An-Najah National University

Faculty of Graduate Studies

Rooftop Rainwater Harvesting to Alleviate Domestic Water Shortage in the West Bank, Palestine

By

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Dedication

To my first friend and my teacher…….. To my father

To my mother whose prayers have always saved me in hard times

To my sister who has always placed trust in me when I was about to lose trust in myself

To my brothers who have constantly supported me with achieving my dreams

Acknowledgement

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الإقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

Rooftop Rainwater Harvesting to Alleviate Domestic Water Shortage in the West Bank, Palestine

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

Declaration

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

Student's Name:	**اسم الطالب:**
Signature:	**التوقيع:**
Date:	**التاريخ:**

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List of Abbreviations

ARIJ	Applied Research Institute Jerusalem
DRWHS	Domestic Rainwater Harvesting Suitability
DWP	Domestic Water Poverty
DWPI	Domestic Water Poverty Index
DWSD	Domestic Water Supply-Demand
HEC	Hydro Engineering Consultancy
HP/VHS	High Poverty/Very High Suitability Zone
HP/HS	High Poverty/High Suitability Zone
l/c/d	Liter per Capita per Day
MCM	Million cubic meters
PCBS	Palestinian Central Bureau of Statistics
PDWS	Potential for Domestic Water Saving
PMD	Palestinian Metrological Department
PWA	Palestinian Water Authority
RRWH	Rooftop Rainwater Harvesting
RWH	Rainwater Harvesting
VHP/HS	Very High Poverty/High suitability Zone
VHP/VHS	Very High Poverty/Very High Suitability Zone
WHO	World Health Organization
WPI	Water Poverty Index
WP	Water Poor Areas

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Abstract

Water is a key factor for sustainable development. In arid and semi-arid regions, water is becoming less in quantity and bad in quality. This is due to the increasing demand of water for different uses. Among which, the domestic use is the most important. This situation compiled the dire need to look for a new and sustainable water resources (e.g. rooftop rainwater harvesting, RRWH). This study aims to assess the domestic water supply-demand (DWSD) gap (deficit) in the different West Bank governorates and to evaluate the possibility of RRWH technique to bridge this gap. Moreover, to evaluate the possibility of adopting RRWH to alleviate the domestic water shortage in water poor (WP) yet highly domestic rainwater harvesting suitability (DRWHS) areas. Additionally, the potential volume for domestic water saving (PDWS) from RRWH in the different West Bank governorates were evaluated. The methodology of this study mainly rely on the geographic information system (GIS) together with MS Excel. RRWH volumes were estimated for the different West Bank governorates based on the available GIS shapefiles of buildings and long-term areal annual average rainfall. According to Palestinian Water Authority (PWA) data for the year 2017, the DWSD gap in the West Bank is nearly 32 million cubic meters (MCM). Generally, there are many strategic options for water resources management to increase water availability and to bridge the DWSD gap. In the West Bank, and given the uncertain water supply from conventional resources (e.g. groundwater), RRWH would be a strategic option to bridge the DWSD gap. The results of this study show that the RRWH volume that can be harvested from the West Bank rooftops is nearly 37 MCM. Additionally, the adoption of RRWH in the West Bank can bridge the DWSD gap in Tubas, Salfit, Ramallah & Al-Bireh and Jerusalem governorates. Moreover, the adoption of RRWH in the high to very high DRWHS areas can harvest nearly 89% of the total RRWH volume in the West Bank. Implementation of RRWH in the high water poor yet suitable areas amounted to 53% of total RRWH volume in the West Bank. This study will help potential stockholders toward adopting of RRWH as a viable water resources option to minimize the domestic water shortage mainly in the water poor areas in the West Bank.

Chapter One

Introduction

1.1 General Background

Worldwide, population increase leads to an increase in water demand for different purposes (Liuzzo et al., 2016). People living in water poor (WP) areas around the world suffer from lack of access to drinking water (Sturm et al., 2009). In these areas, Rooftop Rainwater Harvesting (RRWH) techniques (e.g. cisterns) are still practiced as a main source for drinking purposes (Mbua, 2013; O’Brien, 2014).

In different countries, the consumption of domestic water ranges from seven to 300 liter per capita per day (l/c/d) (Thomas, 1998). In arid and semi-arid regions (e.g. Palestine) which are characterized by high temporal and spatial rainfall variation and uncertain water supply, Rainwater Harvesting (RWH) becomes a sustainable option to alleviate domestic water shortage in high WP areas.

RWH is a very old practice and several countries all over the world used different RWH techniques among which those used for domestic purposes (Li and Gong, 2002; Fooladman and Sepaskhah, 2004; Villarreal and Dixon, 2005; Sazakli et al., 2007; Mwenge Kahinda et al., 2007; Abdul-Hamid, 2008; Barnes, 2009; Ghisi et al., 2009; Despins et al., 2009; Abdulla and Al-Shareef, 2009; Sturm et al., 2009; Shadeed and Lange, 2010; Imteaz et al., 2012; Vialle et al., 2012; Liaw and Chiang, 2014; Lizárraga-Mendiola et al., 2015; Adugna et al., 2018).

Water resources are classified in to conventional (e.g. groundwater, surface water) and non-conventional (e.g. desalinated water, RWH, treated wastewater). Due to political constraints, conventional water resources in Palestine become limited. As, such Palestinians have to look in to non-conventional resources to bridge the increasingly DWSD gap. RRWH is seen to be a sustainable one. The implementation of RRWH has several advantages such as the RRWH system needs low energy to operate the system, the RRWH system requires limited technical knowledge, the system requires local material for construction and the RRWH system is usually socially, economically and environmentally acceptable.

The RRWH techniques (e.g. cisterns) were widely used in Palestine back to 4000 year ago (Critchley et al., 1991; ARIJ, 2012). According to PWA (2011), the RWH from cisterns provided nearly four million cubic meters (MCM) of water for domestic use in the West Bank.

1.2 Research Goal and Objectives

The main goal of this research study is to assess the potential of adopting RRWH to alleviate the domestic water shortage in the West Bank, Palestine. In light of the above, the following objectives are achieved for the different West Bank governorates:

1. Assess the existing domestic water supply-demand (DWSD) gap.
2. Estimate the potential volume of RRWH.
3. Evaluate the possibility of adopting RRWH to bridge the DWSD gap.

4. Evaluate the possibility of adopting the RRWH to alleviate the domestic water shortage in high WP yet highly DRWHS areas.

5. Estimate the potential for domestic water saving (PDWS) from adopting of RRWH.

1.3 Research Questions

The following are the research questions:

1. What is the status-quo of DWSD gap in the different West Bank governorates?

2. What is the potential volume of RRWH for the different West Bank governorates?

3. Does adopting RRWH bridge the DWSD gap in the different West Bank governorates?

4. Does the implementation of RRWH alleviate the domestic water shortage in the high WP yet highly DRWHS areas?

5. What is the PDWS from adopting RRWH in the different West Bank governorates?

1.4 Research Methodology

To achieve the objectives of this research, firstly the research problem (DWSD gap) and objectives were identified. In this study, data were collected from different sources which include:

- Water resources data from PWA.
- Population data from Palestinian Central Bureau of Statistics (PCBS).
- Rainfall map from Hydro Engineering Consultancy (HEC) database as GIS raster (IDW).
- Governorates and buildings (rooftops) shapefiles from Ministry of Local Government (GeoMOLG) database as vector data.
- Domestic water poverty (DWP) and domestic rainwater harvesting suitability (DRWHS) maps from Shadeed et al. (2019) as rasters.

The DWSD gap was estimated based on PWA water resources data for the year 2017. The available DWP and DRWHS raster were analyzed for the selection of WP yet DRWHS areas in West Bank. RRWH volume was estimated based on rooftop areas and long term annual average rainfall for each governorate. Depending on the West Bank buildings shapefile and by GIS, the rooftop areas for the West Bank buildings for the different governorates were estimated.

In this study, the potential volume of RRWH in each governorate was estimated using the following equation (Gould and Nissen-Petersen, 1999):

$$V = \sum_{i=1}^{n} R_c \times R_i \times A_i \quad \text{..Eq (1)}$$

where:

V: Potential volume of RRWH.

n: Number of rooftops.

R_i: Average annual rainfall for each rooftop.

A_i: Area for the i^th rooftop.

R_c: Runoff coefficient.

In this study, R_C of 0.9 was assumed, which in the range of R_C values used in several studied for concrete rooftops (see Table 1).

Table (1): Summary of Concrete Runoff Coefficient

R_C	References
0.8	Ghisi et al. (2006)
0.9	Lancaster (2006)
0.85	Thomas and Martinson (2007)
0.7-0.9	Abdul-Hamid (2008)
0.8	Abdulla and Al-Shareef (2009)
0.7-0.95	Farreny et al. (2011)
0.85	Al-Houri et al. (2014)
0.95	Hari et al. (2018)

GIS was utilized to estimate volume of RRWH for the different governorates. The following summarizes the main steps that were followed:

1- Rainfall map was converted from raster to vector (points).
2- Spatial join between buildings and rainfall map to estimate the average annual rainfall for each rooftop.
3- Field calculator was used to multiply the average annual rainfall and rooftop areas with runoff coefficient.

The entire process was automated by ModelBuilder in GIS environment so as to calculate RRWH volume for the different governorates (see Figure 1).

The potential for domestic water saving from the adoption of RRWH was calculated using the following equation (Abdulla and Al-Shareef, 2009):

$$\mathrm{PDWS} = 100 \times \frac{\mathrm{V}}{\mathrm{DWD}} \text{..} \text{Eq (2)}$$

where:

PDWS: Potential for domestic water saving (%).

V: Potential volume of RRWH for each governorate.

DWD: Domestic water demand for each governorate of the year 2017.

Finally, conclusions and recommendations were introduced. The overall methodological framework used in this research study is illustrated in Figure (2).

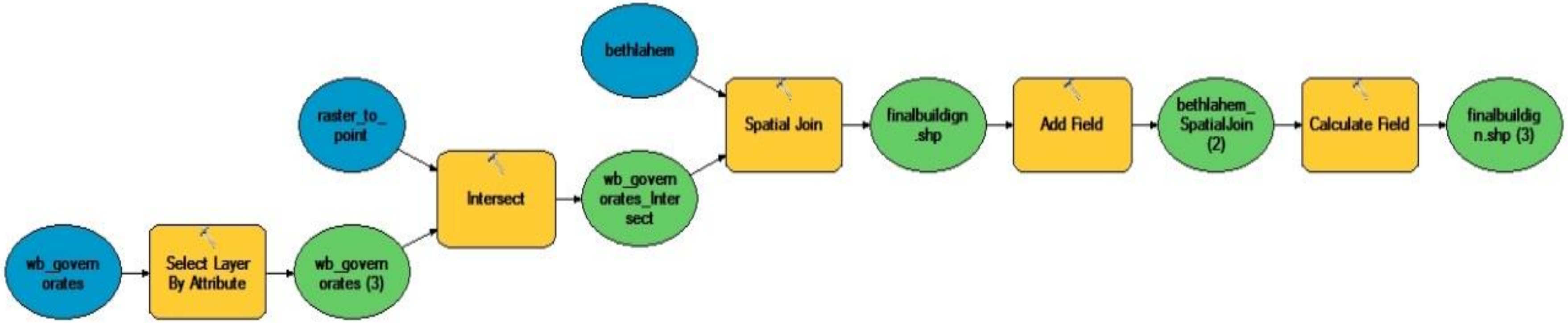

Figure (1): ModelBuilder for the Estimation of RRWH Volume for the Different West Bank Governorates

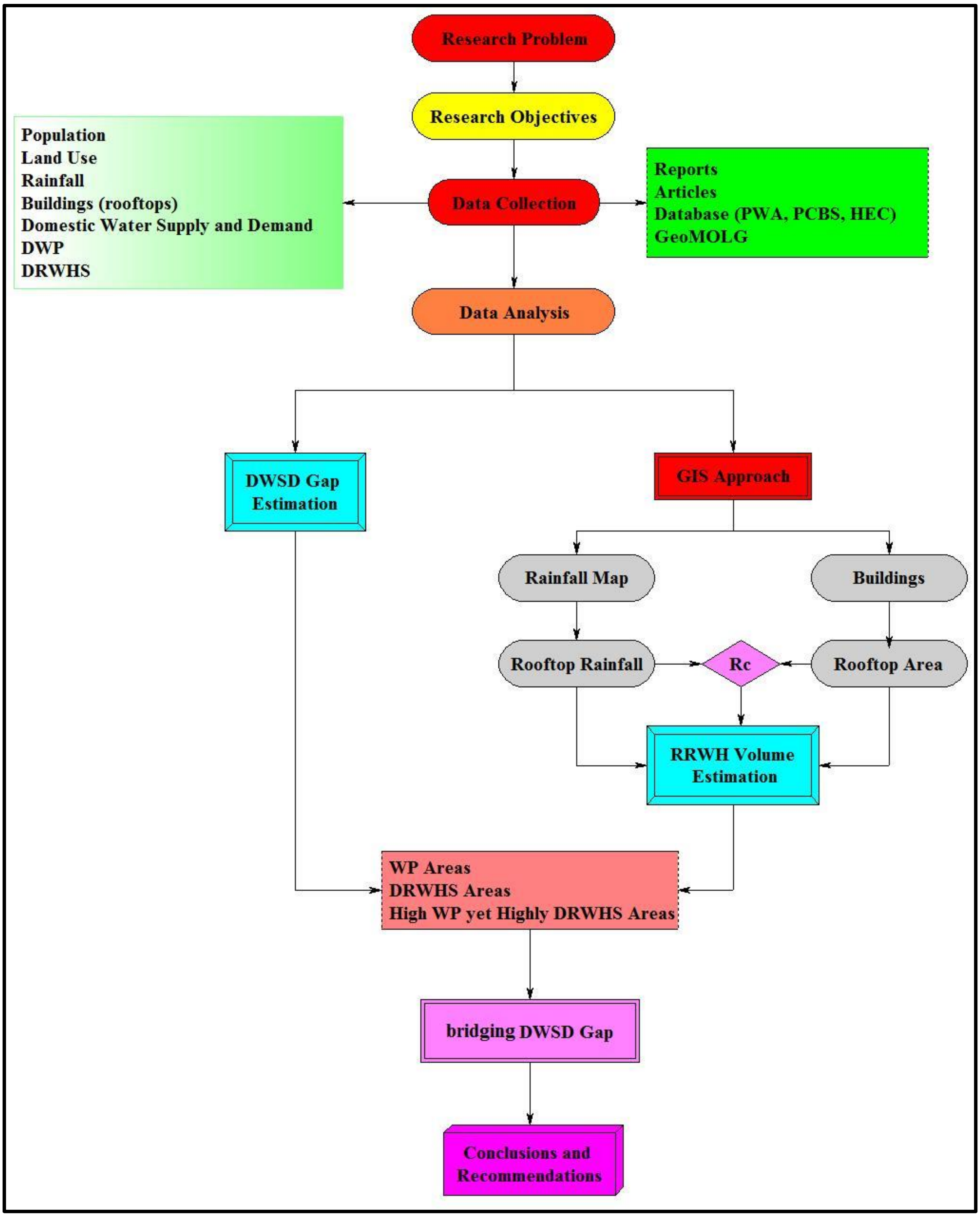

Figure (2): Methodological Framework

Chapter Two

Literature Review

2.1 Background

The term RWH is used in different manners and no global definition has been adopted (Ngigi, 2003). RWH is simple and low cost method of collecting and storing rainwater from roofs and surface catchments to be used for different purposes (Mwenge Kahinda et al., 2007; González, 2012).

RWH system consists of three main components:

1. Catchment surface: is the surface that receives rainwater and drains off the runoff to the drainage system (Worm and Hattum, 2006). There are many types of catchment system which include (Mbua, 2013; Gould and Nissen-Petersen, 1999):
    - Rooftop catchment system
    - Rock catchment system
    - Ground catchment system
    - Check and earth dams
2. Conveyance system: is the system that convert harvested rainwater from catchment surface to storage tank (Mwenge Kahinda et al., 2008). The conveyance system consist of three main components which include gutter, pipes and filter in some cases (Mbua, 2013).

3. Storage system: the harvested rainwater is usually stored in above ground or underground tanks (Mwenge Kahinda et al., 2007) which are made from steal, plastic and concrete (Mbua, 2013). In Palestine concrete is the most common material used for construction of storage tanks. Based on their shape, the storage tanks (cisterns) were divided into two main types; pear shaped and rectangular/square shaped. The shape of cistern is being selected based on existing conditions of soil type (stability), size and cost of excavation and construction.

This research study focuses on rooftop catchment system. As such, buildings (e.g. houses, schools, mosques, hospitals etc.) over the entire West Bank were considered as rooftop catchments which were used to estimate the RRWH volume in different governorates. Figure (3) illustrates the schematic of RWH using roof catchment.

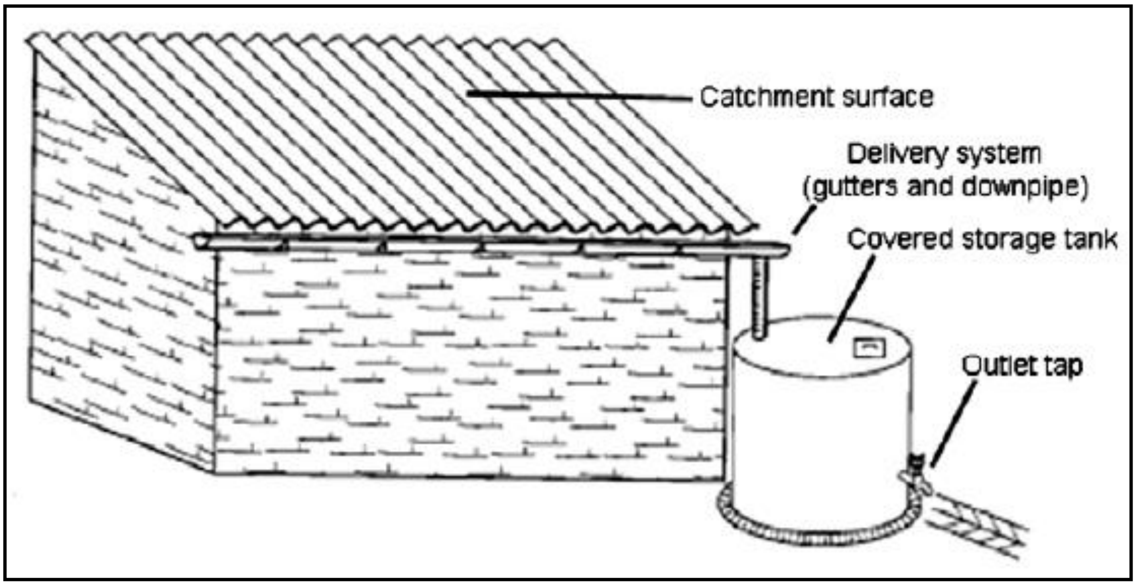

Figure (3): Schematic of RWH Using Roof Catchment (source: Gould and Nissen-Petersen, 1999)

2.2 Domestic Water Poverty

All over the world, domestic water demand is being increased due to rapid population growth, urbanization and climatic conditions (Cowden, 2008; Villarreal and Dixon, 2005). Many indices have been developed to assess water scarcity. These indices depend on human water needs and water availability (Brown and Matlock, 2011).

Poverty defines as "lack of access to different livelihood capitals" (e.g. water) (Sen, 1999). Water consumption and poverty are highly related. In fact, it is difficult to reduce extreme poverty without enough access to water (Sullivan et al., 2006). Moreover, water and poverty are related to each other through different aspects which include water for hygiene and health, water for production (Rijsberman, 2003). Thus, the linkage between water and poverty can not be described as a single value (Sullivan, 2001).

Water poverty is defined as inadequate available water resources for domestic purposes and food production to stabilize domestic and production requirement. It occurs when water demand is greater than available water supply in specific area (Salameh, 2000). Water poverty is the condition where country cannot afford the cost of water with good quality for all population at any time. Water poverty can be attributed to water scarcity. Water scarcity described by continues water supply-demand gap (Molle and Mollinga, 2003).

Water poverty index (WPI) is an interdisciplinary tool combining physical, social, economic and environment information. WPI related with water scarcity and people ability to access water and to use water for different purposes (Sullivan and Meigh, 2003). WPI is a single numerical value ranging from 0 to 100. High number indicate high poverty while low ones indicate low poverty (Molle and Mollinga, 2003; Jemmali and Matoussi, 2012).

The main purpose of developing WPI is to identify areas of high water needs (Sullivan et al., 2006) and as such to reduce water poverty in these areas (Sullivan and Meigh, 2003).

The use of WPI has several advantages (Sullivan et al., 2006; van der Vyver and Jordaan, 2011):

- It is easy to understand by policy makers as it has numerical values.
- It helps understanding the relationship between physical availability of water; its ease of abstraction and the level of welfare.
- It is a mechanism to prioritize water needs based on actual water deficit.
- It helps improve the situation for population suffering from water poverty conditions.

WPI is being developed based on five different components. These are:

1- Resources: This component focuses on the physical availability of water resources in the study area considering both quality and quantity (Sullivan et al., 2006; Jemmali and Matoussi, 2012).

2- Access: This component means adequate access of water to different users (van der Vyver and Jordaan, 2011).

3- Capacity: This component focuses on effectiveness of service providers to supply and manage water resources (Sullivan and Meigh, 2003).

4- Use: This component focuses on the use of water for different purposes (domestic and agriculture) (Sullivan and Meigh, 2003). The use of water for domestic purposes gets the highest priority (Manandhar et al., 2012).

5- Environment: This component means capture the environmental impact of water management to ensure sustainable environment (Sullivan et al., 2006).

Several studies were conducted to estimate the domestic water poverty index (DWPI). Cullis and Görgens (2015) used six criteria to estimate DWPI in South Africa. Isaac et al. (2008) used 12 criteria to estimate DWPI in the West Bank, Palestine. Shadeed et al. (2019) estimated the DWPI in the West Bank based on several physical criteria.

2.3 Water Poverty Mapping

Water poverty map is a collection of WPI components. Each component represents as a different layer in water poverty map (Cullis and O’Regan, 2004). Water poverty map is developed and used for different purposes, among which:

- To select the high water poverty areas (van der Vyver and Jordaan, 2011).
- To estimate the present and future situations of water poverty in certain study areas (Cullis and Görgens, 2015).
- To provide summary information for socio-economic conditions corresponding to water poverty in any country (Cullis and O’Regan, 2004).

In the West Bank, Shadeed et al. (2019) developed a DWP map. The map was classified into five water poverty classes (based on natural breaks approach in GIS). In this study, the map was used to select the high to very high DWP areas in the West Bank.

The developed DWP map (see Figure 4) shows that 57% and 23% of the West Bank areas are classified as high to very high and moderate DWP areas, respectively. Whereas, low to very low DWP areas accounts for 19% of the West Bank area.

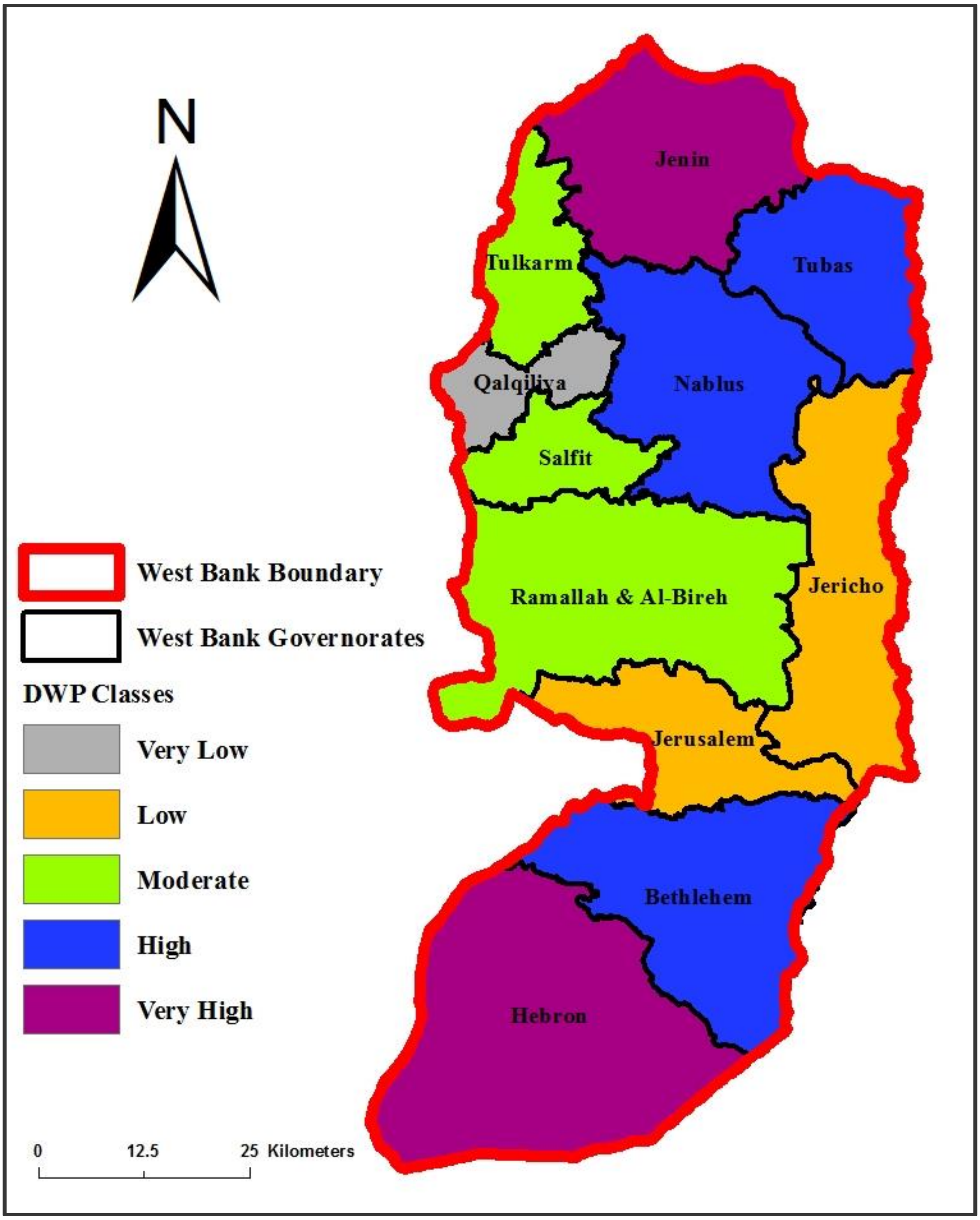

Figure (4): DWP Map for the West Bank (source: Shadeed et al., 2019)

2.4 Domestic Rainwater Harvesting

All over the world, the consumption of water for domestic purposes represents 10% of total water demand. According to PWA (2017), 64% of water supply in the West Bank was used for domestic purposes. Satisfying the domestic water demand is a serious challenge mainly in the water poor areas (Bocanegra-Martínez et al., 2014). Hence, the use of RRWH system to provide water for domestic purposes is essential to alleviate domestic water shortage.

RRWH is a very old technique which is still practiced (Cowden, 2008). In arid and semi arid regions, RWH had been used to provide water for domestic purposes (Mbua, 2013). RRWH is the most commonly used RWH system for domestic purposes (O'Brien, 2014).

The volume of harvested rainwater is affected by total rooftop area and type, annual rainfall amount and economic factors (Liaw and Chiang, 2014; O'Brien, 2014).

Several studies have focused on the estimation of potential amount of RRWH. Ghisi et al. (2006) estimated the saving amounts of drinking water from adoption of RRWH for the residential area of 62 cities in the southern Brazil. Their results indicated that the average potential saving from RRWH for drinking purposes is 69% from water demand.

Abdulla and Al-Shareef (2009) used annual rainfall and total rooftop areas to estimate the potential volume of harvested water. Results show that the total annual volume of RRWH from rooftops in 12 Jordanian governorates equals 15.5 MCM.

Aladenola and Adeboye (2010) estimated the potential volume of RRWH in Abeokuta, Nigeria. Results show that the annual volume of RRWH from Abeokuta rooftops is 74 m^3/household with an average value of 6.16 m^3/household/month.

Mourad and Berndtsson (2011) estimated the RRWH from Syria rooftops. Total rooftop areas for each governorate and annual rainfall in urban areas were used for calculating RRWH volume. From their results, the RRWH amount that can be harvested from urban areas in Syria is nearly 35 MCM.

Pawar-Patil and Mali (2013) estimated the RRWH volume from Pirwadi village of Kolhapur district, Maharashtra (India). From the results of this study the potential volume of RRWH that could be harvested is 11457 m^3.

Al-Houri et al. (2014) estimated the volume of water harvesting from rooftops of two Jordanian districts. They concluded that the annual amount of RRWH from Al-Jubiha and Shafa-Badran is 1.17 and 0.53 MCM, respectively.

Traboulsi and Traboulsi (2015) used annual rainfall and total number of rooftops to estimate the potential volume of RRWH in Lebanon. According to their results, the potential volume of RRWH from Lebanon rooftops is about 23 MCM.

Hari et al. (2018) estimated the RRWH potential in Almasguda, India. Results show that the total RRWH volume is 0.44 MCM.

Adugna et al. (2018) estimated the RRWH from large public institutions in Addis Ababa, Ethiopia. In this study, rooftop areas of large public institutions and average monthly rainfall were used to estimate the RRWH volume. According to their results, the RRWH from large public institutions could supply 2.3% of drinking water in Addis Ababa.

2.5 Domestic Rainwater Harvesting Suitability Mapping

For planning and implementation purposes, it is very important to be able to select the suitable areas for RWH (Mwenge Kahinda et al., 2008). However, the success of any RWH project depends on the proper selection of suitable areas and suitable techniques (Al-Adamat et al., 2012). In semi-arid areas, identification of RWH suitable areas is very essential to increase water availability and land productivity (Mbilinyi et al., 2007). Different methods have been developed to identify the suitable sites for RWH (Ghani et al., 2013). The site selection of RWH depends on different criteria (Mahmoud and Alazba, 2014).

In arid and semi-arid areas several GIS-based studies were conducted to select the suitable sites for RWH based on rainfall, soil, topography, runoff and land use (Prinz and Singh, 2000; Mati et al., 2006; Al-Adamat, 2008; Mwenge Kahinda et al., 2008; Al-Adamat et al., 2010; Adham et al., 2016; Dabiri et al., 2016).

In the West Bank, Shadeed et al. (2019) developed a DRWHS map (see Figure 5). The map was classified into five DRWHS classes (based on natural breaks approach in GIS). In this study, the map was used to select the suitable areas for domestic rainwater harvesting in the West Bank. Their results indicate that 60% of the West Bank areas are classified as high to very high DRWHS.

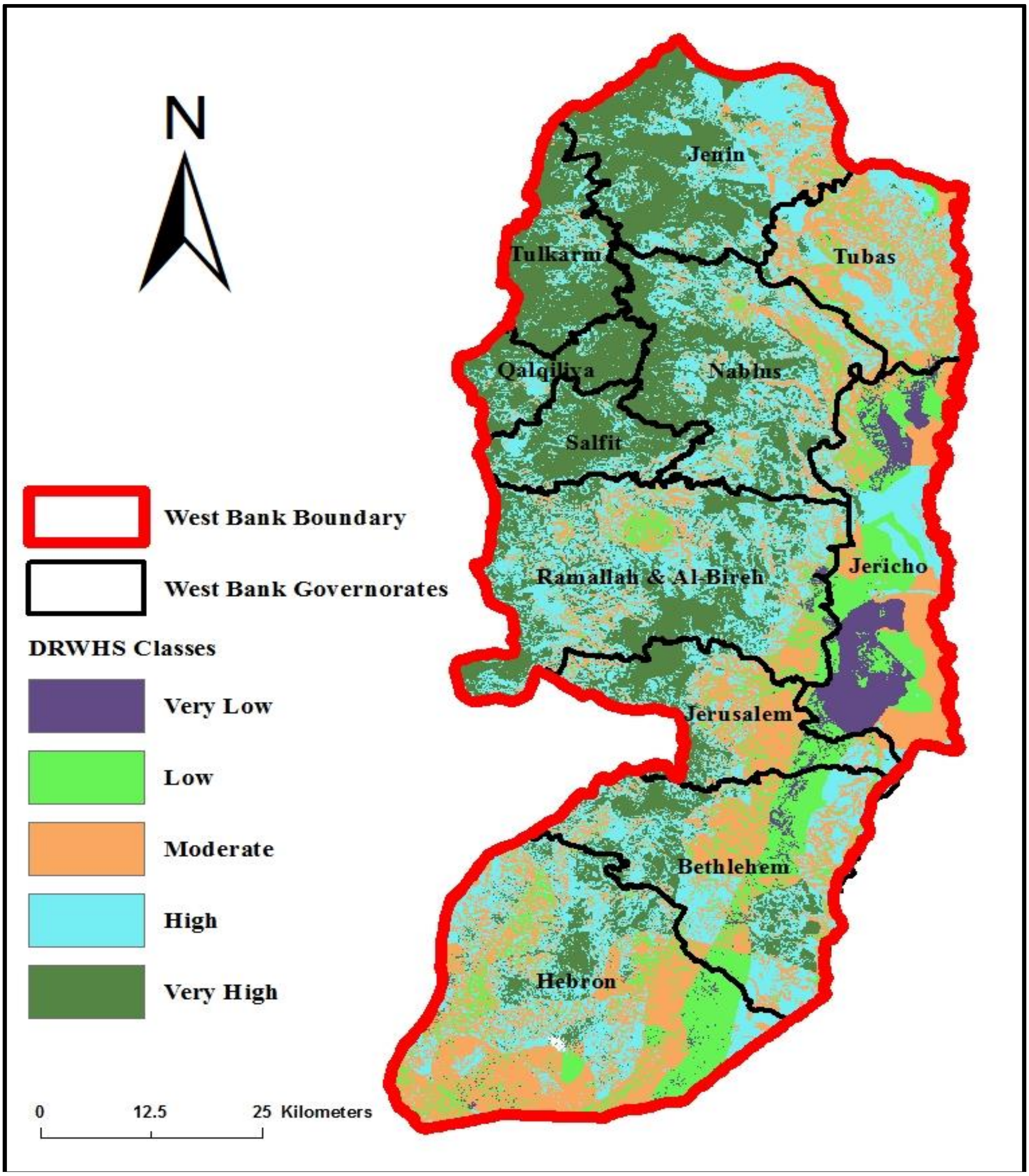

Figure (5): DRWHS Map for the West Bank (source: Shadeed et al., 2019)

2.6 Domestic Water Poverty and Domestic Rainwater Harvesting Suitability Intersection

In this study the available DWP-DRWHS intersection map (Shadeed et al., 2019) is used to select high water poor yet suitable areas in the West Bank (see Figure 6). According to their study, the West Bank areas were classified in to four classes:

- Very high DWP-very high DRWHS areas (VHP/VHS)
- Very high DWP-high DRWHS areas (VHP/HS)
- High DWP-very high DRWHS areas (HP/VHS)
- High DWP- high DRWHS areas (HP/HS)

The study concluded that 31% of the West Bank areas are classified as high to very high DWP yet high to very high DRWHS.

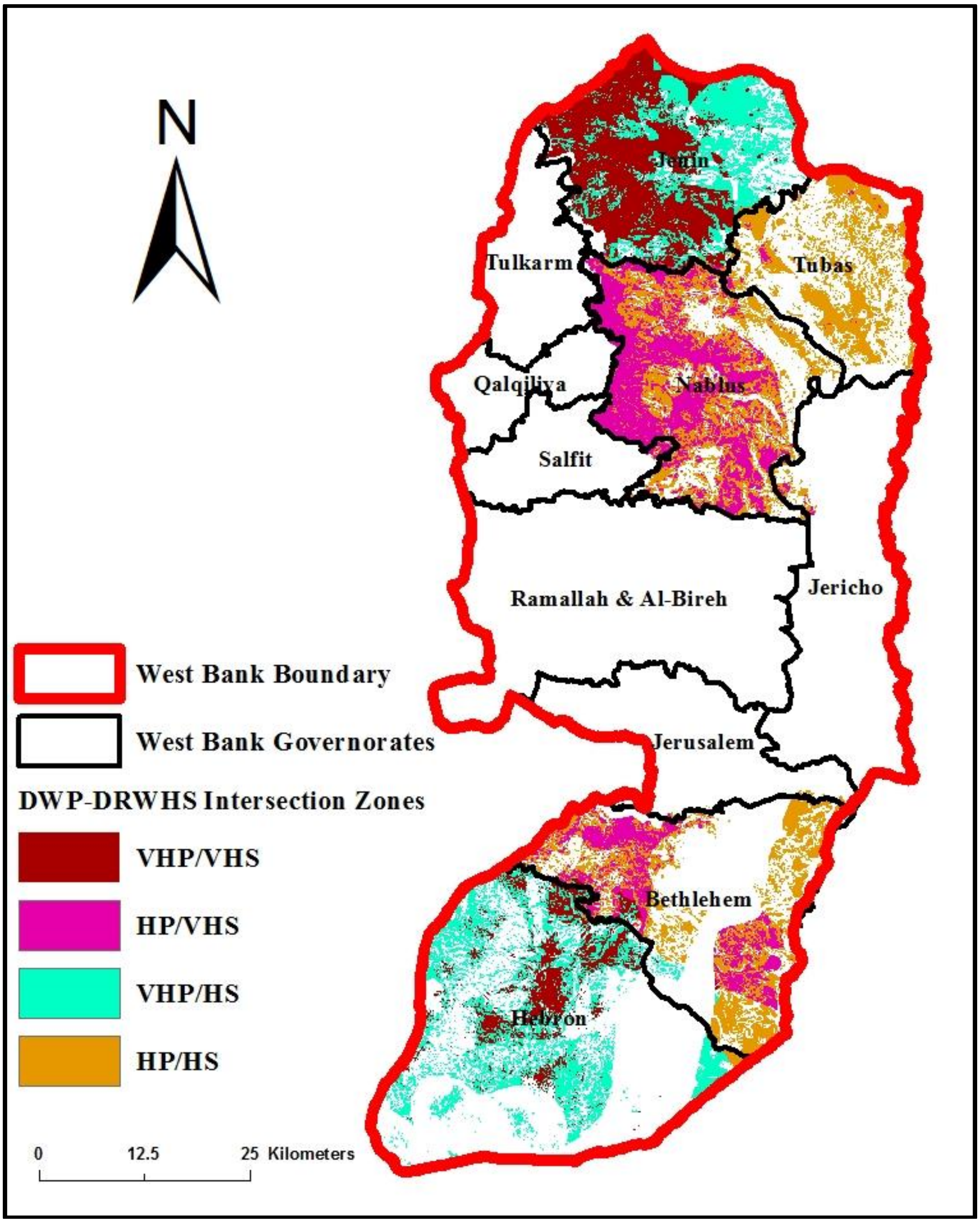

Figure (6): DWP–DRWHS Intersection Map for the West Bank (source: Shadeed et al., 2019)

Chapter Three

Description of the Study Area

3.1 Geography and Topography

The West Bank, Palestine is located in the Middle East, west of the Jordan River. The West Bank has a total area of 5658 km^2. Administratively, the West Bank is divided into 11 governorates. These are: Jenin, Tubas, Tulkarm, Nablus, Qalqiliya, Salfit, Ramallah & Al-Bireh, Jericho, Jerusalem, Bethlehem and Hebron as shown in Figure (4). The surface elevation of the West Bank ranges from 375 meters below sea level in the vicinity of the Dead Sea in Jericho to 1000 meters above sea level in the mountains of Hebron (GeoMOLG, 2018).

3.2 Population

The total population of the West Bank is about 2.88 millions (PCBS, 2017). Hebron governorate has the highest population number and Jericho governorate has the lowest one. Moreover, Jerusalem governorate has the highest population density and Jericho has the lowest one as presented in Table (2).

Table (2): Population Distribution in the West Bank Governorates

Governorate	**Population**	**% of Total West Bank Population**	**Population Density (capita/km^2)**
Jenin	315,382	11	573
Tubas	61,072	2	146
Tulkarm	186,803	6	684
Nablus	388,680	13	620
Qalqiliya	112,670	4	709
Salfit	75,679	3	367
Ramallah & Al-Bireh	329,679	11	391
Jerusalem	436,567	15	1219
Hebron	714,096	25	687
Bethlehem	218,278	8	354
Jericho	50,025	2	88
Total	**2,888,931**	**100**	**-**

3.3 Climate

Mediterranean climate is prevailing in the West Bank which is characterized as hot-dry in summer and wet-cold in winter (UNEP, 2003). In summer, the average monthly temperature ranges between 20.8 to 30 ^oC, whereas in winter, it ranges between 8.7 to 14 ^oC (ARIJ, 2015). The mean average relative humidity in the West Bank ranges between 52 and 69%. The average monthly evaporation ranges between 134 mm and 175 mm (PMD, 2013).

The West Bank rainy season usually extends from early October to early May. Most of the West Bank rain falls during winter from December to February (PWA, 2013).

Based on the rainfall map (see Figure 7), the long-term annual average rainfall in the West Bank is 420 mm. The rainfall map (raster) was manipulated by GIS to estimate the annual areal average rainfall for the different West Bank governorates (see Table 3).

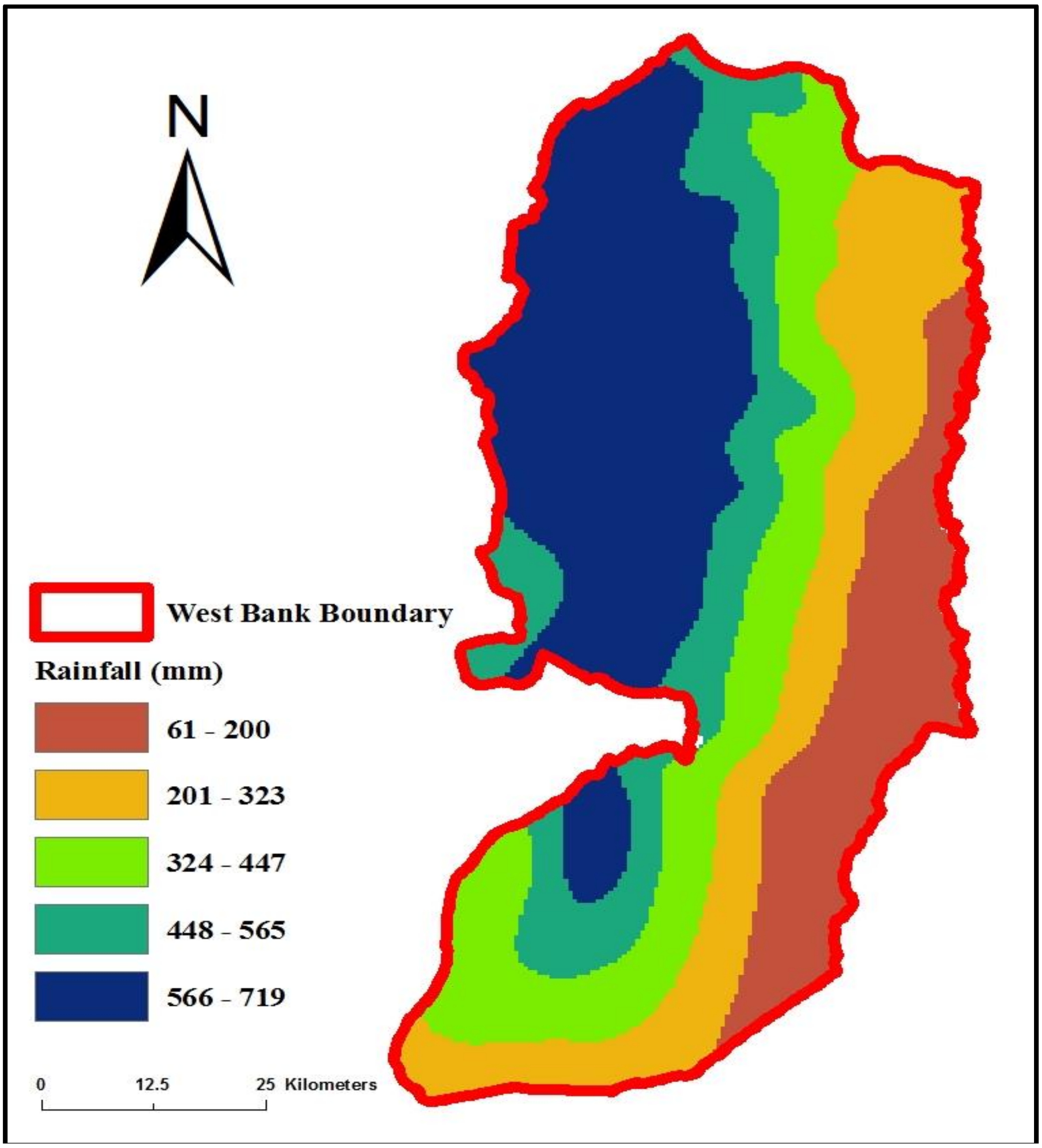

Figure (7): Long Term Annual Average Rainfall Distribution in the West Bank

(source: HEC, 2018)

Table (3): Annual Areal Average Rainfall of Different West Bank Governorates (source: HEC, 2018)

Governorate	Rainfall (mm)
Jericho	177.8
Hebron	374.8
Jerusalem	421.2
Bethlehem	267.6
Jenin	536.3
Ramallah & Al-Bireh	536.6
Salfit	634.6
Tubas	270.5
Tulkarm	601.3
Qalqilya	609.0
Nablus	518.5

3.4 Land Use

The land use map of the West Bank is classified into seven categories: Arable Land (supporting grains), Built-up Areas, Irrigated Farming (supporting vegetables), Israeli Settlements, Permanent Crops (grapes, olives, citrus and other fruits trees), Rough Grazing/Subsistence Farming and

Woodland/Forest. Most of the West Bank (62%) is classified as Rough Grazing/Subsistence Farming as shown in Figure (8).

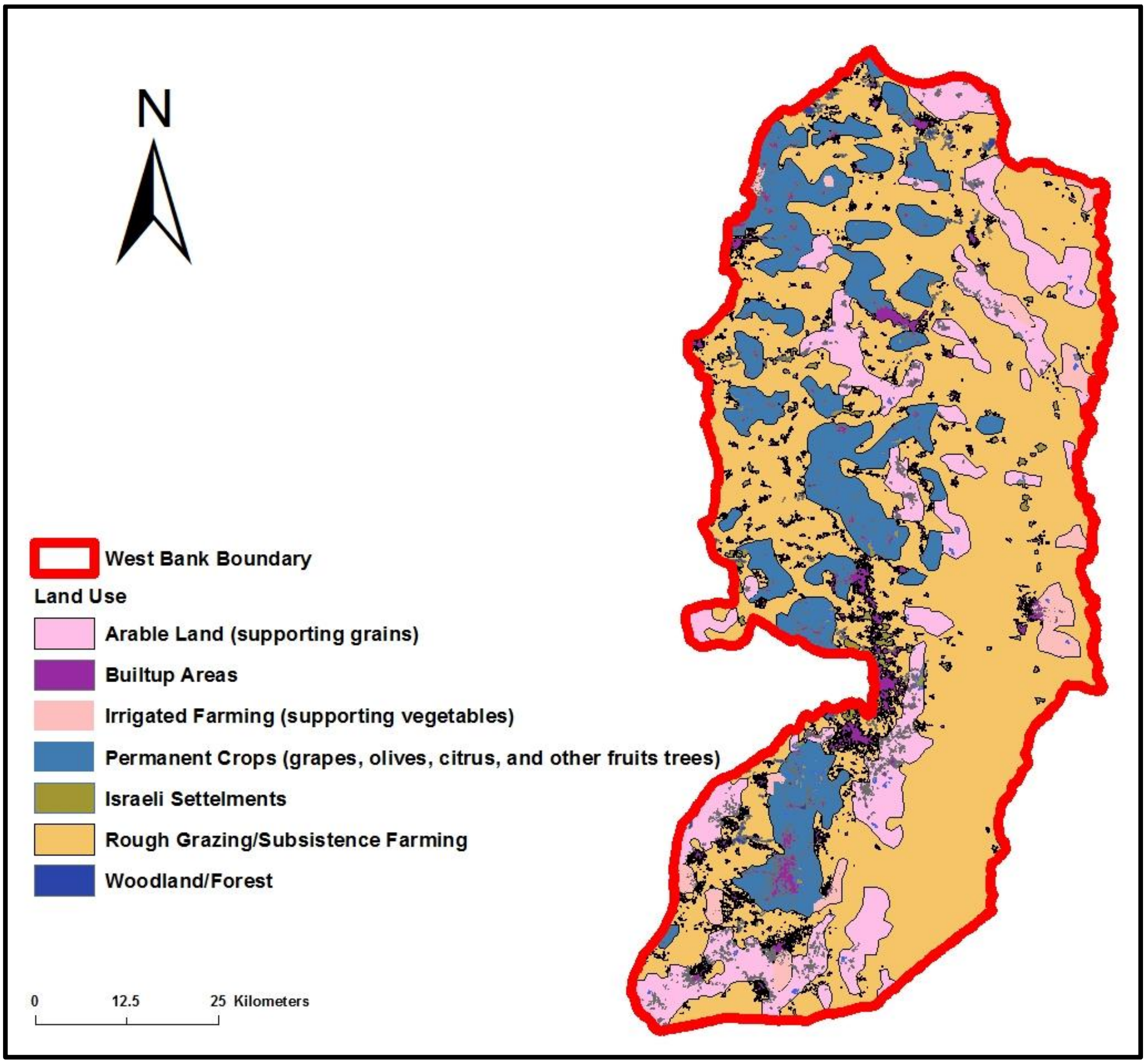

Figure (8): Land Use Map of the West Bank (source: GeoMOLG, 2018)

3.5 Domestic Water Supply-Demand Gap

In the West Bank, groundwater (from wells and springs) besides the purchased (from Israeli water company, Mekorot) are considered as the main water resources available for Palestinians for different uses. In 2017, the total available amount of water for different purposes is 182 MCM. However, 86

MCM were obtained from groundwater wells, springs provide nearly 24 MCM and 73 MCM is purchased from Mekorot (PWA, 2017).

In 2017, the total water supply for domestic use in the West Bank is about 117 MCM. Additionally, the total demand of water for domestic use in the West Bank is 143 MCM (based on a water demand of 150 l/c/d, according to WHO standards). Moreover, the total amount of water consumed for domestic use in the West Bank is 84 MCM as shown in Table (4). Based on the Table (4), the DWSD gap in the West Bank for the year 2017 was 32 MCM and the DWSD gap (including losses) was nearly 60 MCM. Additionally, it is clear that the West Bank governorates have DWSD gap ranges between 0.2 and 13.5 MCM (PWA, 2017).

Table (4): DWSD Gap in the Different West Bank Governorates

Governorate	**Population (2017)**	**Water Demand* (MCM)**	**Water Supply (MCM)**	**Water Consumption (MCM)**	**DWSD Gap (MCM)**	**Actual DWSD Gap (MCM)**
Jenin	315,382	17.3	8.2	5.8	9.1	11.5
Tubas	61,072	3.3	3.1	2.3	0.2	1.0
Tulkarm	186,803	10.2	10.4	6.4	***	3.8
Nablus	388,680	21.3	14.5	10.0	6.8	11.3
Qalqiliya	112,670	6.2	8.2	6.1	***	0.1
Salfit	75,679	4.1	3.2	2.6	0.9	1.5
Ramallah & Al-Bireh, and Jerusalem	484,333**	26.5	25.2	20.4	1.3	6.1
Jericho	50,025	2.7	6.4	4.3	***	***
Bethlehem and Hebron****	932,374	51.1	37.6	26.2	13.5	24.9
West Bank	**2,607,018**	**142.7**	**116.8**	**84.1**	**31.8**	**60.2**

* Needed quantity of water is calculated based on a water demand of 150 l/c/d, according to WHO standard.

**Data exclude those parts of Jerusalem which were annexed by Israeli Occupation in 1967. Where this part inhabited by 281,913 Palestinian citizens whom holding Jerusalem identity card and no information is available about the water supplied for them.

*** Domestic water supply is greater than domestic water demand (sufficient water resources).

**** Due to water supply system in Bethlehem and Hebron governorates, separation of data for each governorate is not possible.

Chapter Four

Results and Discussion

4.1 The Estimated Rooftop Rainwater Harvesting Volume

In the West Bank, the total rooftop areas are 78.3 km^2. whereas, the total built-up areas are 281 km^2 (5% of the total West Bank area). The potential volume of RRWH that could be harvested from the West Bank rooftops is estimated of about 37 MCM (see Table 5). From the table, it is clear that rooftops can annually harvest about 1.5% from the average West Bank rainfall volume (2384 MCM). Figure (9) illustrates the RRWH volume percentage for each governorate from the total West Bank RRWH volume. From the figure, Hebron governorate has the largest volume of RRWH which represents nearly 22% from the total volume of RRWH in the West Bank. This can be attributed to the high rooftop areas (26% from the total West Bank rooftop areas). Additionally, the potential volume of RRWH from Tubas and Jericho rooftops account for 1.5% and 0.7% of the total West Bank RRWH volume, respectively. However, Jericho has much more rooftop areas than Tubas, the potential harvested RRWH volume is less than that of Tubas. This is due to the fact that the long term annual average rainfall in Jericho (177.8 mm) is less than that of Tubas (270.5 mm).

Table (5): Potential Volume of RRWH in the Different West Bank Governorates

Governorate	Total Area (km^2)	Built-up Areas (km^2)	Number of Buildings	Rooftop Areas (km^2)	(%)*	(%)**	Rainfall Volume (MCM)	RRWH Volume (MCM)	(%)***
Jericho	569	10	13,307	2.1	20	3	101.2	0.3	0.3
Hebron	1,040	77	119,559	20.2	26	26	389.8	8.2	2.1
Jerusalem	358	37	25,273	4.6	12	6	150.8	2.2	1.4
Bethlehem	616	27	36,952	6.8	25	9	164.9	2.8	1.7
Jenin	550	23	65,263	9.9	43	13	295.0	4.8	1.6
Ramallah & Al-Bireh	843	39	58,705	11.0	29	14	452.3	6.1	1.3
Salfit	206	7	17,724	2.5	37	3	130.7	1.4	1.1
Tubas	417	5	11,826	1.6	31	2	112.8	0.5	0.5
Tulkarm	273	21	36,480	5.7	27	7	164.2	3.1	1.9
Qalqilya	159	7	20,469	3.1	45	4	96.8	1.7	1.7
Nablus	627	28	66,741	10.9	39	14	325.1	5.7	1.7
Total	**5,658**	**281**	**472,299**	**78.3**	**28**	**100**	**2383.5**	**36.6**	**1.5**

RRWH= rooftop rainwater harvesting.

*Percentage of governorate rooftop areas from the governorate built-up areas.

**Percentage of governorate rooftop areas from the total West Bank rooftop areas.

***Percentage of RRWH volume from rainfall volume.

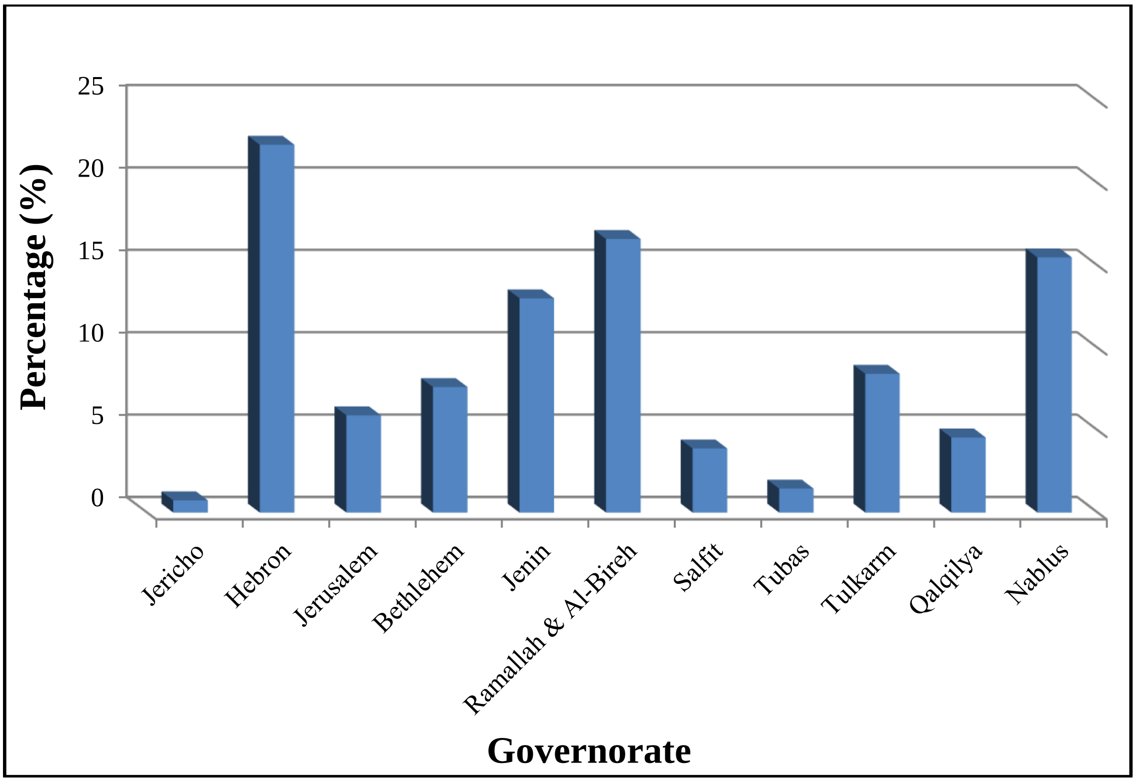

Figure (9): Percentage of RRWH Volume for each Governorate from the Total West Bank RRWH Volume

4.2 Rooftop Rainwater Harvesting to Alleviate Domestic Water Shortage

4.2.1 Rooftop Rainwater Harvesting to Alleviate Domestic Water Supply-Demand Gap

The main purpose for implementation of the RRWH technique in the West Bank is to alleviate the domestic water shortage. Based on the DWSD gap analysis in section 3.5 (see Table 4), the DWSD gap in the West Bank for the year 2017 amounted to 32 MCM and the volume of RRWH that could be harvested from the West Bank rooftops is nearly 37 MCM. Thus, the adoption of RRWH can satisfy the DWSD gap in Tubas, Salfit, Ramallah & Al-Bireh, and Jerusalem governorates as shown in Figure (10).

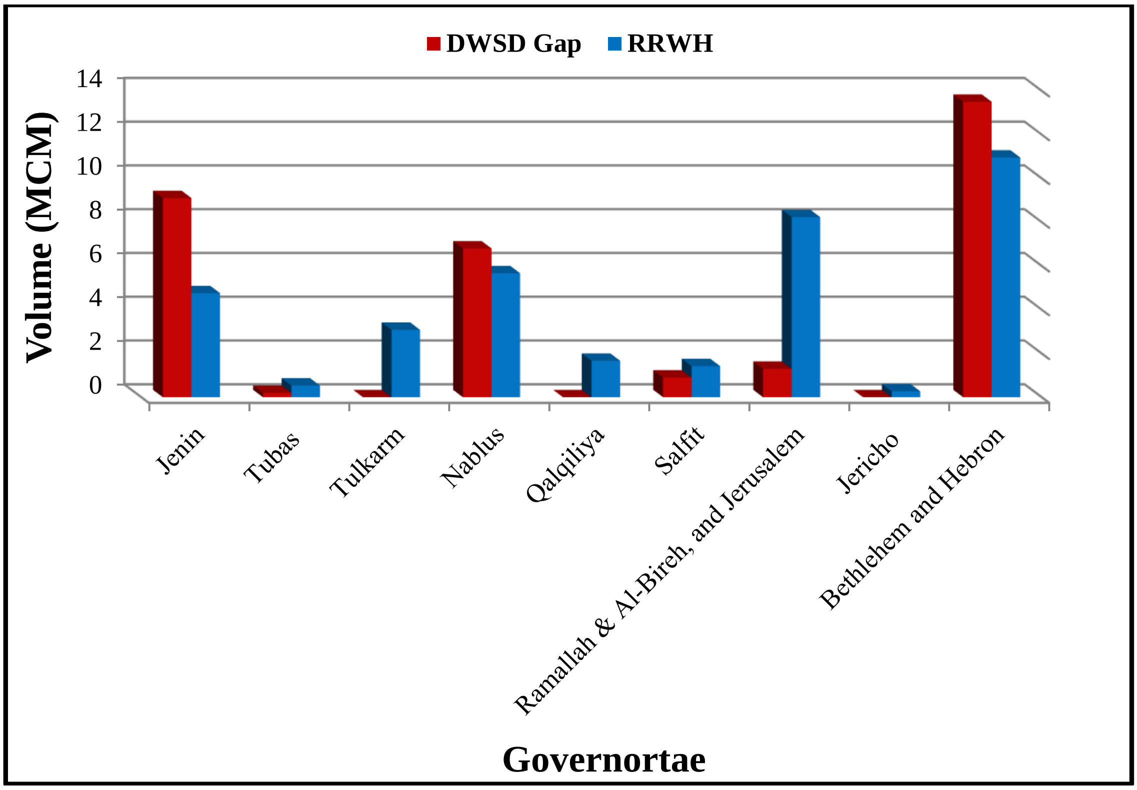

Figure (10): DWSD Gap and RRWH Volume in the Different West Bank Governorates

4.2.2 Rooftop Rainwater Harvesting to Alleviate Domestic Water Shortage in Water Poor Areas

Based on the developed DWP map by (Shadeed et al., 2019) (see Figure 4), Jenin, Tubas, Nablus, Hebron and Bethlehem governorates are under high to very high domestic water poverty.

Table (6) represents the DWSD gap after adopting of RRWH in the highly domestic WP areas. From the table, the implementation of RRWH can reduce the DWSD gap in Jenin from 9.1 MCM to 4.3 MCM, in Bethlehem and Hebron from 13.5 MCM to 2.5 MCM and from 6.8 MCM to 1.1 MCM in Nablus. In Tubas, Salfit, Ramallah & Al-Bireh, and Jerusalem governorates the implementation of RRWH can satisfy the DWSD gap.

Furthermore, the adoption of RRWH in the high to very high domestic water poverty areas can save nearly 16% to 28% of domestic water demand in these areas.

Table (6): Adopting of RRWH to Alleviate Domestic Water Shortage in Highly Domestic WP Areas

Governorate	**DWP classes**	**DWSD Gap (MCM)**	**RRWH Volume (MCM)**	**DWSD Gap after Adopting of RRWH (MCM)**	**PDWS (%)**
Jenin	Very high	9.1	4.8	4.3	27.5
Tubas	High	0.2	0.5	-	16.1
Tulkarm	Moderate	-	3.1	-	30.2
Nablus	High	6.8	5.7	1.1	26.6
Qalqiliya	Very Low	-	1.7	-	26.9
Salfit	Moderate	0.9	1.4	-	34.7
Ramallah & Al-Bireh, and Jerusalem	Low and Moderate	1.3*	8.2	-	31.1
Jericho	Low	-	0.3	-	10.0
Bethlehem and Hebron	High and Very high	13.5	11.0	2.5	21.4

WP= water poor, DWP= domestic water poverty, DWSD= domestic water supply-demand, RRWH= rooftop rainwater harvesting, PDWS= potential for domestic water saving.

*Data exclude those parts of Jerusalem which were annexed by Israeli Occupation in 1967. Where this part inhabited by 281,913 Palestinian citizens whom holding Jerusalem identity card and no information is available about the water supplied for them.

4.2.3 Rooftop Rainwater Harvesting to Alleviate Domestic Water Shortage in the Domestic Rainwater Harvesting Suitability Areas.

Depending on Shadeed et al. (2019), 60% of the total areas in the West Bank are classified as high to very high DRWHS areas (see Figure 5). The adoption of RRWH in these areas can generate 32 MCM (89% of the total RRWH volume in the West Bank) as present in Table (7). Accordingly, the adoption of RRWH in the high to very high DRWHS areas can satisfy the DWSD gap in Tubas, Salfit, Ramallah & Al-Bireh, and Jerusalem governorates and reduce the gap to 4.7 MCM, 1.4 MCM and 4.7 MCM in Jenin, Nablus, Bethlehem and Hebron governorates, respectively (see Table 8). The implementation of RRWH in these areas can save nearly 23% of the domestic water demand in the West Bank. The saved amount of domestic water demand after adopting of RRWH in the high to very high DRWHS areas ranged from 12% to 34% for all of the West Bank governorates except Jericho.

However, 28% of the total West Bank areas are classified as very high DRWHS. The total rooftop areas located in the very high DRWHS class is nearly 49 Km^2**.** From which 25 MCM (67% from the total West Bank RRWH volume) can be harvested (see Figure 11). Moreover, 35% of this volume is being harvested from Ramallah & Al-Bireh and Nablus governorates.

Table (7): RRWH Volume from the Different DRWHS Classes

Governorate	RRWH From Very High DRWHS Class (MCM)	RRWH From High DRWHS Class (MCM)	RRWH From Moderate DRWHS Class (MCM)	RRWH From Low and Very Low DRWHS Classes (MCM)	Total (MCM)
Jericho	0.006	0.010	0.012	0.242	0.27
Hebron	3.793	2.515	1.580	0.235	8.12
Jerusalem	1.377	0.518	0.241	0.022	2.16
Bethlehem	1.940	0.567	0.247	0.027	2.78
Jenin	3.121	1.259	0.345	0.017	4.74
Ramallah & Al-Bireh	4.397	1.124	0.492	0.059	6.07
Salfit	1.194	0.208	0.021	-	1.42
Tubas	0.151	0.227	0.136	0.018	0.53
Tulkarm	2.799	0.251	0.025	-	3.08
Qalqilya	1.462	0.174	0.027	0.001	1.66
Nablus	4.294	1.069	0.287	0.015	5.66
Total	**24.534**	**7.923**	**3.415**	**0.635**	**36.51**

RRWH= rooftop rainwater harvesting, DRWHS= domestic rainwater harvesting suitability.

Thus, the implementation of RRWH in this class could be satisfying the DWSD gap in Salfit, Ramallah & Al-Bireh, and Jerusalem governorates. Additionally, reduce the DWSD gap into 6 MCM in Jenin, .05 MCM in Tubas, 2.5 MCM in Nablus and 8 MCM in Bethlehem and Hebron governorates. The PDWS in this class ranged from 20% to 29% in Tulkarm, Nablus, Qalqiliya, Salfit, Ramallah & Al-Bireh, and Jerusalem governorates.

The high DRWHS class located in the West Bank (32% of total West Bank area) has total rooftop areas of 18 Km^2. The RRWH volume from this class is 8 MCM, which represents 22% of the total RRWH volume in the West Bank. The potential volume of RRWH in high DRWHS class could satisfy the DWSD gap in Tubas, Ramallah & Al-Bireh, and Jerusalem governorates.

Finally, adoption of RRWH in the moderate, low and very low DRWHS class can save nearly 3% of total domestic water demand in the West Bank. From the Figure (12), 46% to 91% of RRWH volume in Jerusalem, Bethlehem, Jenin, Ramallah & Al-Bireh, Salfit, Tulkarm, Qalqilya, Hebron and Nablus governorates could be harvested from the very high DRWHS areas. However, 43% and 28% of RRWH volume in Tubas governorate can be harvested from high and very high DRWHS classes, respectively. Moreover, 90% of potential volume of RRWH in Jericho governorate can be harvested from low to very low DRWHS classes.

Table (8): RRWH Volume from High and Very High DRWHS Classes

Governorates	**DWSD Gap (MCM)**	**RRWH Volume (MCM)**	**DWSD Gap after Adopting of RRWH (MCM)**	**PDWS (%)**
Jenin	9.1	4.38	4.7	25.3
Tubas	0.2	0.38	-	11.5
Tulkarm	-	3.05	-	29.9
Nablus	6.8	5.36	1.4	25.2
Qalqiliya	-	1.64	-	26.4
Salfit	0.9	1.40	-	34.2
Ramallah & Al-Bireh, and Jerusalem	1.3*	7.42	-	28.0
Jericho	-	0.02	-	0.6
Bethlehem and Hebron	13.5	8.82	4.7	17.3

RRWH= rooftop rainwater harvesting, DRWHS= domestic rainwater harvesting suitability, DWSD= domestic water supply-demand, PDWS= potential for domestic water saving.

* Data exclude those parts of Jerusalem which were annexed by Israeli Occupation in 1967. Where this part inhabited by 281,913 Palestinian citizens whom holding Jerusalem identity card and no information is available about the water supplied for them.

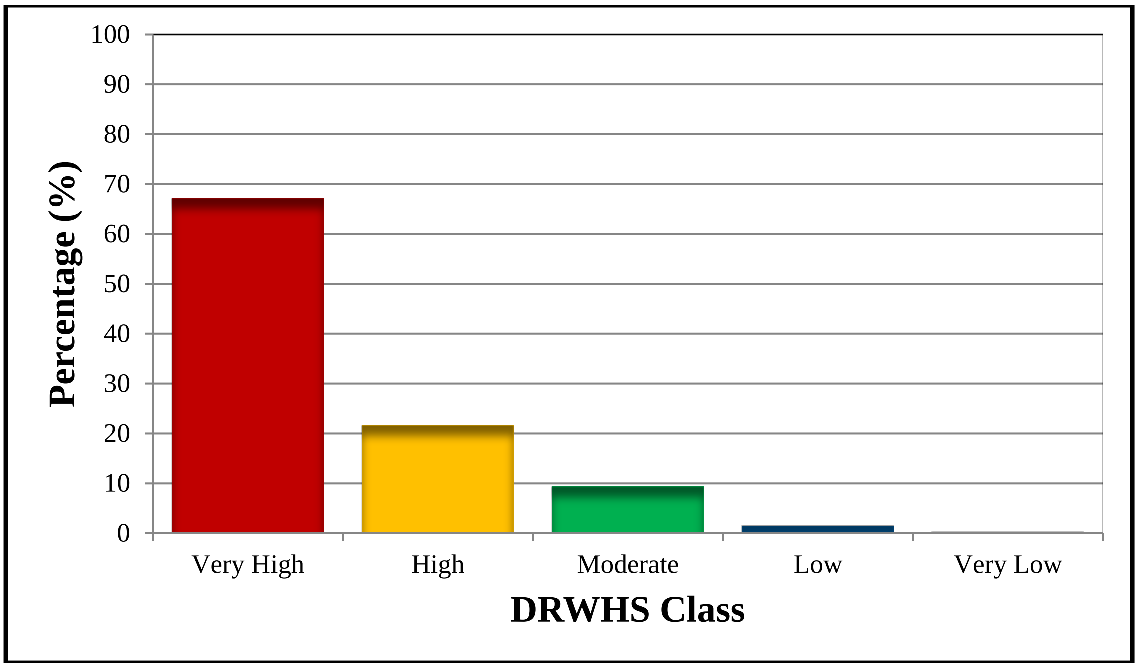

Figure (11): Percentage of RRWH Volume for Different DRWHS Classes in the West Bank

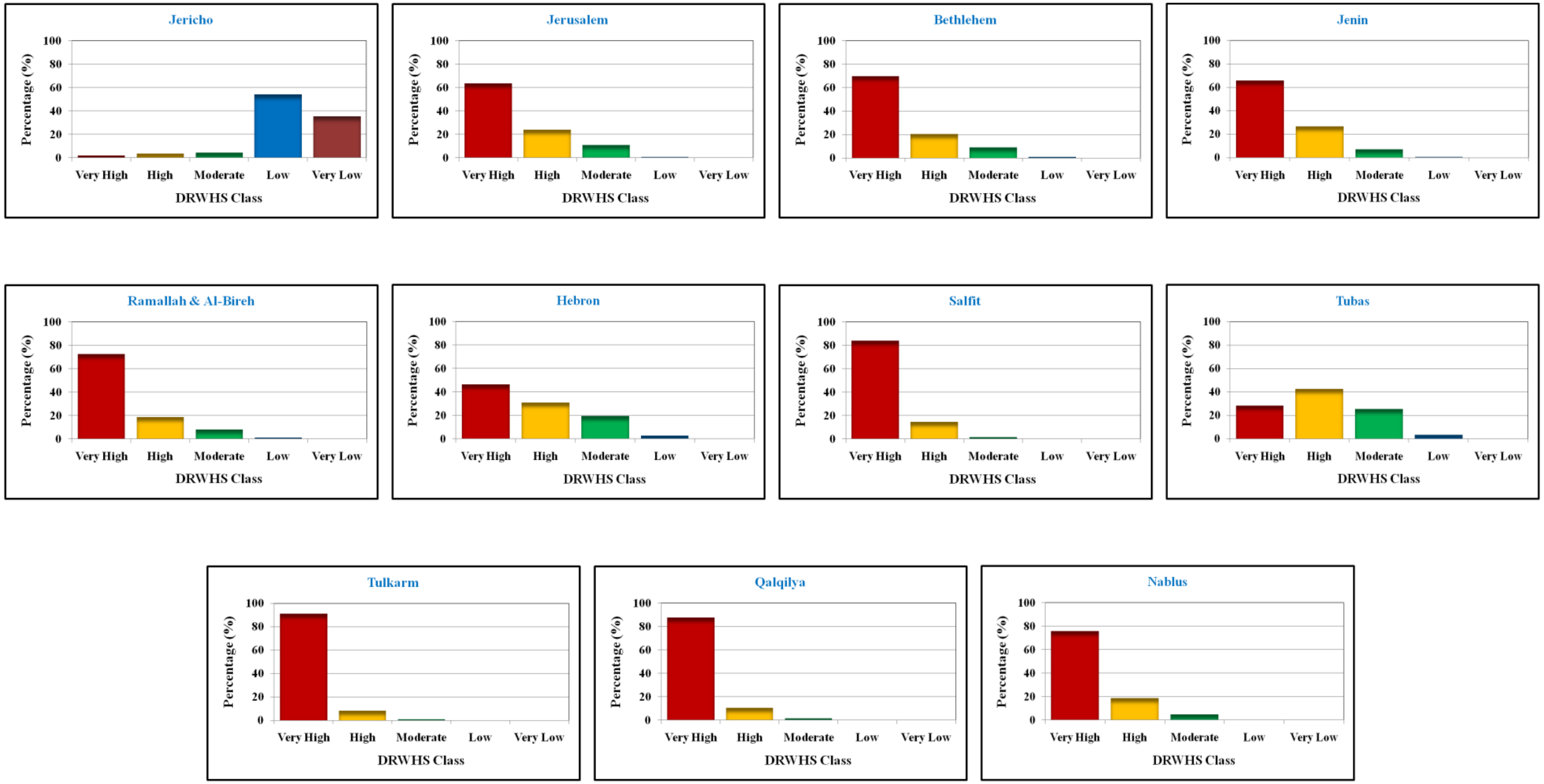

Figure (12): Percentage of RRWH Volume for Different DRWHS Classes in the Different West Bank Governorates

4.2.4 Rooftop Rainwater Harvesting to Alleviate Domestic Water Shortage in High Water Poor yet Highly Suitable Areas

Based on Shadeed et al. (2019), intersection map between DRWHS map and DWP map (see Figure 6), the high to very high DWP and high to very high DRWHS zones represent nearly 31% of the total West Bank area. The total rooftop areas in these zones are nearly 43 km^2. The RRWH that could be harvested from these zones account for 19 MCM (see Table 9). This volume contributes nearly 53% from total RRWH volume in the West Bank (see Figure 13). Additionally, 63% of this volume can be harvested from Nablus and Hebron governorates.

From Table (9), it is clear that 83% to 95% of RRWH volume from Nablus, Jenin, Bethlehem and Hebron governorates could be generated from rooftops within these zones. However, the adopting of RRWH in these zones can satisfy the DWSD gap in Tubas governorate and reduce the gap in the most of the West Bank governorates as presented in Table (10). In the West Bank, the adopting of RRWH in these zones can save nearly 14% of the domestic water demand.

However, VHP/VHS zone (7% of the total West Bank area) generates the highest volume of RRWH (7 MCM) which presents nearly 19% of total volume of RRWH in the West Bank. In this zone, the PDWS in Jenin governorate is 18%.

Figure (14) illustrates the percentage of RRWH volume for different DWP-DRWHS intersection zones in the different West Bank governorates. From the figure, 46% of RRWH in Hebron governorate and 65% of RRWH in Jenin governorate can be harvested from VHP/VHS zone. However, 76% and 67% of RRWH from Nablus and Bethlehem governorates can be harvested from HP/VHS zone. Additionally, 43 % of Tubas RRWH can be harvested from HP/HS zone.

Adopting of RRWH in the very high poor yet highly suitable zones (15% of the total West Bank area) generates nearly 11 MCM (30% of total volume of RRWH in the West Bank). Hebron governorate contributes about 61% of this volume. Thus, the adoption of RRWH in these zones can save nearly 25% and 13% of domestic water demand in Jenin, Bethlehem and Hebron governorates, respectively (see Table 11).

The implementation of RRWH in the high WP yet suitable zones (16% of the total West Bank area) harvest nearly 8 MCM (23% of the total RRWH volume in the West Bank). Moreover, 65% of this RRWH volume generated from Nablus governorate. The adopting of RRWH in these areas saves nearly 11% and 25% in Tubas and Nablus governorates, respectively (see Table 12).

Table (9): RRWH Volume from High WP yet Highly Suitable Areas

Governorate	RRWH (MCM)					RRWH Volume to Governorate RRWH Volume (%)
	(VHP/VHS) Zone	(VHP/HS) Zone	(HP/VHS) Zone	(HP/HS) Zone	Total	
Hebron	3.771	3.003	0.023	0.009	6.805	83.33
Jerusalem	-	-	0.001	-	0.001	0.07
Bethlehem	0.020	0.009	1.868	0.551	2.449	87.88
Jenin	3.089	1.252	0.005	0.004	4.351	91.49
Ramallah & Al-Bireh	-	-	-	0.001	0.002	0.02
Salfit	-	-	0.027	0.008	0.034	2.42
Tubas	-	-	0.151	0.227	0.378	71.02
Tulkarm	0.006	0.002	-	-	0.008	0.25
Qalqilya	-	-	0.002	-	0.002	0.12
Nablus	-	-	4.289	1.067	5.357	94.56
Total	**6.886**	**4.266**	**6.366**	**1.868**	**19.386**	**53.00**

RRWH= rooftop rainwater harvesting, WP= water poor, VHP/VHS= very high poverty/very high suitability, VHP/HS= very high poverty/high suitability, HP/VHS= high poverty/very high suitability, HP/HS= high poverty/high suitability.

Table (10): Adopting of RRWH to Alleviate Domestic Water Shortage in the Domestic WP yet Suitable Areas in the West Bank

Governorate	DWSD Gap (MCM)	RRWH Volume (MCM)	DWSD Gap after Adopting of RRWH (MCM)	PDWS (%)
Jenin	9.1	4.351	4.7	25.15
Tubas	0.2	0.378	-	11.46
Tulkarm	-	0.008	-	0.08
Nablus	6.8	5.357	1.4	25.15
Qalqiliya	-	0.002	-	0.03
Salfit	0.9	0.034	0.9	0.84
Ramallah & Al-Bireh, and Jerusalem	1.3*	0.003	1.3	0.01
Jericho	-	-	-	-
Bethlehem and Hebron	13.5	9.253	4.2	18.11

RRWH= rooftop rainwater harvesting, WP= water poor, DWSD= domestic water supply-demand, PDWS= potential for domestic water saving.

* Data exclude those parts of Jerusalem which were annexed by Israeli Occupation in 1967. Where this part inhabited by 281,913 Palestinian citizens whom holding Jerusalem identity card and no information is available about the water supplied for them.

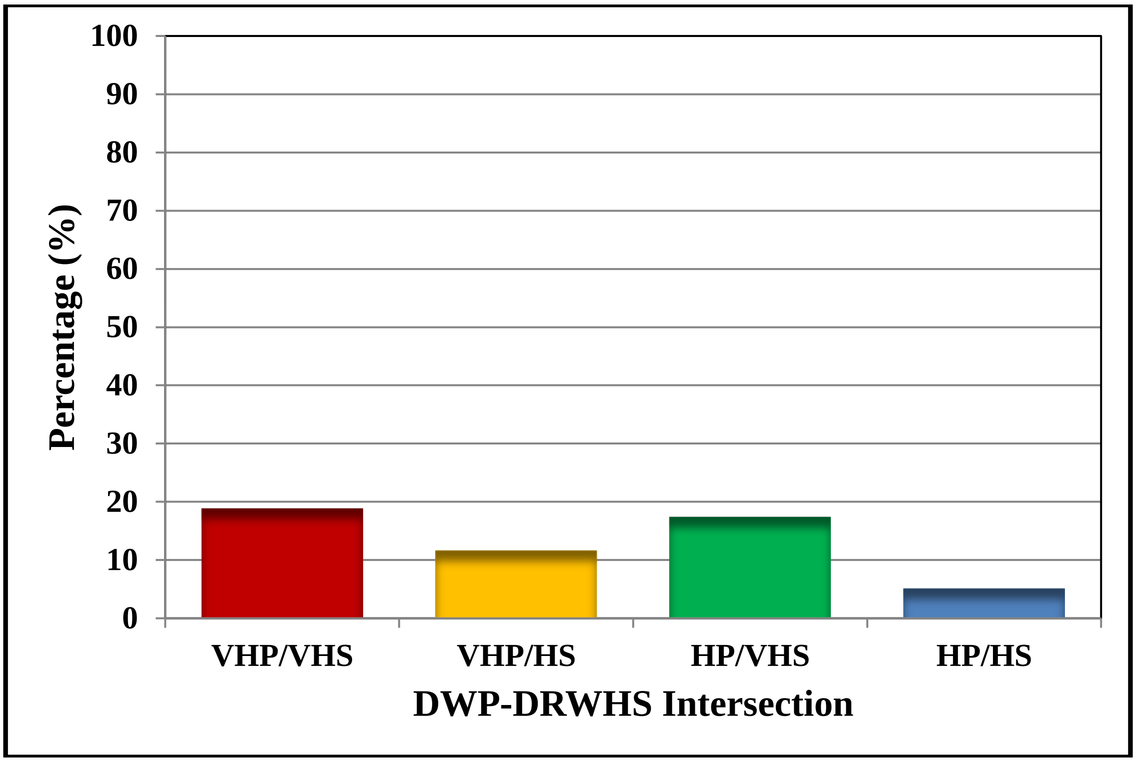

Figure (13): Percentage of RRWH Volume for Different DWP-DRWHS Intersection Zones in the West Bank

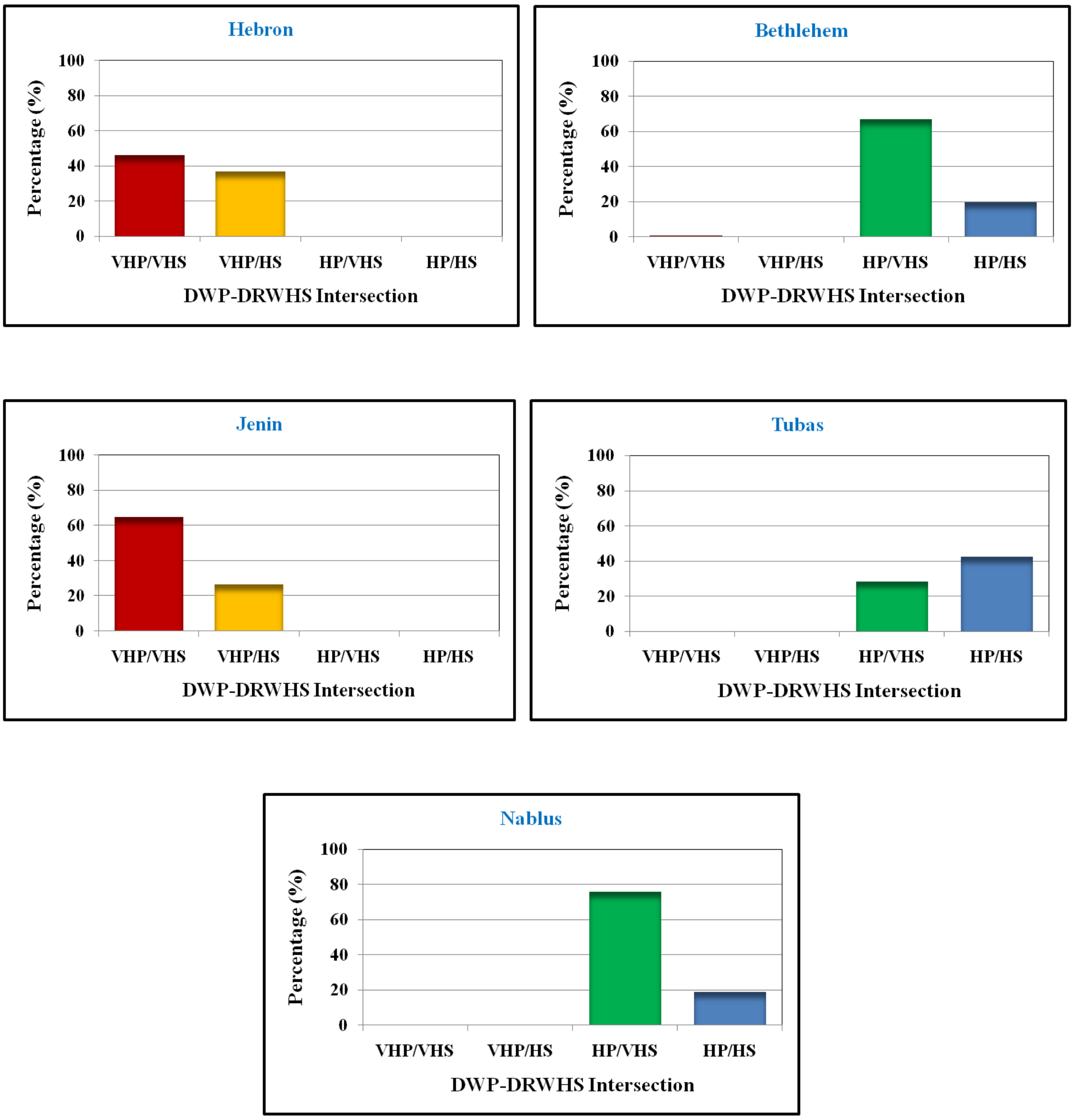

Figure (14): Percentage of RRWH Volume for Different DWP-DRWHS Intersection Zones in the Different West Bank Governorates

Table (11): Adopting of RRWH to Alleviate Domestic Water Shortage in the Very High WP yet Suitable Areas in the West Bank

		VHP/VHS		VHP/HS		VHP/VHS and VHP/HS		
Governorate	**DWSD Gap (MCM)**	**RRWH Volume (MCM)**	**DWSD Gap after Adopting RRWH (MCM)**	**RRWH Volume (MCM)**	**DWSD Gap after Adopting RRWH (MCM)**	**RRWH Volume (MCM)**	**DWSD Gap after Adopting RRWH (MCM)**	**PDWS (%)**
Jenin	9.1	3.089	6.0	1.252	7.85	4.341	4.8	25.09
Tubas	0.2	-	0.2	-	0.20	-	0.2	-
Tulkarm	-	0.006	-	0.002	-	0.008	-	0.08
Nablus	6.8	-	6.8	-	6.80	-	6.8	-
Qalqiliya	-	-	-	-	-	-	-	-
Salfit	0.9	-	0.9	-	0.90	-	0.9	-
Ramallah & Al-Bireh, and Jerusalem	1.3	-	1.3	-	1.30	-	1.3	-
Jericho	-	-	-	-	-	-	-	-
Bethlehem and Hebron	13.5	3.791	9.7	3.012	10.49	6.803	6.7	13.31

RRWH= rooftop rainwater harvesting, WP= water poor, VHP/VHS= very high poverty/very high suitability, VHP/HS= very high poverty/high suitability, DWSD= domestic water supply-demand, PDWS= potential for domestic water saving.

Table (12): Adopting of RRWH to Alleviate Domestic Water Shortage in the High WP yet Suitable Areas in the West Bank

		HP/VHS		HP/HS		HP/VHS and HP/HS		
Governorates	**DWSD Gap (MCM)**	**RRWH Volume (MCM)**	**DWSD Gap after Adopting RRWH (MCM)**	**RRWH Volume (MCM)**	**DWSD Gap after Adopting RRWH (MCM)**	**RRWH Volume (MCM)**	**DWSD Gap after Adopting RRWH (MCM)**	**PDWS (%)**
Jenin	9.1	0.005	9.1	0.004	9.1	0.009	9.1	0.05
Tubas	0.2	0.151	-	0.227	-	0.378	-	11.46
Tulkarm	-	-	-	-	-	-	-	-
Nablus	6.8	4.289	2.5	1.067	5.7	5.357	1.4	25.15
Qalqiliya	-	0.002	-	-	-	0.002	-	0.03
Salfit	0.9	0.027	0.9	0.008	0.9	0.034	0.9	0.84
Ramallah & Al-Bireh, and Jerusalem	1.3	0.001	1.3	0.002	1.3	0.003	1.3	0.01
Jericho	-	-	-	-	-	-	-	-
Bethlehem and Hebron	13.5	1.891	11.6	0.560	12.9	2.451	11.0	4.80

RRWH= rooftop rainwater harvesting, WP= water poor, HP/VHS= high poverty/very high suitability, HP/HS= high poverty/high suitability, DWSD= domestic water supply-demand, PDWS= potential for domestic water saving.

Chapter Five

Conclusions and Recommendations

5.1 Conclusions

The adoption of rooftop rainwater harvesting (RRWH) to alleviate the domestic water shortage in the West Bank, Palestine was evaluated in this study. Based on the long term average annual rainfall and rooftop areas, the potential volume of RRWH in the different West Bank governorates was estimated. Depending on the available domestic water poverty (DWP) map, domestic rainwater harvesting suitability (DRWHS) map and domestic water poverty-domestic rainwater harvesting suitability (DWP-DRWHS) intersection map, the RRWH volume from these areas were calculated. GIS was used to estimate the area and average areal annual rainfall for each rooftop through spatial join tool. Field calculator was used to multiply area, rainfall and R_C value together.

Depending on the PWA data the domestic water supply-demand (DWSD) gap in the West Bank was nearly 32 MCM. According to this study, 37 MCM could be harvested from the West Bank rooftop areas. Thus, the implementation of RRWH can satisfy the DWSD gap in the West Bank. Additionally, the West Bank rooftops can harvest nearly 1.5% of total West Bank rainfall. However, the estimated RRWH volume is a potential one as it is not practiced yet in most of the West Bank governorates specially in urban areas.

The results of this study show that, the adoption of RRWH in the high to very high DRWHS classes can harvest nearly 32 MCM. The potential for domestic water saving (PDWS) from implementation of RRWH in the high to very high domestic water poor areas ranged from 16 to 28%. However, 25 MCM can harvest from very high DRWHS class and eight MCM can be harvested from high DRWHS class. Additionally, 19 MCM could be harvested from high water poor yet highly suitable zones in the West Bank.

In this study, the estimated RRWH volumes are subjected to some uncertainty reasons. The available buildings shapefile from the Geomolg does not mapped the entire rooftops in the West Bank and thus needs to be updated regularly. The used map was developed by one of the most commonly used interpolation technique (the IDW one). However, there are different technique (e.g. Spline and Kriging) which can be used to end up with different rainfall spatial patterns that might affect the obtained results. Although, this research thesis managed to provides a realistic estimation of the potential RRWH volumes in the West Bank.

To conclude, this thesis can provide key decision makers with robust outputs that could be successfully implemented toward a sustainable water resources management in Palestine.

5.2 Recommendations

Based on this research outputs, it is recommended to:

1. Adopt RRWH as a viable strategy to sustainably satisfy water needs for domestic use mainly in the highly domestic water poor areas in the West Bank.

2. Raise the public awareness in the water poor areas regarding the importance of adopting RRWH to alleviate the domestic water shortage in these areas.
3. Use of DRWHS map to prioritize the use of RRWH with emphasis on high to very high domestic water poor areas.
4. Propose the optimal tank size (cistern) to collect the potential amount of RRWH which can be used to bridge the increasing DWSD gap in most of the West Bank governorates given the uncertain water supply.
5. Conduct a sensitivity analysis by changing the rainfall interpolation techniques to best map the actual areal rainfall extent in the West Bank and accordingly to update the RRWH estimation values.
6. Study the economic feasibility (cost-benefit analysis) of adopting RRWH techniques in Palestine.

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كلية الدراسات العليا

الحصاد المائي من أسطح المباني للتخفيف من النقص المائي المنزلي في فلسطين

إعداد

ساندي مفلح غازي علاونة

إشراف

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قدمت هذه الأطروحة استكمالا لمتطلبات الحصول على درجة الماجستير في هندسة المياه والبيئة، بكلية الدراسات العليا، في جامعة النجاح الوطنية، نابلس– فلسطين.

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الملخص

الماء عامل رئيسي للتنمية المستدامة. في المناطق الجافة وشبه الجافة، أصبح الماء شحيحاً في كميته سيئاً في نوعيته يرجع ذلك إلى الطلب المتزايد على المياه للاستخدامات المختلفة كالاستخدام المنزلي مثلاً. هذا الوضع جعل هناك حاجة ملحة للبحث عن موارد مائية جديدة ومستدامة (مثل حصاد المياه من أسطح المباني). تهدف هذه الدراسة إلى تقدير الفجوة بين العرض والطلب على المياه للاستخدام المنزلي في مختلف محافظات الضفة الغربية وتقييم إمكانية الاعتماد على الحصاد المائي من أسطح المباني لجسر هذه الفجوة. إضافة لذلك، تهدف الدراسة إلى تقييم إمكانية استخدام المياه المحصودة من أسطح المباني للتقليل من مشكلة نقص المياه خاصة في أكثر المناطق فقراً للمياه المنزلية وفي نفس الوقت أكثرها ملاءمة للحصاد المائي. إضافة لذلك، تقدير كمية المياه المتوقع توفيرها للاستخدامات المنزلية جراء توظيف تقنيات الحصاد المائي من أسطح المباني في مختلف محافظات الضفة الغربية. تعتمد منهجية هذه الدراسة بشكل رئيسي على استخدام برنامج نظم المعلومات الجغرافية و برنامج الاكسل لتقدير كمية المياه المتوقع حصادها من أسطح المباني لمختلف محافظات الضفة الغربية وذلك اعتماداً على الخرائط المكانية المتوفرة لتوزيع المباني والأمطار لمختلف المحافظات. وفقًا للبيانات المائية المتوفرة في سلطة المياه الفلسطينية للعام 2017، تبلغ الفجوة بين العرض والطلب على المياه المتاحة للاستخدام المنزلي في الضفة الغربية حوالي 32 مليون متر مكعب. بشكل عام، هنالك العديد من الخيارات الاستراتيجية لإدارة مصادر المياه وزيادة الكمية المتاحة وجسر الفجوة بين العرض والطلب على المياه للاستخدام المنزلي. في الضفة الغربية وذلك بسبب عدم موثوقية التزود من المصادر التقليدية (المياه الجوفية على سبيل المثال) يمكن الاعتماد على الحصاد المائي من أسطح المباني لجسر هذه الفجوة. تظهر نتائج هذه الدراسة أن كمية

المياه التي يمكن حصادها من أسطح المباني في الضفة الغربية حوالي 37 مليون متر مكعب. بالتالي، فإن الاعتماد على الحصاد المائي من أسطح المباني يمكن أن يؤدي إلى جسر الفجوة بين العرض والطلب على المياه للاستخدام المنزلي في محافظات طوباس، سلفيت، رام الله والبيرة والقدس. إضافة لذلك، فإن توظيف الحصاد المائي من أسطح المباني في المناطق الأكثر ملاءمة للحصاد المائي يمكن أن يحصد ما يقرب من 89% من إجمالي كمية المياه المحصودة من أسطح المباني في الضفة الغربية. أخيراً، يشكل توظيف تقنيات الحصاد المائي من أسطح المباني في المناطق الفقيرة وفي نفس الوقت الملائمة للحصاد المائي للاستخدام المنزلي حوالي 53% من أجمالي كمية المياه التي يمكن حصادها من أسطح المباني في الضفة الغربية. هذه الدراسة ستسهم في مساعدة أصحاب العلاقة لتبني تقنيات الحصاد المائي من أسطح المباني للتقليل من الفجوة بين العرض والطلب على المياه للاستخدام المنزلي وخاصة في المناطق الأكثر فقراً للمياه في الضفة الغربية.