

# The Potential of Roof Top Rain Water Harvesting as a Water Resource in Jordan: Featuring Two Application Case Studies

Zain M. Al-Houri, Oday K. Abu-Hadba, Khaled A. Hamdan

**Abstract**—Roof top rainwater harvesting (RWH) has been carried out worldwide to provide an inexpensive source of water for many people. This research aims at evaluating the potential of roof top rain water harvesting as a resource in Jordan. For the purpose of this work, two case studies at Al-Jubiha and Shafa-Badran districts in Amman city were selected. All existing rooftops in both districts were identified by digitizing 2012 satellite images of the two districts using Google earth and ArcGIS tools. Rational method was used to estimate the potential volume of rainwater that can be harvested from the digitized rooftops. Results indicated that 1.17 and 0.526 MCM/yr can be harvested in Al-Jubiha and Shafa-Badran districts, respectively. This study should increase the attention to the importance of implementing RWH technique in Jordanian residences as a viable alternative for ensuring a continued source of non-potable water.

**Keywords**—Amman districts, ArcGIS, Rational method, Roof top rain water harvesting.

## I. INTRODUCTION

WATER is a one of the most vital requirements for economic and social development. In Jordan, the availability of this resource represents a challenge for engineers and water planners since Jordan ranks on the world's 10 most water stressed countries. Renewable freshwater resources are about 850 million cubic meters (MCM) with approximately 65% derived from surface water and 35% from groundwater sources [1]. The scarcity of water resources in Jordan is imposed by climatic conditions, such as aridity, and urban development [2]. In addition, the human population in Jordan is increasing thereby increasing the demand for water for domestic, agricultural and industrial uses. To meet the increasing demand, more pressure has been put on existing water resources such as over-exploitation of groundwater, and deterioration of water quality. The pressures on water are marked in Amman the capital where the vast majority of households receive water only on one or two days per week [3], [4]. Attention is now focusing on developing a strategy to manage Amman's water resources sustainability making full use of all available water resources. Rainwater harvesting (RWH) from rooftops, roads and other impervious surfaces, or catchments can be a supplementary water source with multipurpose functions.

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Roof top rain water harvesting consists of collecting domestic rain water from rooftops and storing it in tanks and cisterns. Water harvested from rooftops can replace potable water for several domestic uses such toilet flushing and watering domestic gardens [5]. The greater attraction of rain water harvesting system is its low cost, accessibility and easy maintenance at the household level. Rain water harvesting from building roof tops can be considered as an important step towards maximizing the water availability for domestic and landscape uses.

Rainwater harvesting has a significant role to play in water saving. Numerous articles have been published concerning the water harvesting and its role in promoting significant water saving in residences in different countries [6]-[12].

In Jordan, the absence of stormwater systems in many rural and urban areas within the country made the rain water harvesting an excellent source of water for potable and non-potable applications. Rain water harvesting has been practiced by individuals in many rural and urban areas within the country for thousands of years [13]. However, its significance as a source of water in Jordan has not been taken into consideration by the government among the implemented water management strategies till recently. A number of researchers investigated the potential of water saving using rain water harvesting by applying different approaches [14]-[16]. In this work, Google earth and ArcGIS tools are used to identify the roof tops that can be used for rain water harvesting. The potential volume of rainwater that can be harvested from building roof tops is then estimated. The study should encourage the residents in Jordan to use this technology, and increase the awareness of decision makers to implement this technique among the water management plans.

## II. METHODOLOGY

### A. Study Area

For the purpose of this research, two districts; Shafa-Badran and Al-Jubiha within Amman city have been chosen as two application case studies (Fig. 1). Table I illustrates the general specification of the study area. Both districts consist of a number of administrative sub zones as shown in Fig. 2. Table II presents the sub districts within each district. The average annual rainfall in the study area ranges from 450 mm to 550 mm falls mainly between September and May. The summer maximum temperatures average 32°C. The winter maximum temperatures average 14-17°C, while minimum temperatures average 1-40C [17].

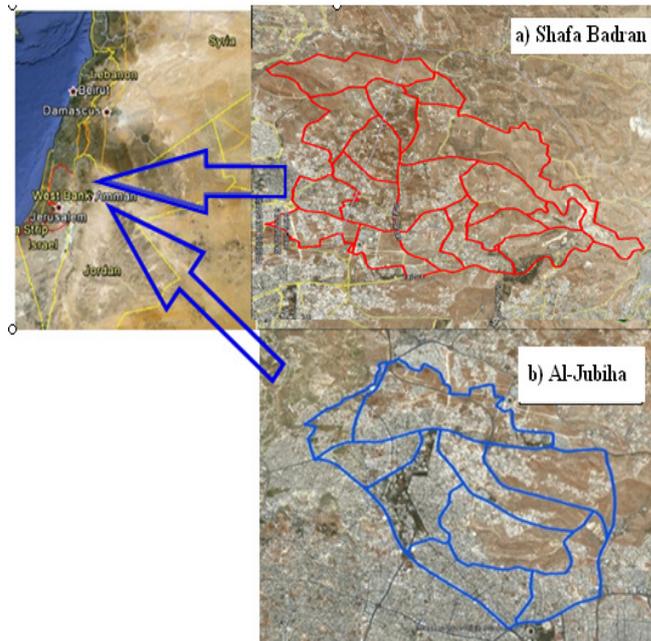


Fig. 1 Satellite images for a) Shafa-Badran, and b) Al-Jubiha districts in Amman, Jordan



Fig. 2 The administrative subzones within a) Al-Jubiha, and b) Shafa-Badran districts

TABLE I  
 GENERAL SPECIFICATIONS OF THE STUDY AREA

	Al-Jubiha	Shafa-Badran
Area (km <sup>2</sup> )	25.92	45.76
Population	64849	19528
No. of sub districts	9	17

### B. Google Earth

In this work, recent satellite images that cover the two areas of interest in this work are obtained from Google Earth 2012. The acquired satellite images are used to digitize all the building's rooftops in each study area using the polygon tool available in Google Earth. The digitizing process involves

tracing of building roof tops directly on top of the satellite imagery in order to classify the rooftops from other objects within each district (Fig. 3). This process resulted in digitized maps with thousands of boundaries that have been saved as several KMZ files each representing the building roof tops of an administrative sub district. Figs. 4 and 5 show the final digitized maps for both Shafa-Badran and Al-Jubiha districts, respectively.

TABLE II  
ADMINISTRATIVE SUB DISTRICTS WITH THEIR ASSOCIATED AREAS

Sub-District Name	District	Area km <sup>2</sup>	Sub-District Name	District	Area km <sup>2</sup>
Um Hjair	SB	1.22	Thehebah	SB	2.08
Al Qasbat	SB	1.70	Um Balanah	SB	1.71
Yajouz	SB	2.03	Um Shterat	SB	2.78
Al Ameer Hamzh	SB	2.39	Al Moroj	SB	3.34
Vun 1	SB	3.93	Al Baldyah	J	1.65
Al Shoroq	SB	10.7	Al Kolyah Aleslamyah	J	2.65
Alkoam Al Sharqi	SB	1.69	Al Mansour	J	3.54
Ubo Al Qeram	SB	1.85	Al Rashead	J	2.51
Um Aloroq	SB	1.12	Al Jamah	J	3.16
Almohdian	SB	1.96	Al Sedq	J	37.64
MarjAlfars	SB	3.71	Al Zaytonah	J	4.97
Tab Kra'a	SB	1.13	Qotnah	J	2.44
AlkoamAlgharbi	SB	2.27	Ubn Oaf	J	1.20

SB=SHAFA-BADRAN, J=JUBIHA



Fig. 3 An example output digitized map for Al-Mansour Sub district building rooftops

#### A. Roof Top Area Calculation Using Arc-GIS Tool

Geographic Information System (GIS) has become a critical tool in hydrological modeling in view of its capacity to handle digital information for which various digitized data creation methods are used. In this work, digitization and georeferencing capabilities in ArcGIS are used. The KMZ files for each sub district are converted to shape files. The coordinate system for each shape file is defined as WGS 1984 UTM Zone 36N to be able to compute the areas of the digitized features automatically by the geometry calculation tool available in ArcGIS model (Fig. 6).

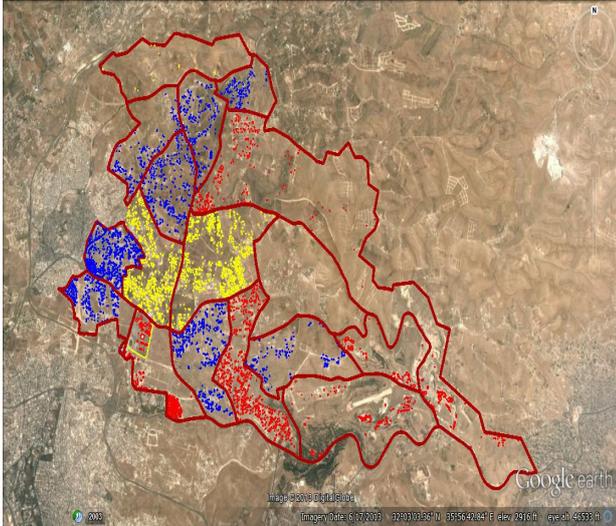


Fig. 4 Digitized Building roof tops in Shafa-Badran district

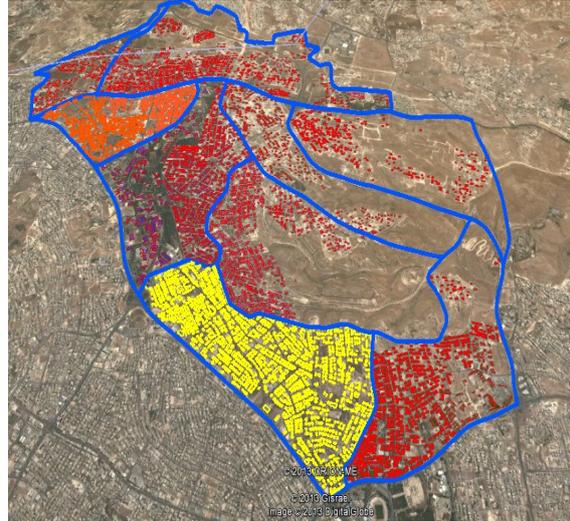


Fig. 5 Digitized Building roof tops in Al-Jubiha district

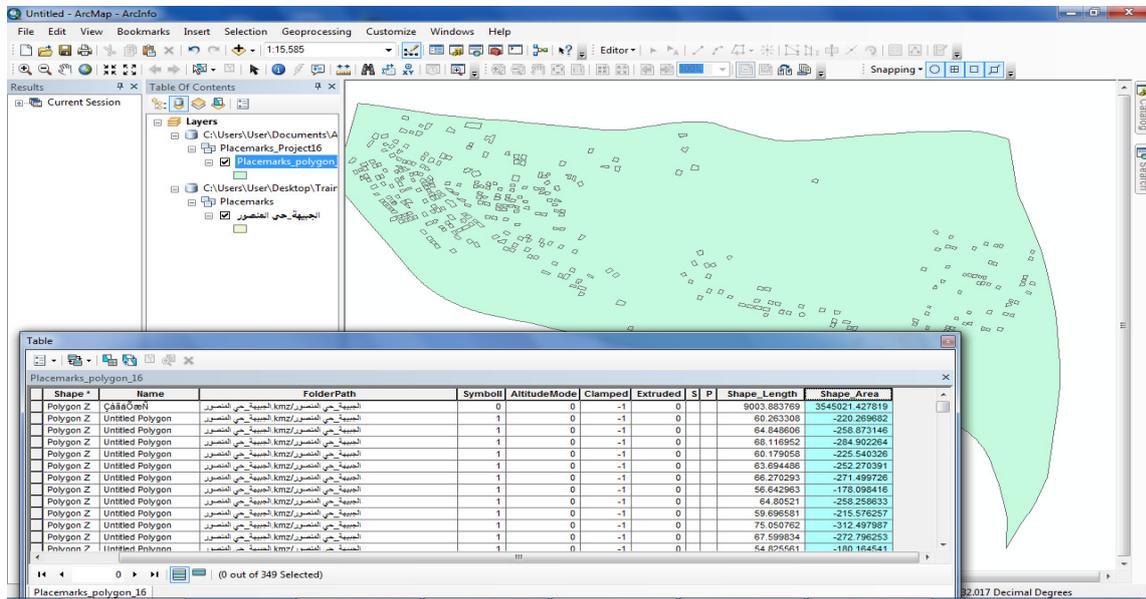


Fig. 6 An example layer for Al-Mansour sub district using ArcGIS, and the associated attribute table

**B. Corrections of Digitized Areas**

To verify the accuracy of the digitized areas obtained by the approach of this work, actual roof area for several selected buildings within the districts are measured and compared to its associated digitized area obtained by ArcGIS geometry calculation tool (Fig. 7). Table III presents a comparison between the actual measured roof tops with its associated digitized areas using the digitization tool for selected building roof tops. Based on this comparison, an average correction factor of the digitized area is estimated as 1.032.

TABLE III  
COMPARISON BETWEEN ACTUAL MEASURED AND DIGITIZED AREAS FOR SELECTED BUILDINGS

Rooftop number	Digitized Area (m <sup>2</sup> )	Actual Measured Area (m <sup>2</sup> )	Calculated Correction factor
1	404.5	436	1.078
2	432.1	448.5	1.038
3	311.6	311	0.998
4	331	336	1.015

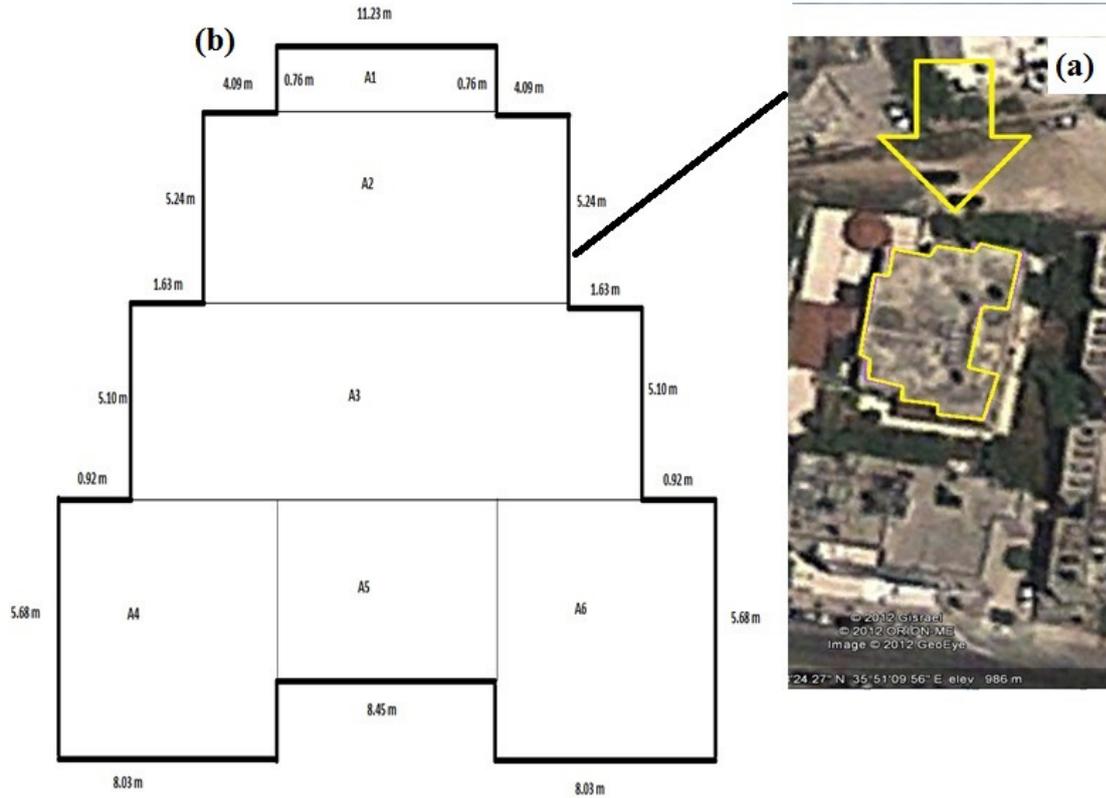


Fig. 7 An example area correction factor for a building roof top; a) Digitized building roof top, b) Actual measured building rooftop

Figure 8 shows a screenshot of an Excel spreadsheet titled "AL-MANSOUR SUBDISTRICT". The spreadsheet contains a table with columns for "Pol.ID", "Shape\_Leng (m)", "Shape\_Area (m<sup>2</sup>)", "ABSArea (m<sup>2</sup>)", and "Monthly Volume of Harvested Rainwater During Wet Seasons (m<sup>3</sup>/month)". The monthly volume is broken down by month: OCT, NOV, DEC, JAN, FEB, MAR, APR, and MAY. The table lists 26 polygons (Pol.ID 1 to 26) with their respective dimensions and monthly harvested rainwater volumes. A "Runoff Coefficient" of 0.75 is also indicated.

Pol.ID	Shape_Leng (m)	Shape_Area (m <sup>2</sup> )	ABSArea (m <sup>2</sup> )	Monthly Volume of Harvested Rainwater During Wet Seasons (m <sup>3</sup> /month)							
				OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
1	60.26331	-220.26968	220.26968	2.405909	8.288091	15.44301	19.39211	17.17577	14.04076	4.133137	2.340126
2	64.84861	-258.87315	258.87315	2.827558	9.740624	18.14948	22.79069	20.18591	16.50147	4.857491	2.750246
3	68.11695	-284.90226	284.90226	3.111862	10.72002	19.97437	25.08224	22.21556	18.16066	5.345901	3.026777
4	60.17906	-225.54033	225.54033	2.463478	8.486409	15.81253	19.85613	17.58675	14.37672	4.232035	2.396121
5	63.69449	-252.27039	252.27039	2.755439	9.492182	17.68657	22.20939	19.67106	16.08059	4.733597	2.680099
6	66.27029	-271.49973	271.49973	2.965472	10.21572	19.03473	23.9023	21.17049	17.30634	5.094416	2.884389
7	56.64296	-178.09842	178.09842	1.945291	6.701312	12.4864	15.67944	13.88742	11.35261	3.341836	1.892102
8	64.80521	-258.25863	258.25863	2.820846	9.717502	18.1064	22.73658	20.138	16.46623	4.845961	2.743717
9	59.69558	-215.57626	215.57626	2.354645	8.111491	15.11396	18.97891	16.80979	13.74158	4.045069	2.290263
10	75.05076	-312.49799	312.49799	3.413278	11.75837	21.9091	27.51171	24.36737	19.91971	5.863707	3.119951
11	67.59983	-272.79625	272.79625	2.979634	10.26451	19.12562	24.01645	21.27158	17.38898	5.118744	2.898164
12	54.82556	-180.16454	180.16454	1.967858	6.779054	12.63126	15.86133	14.04853	11.48431	3.380604	1.914052
13	78.99209	-388.80205	388.80205	4.246714	14.62946	27.25874	34.22937	30.31726	24.7836	7.295475	4.130599
14	67.28301	-270.99125	270.99125	2.959918	10.19659	18.99908	23.85754	21.13084	17.27393	5.084875	2.878988
15	59.46264	-220.65755	220.65755	2.410146	8.302685	15.4702	19.42626	17.20601	14.06548	4.140415	2.344247
16	62.07737	-220.73340	220.73340	2.410974	8.305539	15.47552	19.43294	17.21193	14.07031	4.141838	2.345052
17	59.41782	-204.36889	204.36889	2.232232	7.689791	14.32821	17.99224	15.93589	13.02718	3.834774	2.171197
18	57.53051	-203.67937	203.67937	2.2247	7.663847	14.27987	17.93153	15.88212	12.98323	3.821836	2.163872
19	61.00472	-231.86575	231.86575	2.532568	8.724416	16.25601	20.41301	18.07998	14.77993	4.350725	2.463322
20	58.55380	-209.00555	209.00555	2.282876	7.864255	14.65329	18.40044	16.29743	13.32274	3.921777	2.220457
21	61.33785	-233.18899	233.18899	2.547021	8.774206	16.34878	20.5295	18.18316	14.86428	4.375554	2.47738
22	59.90905	-223.04653	223.04653	2.436239	8.392575	15.63769	19.63658	17.3923	14.21776	4.185241	2.369627
23	60.44015	-224.19938	224.19938	2.448831	8.435954	15.71852	19.73807	17.48219	14.29125	4.206873	2.381875

Fig. 8 A picture illustrates part of the automated Excel Spread Sheet used in calculating the potential harvested rainwater volumes

### III. CALCULATION OF POTENTIAL HARVESTED RAINWATER VOLUMES

Using the areas computed by ArcGIS, the rational Method is then used in an automated excel sheet to estimate the volumes of rainwater that can be collected from buildings' rooftops during winter in each sub district (Fig. 8). The

harvested volumes are evaluated by using the rainfall intensities presented in Table IV. A runoff coefficient value of 0.85 is used to describe the concrete roofing, commonly used, in Jordan.

TABLE IV  
AVERAGE MONTHLY RAINFALL INTENSITY (SOURCE [18])

Month	Intensity (mm/month)
December	93.5
January	117.4
February	104
March	85
April	25
May	14.2
December	93.5

IV. RESULTS AND DISCUSSION

In this study, rain water harvesting for residential roofs in two districts in Amman was estimated to evaluate the potential of filling the gap between the water demand and water supply, hence mitigating the problems of water scarcity. The volumes of rainwater that can be harvested in each of the sub districts within Al Jubiha and Shafa-Badran districts were calculated considering the monthly rainfall data, the roof area, and a runoff coefficient value of 0.85. The total volumes of harvested rainwater that can be collected from each sub district within Al- Jubiha and Shafa-Badran districts are presented in Tables V and VI, respectively. Results revealed that the maximum volumes of harvested rainwater can be collected in the month of January since the average monthly rainfall value is the highest during this month. Figs. 9 and 10 illustrate the total potential monthly harvested volumes for Al-Jubiha and Shafa-Badran districts.

Volumes of harvested rainwater from building rooftops during winter will significantly affect the problem of water shortage. Harvested rainwater can be used to conserve potable water and help reduce the impact of restrictions on outdoor water uses such as irrigation, vehicle washing, toilet flushing and other non-potable uses.

TABLE V  
TOTAL HARVESTED RAINWATER VOLUMES FOR AL- JUBIHA DISTRICT

Sub-districts Name	Total Harvested volumes (m <sup>3</sup> )
Baladeyah	107163.3
Ibn Ouf	54694.8
Al-Jama'a	235516.7
Al-Koliyeh	65001.2
AlMansour	45111.2
Qutnah	127219.3
Al-Rashed	206916.5
Al-Siddeeq	126830.3
Zaiton	198679.1
Σ Summation	1167132.5

TABLE VI  
TOTAL HARVESTED RAINWATER VOLUMES FOR SHAFI-BADRAN DISTRICT

Sub-districts Name	Total harvested volumes (m <sup>3</sup> )
Um Hjair	36616.51
Al Qasbat	35813.69
Yajouz	39637.12
Al Ameer Hamzh	59647.26
Vun l	15073.19
Al Shoroq	34472.74
Alkoam Al Sharqi	8718.605
Ubo Al Qeram	27424.54
Um Aloroq	8972.204
Almohdian	14450.65
MarjAlfars	24309.28
Tab Kra'a	53348.12
AlkoamAlgharbi	13449.07
Thehebah	70403.2
Um Balanah	17121.16
Um Shterat	995.4659
Al Moroj	65479.01
Σ Summation	525931.8

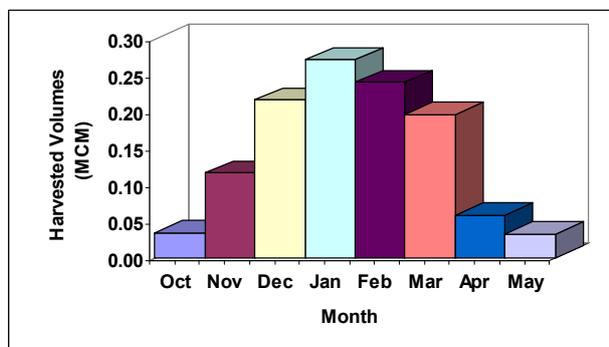


Fig. 9 Monthly potential volumes of harvested rainwater in Al-Jubiha district

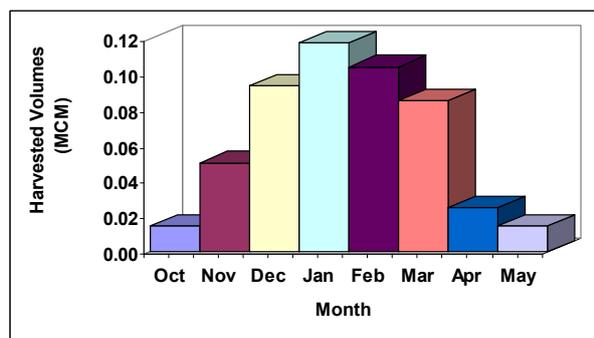


Fig. 10 Monthly potential volumes of harvested rainwater in Shafa-Badran district

V. CONCLUSION

The most severe environmental challenge that Jordan faces today is water scarcity. Many techniques have been suggested to increase the water supply and mitigate the problem of water scarcity. Among these is rainwater harvesting. In this study, two case studies; 1) Al-Jubiha, and 2) Shafa-Badran districts

have been selected to investigate the potential of building rooftops water harvesting as a resource in Amman city. To achieve the goal of this work, Google Earth, ArcGIS and the rational method tools were used to estimate the volumes of water that can be harvested from building rooftops within each district. Results showed that approximately 1.17 and 0.526 MCM can be harvested annually in Al-Jubiha and Shafa-Badran districts, respectively. A rainwater harvesting systems can be constructed from inexpensive local materials, and is likely to be successful in most housing sites. Rainwater collected from rooftops and local institutions can provide an important contribution to the provision of potable water, and can be also considered an effective way to solve the problem of water shortage to some extent if implemented and managed appropriately.

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