about 23%-35% of household in Palestine is connected to wastewater collection system but the rest of wastewater goes to Israel for treatment and reuse in Israel. These wastewater goes from (Tulkarm, Jenin, Nablus, Ramallah, Beit Jala, and Hebron) they dedicate around 42 million dollar from Palestinian tax revenues for the construction and maintenance of wastewater treatment plants without any compensation to Palestinians, in Gaza strip there are about four treatment plants and the quality of wastewater treated is below the Palestinians and international standards (PWA, 2012).

2.5.2 Palestinian standards and regulations on wastewater

Palestine did not have any specific wastewater regulations. References were usually made to the WHO recommendations or to the neighboring countries' standards (Egypt, Jordan). Recently in Palestine (the West Bank & the Gaza Strip), there is a Palestinian Standard (PS) for the Treated Wastewater which has been established by the Palestinian Ministry of the Environment and accredited by the Palestinian Standards Institute, after the establishment of Palestinian law in 1999, which states in (Article 29): "The Ministry of Environmental Affairs (MENA), in coordination with the competent agencies, shall set standards and norms for collecting, treating, reusing, or disposing wastewater and storm water in a sound manner, which comply with the preservation of the environment and public health" (EQA, 1999). The Palestinian standards developed in 2003 have general criteria for the treated wastewater reuse in agriculture:

• The treated wastewater must meet the specified standards that vary according to the planned use;

• When treated effluent is used for irrigation of fruit trees, cooked vegetables and fodder crops, irrigation must be ceased two weeks before collecting the products. Fallen fruit should be discarded;

• The adverse effect of certain effluent quality parameters on the soil characteristics and on certain crops should be considered;

• Use of sprinkler systems for irrigation is prohibited;

• Use of treated effluent in the irrigation of crops that can be eaten raw such as tomatoes, cucumber, carrots, lettuce, radish, mint, or parsley is prohibited;

• Closed conduits or lined channels must be used for transmission of treated effluent in areas where the soil permeability is high, which can affect underground and surface water that could be used for potable purposes;

• Dilution of treated water effluent by mixing at the treatment site with clean water in order to achieve the requirements of this standard is prohibited (EQA, 2003).

2.5.3 Constrains on using treated wastewater

Five constraints can be discerned regarding the reuse of treated wastewater

1-Degree of treatment: it has direct impact on the quality of the treated wastewater

2-The chemical properties of the treated wastewater: chemical tests on the treated wastewater because it has direct impaction the type of soil use and type of crops. The most important tests are COD, TDS, electrical conductivity, heavy metals.

3- Biological properties: it is important to determine the percentage of pathogens because it has direct impact on the human health. The tests are BOD, fecal coliform, and worms. When the percentage is higher than the allowable level, it is prohibited for reuse

4-Type of crops: according to Palestinian regulation it is prohibited to use the treated wastewater to irrigate vegetables weather it is eaten raw or cooked even if the water quality is high but it can use to irrigate fruit trees like olive trees, Feed, cotton , fiber , forest , yards , green spaces.

5-The irrigation network used: the type of irrigation network has direct contact with the type of crops to be irrigated sprinklers can be used to irrigate feeds but the drip irrigation use to irrigate the fruit trees like olive trees and parks (Regional Agricultural Program, (2014

2.5.4 Conditions to use treated wastewater for irrigation

- The properties of treated wastewater must match the Palestinian regulation before using it.
- It must prevent using the treated wastewater of three weeks before collecting the crops, and don't collect the falling fruits and reach the floor.
- Prohibit using treated wastewater of all types of crops.
- It is prohibited to use the treated wastewater to recharge the underground water by direct irrigation (Regional Agricultural Program, 2014).

2.6 Water Quality in Palestine

The analysis of water quality done for chloride and nitrate content only, in Jordan Valley the concentration of nitrate most of its wells is increased gradually, but in Qalqilia and Tulkarm no increase in the nitrate concentration, but the concentration of chloride increase gently but doesn't increase above the international standards (PWA, 2012).

In the Gaza Strip, the water situation is much more complex than in West Bank because of over pumping of coastal aquifer, the nitrate concentration range of 50-300 and the chloride concentration range of 100-1000 which is less than the WHO guidelines, so the water pumped is not suitable for drinking or irrigation (PWA, 2012).

2.6.1 Wastewater in the West Bank

Wastewater sector in Palestine is neglected under Israeli occupation since 1967.the wastewater sector has been marginalized by the creation of Palestinian Authority around 31% of West Bank population is connected to wastewater collection networks. Many of these networks are old and poorly maintained, and this the reason behind the spillages and leaks contaminating the surrounding area the rest of population depend on cesspits, open ditches, and septic tanks (PWA, 2012).

2.6.2 Quantities of wastewater

Wastewater generated in West Bank is approximately 62 MCM/Y including municipal , and industrial wastewater. In addition 35 MCM/Y of untreated wastewater discharged by Israeli settlements and industrial zones into the West Bank more than 50% of the wastewater is generated from industrial activities in Nablus, Ramallah and, Hebron.

15 MCM/Y of wastewater treated in Israeli wastewater treatment plants, 6 MCM/Y is untreated and flows to the east and to the north east of the West Bank and, 41 MCM/Y of wastewater is collected in cesspits. (PWA, 2012).

2.7 Agriculture in Palestine

Generally, there has been a decrease in the area of cultivated lands in Palestine, but an increase in plant production. In 2005, the agricultural area was 4.6% smaller than in 1995. Production varies year to year due to a wide range of factors including climate. The olive harvest in particular has great annual variation due to the olive's two-year cycle and the fact that 50.9% of the total cultivated area is covered by olive trees. 1999 was an exceptionally low production year, probably as a result of severe drought impacting rainfed areas, with cultivated areas yielding the lowest amounts on record. Plant production in 2004/2005 amounted to 1.06 million tons distributed between vegetables (56.2%), fruit trees (24.7%) and field crops (19.1%). The Gaza strip contributes 36.1% of the plant production, and the West Bank contributes 63.9% (Azahar, 2007).

About 105 types of crops are cultivated, include 36 types of fruit trees such as (almond, plums, olives, pears, apricots, nuts, etc) and 37 types of vegetable crops (snake cucumber, onion, cucumber, tomato, etc.), about 30 types of flowers and grain (wheat, check peas, vetch), most of these types are rainfed agriculture where the olive trees represent about 81.4% of fruit trees in Palestine the plantation prevailing at Tulkarm, Nablus, Jenin, Qalqilia, the production of these crops need very depend on water, grapes also another rainfed agriculture with a production of 50,000 tons of the total annual production (Azahar, 2007).

2.7.1 Constraints Facing the Agriculture Sector

1. **Impact of Increased Closures and Restrictions on Movement**

   Walls, trenches, gates, fences, checkpoints, separation walls, no access to Israeli only roads, these physical impediments isolate farmers from accessing to their lands, the natural resources, markets, lands, crops (Azahar, 2007).

2. **Restricted Access to Land**

   The Zone cuts through the western part of the West Bank and runs from north to south grabbing fertile agricultural lands, isolating Palestinian communities in enclaves, undermining the territorial contiguity between the Palestinian villages and cities, and commandeering natural resources (Azahar, 2007).

3. **Restricted Access to Water Resources, and Deteriorating Water Quality**

   About 136 water wells presents in West Bank and the average pumping rate approximately 44.1 MCM (million cubic meters). The numbers of springs are 46. The Palestinians are prohibited from extracting water from wells behind the separation wall, the drilling of new wells need to have licenses form the Joint Water Committee and the Israeli Water Officer but no new licenses have been issued since the Oslo accords. In the Gaza Strip, limited water availability is compounded by the fact that what groundwater there is, is becoming increasingly saline resulting from salt water intrusion, as well as increasingly contaminated as a result of leachate from sewage cesspits and untreated wastewater dumping. Polluted and saline water, unfit for human consumption, is therefore also unfit for direct irrigation of crops whereby it may come directly into contact with human food supply (Azahar, 2007).

Chapter Three: The Study Area: Jenin Governorate

3.1 Location and Population

Palestine contains two geographical areas: West Bank and Gaza. They are geographically separated, but the geo-political conditions are the same. The total area of Palestine is 6245 km^2. The total population numbers are around 4,420,549 in the mid of 2013, where around 2,719,112 in West Bank and 1,701,437 in Gaza strip. The number of localities in the West bank around 557 and 524 in Gaza strip (PCBS, 2013).

The Jenin Governorate area is about 583 km^2, located in the northern part of the West Bank, on the northern tip of the main mountain range crossing the interior area of Palestine, with its north and east mountains extending towards Bissan and the Jordan Valley. Located next to the bottom of mountains overlooking the Marj Ibn Amer plain, the Governorate is a confluence of three environments [plains valleys (Aghwar) and mountainous]. It is bordered by the Nablus Governorate to the south, the Tulkarm Governorate to the south-west, the Tubas Governorate to the southeast, and the Green Line along the other borders. It has one of the most fertile agricultural lands in Palestine (Government, 2008). The population of the Jenin Governorate is about 295,985 in 2013 and there growth rate is 2.5 (PCBS, 2013) represents in 80 localities with a 42% urban population, 54% rural, and 4% inhabitants of the Jenin refugee camp. The population is spread across 80 localities, with 39,004 people living in Jenin city and 10,371 in Jenin refugee camp. In five town towns the size of population exceeds 9000, namely: Silat Al-Harthia, Yabad, Arraba, Qabatiya, and Yanoun (PCBS, 2013) as such, 46% of the Governorate's population resides in six localities, in addition to the refugee camp. The local governance and administration of the Governorate consists of 12 Municipal Councils, 30 Village Councils and 34 Project Committees. However, there are a number of localities which have no local official administrative structure (Government, 2008).

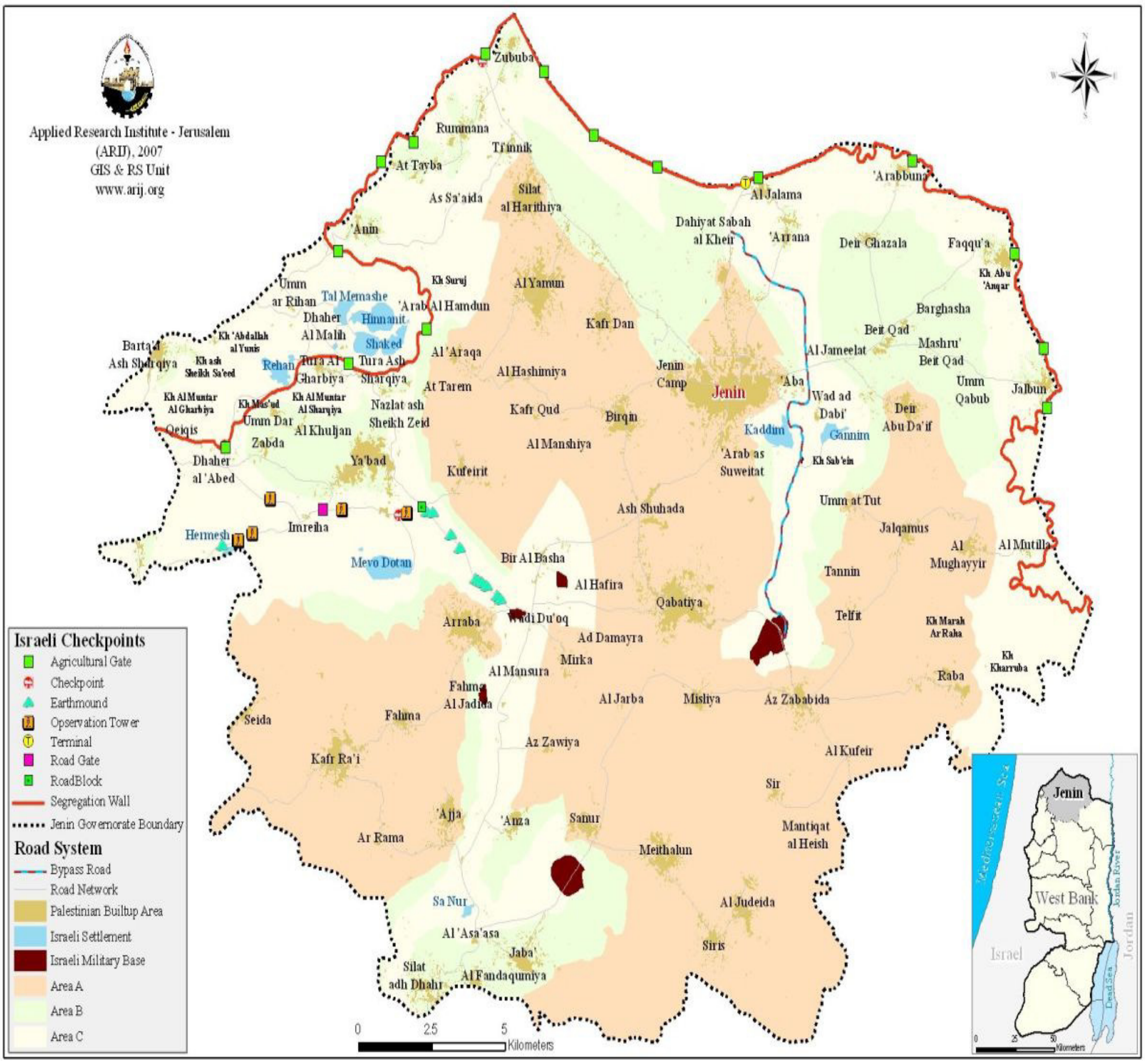

Figure (3.1): Jenin Governorate map; Distribution of localities in the Governorate (OICA, 2007)

3.2 Topography

The area of Palestine is about 6209 km^2 where the West Bank is 58441 km^2 and Gaza strip is 365 km^2. Lebanon and Syria located in the north of Palestine, Jordan in the east Mediterranean Sea in the west, and Egypt in the south.

The Palestinian built up areas is (3.67%), Israeli settlements (1.34%), closed military areas (20.23%), Military bases (0.28%), left as state land (24.23%), nature reserves (5.68%), forests (1.1%), Palestinian cultivated areas (28.90%), Israeli cultivated area

(1.09%), Dead Sea (3.05%), and others (i.e. dumping sites, industrialized zones, etc.) cover about 10.43 percent (PCBS,2006).

The Land Research Centre, within the land system classification study, presented estimations for the agricultural and urban areas. The estimations were as follows: cultivated hills (46%), uncultivated hills (34%), arable plains (12%) and the rest are made of other minor forms of land use. These data are approximate and depending on the general use of the land unit in each land system.

In the context of the land system study for the Gaza Strip, the following is estimation for the land use: periodically irrigated land (17%), discontinuous urban fabrics (15%), non-irrigated land (42%), citrus plantations (9%), Sclerophyllous vegetation (8%) and continuous urban fabric (9%), (Land Research Centre, 2000). There are variations in land elevation from the sea level in Jenin Governorate, for example village Al- Mqeblah which is located at the lowest part 90 msl, and the highest part 750 msl located at Al- Horsh Mountain about 3.5 Km east of Jaba' town (ARIJ,2006).

Figure (3.2): Palestine's Topography (Statement, 2001)

3.3 Climate

Palestine climate remains moderate with hot and dry summer, cold and rainy winter, and the movement of wind is gentle. It has five months of winter. The rainfall months are from November to February where the temperature may reach zero or below, and seven months of Summer where temperature may reach 35 C or above. Palestine is often affected by the Arabian desert climate with seven hours of sun shine in winter, and thirteen hours of sun shine in summer.

Palestine has three climatic regions: arid, semi-arid and Mediterranean. Arid climate has comparatively low amount of rainfall (<200mm) with temperate winter, and very hot summer. Semi-arid has medium amount of rainfall (200-500 mm) with temperate winter and hot summer. Mediterranean climate has the highest amount of rainfall (>500) with cool winters and hot summer.

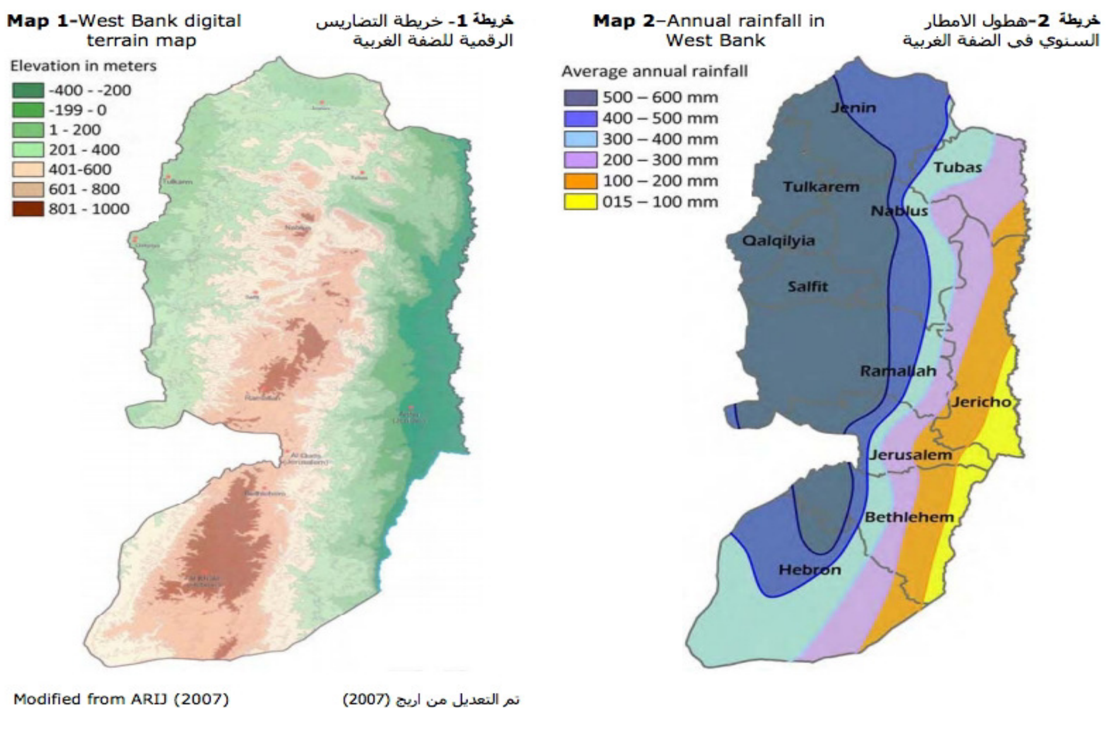

Figure (3.3): Distribution of rainfall in West Bank (ARIJ, 2007)

Jenin is one of the most important governorates in Palestine because of its fertile agricultural lands that made it the agricultural center in the West Bank. Its boundaries are Marj Ibn Amer from the north, the Jordan Valley from the eastern portion, Tulkarm from the south, and Nablus from the south eastern part (Sawalha, et al., 2003).

3.3.1 Jenin Governorate is divided into four regions according to rainfall and agricultural production patterns

1- Eastern Part:

This part contain Arraneh, Der Ghazaleh, Um Al-Toot, Der Abu Deef, and Bet Qad, with rainfall range from 200 to 300 mm, and it is cultivated with rainfed agriculture (Hamarsheh, 2010).

2- The South East Part:

Contain Methaloon, Sanoor, Al-Zababdeh, and Qabatyia. The prevailing agricultures are cereals and olive trees with rain fall range from 350 to 500 (Hamarsheh, 2010).

3- The Northern Part and the North West:

The villages like Al-Galameh, Kofradan, Romaneh, Aselah al Harthea, and Al Eamoon located in this part. In these villages the source of water are wells, the rainfall range from 300 to 400 mm, the main agricultures are rainfed agricultures, and vegetables (Hamarsheh, 2010).

4- The Western Part and the South West:

Villages like Selat Al Daheer, Arabeh, Ya'bad, Al-Fondoqomeah, Al-Rameh, and Agah located in this part The average amount of rain fall is about 600 - 700 mm, it cultivated with almonds, un irrigated field crop, vegetables, tobacco, and olive trees (Hamarsheh, 2010).

Table (3.1): Annual Rainfall Quantity in Jenin by Year and Station Location, 2000-2012 (mm)

2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
477.6	311.8	……	649.3	424.8	431.1	…..	232.5	248.8	593.1	336.5	459.3	544.9

There are three water sheds in Jenin: the central high lands that are located from 400-650 m above the sea level where the annual rainfall in this zone from 400-600 mm (Zone II, **Figure 3.4**), the second region is located to the west of Jordan Valley and rise to the central high lands that has drier, warmer winter and receive the lowest precipitation quantity (Zone III, **Figure 3.4**), the western part has more humid and colder areas.

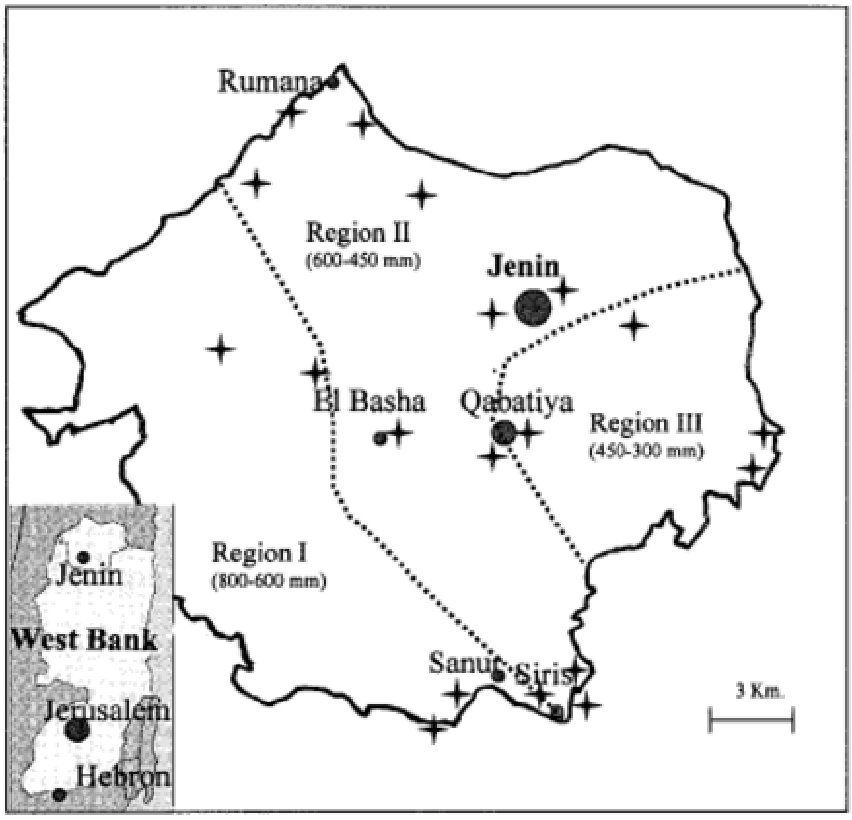

Figure (3.4): The terrains of Jenin Governorate (Sawalha, et al., 2003)

3.3.2 Temperature, sunshine, and humidity in Jenin Governorate

The average temperature in winter from December to March is 13.4 °C, with maximum temperature of 19 °C, and minimum temperature 7.8 °C. The average maximum temperature in summer is 33.6 °C, while the average minimum temperature is 19.3 °C.

The sunshine hours in summer are 10.8 and 5.8 hours in winter from October to February. The average humidity in Jenin Governorate is 65.5% in winter with maximum humidity 84% and the minimum in May of about 39% (Saqer, 2005).

3.4 Soil Types and Problems

3.4.1 Soil types

There are four types of soil in Jenin Governorate

1. Terra Rossa:

   This type of soil occupied area of about 28699 hectares, that about 50% of Jenin Governorate. Around 30-50% of these soils are out cropped with rocks.

   The native vegetation cover is Pistacia Palestina, Pistaca Atlantica, Pistaca Lentiscus, Quercus Calliprious. The dominant agriculture prevail in this type are viney yards, olive and fruit trees, wheat and barley (ARIJ, 1996).

2. Brown Rendzinas and Pale Rendzinas:

   This type occupies a total area of 11397 hectares; the rocks outcrops cover 30-50% of the soil. The native vegetation prevailing in this type are Pinus Halepensis, Pistacia Lentiscus, and Ballotetalia Unduloctae.

   Cultivation of grapes, olives, wheat barely, and grazing are the main land use, especially in steep, sloping, shallow areas (ARIJ, 1996).

3. Pale Rendzinas:

   This type occupies relatively small areas of about 466 hectare, south of Yaabad that is highly calcareous gray and grayish brown alluvial soil. Materials in this type are marl and soft chalk, major vegetation are woods, olives, field crops, the shallow soils are used for grazing (ARIJ, 1996).

4. Grunmusols:

   This type cover 1670 hectares, its topography is flat most of its natural agriculture was destroyed, and only segetal vegetation like prosopis fracata can be found. This type of soil is limiting to cultivate wheat (ARIJ, 1996).

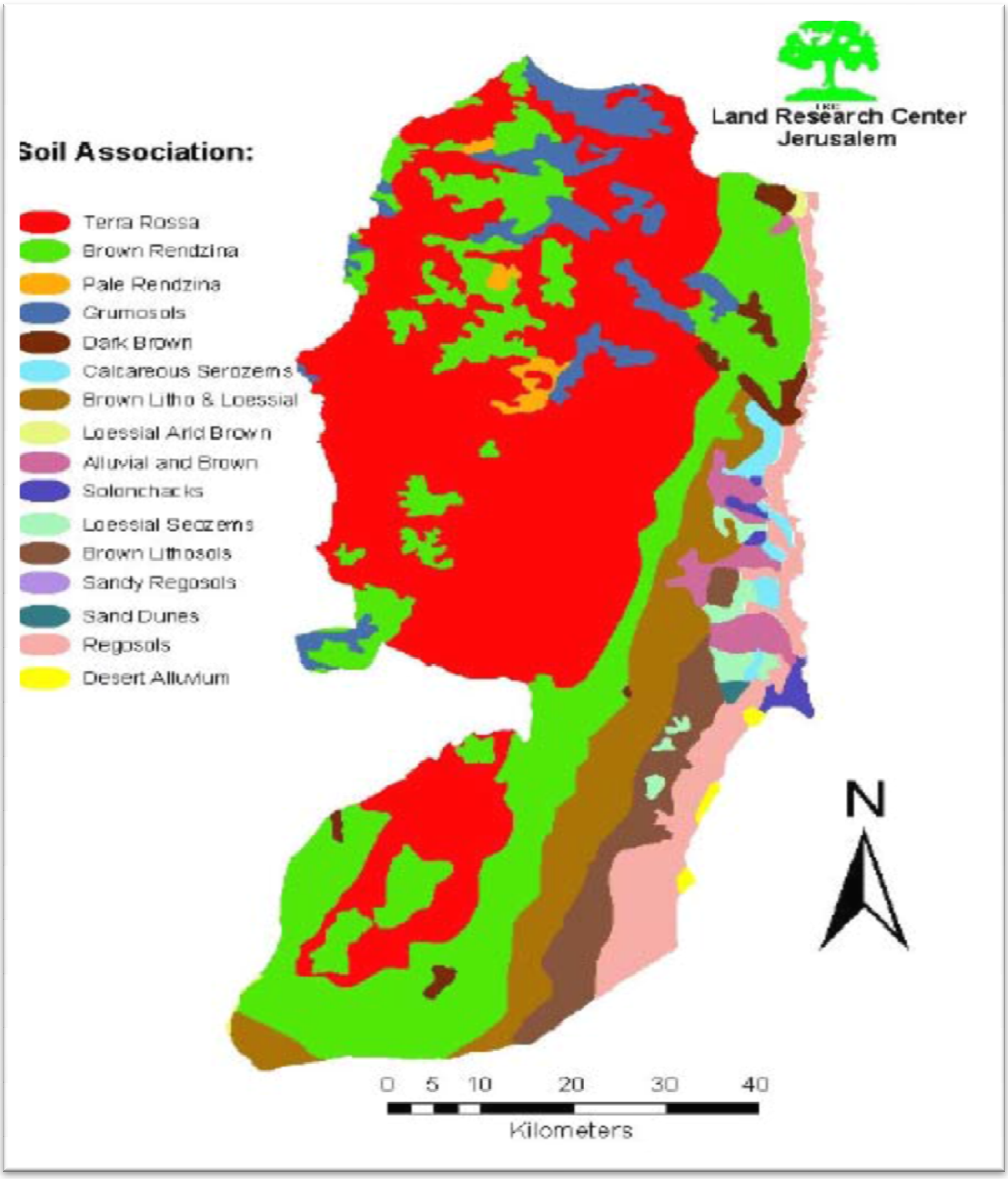

Figure (3.5): Soil Map of the West Bank (Hamarsheh, 2010).

3.4.2 Soil problems

Soil degradation: Soils are degraded as a result of many factors, including erosion, acidification and Stalinization. Two categories of soil deterioration process are recognized in the Palestinian territory. These are displacement of soil material (e.g.; soil erosion by water and wind), and in-situ soil deterioration, covering chemical and physical soil degradation. Incorrect agriculture management, such as scarcity of water, uncontrolled domestic and industrial dumping sites, and the heavy usage of fertilizer are the main in-situ soil degradation causes in the West Bank area (Hamarsheh, 2010).

Soil Salinity: The causes of salinity are due to increasing of irrigation rate, fertilization, and type of irrigation specially the irrigated agriculture. Salinity cause falling of agriculture (Saqer, 2005).

3.5 Agriculture in the Jenin Governorate

Agriculture depends on soil, rainfall, solar radiation. Jenin Governorate has the most fertile lands in Palestine; the agriculture areas in Jenin Governorate are 208,352 Dunums and the cultivated areas about 189,218 Dunums which represents 90.8% of the agriculture areas in Jenin Governorate.

The largest agriculture areas are located at Qabatya represent 7.5% of the cultivated about 14,275 Dunums , but the uncultivated areas represents about 9.2% of the agriculture areas located mostly in Kufr-Raai of about 2,021 Dunums which represent 10.6% (PCBS, 2010).

3.5.1 Agriculture crops

1. Field crops: the total cultivated with field crops are about 55,366 Dunums , about 99.3% of them are rainfed agriculture these areas located mostly in Maythalon about 384 Dunums.
2. Vegetables: the total cultivated areas of vegetables are about 19,186 Dunums of agriculture areas, including 4,378 Dunums are rainfed that represent about 22.8% , 10814donum irrigated that 56.4% (PCBS, 2010).
3. Tree horticulture crops: The total cultivated areas of this type are about 102,719 Dunums where the olive trees represent about 93.8%, the total

cultivated area of this type about 96.7% of the cultivated areas are rainfed (PCBS, 2010).

3.6 Water Resources in Palestine

Local springs and rainfall collection cisterns are the major sources of water supply for domestic and agricultural use in many Palestinian communities and provide more than 90% of water supply. The quantity of rainfall range from 650mm in the western part to 100 mm in the east. The average is 454 mm. In Gaza strip the average rainfall is 372.1mm surface water represent by the Jordan River and the Wadies that flowing toward the West Bank and Gaza Strip, Jordan Valley and the Dead Sea.

Palestinians are the poorest people in terms of water resources in the Middle East. According to the Oslo agreement the Israeli take about 90% of water resources in Palestine (Hamarsheh, 2010).

3.6.1 Water supply and demand

58% of the water supplied in Palestine is used for domestic purposes with 88 MCM for the west Bank and 98 MCM for Gaza strip. And the rest 42% of water supplied for agriculture purpose with 51 MCM for the west Bank and 86 MCM supplied to Gaza Strip.

There is a gap between the supply and demand where the recommended quantity per capita per day is 150 L/C/D the actual quantity in Palestine about 68 L/C/D.

3.6.2 Water resources in Jenin

There are two resources of water in Jenin:

1. Groundwater from wells and springs is the basic resource of water in Jenin represents. There are 63 artesian wells used for irrigation and daily use. 58 of the wells are owned by the Palestinian private sector and used for irrigation. The other 5 wells are general wells owned by the Palestinian municipalities (Jenin and Yabad) or owned by Mekorot (wells of Araba, Qabatia, Sanour) for domestic use.
2. There are also 42 springs in the Jenin Governorate but most of them are seasonal and dry due to evaporation.

Table (3.2): Annual Pumping Water Quantity in Jenin and Use, 2012 (PCBS, 2010)

Domestic	3.2
Agriculture	0.6
Total	3.8

Unit: Mm^3/y

Table (3.3): Quantity of Water Supply for Domestic Sector and Population and Daily Allocation per Capita in Jenin, 2012 (PCBS, 2010)

Quantity of water supply (Million m^3)	5.9
Quantity of water consumed (Million m^3)	3.7
Total Losses (Million m^3)	2.2
Daily allocation per capita (Liter/capita/day)	34.7

Table (3.4): Localities by Availability of Water Network, Jenin, 2013 (PCBS, 2013)

Availability of Water Network	
Available	58
Not available	22
Total	80

Chapter Four: Methodology

Jenin was chosen as the study site, since it has one of the largest agriculture area in the West Bank and one of the largest agriculture activity, contributing about 16.2% of agriculture production. (BCPS, 2005) information about agricultural sector, quantity of water and wastewater, its collecting system, and number of population all these information about Jenin were collected from different sources.

4.1 Data Sources and Collection

The required data for this thesis based on:

1-The Palestinian Central Bureau of Statics (number of population from 2010 to 2015, there growth rate).

2-The Ministry of Agriculture (the rain infiltration rate, the agriculture areas).

3- The Palestinian Water Authority (number of wastewater treatment plants, number of cesspits, the quantity of wastewater produced and how much reach the WTPs).

4- The Meteorological Station (quantity of rain fall, days of rain fall, the evaporation quantity).

The information was rearranged in order to calculate the quantity of treated wastewater available to irrigate the chosen rainfed agriculture.

4.2 Crops Information

Information about crop types grown with rainfed agriculture, their cultivated areas in Jenin, and their irrigation requirements were obtained from the Palestinian Ministry of Agriculture, the Palestinian Central Bureau of Statistics, and Baha' Hamarsha MSc Thesis. For each crop, was calculated by using the following equation:

Quantity of water needed = irrigation requirements*cultivated areas

4.3 Wastewater Information

4.3.1 Quantity of wastewater

- The current quantity of wastewater for each Governorate in Jenin governorate was calculated for the recent year depending on the quantity of water that is available in each town and village in Jenin Governorate

  Quantity of wastewater (2015) (m^3/y) = Quantity of water (m^3/y)*0.69*0.8

  1. Assuming
     - loss in water networks 31%
     - 80% the quantity of water goes to the sewerage networks or cesspits.

- The quantity of wastewater for the coming years (2020, 2025) was calculated depending on the population growth for those years.
  - Population growth rate was calculated by bring the number of population for previous years for all Jenin Governorates the growth rate was found equal 2.3%
- The water consumed by each person = 55 L/capita/day
- The annual quantity of wastewater is calculated by using the following equation: Quantity of wastewater (m^3/y) = population of each Governorate *average water consumed*365 day*0.8

4.3.2 Areas that can be irrigated by treated wastewater

Areas to be irrigated by treated wastewater were calculated by dividing the quantity produced in each Governorate over the average of irrigation requirement for the selected crops

The irrigation requirements for each plant selected crop range from50 m^3/y to 950 m^3/y

The average irrigation requirement per crop for natural condition=

(914.23+611.64+467.47+293.59+293.59+293.59+768.11+241.06+34.18)/9 = 435.3 m3/y

The average irrigation requirement per crop for worst condition=

(999.28+681.6 +515.11+336.69+336.69+336.69+854.12+290.67+75.18)/9=492.78 m3/

4.3.3 Areas to be irrigated for each type of crop in each Governorate

The areas that could be irrigated with treated wastewater were calculated by dividing the quantity of wastewater produced in each Governorate over the irrigation requirement for each crop in natural conditions and irrigation requirement in worst conditions. There is an extreme relationship between increasing number of years and the areas to be irrigated in natural and worst conditions

4.3.4 Quality of wastewater exit from wastewater treatment plants

Effluent from Anza wastewater treatment plant better than effluent from Jenin wastewater treatment plant. In Anza station wastewater subjected to chlorination disinfection, but in Jenin station only secondary treatment exists so pathogens don’t remove.

Chapter Five: Results and Discussions

5.1 General

Wastewater reuse affects rainfed agriculture yield, causing increase in agricultural production. The study examines the potential impact wastewater reuse on rainfed agriculture in the Jenin Governorate.

The data collected cover all Jenin Governorate, there water, the areas of rainfed agriculture, there irrigation requirements, and information about the quality of treated wastewater produced from wastewater treatment plants.

5.2 Quantity of Wastewater

The quantity of wastewater in most of Jenin towns calculated by using the quantity of water in these towns, the quantity calculated for 2015, 2020, 2025, the quantity of wastewater increase according to population growth by a growth rate of 2.3% .

Not all towns in Jenin have water network these are (Khrbit Sroh, Dahiet Sabah Al-Kher, Arab Hamdon, Kherbit Al-Shakh Saed, Um Qboob, Kherbit Al-Mentar Al-Sharqia, Aba, Kekas, Al-Mansia, Arab Sotiat, Kherbit Sabean, Um Reha, Tnen, Al-Damayra, Al-Khafera, Khrbit Marah Al-Raha, Al-Hees, Um Al-Rayhan). So the quantity of wastewater cannot be measured. However they depend on buying water from water venders, for this reason the quantity of wastewater is expected to be small.

There are two wastewater treatment plants existing already in the Jenin Governorate. The first one is Jenin wastewater treatment plant, which is located in Jenin city with a capacity of treating 3500 m^3/d and receiving wastewater from Jenin city and its refugee camp. The second one is the Anza wastewater treatment plant with capacity of treating 1200 m^3/d and receiving wastewater from all Anza town. The treated wastewater that exits from both Anza and Jenin goes to reservoirs and their capacities are 500 m3 and 3000 m3 respectively. The treated wastewater goes to those tanks and then it is distributed for supplementary irrigation of rainfed agriculture. The rest of treated wastewater goes to valley.

There are plans to design wastewater treatment plants in the coming few years like (Alyamon, Anin, Qabatya, Ya’bad) towns and the villages near them.

As an example, the schematic diagram of the planned Alyamon wastewater treatment plant is shown in Figure 5.1.

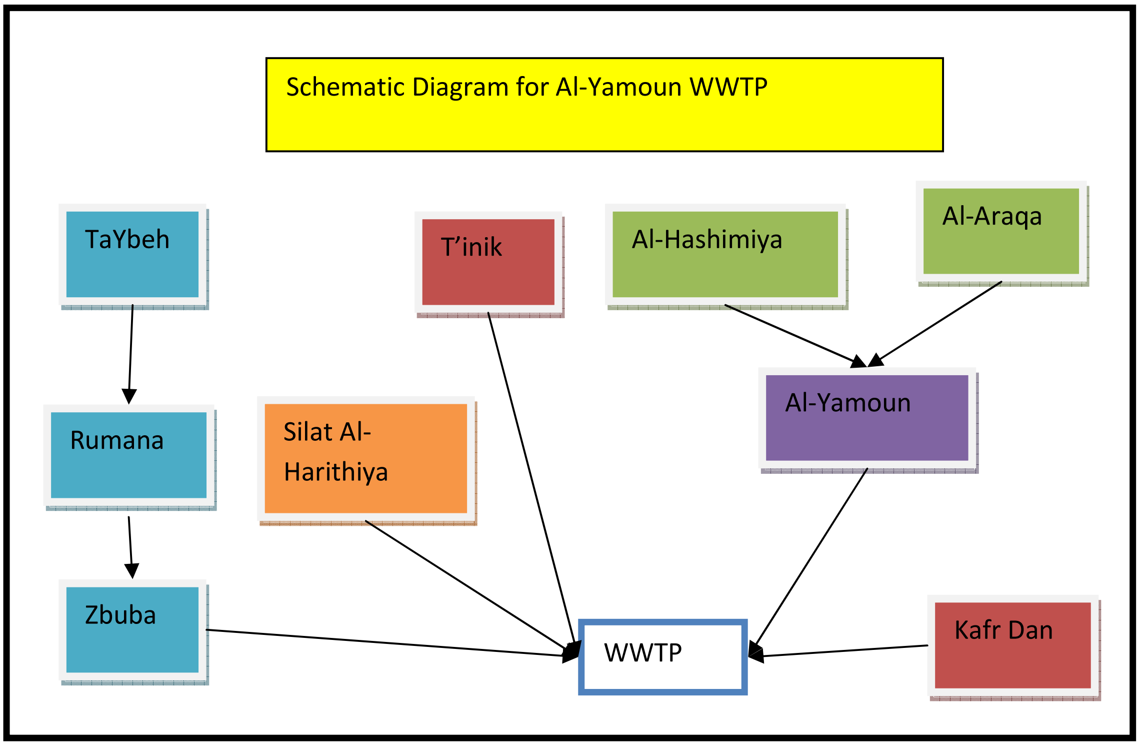

Figure (5.1): Schematic Diagram for Al-Yamoun WWTP

5.3 Crops in Jenin Governorate

5.3.1 Crops areas and there water need

Jenin is famous for its diversity of crops, the main trees vegetated in Jenin are olive, almonds, figs, citrus trees, and the main vegetables and field crops are wheat, barley, onion, sesame, anise, chick peas, clover, local tobacco.

Not all crops are allowed to be irrigated by wastewater according to Alshare'a, and Palestinian standards. These crops that are not eaten raw or eaten cocked are acceptable The irrigation requirements of crops selected in natural and worst conditions are obtained from Baha'Hamarsha thesis and shown in Table 5.1.

Table (5.1): Irrigation requirements and areas for the selected crops.

Crops	areas	IR in natural conditions	IR in worst conditions	Quantity of water needed
Aloe	11.7	914.23	999.28	10,696
Grape	380.2	611.64	681.64	232,546
Almond	3,442.82	467.47	515.11	1,609,415
Plums	41.96	293.59	336.69	12,319
Peach	77.55	293.59	336.69	22,768
Apricot	50.61	293.59	336.69	14,859
Olive	91,083.55	768.11	854.12	69,962,186
Barely	4,020.41	241.06	290.67	969,160
Clover	9,306.32	34.18	75.18	318,090

5.3.2 Areas of rainfed agriculture that can be irrigate with treated wastewater

The current quantity of treated wastewater is 1,309,744 m^3/y and it can irrigate on average 2,911 Dunums/y, assuming that all wastewater will go to the existing treatment plants and exit from them without any loss as shown in Table 5.2.

Table (5.2): Areas to be irrigated by treated wastewater 2015

Community name	Quantity of wastewater produced in 2015 (m^3/year)	Areas to be irrigated in 2015 (Dunum/y)
Jenin	1,277,135	
Anza	32,609	
Summation	**1,309,744**	**2,911**

In 2020 the quantity will be 2,714,768 m^3/y and will irrigate in average 6033 donum/y, and in 2025 the quantity will be 3,302,819 m^3/y that will irrigate 7340 Dunum/y. So the quantity will increase during the following years and therefore the areas that can be irrigated will also increase as shown in tables 5.3 and 5.4. treated wastewater in Anza used for irrigate olive trees

Table (5.3): Areas to be irrigated by treated wastewater in 2020

Community name	Quantity of wastewater produced in 2020 (m^3/year)	Areas to be irrigated in 2020 (dounum/y)
Jenin	1,077,530	
Anza	40889	
Alyamoon	357544	
Alaraqa	47,168	
kfrDan	112,356	
Alhashemya	22950	
t'annk	21826	
Qabatya	418,925	
Sir	16,237	
Telfet	5,203	
Ya'bad	297,672	
Arraba	216,489	
Alzababda	79,979	
Summation	2,714,768	6,033

Table (5.4): Areas to be irrigated by treated wastewater in 2025

Community name	Quantity of wastewater produced in 2025 (m^3/year)	Areas to be irrigated in 2025 (dounum/y)
Jenin	1,207,262	
Anza	45,803	
Alyamoun	400585	
Al'raqa	52,837	
Kufr Dan	125,878	
Alhashemya	25712	
T'annak	24459	
Qabatya	469,370	
Kferet	52,500	
Sir	18,180	
Talfet	5,830	
Ya'bad	333,518	
Arraba	242,554	
Alzababda	89,615	
Bir Al-Basha	31,959	
Altayba	52,693	
Rummana	76,767	
Zbuba	47,297	
Summation	3,302,819	7,340

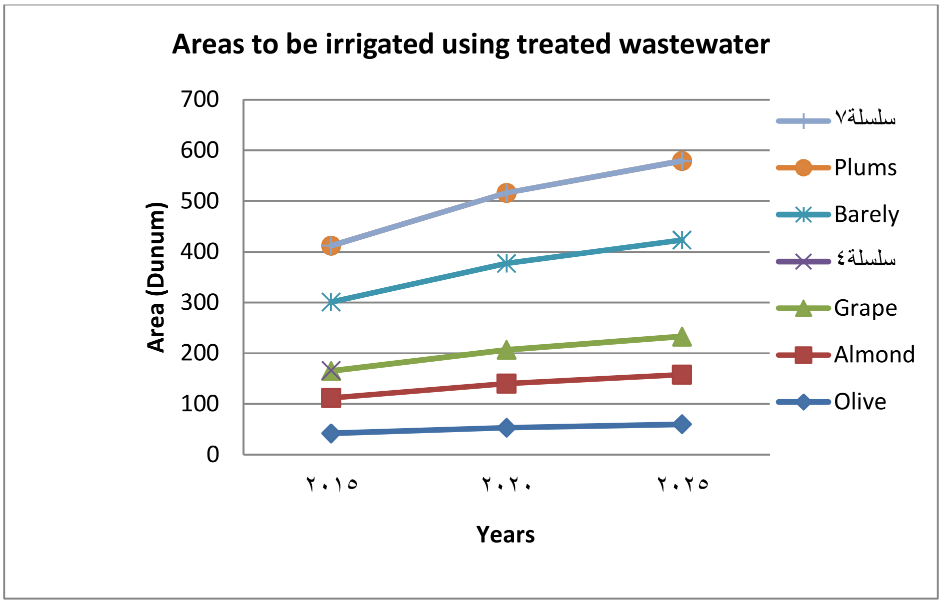

Figure (5.2): Quantity of treated wastewater that can irrigate the selected crops in natural conditions from Anza Wastewater Treatment Plant

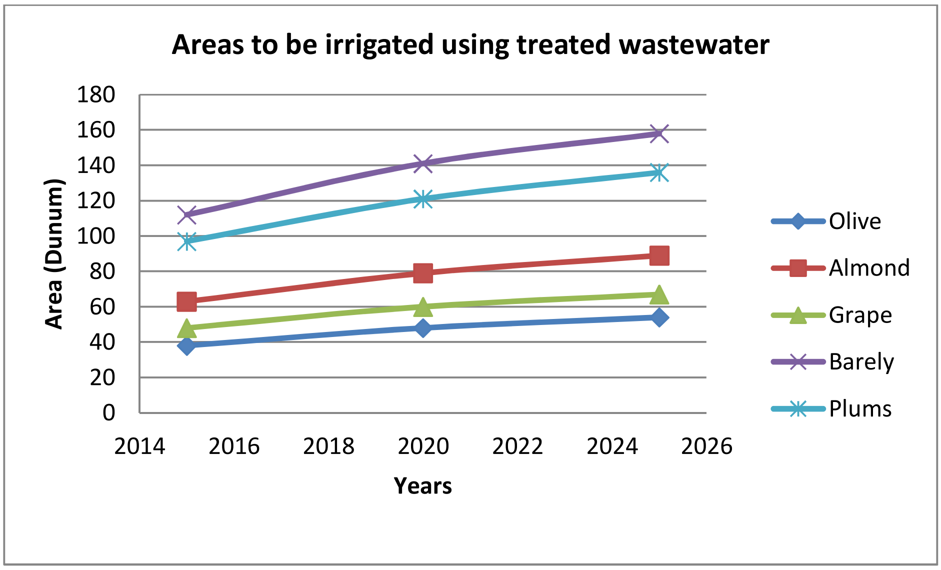

Figure (5.3): The quantity of treated wastewater that can irrigate the selected crops in worst conditions from Anza Wastewater Treatment Plant

Figures above show the areas and types of crops that can be irrigated by using wastewater produced from Anza wastewater treatment plant. In natural condition the areas to be irrigate are larger than in worst conditions (worst conditions mean temperature increase by 3°C and precipitation reduce by 30%). Farmers are using treated wastewater that exit from Anza station already for olives tree irrigation, so the Analysis for Anza was done for this reason. Jenin station use secondary treatment only so effluent need farther treatment in order to use it for irrigation.

5.4 Quality of Treated Wastewater

FAO and WHO put guidelines for reusing the treated wastewater for irrigating crops that are eaten raw or cooked, trees, fodder crops, herbs, cereal crops according to Table (T.6 and T.7) but the Palestinian guidelines don't include vegetables that are eaten raw or cooked according to Table (T.8).

Table (5.5) Analysis of the treated wastewater from Jenin Wastewater Treatment Plant

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Treated wastewater in Jenin	Inlet	outlet
13/3/2014		
BOD(mg/l)	510	16
COD(mg/l)	1760	128
TSS(mg/l)	378	26
TDS(mg/l)	1508	1428
NO3-N(mg/l)	13	11
TKN(mg/l)	399	353.6
Pb(mg/l)	0.1	0.09
F.C(CFU/ml)	27100	15
e.coli(CFU/ml)	26600	14
Nematods(Eggs/L)	1600	200

As shown in Table (5.5), the analysis of treated wastewater that exit from Jenin wastewater treatment plant is not as recommended in FAO or Palestinian guidelines. So in order to use treated wastewater that exit from Jenin plant it must go to tertiary treatment using chlorine or UV radiation.

The analyses of wastewater exit from Anza wastewater treatment plant agree with national and local guidelines because they use chlorine as tertiary treatment.

Table (5.6): Analysis of the treated wastewater from Anza Wastewater Treatment Plant

Treated wastewater in Anza	inlet	outlet
2/9/2015		
PH	6.99	7.42
Ec	1709	1238
BOD	305	23
COD	640	97
TSS	870	22
NH_3-N	133.67	36.44
NO_3-N	0.36	BDL
TKN	178.75	54.91
TPO_4	18.2	7.3
T.C(CFU/100ml)	1390000	620
F.C(CFU/100ml)	1010000	12

The analyses of wastewater exit from Anza wastewater treatment plant agree with national and local guidelines because they use chlorine as tertiary treatment.

5.5 Seasonal Variations

According to information from Palestinian Water Authority it was recognized there is a seasonal variation regarding the quantity of wastewater produced. In summer the quantity of water consumed will increase by factor of 1.6 and so the quantity of wastewater will increase. This will cause an increase in areas that can be irrigated with wastewater and the quality of effluent will be better because wastewater will be diluted.

But in winter the quantity of wastewater will be smaller than in summer and its quality will be not good as in summer because it is more concentrated and so the analysis of treated wastewater will be worst than in summer.

Chapter Six: Conclusions and Recommendations

6.1 Conclusions

Using treated wastewater is a non - conventional way for irrigation and it is an innovation that most farmers are still unconvinced about it. This thesis shows how using the treated wastewater for supplementary irrigation affects the selected crops which are grown with rainfed agriculture, by increasing their yield and cultivation areas. The research takes Jenin Governorate as a case study.

The main conclusions of this thesis are as follows:

- The cultivation areas of selected crops significantly increase by increasing the quantity of treated wastewater that can be used for irrigation.
- The quality of treated wastewater that exits from Anza wastewater treatment plant is suitable for using it in irrigation, but the treated wastewater from Jenin wastewater treatment plant is not suitable for irrigation.
- Crops for this study were chosen depending on their areas, their stamina of using treated wastewater, and their irrigation requirements. These crops are Olive, Almond, Grape, Plums, Cover, Barely

6.2 Recommendations

Based on the results and conclusions, the following measures are recommended:

- ✓ A comprehensive study should take place in all the Palestinian Governorates in order to integrate and upscale the results from different regions.
- ✓ There should be comparative studies between the different Governorates in order to identify the most vulnerable and affected Governorate in all Palestinian territory.
- ✓ Ministry of agriculture, municipalities, and villages councils in Jenin should use the result of this study in order to get the benefit from the treated wastewater to reduce water scarcity and to increase crop productions.
- ✓ Many areas in Jenin have high quantity of wastewater that goes to cesspits or sewerage networks without treatment and drain to valleys, carrying diseases and affect public health.

- ✓ Ministry of Agriculture should raise the awareness of farmers regarding the importance of using the treated wastewater in alleviating water scarcity and providing the important nutritional elements for crops such as N, P, and K.
- ✓ Agricultural policies should encourage the cultivation of crops, only where suitable water, soil and climate conditions exists.

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Annexes

Table (T.1): Quantity of wastewater in all Governorates in Jenin governorate in 2015

Locality Name	Quantity of water (m^3/y)	Quantity of wastewater (m3/y)	Quantity of Wastewater (m^3/d)
Um Al-Toot	11,095	6,124	17
Anza	59,074	32,609	89
Ajja	198,104	109,353	300
Raba	51,015	28,160	77
Jalqamos	25,057	13,831	38
Al-Jalama	85,000	46,920	129
Kferet	72,817.0	40,195	110
'Bartaa Al-Sharqya	225141	124,278	340
Fahma	67,334	37,168	102
Tora Al-Gharbia	35,492	19,592	54
Kherbit Al-Mentar Al-Sharqia	850	469	1
Atttarm	44,186	24,391	67
Nazlet Ashikh Zaid	67,334	37,168	102
Merka	48,592	26,823	73
Al-Mghayer	31,401	17,333	47
Azzawya	46,600	25,723	70
Deer Ghazalah	69,234	38,217	105
Arrama	38,377	21,184	58
Fahma Al-Jadeda	17,565	9,696	27
Ashuhada	78,325	43,235	118
Al-Fondoqomya	65,087	35,928	98
Beer Al-Basha	51,300	28,318	78

Zbda	40,000	22,080	60
Telfet	3,854	2,127	6
Khrbit Abdalla Al-Yones	5,663	3,126	9
Sanour	136,851	75,542	207
Um Dar	124,740	68,856	189
Al-Kfer	3,608	1,992	5
Dahr Al-Maleh	8,000	4,416	12
Al-Asa'sa	11,312	6,244	17
Kofr Dan	71246	39,328	108
Al-Yamoon	201020	110,963	304
Al-Seela Al-Harthya	124954	68,975	189
Rumana	58214	32,134	88
Anin	48722	26,895	74
Attayba	38562	21,286	58
Al-Hashemya	15260	8,424	23
Kofr Qud	24137	13,324	37
Zboba	26142	14,430	40
T' annak	13499	7,451	20
Al-'araqa	32992	18,212	50
Qabatya	400000	220,800	605
Silt Al-Daher	166637	91,984	252
Yaabad	446604	246,525	675
Azzababda	123455	68,147	187
Kofr Raie	288885	159,465	437

Brqeen	244312	134,860	369
’Jaba	251567	138,865	380
Arraba	573875	316,779	868
Bet Qad) Marj Bin Amer Arbona‹Arrana‹Jalbon	179911	99,311	272
Jenin	2313650	1,277,135	3,499
Al-Jadeda‹Maythalon) Al-‹Seer‹Mslya‹Seres‹ (Jarba	477800	263,746	723
Faqoa	60000	33,120	91
Aba Al-Sharqya	4500	2,484	7

Table (T.2): quantity of wastewater that will be produced in 2020 and 2025 according to population growth rate.

Locality Name	**Population # in 2013**	**Population # in 2014**	**Population # in 2015**	**Population # in 2016**	**Population # in 2020**	**Population # in 2025**	**Quantity of wastewater in 2020**	**Quantity of wastewater in 2025**
Zboba	2,231	2,288	2,346	2,404	2628	2945	42206	47297
Rummana	3,622	3,714	3,808	3,903	4267	4780	68528	76767
T'annak	1,153	1,183	1,213	1,243	1359	1523	21826	24459
Attayba	2,486	2,549	2,614	2,678	2929	3281	47040	52693
Arbona	934	958	982	1,007	1100	1233	17666	19802
Al-Jalama	2,376	2,437	2,498	2,560	2799	3136	44952	50364
Silt Al-Harthya	10,867	11,146	11,427	11,711	12803	14345	205616	230381
Anin	4,257	4,366	4,476	4,588	5015	5619	80541	90241
Arrana	2,302	2,361	2,421	2,481	2713	3039	43571	48806
Deer Ghazalah	1,032	1,059	1,085	1,112	1216	1362	19529	21874

Faqoa	3,999	4,101	4,205	4,309	4711	5279	75659	84781
Al-Yamoon	18,896	19,380	19,870	20,363	22263	24943	357544	400585
Kofr Dan	5,938	6,090	6,244	6,399	6996	7838	112356	125878
Khrbit Abdallah Al-Youns	159	163	167	172	187	210	3003	3373
Dohr Al-Maleh	228	234	240	246	269	301	4320	4834
Barta'a Asharqya	4,817	4,940	5,065	5,190	5675	6358	91141	102109
Al-Araqa	2,493	2,556	2,621	2,686	2937	3290	47168	52837
Bet Qad	1,669	1,712	1,755	1,799	1966	2203	31574	35380
Tora Al-Gharbya	1,059	1,086	1,113	1,141	1247	1397	20027	22436
Tora Al-Sharqya	201	206	211	216	236	265	3790	4256

Al-Hashemya	1,212	1,243	1,275	1,306	1429	1601	22950	25712
Nazlet Ashekh Zaid	812	833	854	875	957	1072	15369	17216
Attorm	426	437	448	459	502	562	8062	9026
Jenin	44,987	46,139	47,305	48,479	53001	59383	851196	953691
Jenin Camp	11,962	12,268	12,578	12,890	14093	15789	226334	253571
Jalbon	2,757	2,827	2,899	2,971	3248	3639	52163	58442
Aba	235	241	247	254	277	310	4449	4979
Kofr Qoud	1,318	1,352	1,386	1,421	1553	1740	24941	27944
Der Abu Deaf	6,427	6,591	6,758	6,926	7572	8483	121606	136237
Brqeen	6,557	6,725	6,895	7,066	7725	8655	124064	138999

Um Dar	642	659	676	692	757	849	12157	13635
Al-Kholjan	587	602	617	633	691	775	11097	12447
Wadi Addabe	474	486	498	511	558	625	8961	10038
Dohr Al-Abed	419	429	440	451	493	552	7918	8865
Zbda	1,089	1,117	1,145	1,173	1283	1437	20605	23078
Ya'bad	15,732	16,135	16,543	16,953	18535	20767	297672	333518
Kferet	2,775	2,846	2,918	2,990	3269	3663	52500	58828
Um Atoot	1,141	1,170	1,199	1,229	1343	1505	21569	24170
Ashohada	2,016	2,068	2,120	2,173	2375	2661	38143	42736
Jalqamos	2,298	2,356	2,416	2,476	2707	3033	43474	48710
Al-Mogher	2,791	2,863	2,935	3,008	3288	3684	52805	59165
Al-Motela	340	349	358	367	401	449	6440	7211

Beer Al-Basha	1,507	1,546	1,585	1,625	1776	1990	28523	31959
Qabatya	22,142	22,709	23,282	23,860	26085	29226	418925	469370
Arraba	11,442	11,735	12,031	12,330	13480	15103	216489	242554
Telfet	275	282	289	296	324	363	5203	5830
Merka	1,858	1,906	1,954	2,002	2189	2453	35155	39395
Wadi D’oq	142	146	149	153	167	187	2682	3003
Fahma Al-Jadeda	426	437	448	459	502	562	8062	9026
Raba	3,627	3,720	3,814	3,909	4273	4788	68624	76895
Al-Mansoura	200	205	210	215	235	264	3774	4240
Meslya	2,754	2,825	2,896	2,968	3245	3635	52115	58378
Az-Zababda	4,227	4,335	4,445	4,555	4980	5580	79979	89615
Fahma	2,867	2,941	3,015	3,090	3378	3785	54251	60787

Az-Zawya	888	911	934	957	1046	1172	16799	18822
Kofr Raie	8,494	8,711	8,931	9,153	10006	11211	160696	180049
Sir	858	880	902	925	1011	1132	16237	18180
Ajja	5,830	5,980	6,131	6,283	6869	7696	110316	123598
Anza	2,160	2,216	2,272	2,328	2546	2852	40889	45803
Sanour	4,691	4,811	4,933	5,055	5527	6193	88764	99460
Ar-Rama	1,112	1,140	1,169	1,198	1310	1467	21039	23560
Maythaloon	8,022	8,227	8,435	8,645	9451	10589	151783	170059
AL-Jadeda	5,465	5,605	5,746	5,889	6438	7213	103394	115841
Al-asa'sa	535	549	563	577	631	707	10134	11354
Al-Attara	1,337	1,371	1,406	1,441	1575	1765	25295	28346
Serees	5,636	5,780	5,926	6,073	6640	7439	106638	119470
'Jaba	9,795	10,046	10,299	10,555	11539	12929	185316	207640

Al-Fondoqomya	3,923	4,023	4,125	4,227	4622	5178	74229	83159
Silt Ad-Dah	6,683	6,854	7,027	7,201	7873	8821	126440	141665

Table (T.3): Treated wastewater analyze from Anza WWTP in 23/3/2015

Treated wastewater in Anza	**Inlet**	**Outlet**
23/3/2015		
PH	6.62	6.77
Ec	2720	2460
BOD	910	233
COD	1964	873
TSS	456	28
NH3-N	146.3	44.2
NO3-N		3
TKN	211.17	179.49
TPO4	4.2	6.3
T.C(CFU/100ml)	1600000	1740
F.C	1220000	1209

Table (T.4): Treated wastewater analyze from Anza WWTP in 15/1/2015

Treated wastewater in Anza	inlet	outlet
BOD	322	19
COD	683	71
TSS	268	0
NH3-N	141.46	49.96
NO3-N	0.56	BDL
TKN	170.55	62.71
TPO4	17.4	6.2
T.C(CFU/100ml)	380000	320
F.C	215000	23

Table (T.5): Treated wastewater analyze from Jenin WWTP in 26/2/2014

Treated wastewater in Jenin	**Inlet**	**Outlet**
26/2/2014		
Na(ppm)	195	195
Mg(ppm)	0	0
Ca(ppm)	2.44	7.9
NO3(ppm)	173	22
K(ppm)	26.8	26.5
TSS(ppm)	525	28
TDS(g/l)	0.83	0.68
COD(ppm)	1315	520
Turbidity(FAU)	836	35
Ec(ms/cm)	1.68	1.36
PH	6.77	7.1

Table (T.6): FAO and WHO guidelines for reusing treated wastewater

Potential irrigation problem		**Units**	**Degree of restriction on use**		
			None	**Slight to moderate**	**Severe**
Salinity					
Ec		dS/m	< 0.7	0.7 - 3.0	> 3.0
Or					
TDS		mg/l	< 450	450 – 2000	> 2000
Infiltration					
SAR = 0 - 3 and EC			> 0.7	0.7 - 0.2	< 0.2
	3 -6		> 1.2	1.2 - 0.3	< 0.3
	6-12		> 1.9	1.9 - 0.5	< 0.5
	12-20		> 2.9	2.9 - 1.3	< 1.3
	20-40		> 5.0	5.0 - 2.9	< 2.9
Specific ion toxicity					
Sodium (Na)					
	Surface irrigation	SAR	< 3	3 – 9	> 9
	Sprinkler irrigation	me/I	< 3	> 3	
Chloride (Cl)					
	Surface irrigation	me/I	< 4	4 – 10	> 10
	Sprinkler irrigation	m^3/l	< 3	> 3	
Boron (B)		mg/l	< 0.7	0.7 - 3.0	> 3.0
Trace Elements					
Miscellaneous effects					
Nitrogen (NO_3-N)		mg/l	< 5	5 – 30	> 30
Bicarbonate (HCO_3)		me/I	< 1.5	1.5 - 8.5	> 8.5
pH		Normal range 6.5-8			

Table (T.7): Categories of treated wastewater and its reusing conditions according to FAO organization

Category	Reuse condition	Exposed group	Intestinal nematodes (arithmetic mean no. of eggs per litre	Faecal coliforms (geometric mean no. per 100 ml)	Wastewater treatment expected to achieve the required microbiological quality
A	Irrigation of crops likely to be eaten uncooked, sports fields, public parks	Workers, consumers, public	≤ 1	≤ 1000	A series of stabilization ponds designed to achieve the microbiological quality indicated, or equivalent treatment
B	Irrigation of cereal crops, industrial crops, fodder crops, pasture and trees	Workers	≤ 1	No standard recommended	Retention in stabilization ponds for 8-10 days or equivalent helminth and faecal coliform removal
C	Localized irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology, but not less than primary sediment Action

Table (T.8): Palestinian guidelines for irrigation using treated wastewater.

property	Dry Fodder irrigation		Gardens Irrigation	Seeds Irrigation	Forests Irrigation	Citrus Irrigation	Olive Irrigation	Almonds Irrigation
BOD5	60	45	40	60	60	45	45	45
COD	200	150	150	200	200	150	150	150
DO	≤0.5	≤0.5	≤0.5	≤0.5	≤0.5	≤0.5	≤0.5	≤0.5
TDS	1500	1500	1200	1500	1500	1500	1500	1500
TSS	50	40	30	50	50	40	40	40
pH	6-9	6-9	6-9	6-9	6-9	6-9	6-9	6-9
Fat Oil& Grease	5	5	5	5	5	5	5	5
Phenol	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
NO3-N	50	50	50	50	50	50	50	50
NH4-N	-	-	50	-	-	-	-	-
PO4-P	30	30	30	30	30	30	30	30
Cl	500	500	350	500	500	400	600	400
SO4	500	500	500	500	500	500	500	500
Na	200	200	200	200	200	200	200	200
Mg	60	60	60	60	60	60	60	60
Ca	400	400	400	400	400	400	400	400
SAR	9	9	10	9	9	9	9	9

Pathogen	-	-	-	-	-	-	-	-
Coliform(CFU/100 ml) Faecal	1000	1000	1000	1000	200	1000	1000	1000
Nematodes (Eggs/L)	-	-	-	-	-	--	-	-

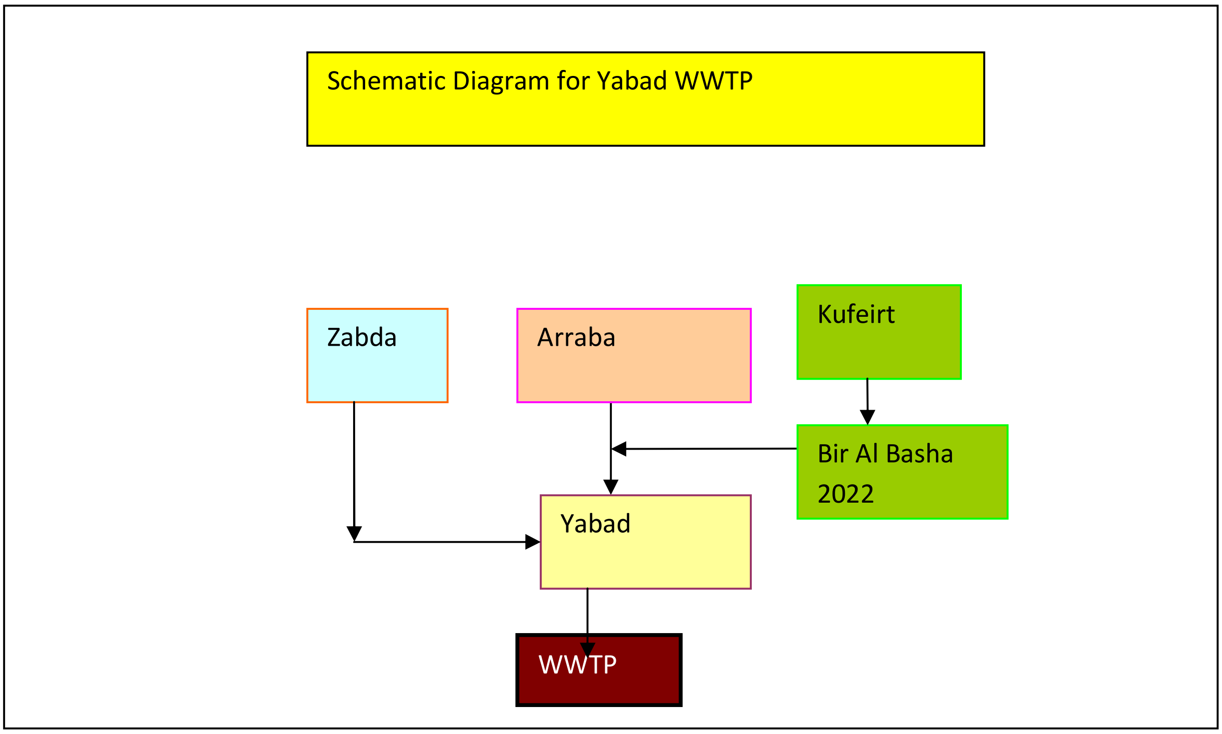

Figure (F.1): Schematic Diagram for Yabad WWTP

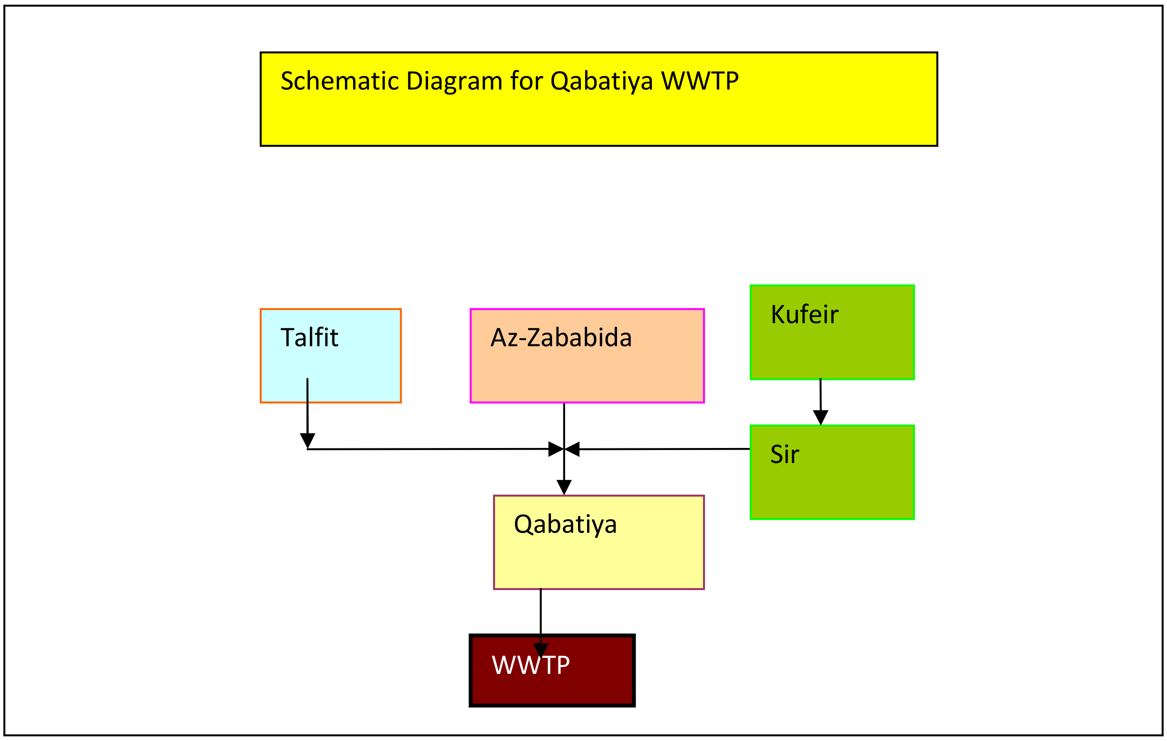

Figure (F.2): Schematic Diagram for Qabatya WWTP

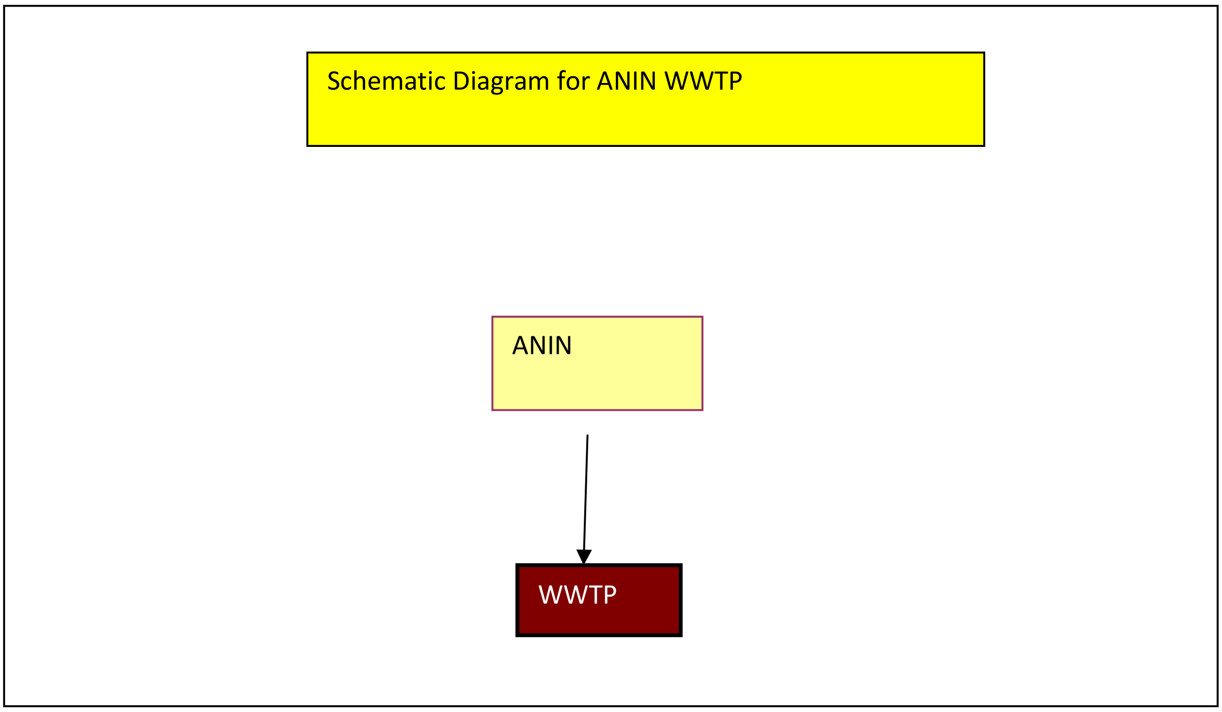

Figure (F.3): Schematic Diagram for Anin WWTP

Table (T.9): Areas that can be irrigated by WW in natural and worst conditions in 2020

		Areas that can be irrigated by WW in natural condition							**Areas that can be irrigated by WW in worst condition**						
Community	quantity of WW in 2020	Aloe	Grape	Almond	Plums	olive	Barely	clover	Aloe	Grape	Almond	Plums	olive	Barely	Clover
Zboba	42206	46	69	90	144	55	175	1235	42	62	82	125	49	145	561
Rommana	68528	75	112	147	233	89	284	2005	69	101	133	204	80	236	912
Taanek	21826	24	36	47	74	28	91	639	22	32	42	65	26	75	290
At-Tayba	47040	51	77	101	160	61	195	1376	47	69	91	140	55	162	626
Arbona	17666	19	29	38	60	23	73	517	18	26	34	52	21	61	235
Al-Jalama	44952	49	73	96	153	59	186	1315	45	66	87	134	53	155	598
Silt Al-Harthya	205616	225	336	440	700	268	853	6016	206	302	399	611	241	707	2735
Anin	80541	88	132	172	274	105	334	2356	81	118	156	239	94	277	1071
Arrana	43571	48	71	93	148	57	181	1275	44	64	85	129	51	150	580
Der Ghazala	19529	21	32	42	67	25	81	571	20	29	38	58	23	67	260

Faqua	75659	83	124	162	258	99	314	2214	76	111	147	225	89	260	1006
Al-Yamoon	357544	391	585	765	1218	465	1483	10461	358	525	694	1062	419	1230	4756
Kofr Dan	112356	123	184	240	383	146	466	3287	112	165	218	334	132	387	1494
Khrbit Abdalla Al-Younes	3003	3	5	6	10	4	12	88	3	4	6	9	4	10	40
Dohr Al-Maleh	4320	5	7	9	15	6	18	126	4	6	8	13	5	15	57
Bataa Al-Sharqya	91141	100	149	195	310	119	378	2667	91	134	177	271	107	314	1212
Al-Araqa	47168	52	77	101	161	61	196	1380	47	69	92	140	55	162	627
Bet Qad	31574	35	52	68	108	41	131	924	32	46	61	94	37	109	420
Tora Al-Gharbya	20027	22	33	43	68	26	83	586	20	29	39	59	23	69	266
Tora Al-Sharqya	3790	4	6	8	13	5	16	111	4	6	7	11	4	13	50
Al-Hashmya	22950	25	38	49	78	30	95	671	23	34	45	68	27	79	305
Nazlet Al-Shekh Zaid	15369	17	25	33	52	20	64	450	15	23	30	46	18	53	204
At-Term	8062	9	13	17	27	10	33	236	8	12	16	24	9	28	107
Jenin	851196	931	1392	1821	2899	1108	3531	24903	852	1249	1652	2528	997	2928	11322
Jenin Camp	226334	248	370	484	771	295	939	6622	226	332	439	672	265	779	3011
Jalbon	52163	57	85	112	178	68	216	1526	52	77	101	155	61	179	694

Aba	4449	5	7	10	15	6	18	130	4	7	9	13	5	15	59
Kofr Qod	24941	27	41	53	85	32	103	730	25	37	48	74	29	86	332
Deer Abu Deaf	121606	133	199	260	414	158	504	3558	122	178	236	361	142	418	1618
Brqin	124064	136	203	265	423	162	515	3630	124	182	241	368	145	427	1650
Um Dar	12157	13	20	26	41	16	50	356	12	18	24	36	14	42	162
Al-Kholjan	11097	12	18	24	38	14	46	325	11	16	22	33	13	38	148
Wadi Ad-Dabe'	8961	10	15	19	31	12	37	262	9	13	17	27	10	31	119
Dohr Al-Abed	7918	9	13	17	27	10	33	232	8	12	15	24	9	27	105
Zbda	20605	23	34	44	70	27	85	603	21	30	40	61	24	71	274
Yaabad	297672	326	487	637	1014	388	1235	8709	298	437	578	884	349	1024	3959
Kfert	52500	57	86	112	179	68	218	1536	53	77	102	156	61	181	698
Um Atoot	21569	24	35	46	73	28	89	631	22	32	42	64	25	74	287
Al-Shohada	38143	42	62	82	130	50	158	1116	38	56	74	113	45	131	507
Jalqamos	43474	48	71	93	148	57	180	1272	44	64	84	129	51	150	578
Al-Mogher	52805	58	86	113	180	69	219	1545	53	77	103	157	62	182	702
Al-Motela	6440	7	11	14	22	8	27	188	6	9	13	19	8	22	86

Ber Al-Basha	28523	31	47	61	97	37	118	834	29	42	55	85	33	98	379
Qabatya	418925	458	685	896	1427	545	1738	12256	419	615	813	1244	490	1441	5572
Arraba	216489	237	354	463	737	282	898	6334	217	318	420	643	253	745	2880
Telfet	5203	6	9	11	18	7	22	152	5	8	10	15	6	18	69
Merka	35155	38	57	75	120	46	146	1029	35	52	68	104	41	121	468
Wadi Do'uq	2682	3	4	6	9	3	11	78	3	4	5	8	3	9	36
Fahma Al-Jadeda	8062	9	13	17	27	10	33	236	8	12	16	24	9	28	107
Raba	68624	75	112	147	234	89	285	2008	69	101	133	204	80	236	913
Al-Mansora	3774	4	6	8	13	5	16	110	4	6	7	11	4	13	50
Meslya	52115	57	85	111	178	68	216	1525	52	76	101	155	61	179	693
Az-Zababda	79979	87	131	171	272	104	332	2340	80	117	155	238	94	275	1064
Fahma	54251	59	89	116	185	71	225	1587	54	80	105	161	64	187	722
Az-Zawya	16799	18	27	36	57	22	70	491	17	25	33	50	20	58	223
Kofr Rai	160696	176	263	344	547	209	667	4701	161	236	312	477	188	553	2137
Ser	16237	18	27	35	55	21	67	475	16	24	32	48	19	56	216
Ajja	110316	121	180	236	376	144	458	3228	110	162	214	328	129	380	1467

Anza	40889	45	67	87	139	53	170	1196	41	60	79	121	48	141	544
Sanor	88764	97	145	190	302	116	368	2597	89	130	172	264	104	305	1181
Ar-Rama	21039	23	34	45	72	27	87	616	21	31	41	62	25	72	280
Maythalon	151783	166	248	325	517	198	630	4441	152	223	295	451	178	522	2019
Al-Jadeda	103394	113	169	221	352	135	429	3025	103	152	201	307	121	356	1375
Al-Attara	25295	28	41	54	86	33	105	740	25	37	49	75	30	87	336
Serees	106638	117	174	228	363	139	442	3120	107	156	207	317	125	367	1418
Jaba’	185316	203	303	396	631	241	769	5422	185	272	360	550	217	638	2465
Al-Fondoqomya	74229	81	121	159	253	97	308	2172	74	109	144	220	87	255	987
Silt Ad-Daher	126440	138	207	270	431	165	525	3699	127	185	245	376	148	435	1682

Table (T.10): Areas that can be irrigated by WW in natural and worst conditions in 2025

		Areas that can be irrigated by WW in natural conditions							Areas that can be irrigated by WW in worst conditions						
community	quantity of WW in 2025	Aloe	Grape	Almond	Plums	olive	Barely	clover	Aloe	Grape	Almond	Plums	olive	Barely	Clover
Zboba	47297	52	77	101	161	62	196	1384	47	69	92	140	55	163	629
Rummana	76767	84	126	164	261	100	318	2246	77	113	149	228	90	264	1021
T'aank	24459	27	40	52	83	32	101	716	24	36	47	73	29	84	325
At-Tayba	52693	58	86	113	179	69	219	1542	53	77	102	157	62	181	701
Arbuna	19802	22	32	42	67	26	82	579	20	29	38	59	23	68	263
Al-Jalama	50364	55	82	108	172	66	209	1473	50	74	98	150	59	173	670
Silt Al-Harthya	230381	252	377	493	785	300	956	6740	231	338	447	684	270	793	3064
Anin	90241	99	148	193	307	117	374	2640	90	132	175	268	106	310	1200
Arrana	48806	53	80	104	166	64	202	1428	49	72	95	145	57	168	649
Der Ghazala	21874	24	36	47	75	28	91	640	22	32	42	65	26	75	291
Faqu'a	84781	93	139	181	289	110	352	2480	85	124	165	252	99	292	1128
Al-Yamoon	400585	438	655	857	1364	522	1662	11720	401	588	778	1190	469	1378	5328

Kofr Dan	125878	138	206	269	429	164	522	3683	126	185	244	374	147	433	1674
Khrbit Abdalla Al-Younes	3373	4	6	7	11	4	14	99	3	5	7	10	4	12	45
Dhr Al-Maleh	4834	5	8	10	16	6	20	141	5	7	9	14	6	17	64
Barta’a Al-Sharqya	102109	112	167	218	348	133	424	2987	102	150	198	303	120	351	1358
Al-’araqa	52837	58	86	113	180	69	219	1546	53	78	103	157	62	182	703
Bait Qad	35380	39	58	76	121	46	147	1035	35	52	69	105	41	122	471
Tora Al-Gharbya	22436	25	37	48	76	29	93	656	22	33	44	67	26	77	298
Tora Al-Sharqya	4256	5	7	9	14	6	18	125	4	6	8	13	5	15	57
Al-Hashmya	25712	28	42	55	88	33	107	752	26	38	50	76	30	88	342
Nazlet Al-Shekh Zaid	17216	19	28	37	59	22	71	504	17	25	33	51	20	59	229
At-Torm	9026	10	15	19	31	12	37	264	9	13	18	27	11	31	120
Jenin	953691	1043	1559	2040	3248	1242	3956	27902	954	1399	1851	2833	1117	3281	12685
Jenin Camp	253571	277	415	542	864	330	1052	7419	254	372	492	753	297	872	3373
Jalbon	58442	64	96	125	199	76	242	1710	58	86	113	174	68	201	777
Aba	4979	5	8	11	17	6	21	146	5	7	10	15	6	17	66

Kofr Qod	27944	31	46	60	95	36	116	818	28	41	54	83	33	96	372
Der Abu Deaf	136237	149	223	291	464	177	565	3986	136	200	264	405	160	469	1812
Brqin	138999	152	227	297	473	181	577	4067	139	204	270	413	163	478	1849
Um-Dar	13635	15	22	29	46	18	57	399	14	20	26	40	16	47	181
Al-Kholjan	12447	14	20	27	42	16	52	364	12	18	24	37	15	43	166
Wadi Ad-Dabe’	10038	11	16	21	34	13	42	294	10	15	19	30	12	35	134
Dohr Al-Abed	8865	10	14	19	30	12	37	259	9	13	17	26	10	30	118
Zbda	23078	25	38	49	79	30	96	675	23	34	45	69	27	79	307
Ya’abad	333518	365	545	713	1136	434	1384	9758	334	489	647	991	390	1147	4436
Kfert	58828	64	96	126	200	77	244	1721	59	86	114	175	69	202	782
Um At-Toot	24170	26	40	52	82	31	100	707	24	35	47	72	28	83	321
Al-Shohada	42736	47	70	91	146	56	177	1250	43	63	83	127	50	147	568
Jalqamos	48710	53	80	104	166	63	202	1425	49	71	95	145	57	168	648
Al-Mgher	59165	65	97	127	202	77	245	1731	59	87	115	176	69	204	787
Al-Mttala	7211	8	12	15	25	9	30	211	7	11	14	21	8	25	96

Beer Al-Basha	31959	35	52	68	109	42	133	935	32	47	62	95	37	110	425
Qabatya	469370	513	767	1004	1599	611	1947	13732	470	689	911	1394	550	1615	6243
Arraba	242554	265	397	519	826	316	1006	7096	243	356	471	720	284	834	3226
Telfet	5830	6	10	12	20	8	24	171	6	9	11	17	7	20	78
Merka	39395	43	64	84	134	51	163	1153	39	58	76	117	46	136	524
Wadi D’oq	3003	3	5	6	10	4	12	88	3	4	6	9	4	10	40
Fahma Al-Jadeda	9026	10	15	19	31	12	37	264	9	13	18	27	11	31	120
Raba	76895	84	126	164	262	100	319	2250	77	113	149	228	90	265	1023
Al-Mansora	4240	5	7	9	14	6	18	124	4	6	8	13	5	15	56
Meslya	58378	64	95	125	199	76	242	1708	58	86	113	173	68	201	777
Az-Zababdah	89615	98	147	192	305	117	372	2622	90	131	174	266	105	308	1192
Fahma	60787	66	99	130	207	79	252	1778	61	89	118	181	71	209	809
Az-Zawya	18822	21	31	40	64	25	78	551	19	28	37	56	22	65	250
Kofr Raei	180049	197	294	385	613	234	747	5268	180	264	350	535	211	619	2395
Ser	18180	20	30	39	62	24	75	532	18	27	35	54	21	63	242

Ajja	123598	135	202	264	421	161	513	3616	124	181	240	367	145	425	1644
Anza	45803	50	75	98	156	60	190	1340	46	67	89	136	54	158	609
Sanor	99460	109	163	213	339	129	413	2910	100	146	193	295	116	342	1323
Ar-Rama	23560	26	39	50	80	31	98	689	24	35	46	70	28	81	313
Maithalon	170059	186	278	364	579	221	705	4975	170	249	330	505	199	585	2262
Al-Jadeda	115841	127	189	248	395	151	481	3389	116	170	225	344	136	399	1541
Al-Asa’asa	11354	12	19	24	39	15	47	332	11	17	22	34	13	39	151
Al-Attara	28346	31	46	61	97	37	118	829	28	42	55	84	33	98	377
Serees	119470	131	195	256	407	156	496	3495	120	175	232	355	140	411	1589
Jab’	207640	227	339	444	707	270	861	6075	208	305	403	617	243	714	2762
Al-Fondoqomya	83159	91	136	178	283	108	345	2433	83	122	161	247	97	286	1106
Silt Ad-Daher	141665	155	232	303	483	184	588	4145	142	208	275	421	166	487	1884

Table (T.11): Areas that can be irrigated by WW in natural and worst conditions in 2015

		Areas that can be irrigated by WW in natural conditions							**Areas that can be irrigated by WW in worst conditions**						
Community	quantity of WW in 2015	Aloe	Grape	Almond	Plums	olive	Barely	clover	Aloe	Grape	Almond	Plums	olive	Barely	Clover
Um At-Toot	6,124	7	10	13	21	8	25	179	6	9	12	18	7	21	81
Anza	32,609	36	53	70	111	42	135	954	33	48	63	97	38	112	434
Ajja	109,353	120	179	234	372	142	454	3199	109	160	212	325	128	376	1455
Raba	28,160	31	46	60	96	37	117	824	28	41	55	84	33	97	375
Jalqamoos	13,831	15	23	30	47	18	57	405	14	20	27	41	16	48	184
Al-Jalama	46,920	51	77	100	160	61	195	1373	47	69	91	139	55	161	624
Kferit	40,195	44	66	86	137	52	167	1176	40	59	78	119	47	138	535
Barta'a Al-Sharqya	124,278	136	203	266	423	162	516	3636	124	182	241	369	146	428	1653
Fahma	37,168	41	61	80	127	48	154	1087	37	55	72	110	44	128	494
Tora Al-Gharbya	19,592	21	32	42	67	26	81	573	20	29	38	58	23	67	261
Khrbit Al-Mentar Asharqya	469	1	1	1	2	1	2	14	0	1	1	1	1	2	6

At-Torm	24,391	27	40	52	83	32	101	714	24	36	47	72	29	84	324
Nazlet Al-Shekh Zaid	37,168	41	61	80	127	48	154	1087	37	55	72	110	44	128	494
Merka	26,823	29	44	57	91	35	111	785	27	39	52	80	31	92	357
Al-Mogher	17,333	19	28	37	59	23	72	507	17	25	34	51	20	60	231
Az-Zawya	25,723	28	42	55	88	33	107	753	26	38	50	76	30	88	342
Deer Ghazalah	38,217	42	62	82	130	50	159	1118	38	56	74	114	45	131	508
Ar-Rama	21,184	23	35	45	72	28	88	620	21	31	41	63	25	73	282
Fahma Al-Jadeda	9,696	11	16	21	33	13	40	284	10	14	19	29	11	33	129
Ashohada	43,235	47	71	92	147	56	179	1265	43	63	84	128	51	149	575
Al-Fondoqumya	35,928	39	59	77	122	47	149	1051	36	53	70	107	42	124	478
Beer Al-Basha	28,318	31	46	61	96	37	117	828	28	42	55	84	33	97	377
Zbda	22,080	24	36	47	75	29	92	646	22	32	43	66	26	76	294
Telfet	2,127	2	3	5	7	3	9	62	2	3	4	6	2	7	28
Khrbit Abdalla Al-yones	3,126	3	5	7	11	4	13	91	3	5	6	9	4	11	42
Sanoor	75,542	83	124	162	257	98	313	2210	76	111	147	224	88	260	1005

UM Dar	68,856	75	113	147	235	90	286	2015	69	101	134	205	81	237	916
Al-Kfer	1,992	2	3	4	7	3	8	58	2	3	4	6	2	7	26
Dhr Al-Maleh	4,416	5	7	9	15	6	18	129	4	6	9	13	5	15	59
Al-asa’sa	6,244	7	10	13	21	8	26	183	6	9	12	19	7	21	83
Kofr Dan	39,328	43	64	84	134	51	163	1151	39	58	76	117	46	135	523
Al-Yamoon	110,963	121	181	237	378	144	460	3246	111	163	215	330	130	382	1476
Silt Al-Harthya	68,975	75	113	148	235	90	286	2018	69	101	134	205	81	237	917
Rummana	32,134	35	53	69	109	42	133	940	32	47	62	95	38	111	427
Anin	26,895	29	44	58	92	35	112	787	27	39	52	80	31	93	358
At-tayba	21,286	23	35	46	73	28	88	623	21	31	41	63	25	73	283
Al-HHashmya	8,424	9	14	18	29	11	35	246	8	12	16	25	10	29	112
Kofr Qod	13,324	15	22	29	45	17	55	390	13	20	26	40	16	46	177
Zbuba	14,430	16	24	31	49	19	60	422	14	21	28	43	17	50	192
Tannek	7,451	8	12	16	25	10	31	218	7	11	14	22	9	26	99
Al-Araqa	18,212	20	30	39	62	24	76	533	18	27	35	54	21	63	242

Qabatya	220,800	242	361	472	752	287	916	6460	221	324	429	656	259	760	2937
Silt Ad-Daher	91,984	101	150	197	313	120	382	2691	92	135	179	273	108	316	1224
Yaabad	246,525	270	403	527	840	321	1023	7213	247	362	479	732	289	848	3279
Az-Zababda	68,147	75	111	146	232	89	283	1994	68	100	132	202	80	234	906
Kofr Raie	159,465	174	261	341	543	208	662	4665	160	234	310	474	187	549	2121
Borqin	134,860	148	220	288	459	176	559	3946	135	198	262	401	158	464	1794
Jaba’	138,865	152	227	297	473	181	576	4063	139	204	270	412	163	478	1847
Arraba	316,779	346	518	678	1079	412	1314	9268	317	465	615	941	371	1090	4214
Marj Ibn Amer	99,311	109	162	212	338	129	412	2906	99	146	193	295	116	342	1321
Jenin	1,277,135	1397	2088	2732	4350	1663	5298	37365	1278	1874	2479	3793	1495	4394	16988
Maithalon, Ajdeda, Serees, Meslya, Ser, Al-Jarba	263,746	288	431	564	898	343	1094	7716	264	387	512	783	309	907	3508
Faqua	33,120	36	54	71	113	43	137	969	33	49	64	98	39	114	441
Wadi Ad-Dabe’	2,484	3	4	5	8	3	10	73	2	4	5	7	3	9	33