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

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

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Abstract

Water is a key factor for sustainable development which is in turn contributing to SDG 6 "Ensure access to water for all". Generally, in arid and semi-arid regions, water is becoming less in quantity. This is due to the increasing water demand for different uses and the consequences of climate change. This situation compiled the urgent need to implement a sustainable and non-conventional water resources, among which is rooftop rainwater harvesting (RRWH) which is being studied in this research. This paper aims to estimate potential volume of RRWH and to evaluate the possibility of adopting RRWH as a reliable water resource in trying to bridge the domestic water supply-demand (DWSD) gap in the West Bank. The methodology of this study mainly rely on the use of the geographic information system (GIS) together with MS Excel. RRWH volumes were estimated based on the available GIS shapefiles of rooftops and long-term areal annual average rainfall. According to Palestinian Water Authority (PWA) data for the year 2017, the DWSD

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gap in the West Bank is 32 million cubic meters (MCM). In the West Bank, and given the vulnerable water supply, RRWH was found to be a strategic option to bridge this gap. The results of this study show that the estimated RRWH volume potentially available from West Bank rooftops is 37 MCM. Moreover, the adoption of RRWH in areas with high to very high domestic rainwater harvesting suitability can collect up to 32 MCM. Implementation of RRWH in high domestic water poor areas yet highly suitable for rainwater harvesting amounted to 53% of total RRWH volume in the West Bank. This paper may help potential Stakeholders (e.g. PWA) to adopt RRWH as a sustainable water resource option to alleviate domestic water shortage in the West Bank.

Keywords: Rooftop Rainwater Harvesting; Domestic Water Supply-Demand Gap; West Bank; Domestic Rainwater Harvesting Suitability; Domestic Water Poor Areas.

ملخص

الماء عامل رئيس للتنمية المستدامة، وهذا يتماشى مع الهدف السادس من أهداف التنمية المستدامة "ضمان توفر المياه للجميع". بشكل عام، في المناطق الجافة وشبه الجافة، أصبح الماء شحيحاً في كميته ويرجع هذا إلى الطلب المتزايد على المياه للاستخدامات المختلفة وتبعات التغير المناخي. هذا الوضع جعل هناك ضرورة للبحث عن موارد مائية مستدامة وغير تقليدية من بينها حصاد المياه من أسطح المباني الذي ستتم دراسته في هذا البحث. تهدف هذه الدراسة إلى تقدير كمية المياه المتوقع حصادها من أسطح المباني وتقييم إمكانية الاعتماد على الحصاد المائي من أسطح المباني كمصدر موثوق لجسر الفجوة بين العرض والطلب على المياه للاستخدام المنزلي في مختلف محافظات الضفة الغربية. تعتمد منهجية هذه الدراسة بشكل رئيسي على استخدام برنامج نظم المعلومات الجغرافية و برنامج الاكسل لتقدير كمية المياه المتوقع تجميعها من أسطح المباني وذلك اعتماداً على الخرائط المكانية المتوفرة لتوزيع المباني والأمطار. 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. في الضفة الغربية وذلك بسبب عدم موثوقية التزود 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 هي 37 مليون متر مكعب. إضافة لذلك، فإن توظيف الحصاد المائي من أسطح المباني في المناطق الأكثر ملاءمة للحصاد المائي يمكن أن يجمع ما

مقداره 32 مليون متر مكعب. 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 تجميعها من أسطح المباني في الضفة الغربية. هذه الدراسة ربما تساعد أصحاب العلاقة (سلطة المياه الفلسطينية) لتبني تقنيات الحصاد المائي من أسطح المباني للتقليل من الفجوة بين العرض والطلب على المياه للاستخدام المنزلي في الضفة الغربية.

الكلمات المفتاحية: حصاد المياه من أسطح المباني، الفجوة بين العرض والطلب على المياه المتاحة للاستخدام المنزلي، الضفة الغربية، المناطق الملاءمة للحصاد المائي، المناطق الأكثر فقراً للمياه المنزلية.

Introduction

Worldwide, population increase and climate change leads to increased water demand (Liuzzo *et al*., 2016). People living in water poor areas (limited available water) generally suffer from lack of access to drinking water (Sturm *et al*., 2009). In these areas, rooftop rainwater harvesting (RRWH) is practiced as a main source for drinking purposes (Mbua, 2013; O'Brien, 2014; Khastagir and Jayasuriya 2010).

All over the world, the consumption of water for domestic uses represents 10% of total water demand (Bocanegra-Martínez *et al*., 2014). According to Palestinian Water Authority, PWA (2017), 64% of water supply in the West Bank was used for domestic purposes.

In arid and semi-arid regions (e.g. Palestine) which are characterized by high temporal and spatial rainfall variation and limited water supply, rainwater harvesting (RWH) becomes a sustainable option to alleviate domestic water shortage mainly in high water poor areas (PWA, 2016).

RWH is a simple, low-cost method of collecting and storing rainwater from roofs and surface catchments (Mwenge Kahinda *et al*., 2007; González, 2012). RWH system consists of a catchment surface, and conveyance and storage systems (Worm and Hattum, 2006; Mbua, 2013). There are many types of catchment system which include: rooftop catchment system, rock catchment system, ground catchment system, check and earth dams (Gould and Nissen-Petersen, 1999). This 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.

Several countries all over the world used different RWH techniques among which those used for domestic purposes. For instance, Brazil (Ghisi *et al*., 2009), Canada (Despins *et al*., 2009), China(Li and Gong, 2002), France (Vialle *et al*., 2012), Greece (Sazakli *et al*., 2007), Iran (Fooladman and Sepaskhah, 2004), Jordan (Abdulla and Al-Shareef, 2009), Namibia (Sturm *et al*., 2009), South Africa (Mwenge Kahinda *et al*., 2007), Sweden (Villarreal and Dixon, 2005), Taiwan (Liaw and Chiang, 2014), Ethiopia (Adugna *et al*., 2018), Mexico (Lizárraga-Mendiola *et al*., 2015), Nigeria (Imteaz *et al*., 2012) and Palestine (Abdul-Hamid, 2008; Shadeed and Lange, 2010).

In arid and semi-arid regions, RRWH is the most commonly used RWH system for domestic and agricultural purposes (O'Brien, 2014).

Water resources are classified into conventional (e.g. groundwater, surface water) and unconventional (e.g. desalinated water, RWH, treated wastewater). Due to political constraints and Israeli control, conventional water resources in Palestine are limited access, so it is necessary to look for unconventional resources to bridge the increasing domestic water supply-demand (DWSD) gap. RRWH is seen as sustainable (Sturm *et al*., 2009). The implementation of RRWH has several advantages including low operating energy, limited need for technical knowledge, and use of available materials for construction. RRWH system is usually also socially, economically and environmentally acceptable (Abdulla and Al-Shareef, 2006).

The RRWH technique (e.g. cistern) was widely used in Palestine back to 4000 years ago (Critchley *et al*., 1991; ARIJ, 2012). According to PWA (2012), the RWH from cisterns provided nearly 4 million cubic meters (MCM) of water for domestic use in the West Bank.

Worldwide, several studies have been focused on the estimation of potential amount of RRWH, some of which are as summarized in Table 1.

Table (1): Literature review summary**.**

Reference	Location	Main Result
Ghisi *et al*. (2006)	Southern Brazil	The average potential saving from using RRWH for drinking purposes is 69% from water demand
Abdulla and Al-Shareef (2009)	Jordan	Total annual volume of RRWH from rooftops in 12 Jordanian governorates equals 15.5 MCM
Aladenola and Adeboye (2010)	Abeokuta, Nigeria	The annual volume of RRWH from Abeokuta rooftops is 74 m^3/household
Mourad and Berndtsson (2011)	Syria	The RRWH amount that can be harvested from urban areas in Syria is 35 MCM
Al-Houri *et al*. (2014)	Jordan	The annual amount of RRWH from Al-Jubiha and Shafa-Badran is 1.17 and 0.53 MCM, respectively
Traboulsi and Traboulsi (2015)	Lebanon	The potential volume of RRWH from Lebanon rooftops is 23 MCM
Hari *et al*. (2018)	Almasguda, India	The total RRWH volume is 0.44 MCM
Adugna *et al*. (2018)	Addis Ababa, Ethiopia	The RRWH from large public institutions could supply 2.3% of drinking water in Addis Ababa

The main goal of this paper is to assess the potential of adopting RRWH to alleviate the domestic water shortage in the West Bank, Palestine. Several objectives were achieved: (1) assess the existing 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 water poor yet highly domestic rainwater harvesting suitability (DRWHS) areas and (5) estimate the potential for domestic water saving (PDWS) from adopting RRWH.

Materials and Methods

Study Area

The West Bank, Palestine is located in the Middle East, west of Jordan, and covers 5,658 km^2. Administratively, the West Bank is divided into 11 governorates with a total population of 2.88 million (PCBS, 2017) (See Figure 1).

The climate is Mediterranean, and characteristically hot-dry in summer and wet-cold in winter (UNEP, 2003). In summer, the average monthly temperature ranges between 20.8 and 30 ^oC, whereas in winter, it ranges between 8.7 and14 ^oC (ARIJ, 2015). The mean average relative humidity is between 52 and 69% (PMD, 2013). The rainy season usually extends from early October to mid-May (ARIJ, 2015), and most rain falls from December to February. The long-term annual average rainfall is 420 mm (HEC, 2018).

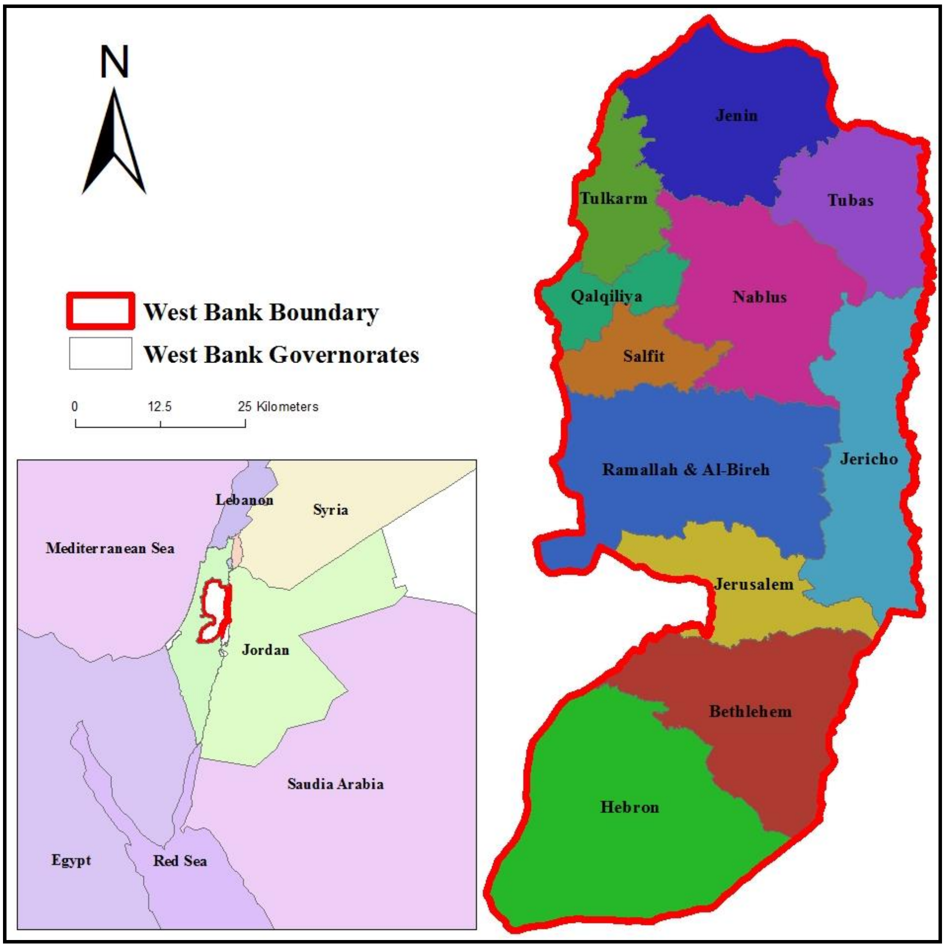

Figure (1): West Bank.

The land use map of the West Bank (see Figure 2) shows seven categories: Arable Land (supporting grains) (14%), Built-up Areas (5%), Irrigated Farming (supporting vegetables) (3%), Israeli Settlements (1%), Permanent Crops (grapes, olives, citrus and other fruits trees) (14%), Rough Grazing (subsistence farming) (62%) and Woodland (forest) (1%) (geomolg, 2018).

In the West Bank, water is drawn either from groundwater (wells and springs) or the Israeli water company, Mekorot (purchased water). In 2017, the total volume available was 182 MCM, 86 MCM from wells, almost 24 MCM from springs and 73 MCM from Mekorot (PWA, 2017). The total supply for domestic use was about 117 MCM. The total domestic water demand, however, was 143 MCM (based on a water demand of 150 l/c/d, according to WHO standards). The DWSD gap in the West Bank for 2017 was thus 32 MCM (Table 2) (PWA, 2017).

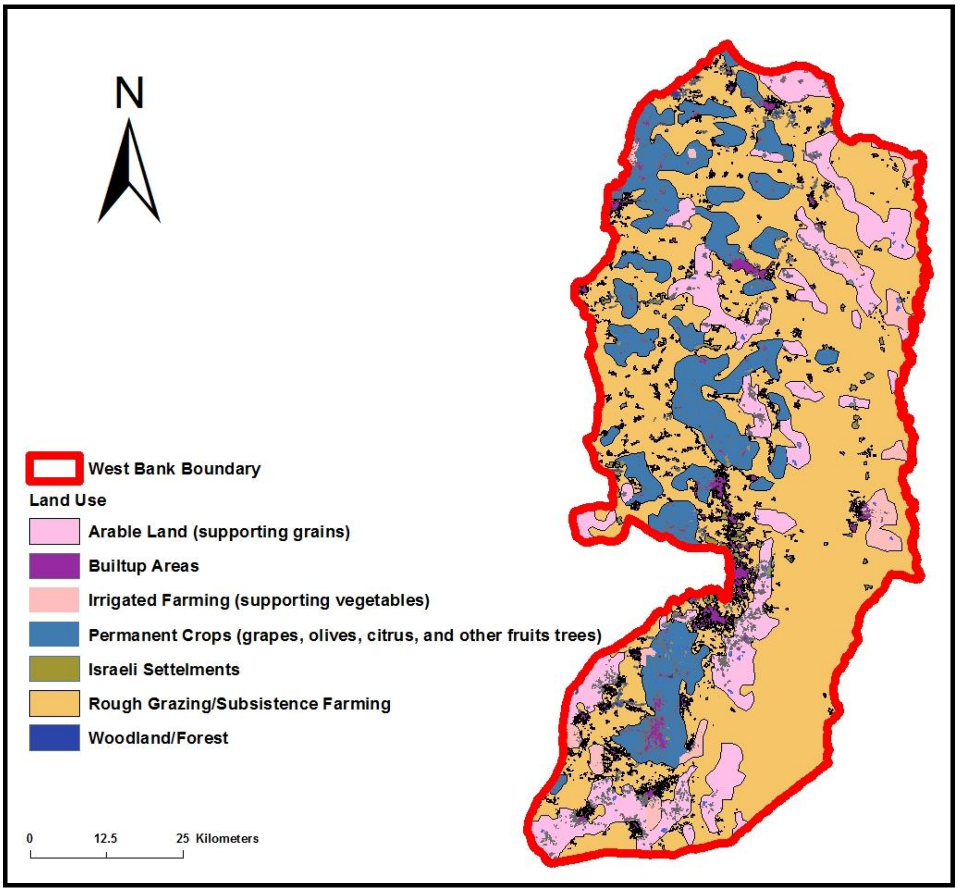

Figure (2): Land Use map of the West Bank**.**

Table (2): DWSD gap in the West Bank governorates.

Governorate	Water Demand [1] (MCM)	Water Supply (MCM)	DWSD Gap (MCM)
Jenin	17.3	8.2	9.1
Tubas	3.3	3.1	0.2
Tulkarm	10.2	10.4	- [3]
Nablus	21.3	14.5	6.8
Qalqiliya	6.2	8.2	- [3]
Salfit	4.1	3.2	0.9
Ramallah & Al-Bireh, and Jerusalem [2]	26.5	25.2	1.3
Jericho	2.7	6.4	- [3]
Bethlehem and Hebron [4]	51.1	37.6	13.5
Total	**142.7**	**116.8**	**31.8**

[1]Quantity required is calculated from a water demand of 150 l/c/d, (WHO standard).
[2]data exclude those parts of Jerusalem annexed by Israeli in 1967, where the Palestinian population is 281,913 but no information is available about their water supply.
[3]Domestic water supply available exceeds demand (sufficient water resources).
[4]The form of the water supply system in the Bethlehem and Hebron governorates, separate data cannot be derived for them.

Methodology

The methodology of this work was totally rely on GIS as depicted on Figure 3. RRWH volume was estimated based on rooftop areas and long term annual average rainfall for each governorate. Depending on the West Bank buildings shapefile (obtained as a vector data from database of Ministry of Local Government, GeoMoLG) (geomolg, 2018) and by GIS, the rooftop areas for the West Bank buildings were estimated. Rainfall map that was obtained as a raster (IDW) from Hydro Engineering Consultancy (HEC, 2018) database was converted from raster to vector (points). Spatial join (closest) between buildings and rainfall map to estimate the average annual rainfall for each rooftop. Field calculator was used to multiply the average annual rainfall and rooftop areas with runoff coefficient. The entire process was automated by ModelBuilder under GIS environment so as to calculate RRWH volume for the different governorates (see Figure 3). The DWSD gap was estimated based on PWA available water resources data for the year 2017 (see Table 2). The available domestic water poverty (DWP) and DRWHS rasters from Shadeed *et al*. (2019) were analyzed for the selection of domestic water poor yet DRWHS areas in West Bank.

The potential volume of RRWH was estimated using equation (1) (Gould and Nissen-Petersen, 1999):

$$V = \sum_{i=1}^{n} Rc \times Ri \times Ai (1)$$

Where V is the potential volume of RRWH, n is the number of rooftops, R_i is the average annual rainfall for each rooftop, A_i is the area for the i^{th} rooftop and R_C is the runoff coefficient. The R_C value depends on the rooftop type. In this work, R_C of 0.9 was assumed, which is in the range of R_C values used in several studies for concrete rooftops (Lancaster, 2006; Abdulla and Al-Shareef, 2009; Farreny *et al*., 2011).

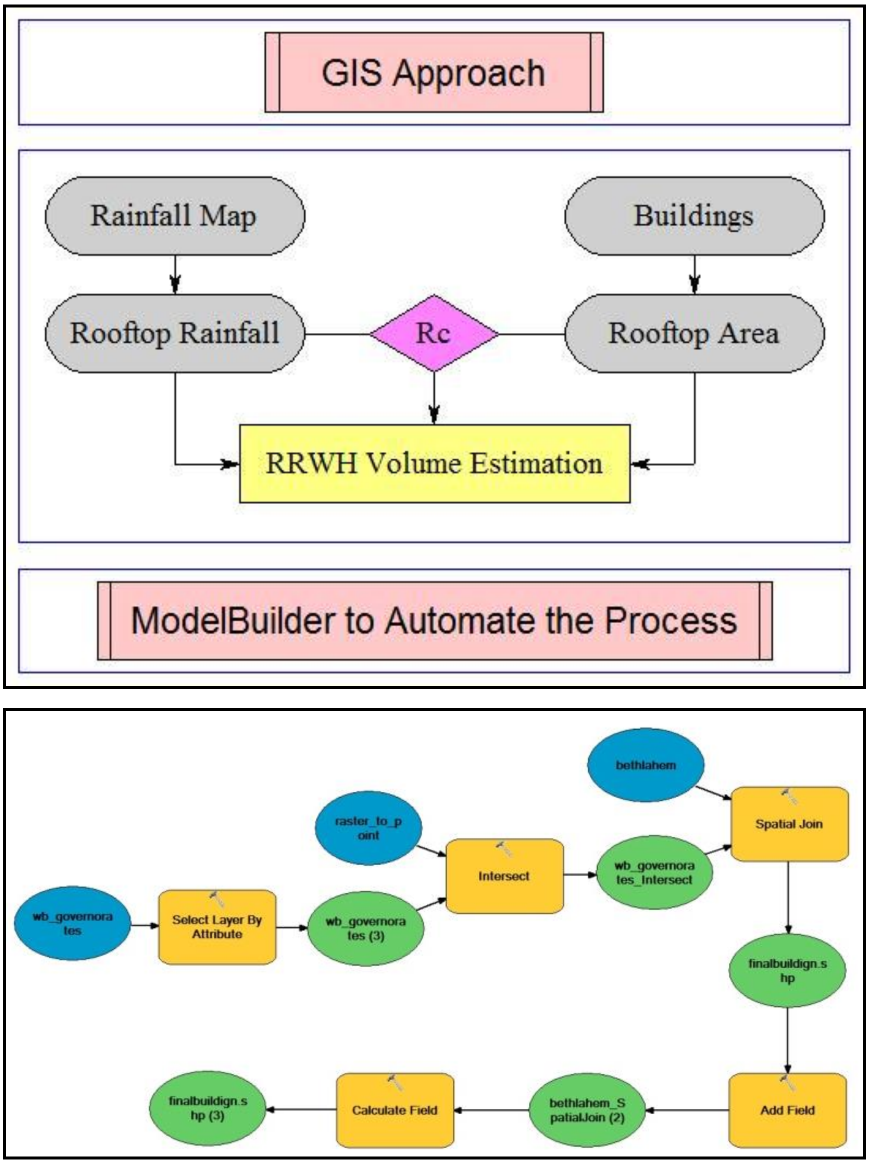

Figure (3): GIS approach for estimating RRWH volume. (top) General approach; (bottom) Model Builder.

Finally, the potential for domestic water saving from the adoption of RRWH was calculated using equation (2) (Abdulla and Al-Shareef, 2009):

$$PDWS = 100 \times \frac{V}{DWD} \quad (2)$$

Where PDWS is the potential for domestic water saving, V is the potential volume of RRWH and DWD is the domestic water demand (see Table 2).

Results

The Estimated (Potential) RRWH Volume

In the West Bank, the total rooftop areas cover 78.3 km^2 (28% of the built-up areas). The potential volume of RRWH is estimated at 37 MCM (see Table 3). Hebron governorate has the largest volume of RRWH, representing nearly 22% of the total from the West Bank. This is because it has 26% from the total West Bank rooftop area in addition, it has a considerable rainfall amount (389.8)

Table (3): Potential volume of RRWH in the West Bank governorates.

Governorate	Rooftop Areas (km^2)	Rainfall Volume (MCM)	RRWH Volume (MCM)
Jericho	2.1	101.2	0.3
Hebron	20.2	389.8	8.2
Jerusalem	4.6	150.8	2.2
Bethlehem	6.8	164.9	2.8
Jenin	9.9	295.0	4.8
Ramallah & Al-Bireh	11.0	452.3	6.1
Salfit	2.5	130.7	1.4
Tubas	1.6	112.8	0.5
Tulkarm	5.7	164.2	3.1
Qalqilya	3.1	96.8	1.7
Nablus	10.9	325.1	5.7
Total	**78.3**	**2383.5**	**36.6**

RRWH to Alleviate Domestic Water Shortage

RRWH to Alleviate DWSD Gap

The main purpose for implementation of the RRWH technique in the West Bank is to alleviate the domestic water shortage. Based on the PWA data, the DWSD gap in the West Bank in 2017 amounted to 32 MCM and the potential volume of RRWH that could be harvested was nearly 37 MCM. Thus, RRWH could bridge the DWSD gap in Tubas, Salfit, Ramallah & Al-Bireh, and Jerusalem governorates as shown in Figure 4.

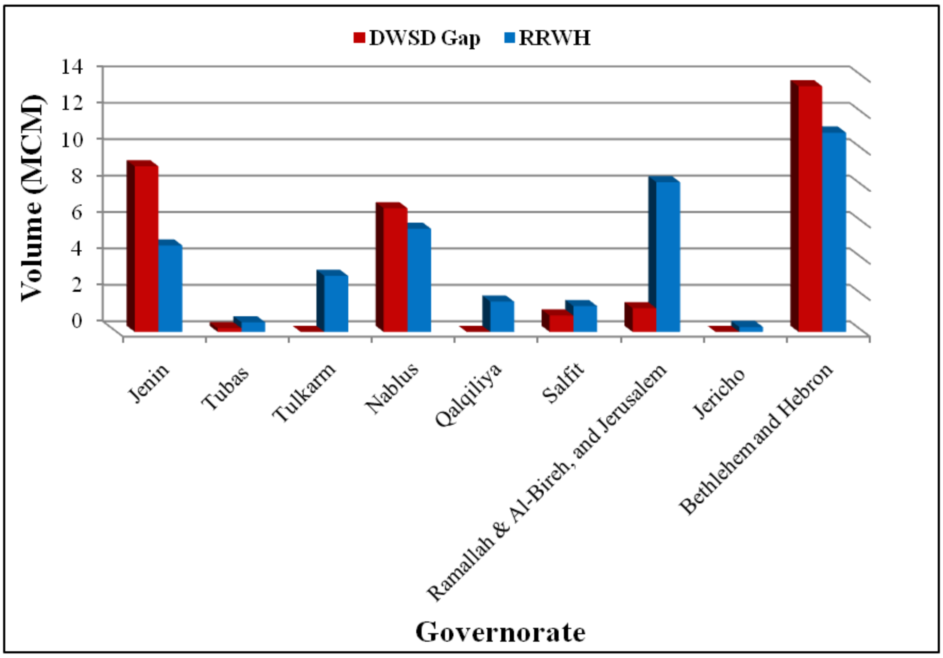

Figure (4): DWSD gap and RRWH volume in the West Bank governorates.

RRWH to Alleviate Domestic Water Shortage in Water Poor Areas

Based on the available DWP map (Shadeed *et al*., 2019), Jenin, Tubas, Nablus, Hebron and Bethlehem governorates are under high to very high domestic water poverty. Table 4 represents the DWSD gap after adopting of RRWH technique in highly domestic water poor 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 bridge the DWSD gap.

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

Table (4): Adopting RRWH to alleviate domestic water shortage in highly domestic water poor areas.

Governorate	DWP classes	DWSD Gap after Adopting of RRWH (MCM)	PDWS (%)
Jenin	Very high	4.3	27.5
Tubas	High	-	16.1
Tulkarm	Moderate	-	30.2
Nablus	High	1.1	26.6
Qalqiliya	Very Low	-	26.9
Salfit	Moderate	-	34.7
Ramallah & Al-Bireh, and Jerusalem	Low and Moderate	-	31.1
Jericho	Low	-	10.0
Bethlehem and Hebron	High and Very high	2.5	21.4

RRWH to Alleviate Domestic Water Shortage in DRWHS Areas

Depending on available DRWHS map (Shadeed *et al.*, 2019), 60% of the total areas in the West Bank are classified as high to very high DRWHS areas. The adoption of RRWH in these areas can potentially make 32 MCM (89% of the total RRWH volume in the West Bank) available for domestic uses as present in Table 5. Moreover, 27% of this volume could be harvested from Hebron and Bethlehem governorates. Accordingly, the adoption of RRWH in high to very high DRWHS areas can bridge 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. In addition, the implementation of RRWH in these areas can save nearly 23% of the Palestinians domestic water demand. The saved amount of domestic water demand after adopting of RRWH in high to very high DRWHS areas ranged from 12% to 34% for all of the West Bank governorates except Jericho.

Table (5): Adopting RRWH to alleviate domestic water shortage in high and very high DRWHS classes.

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

However, 28% of the total West Bank areas are classified as very high DRWHS. The total rooftop areas located in these areas are nearly 49 Km^2**.** From which 24 MCM (67% from the total West Bank RRWH volume) can be harvested (see Figure 5).

The high DRWHS class comprises 32% of total in the area, with a total rooftop area of 18 Km^2. The RRWH volume from this class is 8 MCM, 22% of the total RRWH available.

Finally, adoption of RRWH in the moderate, low and very low DRWHS classes could meet nearly 3% of total domestic water demand. From Figure5, 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.

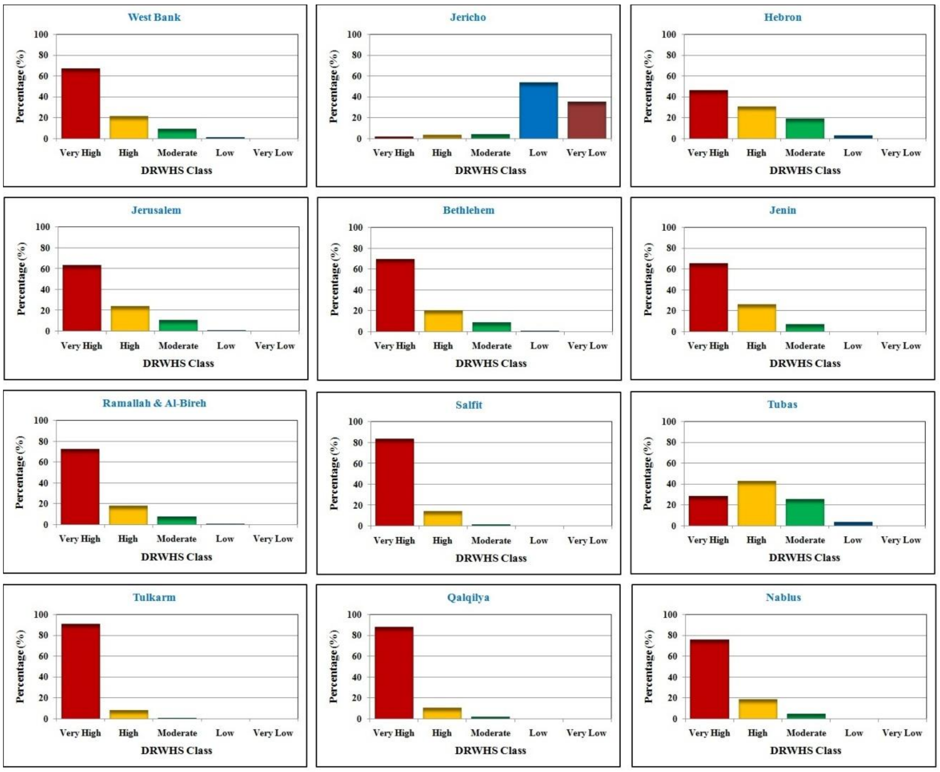

Figure (5): Percentage of RRWH volume for different DRWHS classes in the West Bank.

RRWH to Alleviate Domestic Water Shortage in High Water Poor yet Highly Suitable Areas

Based on the developed intersection map between DRWHS map and DWP map, 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 (Table 6), nearly 53% of the total potential RRWH volume in the West Bank. Additionally, 48% of this volume can be harvested from Hebron and Bethlehem governorates. However, the adopting of RRWH in these areas can bridge the DWSD gap in Tubas governorate and reduce the gap in most of the West Bank governorates. In the West Bank, the adopting of RRWH in these areas can save nearly 14% of the total domestic water demand.

Table (6): Adopting RRWH to alleviate domestic water shortage in water poor yet suitable areas in the West Bank.

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

Figure 6 illustrates the percentage of RRWH volume for different DWP-DRWHS intersection zones in the West Bank. From the figure, 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, 19% (7 MCM) and 17% (6 MCM) of RRWH volume from the West Bank rooftops could be harvested from VHP/VHS and HP/VHS zones, respectively. Moreover, 46% of RRWH volume in Hebron governorate and 65% of RRWH in Jenin governorate could be harvested from VHP/VHS zone. However, 76% and 67% of RRWH from Nablus and Bethlehem governorates could be harvested from HP/VHS zone. Additionally, 43% of Tubas RRWH volume could be harvested from HP/HS zone.

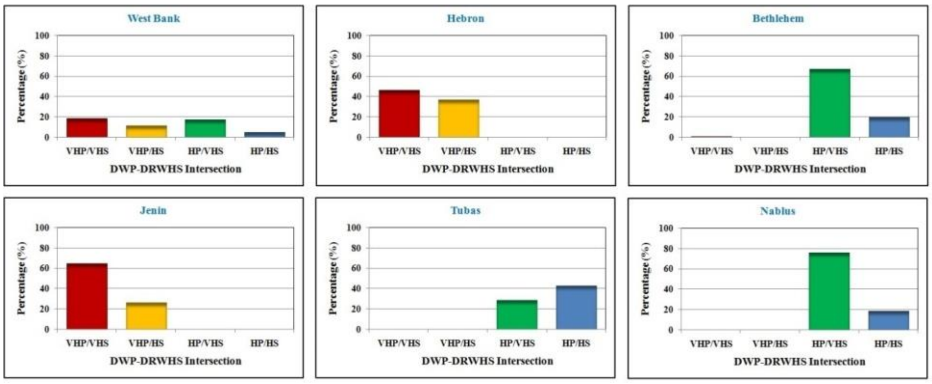

Figure (6): Percentage of RRWH volume for different DWP-DRWHS intersection zones in the West Bank.

Concluding Remarks

In this study, the possibility of adopting RRWH to alleviate domestic water shortages in the West Bank was evaluated. Based on the long-term average annual rainfall and rooftop areas, the total potential volume of RRWH was estimated at 37 MCM. Depending on the available PWA data, the DWSD gap in the West Bank was nearly 32 MCM. Thus, implementation of RRWH could satisfy the DWSD gap. 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 mainly in urban areas. The adoption of RRWH system in most domestic water poor areas, even partially, can fulfil the domestic water demand mainly in the period from June to September where the water resources are very limited. Hence, this can help to reduce the stress on service water providers to make water available for domestic use. In addition, the adoption of RRWH techniques can provide water for some agricultural and industrial uses wherever it is possible. In fact, there exist some amount of 4 MCM that has been already collected in the cisterns which is being used for domestic and agricultural purposes, mainly in the northwestern parts of the West Bank.

The results of this study show that, the adoption of RRWH in the high to very high DRWHS areas could lead to the harvesting of nearly 32 MCM. The PDWS from implementation of RRWH in the high to very high domestic water poor areas ranged from 16% to 28%. However, 24 MCM and eight MCM could be harvested from very high DRWHS and high DRWHS areas, respectively. Further, 19 MCM could be harvested from high water poor yet highly suitable areas in the West Bank.

In this study, the estimated RRWH volumes are subjected to some uncertainties. The buildings shapefile for 2017 doesn't cover all rooftops in the West Bank and needs to be updated. The rainfall map was developed using a very common interpolation technique (IDW). Other interpolation techniques (e.g. Spline, Kriging and Regression) will yield different rainfall spatial patterns that might affect the results. Additionally, the average R_C value (0.9) which assumed that all rooftops have the same construction material which is not 100% true.

To conclude, this paper can provide key decision makers with robust outputs that could be successfully implemented toward a sustainable water resources management in Palestine. Finally, there exist some building regulation regards having a RRWH system (cistern) in the final drawings. But however, such regulation is not being implemented in the building licensing process in most of the governorates. Thus, it is recommended to enforce the application and implementation of such regulation to help water service providers to satisfy domestic water needs mainly in the dry periods (June to September) when water demand is high and the supply is uncertain.

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