AMERICAN UNIVERSITY OF BEIRUT

ASSESSING THE POTENTIAL OF ROOFTOP RAINWATER HARVESTING IN A RAPIDLY URBANIZING SUBURB

by

AMANI HAITHAM MAJZOUB

A thesis
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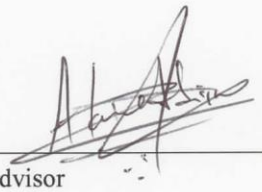

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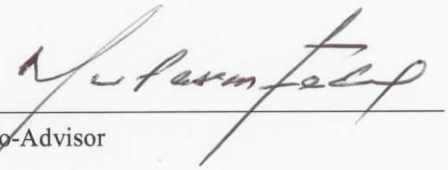

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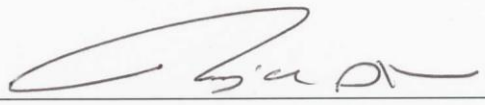

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AN ABSTRACT OF THE THESIS OF

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Major: Environmental Technology

Title: Assessing the Potential of Rooftop Rainwater Harvesting in a Rapidly Urbanizing Suburb

The Hazmieh/Hadath/Baabda area is a rapidly urbanizing Beirut suburb suffering from chronic water shortages. This research examined the current sources of water supplying the area through a household survey and assessed the socioeconomic feasibility of using rainwater harvesting systems on rooftops. A water quality assessment program was carried out in parallel whereby samples from network water, municipal water, well water and rainwater were tested for specific quality indicators. Findings revealed that the quality of network and municipal water supplied to households largely conformed to the Ministry of Environment standards and World Health Organization guidelines. The major problem faced in the area was the deficit between the available supply and actual demand. In the face of chronic shortages, households in the area expressed interest in participating in rainwater harvesting programs. Examining the socio-economic factors affecting the willingness of people to participate in a RWHS, it was found that education and the availability of outdoor space affected the rate of participation positively, while age and the number of floors in a building decreased people's keenness to participate. The results revealed that on average, a household with a monthly income <$1500 was willing to pay $ 0.54 /m^3 to install a RWHS as compared to $ 2.34/m^3 for those whose monthly income is more than $6000. A technical assessment of the feasibility of a rainwater harvesting system (RWHS) revealed that while it is advantageous for a single household with 5 occupants, the harvested volumes for a multistory residential building (50 occupants) were small as compared to demands. The study concludes with a management framework that aims to assure the proper implementation and monitoring of rainwater harvesting practices.

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1 INTRODUCTION

Increases in water demand coupled with a decrease in conventional water supplies in many regions around the world have promoted the development and use of unconventional water sources. While desalination remains the most common alternative sought in water-stressed urban areas, its financial and environmental burdens remain a barrier in many regions (Sanchez *et al.,* 2015). Rainwater harvesting can provide a renewable source of clean water suitable for domestic and landscape uses; yet its use is often limited to small-scale applications (Aladenola & Adeboye, 2010; Hermann & Schmida, 2000). It has been successfully applied in many countries such as Germany (Nolde, 2007; Hermann & Schmida, 2000), Australia (Zhang *et al.*, 2009), Spain (Morales-Pinzon *et al.*, 2012a; Farreny *et al.*, 2011a), Nepal (Domenech *et al.*, 2012), India (Said, 2014; Kumar *et al.*, 2012), and the US (Jones & Hunt, 2010) amongst others. Technically, the components of a rooftop rainwater catchment system typically includes a collection area (roof), a conveyance system with gutters and screens, a cistern or storage tank, a delivery system (gravity or pump), and a treatment system whose components depend on the quality and intended use of the collected rainwater (Texas Water Development Board, 2005)[1]. Although rainwater is naturally "soft"; it often needs treatment (e.g. filtration and/or chlorination), especially if used for drinking purposes but can be used without pre-treatment for non-potable uses such as toilet flushing, laundry, and building/car washing. Several studies have aimed to better understand the viability of rainwater harvesting, taking into account its quality (Farreny *et al.*, 2011a; Lye, 2009; Sazaklia *et al.*, 2007), financial feasibility (Morales-Pinzon *et al.*, 2012a; Farreny *et al.*, 2011b), social acceptance (Domenech & Sauri, 2011; Aklan, 2011), and environmental impacts (Angrill *et al.,* 2011). The success of rainwater harvesting programs is strongly associated with regulations and incentives aimed at promoting its adoption. For example, in the US, rainwater harvesting is mandatory for new buildings in Arizona and New Mexico, and tax exemptions are given

[1] A typical rooftop rainwater harvesting installation is shown in Appendix 1

for buildings in Texas (Texas Water Development Board, 2005). In Europe, Belgium promulgated regulations that require all new buildings with roof area greater than 100 m^2 to install a rainwater harvesting system (RWHS); Germany on the other hand offers rain tax reductions for properties that collect rainwater instead of diverting the flow to the local storm sewers (Hermann & Schmida, 2000). Similarly, several municipalities in Spain approved water saving regulations that mandate new buildings with garden spaces to install rainwater collection tanks (Farreny *et al.,* 2011).

Water scarcity and the imbalance between conventional water sources and demands in urban Mediterranean areas have promoted the adoption of rainwater harvesting. As such, interest in implementing urban rainwater harvesting has been increasing along the Mediterranean basin, especially in Spain (Farreny *et al*., 2011a; Morales-Pinzon, 2012a), Malta (Cardona, 2006), Italy (Campisano *et al.*, 2012), Greece (Sazakli *et al.*, 2007), and the Palestinian Territories (Lange *et al.,* 2012); all of which are facing water shortages that are projected to exacerbate in the coming decades due to population growth and development as well as the effect of climate change (Bates *et al.*, 2008). Generally, these countries share similar Mediterranean climatic conditions characterized by long, hot, dry summers and short, cool, rainy winters. The potential of rainwater harvesting in supplementing domestic water demands at the residential level varies significantly depending on location, ranging from < 1 % to nearly 80% of the total demand. This wide range is attributed to variations in climatic conditions, water demands, and level of urbanization (Palla *et al.,* 2012). Domenech and Sauri (2011) reported that 16% of the total domestic water demand in Sant Cugat del Valles, Spain, was met through rainwater harvesting. In Jordan, the range of water saving as a result of rainwater harvesting varied between 0.27% and 19.7% (Abdulla & Al-Shareef, 2009). In south-eastern Brazil, where rainfall is more abundant, reductions reached 79% (Domenech & Sauri, 2011).

The use of rainwater harvesting in Lebanon has been successfully implemented for agricultural purposes, with many villages constructing land catchment systems, locally referred to as “birkis”, with a capacity ranging between 1,000 to and 10,000 m^3. These systems have proved to be viable with an attainable return on investment of three to five

years (Hayek, 2009). However, the feasibility of promoting urban rainwater harvesting for domestic use remains largely unexplored and has not been incorporated within the National Water Plan.

In this study, the potential of rooftop rainwater harvesting systems in an urban setting is assessed both technically and socio-economically in the context of a fast urbanizing suburb that is facing increasing water shortages. As such, harvested volumes are quantified and compared to existing demands and current deficits, using field ascertained data on building units and water supply systems from the study area. A household survey was developed and administered to assess the willingness of residents to participate and pay as a function of building, demographic, social, water, and educational predictors. The study concludes with a Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis that provide a basis for urban planners and policy makers to consider rainwater as a "productive" water source for future sustainability.

2 METHODOLOGY

2.1 Study Area

The Hazmieh/Hadath/Baabda area is a rapidly urbanizing suburb located south-east of Beirut, Lebanon, extending between 50 to 300 meters above sea level. The geographic boundaries of the study area are presented in Figure 1. The rainy season spans from November till April with an average annual rainfall of 650 mm[2] exceeding the minimum average precipitation (600 mm/year) needed to ensure the feasibility of installing RWHS (Texas Water Development Board, 2005). The study area has a population > 23,500 inhabitants (Baldati, 2013), with most residents living in multi-story residential buildings. According to the Central Administration of Statistics (CAS), the average number of dwellers per household is five, with a per capita water demand estimated at 180 L/day (Ministry of Environment, 2010).

[2] based on a 10-year record collected from the nearby Rafic Hariri International Airport meteorological station

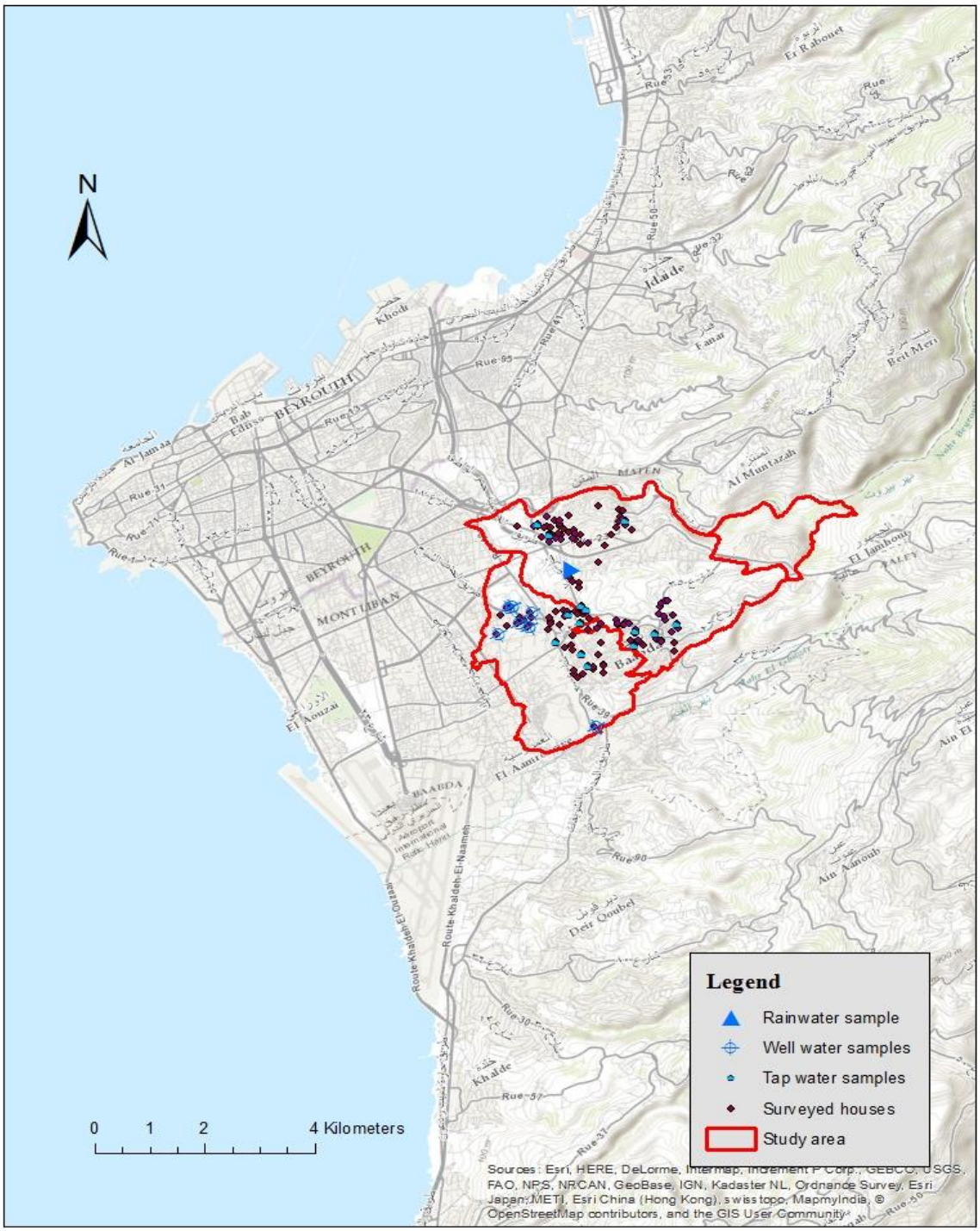


Figure 1: Geographic boundaries of the study area along with sampling points for rainwater, well water, tap water and household questionnaire**s**

2.2 Household Survey

Primary data were collected using a household survey (Appendix 2) developed and administered in the three urbanized areas (Hazmieh, Hadath, and Baabda). A total of 148 household interviews were carried out between November 2014 and January 2015, following a random sampling approach. One-on-one household interviews with household heads living in single households and multi-story residential buildings were completed. Commercial buildings were excluded from the study sample. The questionnaire targeted the collection of data related to socioeconomic and demographic characteristics, water sources, as well as the satisfaction and perception of users regarding network and municipal water quality. Moreover, the willingness to invest in rainwater harvesting systems was gauged. The spatial distribution of residents targeted by the survey is shown in Figure 1. Data were entered into the Statistical Package for the Social Sciences: SPSS version 22.0 (SPSS Inc., 2007) and analysis was conducted using the R statistical software (R Core Team, 2014).

2.3 Water Supply

Like many other urban cities in Lebanon, the public network water supply is the main source of domestic water supplying households. However, water shortages particularly during the summer months are common. Households receive water for a few hours, three days per week during the summer period and up to ten hours every other day during the wet season. Residents pay a fixed annual subscription fee irrespective of the water volume delivered or consumed. When the shortages are accounted for, households end up paying on average \$1.4/m^3 of delivered water. Unlike the city of Beirut, where more than 3,000 licensed and unlicensed private wells were reported in 2010 (Ministry of Energy and Water, 2010), the proliferation of private building-level wells in the study area is still low. Yet, all three municipalities have resorted to drilling licensed municipal groundwater wells in an effort to address deficits (Table 1). The municipality of Hadath has also resorted to installing and operating its private domestic water network (municipal water) that often runs alongside the governmental network which is inconsistent with the concession right given by the central government to the regional water establishment. In Hadath, many

residents are subscribed either to the municipality-operated water network, or to the governmental network, or both.

Table 1: Number of municipality wells in the three towns of the study area

Town	*Number of municipality wells*
Hazmieh	6
Hadath	8
Baabda	2

When interviewed, most respondents in the three towns complained about water shortages and indicated that they often resort to the purchase of water from private vendors through unregulated water tankers. Table 2 shows the sources of the water supplying the households in the 3 towns based on the household questionnaire conducted in the study area.

Table 2: Sources of water supplying households in the study area

Sources of Water	*Hadath (%)*	*Hazmieh (%)*	*Baabda (%)*
Public network water	46.9	100.0	95.7
Municipal water	61.2	0.00	6.50
Well water	24.0	0.00	2.20
Water Tankers	48.0	63.5	52.2
Bottled Water	94.0	92.3	91.3
Hand-carried water	6.00	1.90	2.20
Harvested Rainwater	2.00	0.00	0.00

2.4 Water Sampling and Quality Analysis

Water quality tests were carried out on water samples collected from the tap/network water, private wells, and rainwater at different locations within the study area (Figure 1). A total of sixteen tap water samples were collected from households in the three towns. Four samples were collected from the tap of houses receiving public network water in each town; in addition four samples were collected from houses that received exclusively municipal water in Hadath. Prior to sampling, the water taps were disinfected by flaming and the

water was left running from the tap for almost one minute to avoid the collection of stagnant water. Well water samples were also collected from eleven privately owned wells located South of the Hadath region. The groundwater samples were collected during the rainy season (December 2014) directly from the pipe attached to the wellhead. Additionally, rainwater samples were collected on four occasions between March and April 2015 from rooftops (Appendix 3) and gutters of five-story buildings in Hazmieh, Beirut, and Saida, a coastal city located ~40 Km South of the study area. These were chosen to provide a general idea about the quality of rainwater. Note that unless there is pollution from nearby sources, rainwater is considered a safe water resource. Its quality depends on air quality, receiving roofs, storage tanks, precipitation events, and local weather conditions since prolonged dry periods exacerbate the growth of bacteria and other microorganisms; in addition to dust and debris on rooftops. According to the literature, the quality of harvested rainwater varies over space and time and might contain significant levels of microorganisms, metals, chemicals, and other sediments; thus, necessitating the use of proper treatment. Common contaminants that have been reported in rainwater systems include: dust and ash from the surrounding, pathogenic bacteria from bird and other animal droppings on the roof, heavy metals in industrial areas, some chemicals related to the roof material, and mosquitoes in gutters or storage tanks (Mosley, 2005). Sazakli *et al.* (2007) monitored rainwater quality in a Greek island for a period of three years, concluding that its microbiological quality is greatly affected by the cleanliness level of the receiving roofs, while chemical quality is influenced by human activities and proximity to the sea. The harvesting and reuse of street storm water runoff has not been considered in this study, mostly because it is expected to have a high pollution load. Previous work has shown that the quality of rainwater harvested from streets can contain pollutants such as lead, zinc, copper, cadmium, polycyclic aromatic hydrocarbons, mineral oil hydrocarbons, and other readily soluble salts (Gobel *et al.*, 2007).

One-liter plastic bottles were used to collect samples for the physiochemical analysis, while 150 mL sterilized plastic bottles were used for the bacteriological analysis. Details pertaining to the sampling and parameters tested are summarized in Table 3. All analytical

tests were performed in accordance to the Standard Methods for the Examination of Water and Wastewater (American Public Health Association *et al.,* 2005) at the Environmental Engineering Research Center (EERC) at the American University of Beirut (AUB) as shown in Table 4.

Table 3: List of analyzed parameters based on water source

	Sampling Domain			
	Municipal water	*Network water*	*Rain water*	*Private well water*
Location	Hadath	Hadath Hazmieh Baabda	Hazmieh Beirut Saida	Hadath
Indicator				
Microbiological				
Total Coliform	√	√	√	√
Fecal Coliform	√	√	√	√
Physical				
Total Dissolved Solids	√	√	√	√
Electrical Conductivity	√	√		
Chemical				
pH	√	√	√	√
Nitrates	√	√	√	√
Sulfates	√	√		√
Sodium				√
Potassium				√
Chloride	√	√	√	√
Total Hardness	√	√	√	√
Calcium hardness	√	√	√	√
Magnesium hardness	√	√	√	√
Bicarbonate Alkalinity	√	√	√	√

Table 4: List of analyzed parameters and adopted analytical procedures

Parameter Tested	*Type of Analysis*	*Method of Reference**
Microbiological		
Total Coliform	Membrane filtration technique	9222 D
Fecal Coliform	Membrane filtration technique	9222 B
Physical		
Total Dissolved Solids	Electrometry	2510 B
Electrical Conductivity	Electrometry	2510 C
Chemical		
pH	Potentiometry	4500-H^+ B
Nitrates	Colorimetry: Cd reduction	4500 NO^-_3 B
Sulfates	Colorimetry	4500 SO^{2-}_4 B
Sodium	Photometry	3500-Na B
Potassium	Photometry	3500-K B
Chloride	Titration	4500 D
Total Hardness	EDTA Titration	2340 C
Calcium Hardness	Titration	2340 C
Magnesium Hardness	Titration	2340 C
Bicarbonate Alkalinity	Titration	2320 B

*All analytical tests were performed in accordance to the Standard Methods for the Examination of Water and Wastewater (American Public Health Association *et al.*, 2005)

2.5 Potential for Rainwater Harvesting: Supply and Demand

A critical step in designing RWHS is to optimize the rates of supply to meet the water demands. Supply is determined by the amount of rainfall collected on a given rooftop area (Eq 1) which is dependent on the amount of rainfall, size of the catchment surface, runoff, and water losses due to evaporation.

$$Q = P*A*C/1000 \qquad \text{Eq 1}$$

Where Q is the potential amount of rainwater that can be harvested from rooftops (m^3), P is the amount of rainfall (mm), A is the area of the rooftop (m^2), C is the runoff coefficient dependent on the type of roof material, and 1000 is the conversion factor from mm to m.

Daily rainfall data for the study area for a period of 10 years (2001 through 2010) were obtained from the Rafic Hariri Beirut International Airport meteorological station. Figure 2 shows the average monthly distribution of rainfall based on data collected during the period between 2001 and 2010. Rainfall is seasonal, with a short wet winter and a long dry summer season, typical of a Mediterranean climate. The runoff coefficient (C) is a dimensionless value that estimates the portion of the rainfall that becomes runoff, taking into consideration losses due to spillage, leakage, and evaporation (Singh, 1992). The runoff coefficient is a function of the roof type, slope, and roughness. Appendix 4 lists typical runoff coefficients with respect to different roof material. According to the household questionnaire, 68% of households in the study area have cement roofs (Figure 3). Thus, the runoff coefficient was selected to be 0.7, typical for cement roofs. An average roof area of 300 m^2 was adopted, unless indicated otherwise; since the highest percentage of residences were of this size (Figure 4).

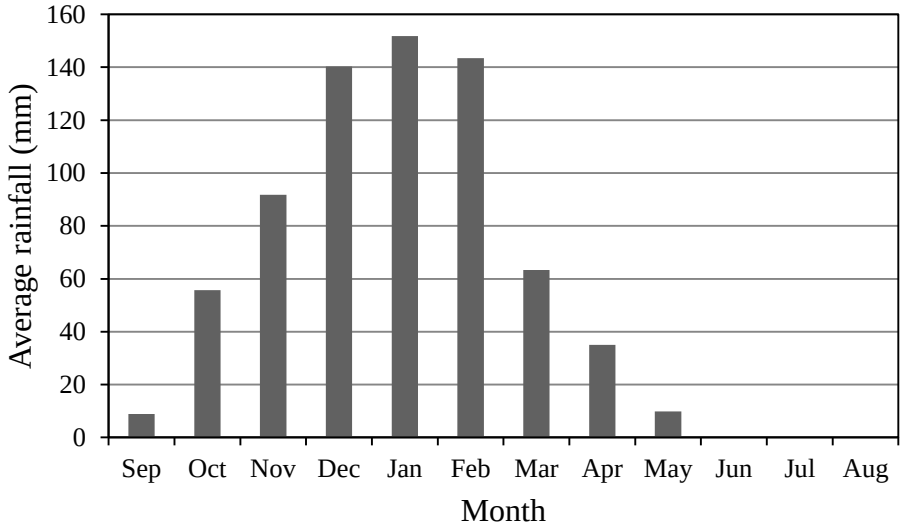


Figure 2: Ten years averaged (2001-2010) monthly rainfall for the study area

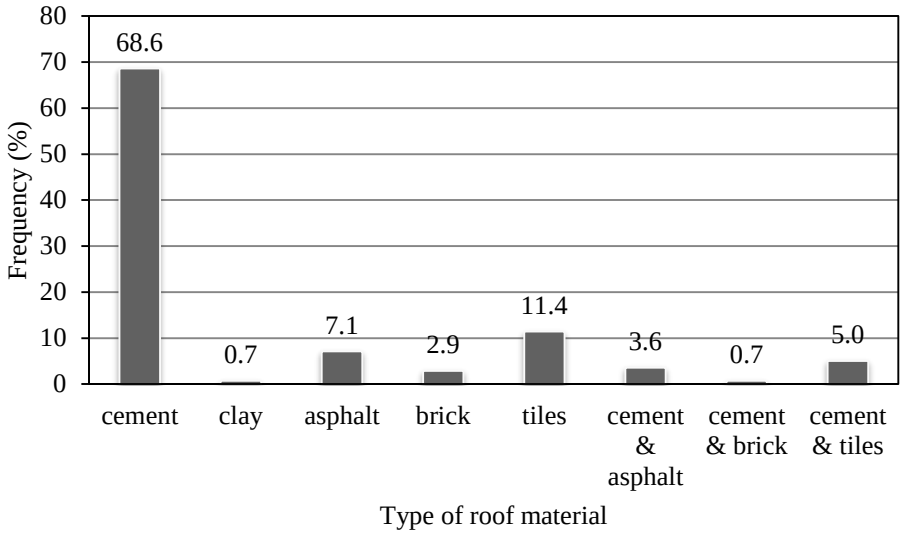


Figure 3: Type of roof material prevalent in the study area

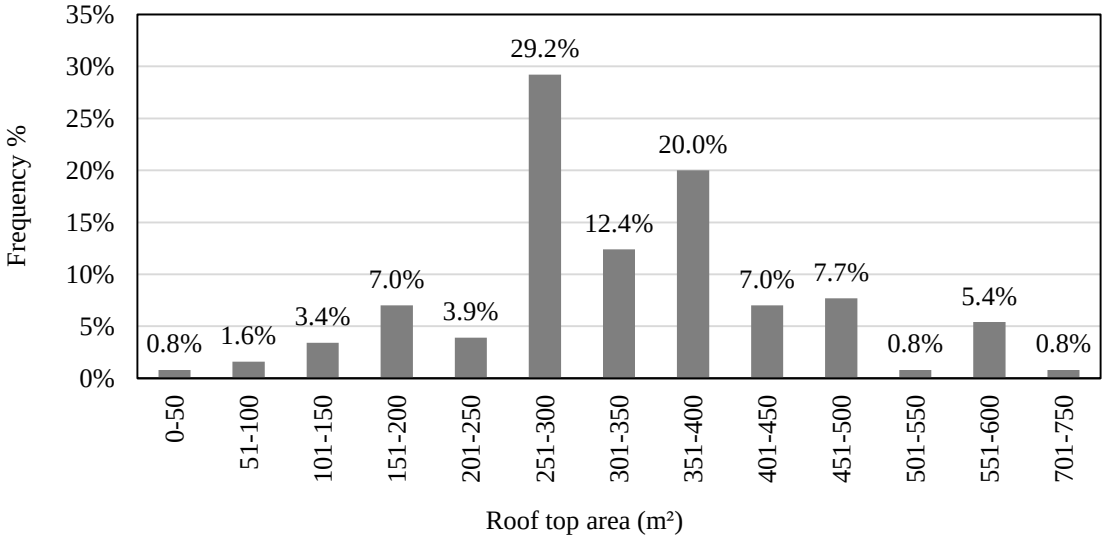


Figure 4: Rooftop area of interviewed households in the study area

Three building types were assessed for RWHS implementation including a single residence, a 5 story ten apartments building, and a 10 story twenty apartments building. These types were the most prevalent in the study area. In an effort to estimate potential volumes under different hydrological years, a wet (2003), a dry (2010), and an average

(2007) year were selected (Figure 5). Water demands were calculated for an average family size of 5 inhabitants per household, with a per capita consumption of 180 L/day.

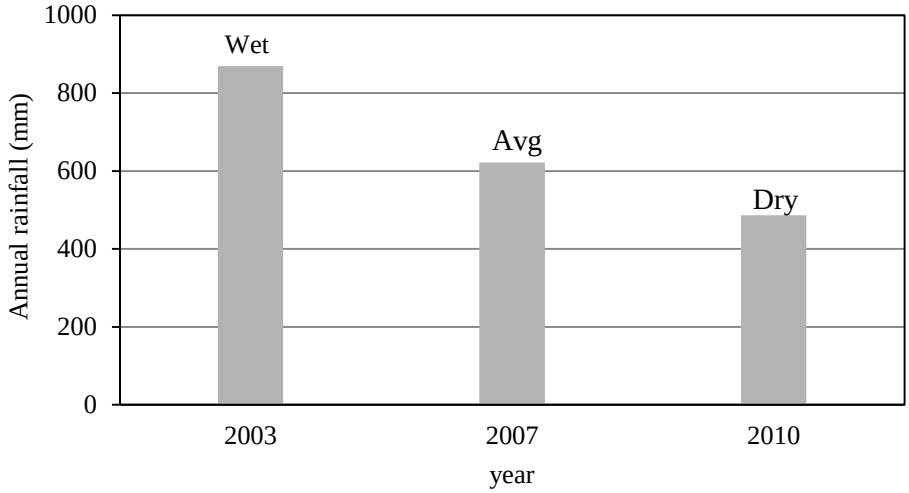


Figure 5: Amount of rainfall (mm) for the three selected hydrological years

The RWHS storage requirements were calculated using the Ripple Method of the Texas Water Development Board (2005). The method uses a mass balance equation, where the capacity of the storage tank is calculated based on monthly demands and precipitation volumes, assuming that 70% of the rainfall falling on the roof is potentially collected in the storage tank. Consequently, the accumulated rainwater from subsequent months are accounted for in calculating the minimum size of storage tank required for a household given its roof size, average monthly rainfall, and family size (Tomaz, 2003).

2.6 Socioeconomic Assessment of Rainwater Harvesting Systems

2.6.1 Cost of Rainwater Harvesting Systems

The household scale rainwater harvesting systems were analyzed, where water collected on rooftops is channeled through pipes to an underground or elevated storage tank, which many houses already have. In order to analyze the cost of a rainwater harvesting system over its life span, the cost of materials required for installing such a system were obtained

from local suppliers and commercial catalogues. Appendix 5 shows a breakdown on various components of a typical rainwater harvesting system. The annual amortized payment was calculated using Eq 2:

$$A = P\frac{i(1+i)^n}{(1+i)^n-1} = \frac{P\times i}{1-(1+i)^{-n}} = P\left(i + \frac{i}{(1+i)^n-1}\right) \quad \text{(Eq 2)}$$

Where A = Annual cost

P = Amount of principal, net of initial payments including capital and maintenance cost

I = Periodic interest rate

n = Total number of payments

The interest rate was assumed at 5%, a rate that is often used when analyzing the financial feasibility of a RWHS (Roebuck *et al.*, 2011; Mitchell *et al.*, 2005). The life span of the RWHS was assumed at 40 years according to similar studies in the Mediterranean areas (Domenech and Sauri, 2011 and Farreny *et al.*, 2011). Note that the cost analysis included the cost of storage tanks, assuming different sizes based on the household size. The total costs associated with the RWHS were then compared to the price of network water, ~\$1.4/m^3, the cost of small household reverse osmosis treatment units, and to water purchased from water tankers.

2.6.2 *Willingness to Participate*

A logistic regression model was developed to assess the factors affecting the resident's willingness to participate in rainwater harvesting systems. Variables such as number of floors, age of the building, purchase of water tankers, satisfaction with current water sources during different seasons, availability of outdoor space to accommodate a rainwater storage tank, the level of trust in public projects, as well as the gender, age and level of education of household respondents were tested for significance. Other socioeconomic variables that were assessed include household ownership and total monthly household income. The logistic linear model is of the form:

$$\text{logit}(p) = \beta_o + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \ldots.\beta_kX_k \quad \text{(Eq 3)}$$

Where *p* is the willingness of a household to participate in a rainwater harvesting program bounded between 0 and 1, the logit is defined as the natural log of the odds of the outcome or $\ln(p[1-p])$, β_0 is the baseline constant, X_1 to X_k are k independent variables, and β_1 to β_k are model coefficients. All model parameters were estimated based on the maximum likelihood procedure using the glm function in R (R Core Team, 2014).

2.6.3 *Willingness* to Pay (WTP)

Willingness to pay is commonly defined as the maximum amount of money a customer is willing to pay for a given quantity of a product or service (Wertenbroch & Skiera, 2002). Therefore, it is considered as a critical input for policy makers that aim to implement effective pricing policies. In this context, the main predictors that explained the variability observed in the amount of money people were willing to pay for installing a RWHS based on the household survey were examined. Factors such as age of the building, total number of floors, current sources of water and level of satisfaction, age of household respondent, gender, education level, household ownership, and total monthly household income and expenditure were tested for significance.

2.7 SWOT Analysis

The SWOT analysis of external opportunities and threats as well as the internal strengths and weaknesses was carried out to evaluate the efficiency of adopting rainwater harvesting systems in the study area. The SWOT analysis is a qualitative examination that pinpoints internal and external factors affecting the viability of a technology (Kajanus *et al.,* 2012; Chang & Huang, 2006). Strengths are defined as the internal assets in terms of technology, finance, and benefits; whereas weaknesses are internal conditions or internal deficits which endanger the competitive position of the system with regards to other water sources. Opportunities are external circumstances which may contribute to the success of a RWHS in an urban setting. Finally, threats are the set of external circumstances which hinder the applicability of the technology. The SWOT analysis was conducted based on the results of the socioeconomic aspects, in addition to the available water resources and related

legislation. Environmental benefits and drawbacks of installing rainwater harvesting systems in similar projects in Mediterranean countries were also considered in the analysis.

3 RESULTS AND DISCUSSION

3.1 Water Quality

The main source of network water in the study area is the Ein el Delbeh spring that feeds both the Daichounieh and Hazmieh water treatment plants. Both facilities were rehabilitated in 2010 by the Kuwait Fund for Arab Economic Development. When asked, most respondents indicated that they were dissatisfied with the quality of their network water mainly due to calcification of pipes, faucets and household fixtures; in addition to high turbidity level; salt water taste and bacteriological contamination were also listed as concerns. Table 5 shows the perception and satisfaction of people with the water supplied by the network in the 3 regions.

Table 5: Satisfaction with the quality of network water variability according to season and region

Satisfaction with the quality of network water during	Hadath		Hazmieh		Baabda	
	Summer	Winter	Summer	Winter	Summer	Winter
Satisfied (%)	54.5	62.8	50.0	46.0	19.6	45.0
Dissatisfied (%)	45.5	37.2	50.0	54.0	80.4	55.0

In order to better assess peoples' perception of their water, samples from the network water (both public and municipal) were tested. The results of the physiochemical and microbiological analysis are presented in Table 6, along with the relevant Ministry of Environment (MoE) and World Health Organization (WHO) guidelines for drinking water quality.

Interviewees' perception of the quality of drinking water provided via the public water network was generally negative in the study area. Yet, the water quality results, shown in Table 6, were within the Lebanese standards and WHO guidelines except for total coliform bacteria which were present in the vast majority of the samples indicating the presence of

organic material in the water source. Only one sample collected from a household connected to the municipal network in Hadath had fecal coliform bacteria (65 CFU/100 mL), which might be caused by cross-contamination during transport.

The water quality results of the network water showed no significant values above the standards and guidelines except for total coliform bacteria; thus, necessitating the use of chlorine to kill or inactivate the disease-causing bacteria so that the water can be safe for use. The microbiological contamination was one of many concerns interviewees raised about the quality of the public network water. When asked about the reasons for their strong negative feeling about the water quality, they attributed their perception to the lack of trust with public authorities, the possibility of contamination due to the absence of wastewater treatment plants in the area, and the objectionable salty taste of the public network water.

Table 6: Water quality results of tap water in the study area

Sample ID	pH	TDS(mg/l)	Conductivity (µS)	Chlorides (mg/l)	Alkalinity (bicarbonate) (mg/L) as $CaCO_3$	Total Hardness (mg/L) as $CaCO_3$	Calcium Hardness (mg/L) as $CaCO_3$	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	NO^{-}_{3} (mg/L)	SO^{2-}_{4} (mg/L)	Total Coliform (CFU/100 mL)	Fecal Coliform (CFU/100 mL)
HT1003M	7.52	403	819	11.3	319.0	388	257	103.0	31.8	25.6	43	TNTC*	65
HT0906M	7.12	238	470	54.8	316.2	379	243	97.4	33.0	8.40	49	67	0
HT3002M	7.01	361	730	62.7	315.4	403	209	83.8	47.1	24.5	20	TNTC	0
HT2003M	7.15	272	522	48.2	312.7	190	218	87.4	99.1	22.4	49	TNTC	0
HT1004N	7.23	320	572	61.4	292.0	396	184	73.7	51.5	15.1	54	33	0
HT2901N	7.32	354	712	32.7	244.6	496	270	108.0	54.9	8.20	39	TNTC	0
HT2002N	7.59	304	517	46.4	210.8	382	224	89.8	38.4	11.3	47	TNTC	0
HT0905N	7.42	318	576	47.1	209.8	320	213	85.3	26.0	2.60	16	6	0
HZ2101N	7.67	157	308	21.5	177.8	209	168	67.3	9.96	2.20	23	1	0
HZ1902N	7.54	148	302	18.5	176.2	253	184	73.7	16.8	1.40	26	15	0
HZ2102N	7.60	151	304	17.8	179.8	214	181	72.5	8.02	1.70	26	TNTC	0
HZ2103N	7.51	221	449	24.2	200.2	240	201	80.6	9.48	20.2	31	0	0
BA1402N	7.19	374	751	40.7	265.8	315	208	83.4	26.0	15.9	27	48	0
BA1403N	7.77	214	429	31.6	177.8	201	175	70.1	6.32	12.8	25	2	0
BA1404N	7.17	372	745	42.2	255.0	307	203	81.4	25.2	12.9	27	27	0
BA1703N	7.52	316	574	32.1	244.2	312	221	88.6	22.1	17.3	22	TNTC	0
MoE standards	*6.5-8.5*	*500*	---	*200*	---	*500*	---	---	---	*50*	*250*	*0*	*0*
WHO guidelines	*6.5-8.5*	*600*	---	*250*	---	*500*	---	---	---	*50*	*250*	*0*	*0*

HZ: Hazmieh N: Network Water
HT:Hadath M: Municipal Water
BA:Baabda * TNTC: Too numerous to count
The shadowed cells show values above MoE standards.

Regarding the private wells located south of the Hadath area, the tested water samples showed high levels of total dissolved solids (TDS) that exceeded the MoE and WHO guidelines (Table 7). The high TDS levels are due to over-pumping that has promoted the intrusion of seawater into fresh water aquifers. This was evident in the high chloride levels in the samples, whereby 9 out of 11 samples had chloride levels above MoE and WHO guidelines with an average chloride and sodium concentrations of 3,038 and > 200 mg/L, respectively exceeding WHO and MoE standards for drinking water quality. Moreover, most samples had high levels of microbiological pollution, indicative of sewage contamination.

Table 7: Water quality results of sampled private wells in the Hadath area

Sample ID	pH	TDS mg/l	Cl^- mg/L	Alkalinity (bicarbonate) mg/l as $CaCO_3$	Total Hard-ness mg/l as $CaCO_3$	Calcium Hard-ness mg/l as $CaCO_3$	Ca^{2+} mg/l	Mg^{2+} mg/l	NO^-_3 mg/l	SO^{2-}_4 mg/l	Na^{2+} mg/l	K^+ mg/l	Total Coliform CFU/100ml	Fecal Coliform CFU/100ml
HT2302	6.67	6180	4340	14.63	3040	960	38.47	505.40	24.7	525	3095.3	32.4	TNTC[2]	5
HT2303-1	6.88	4620	3160	280.0	8040	770	308.6	1766.6	31.8	300	1258.2	34.4	TNTC	59
HT2303-2	6.76	4520	3050	508.4	1494	978	391.9	125.38	19.1	325	1314.1	45.0	TNTC	86
HT2304	6.98	6650	4600	305.2	2630	1010	404.8	393.66	24.6	650	1939.4	10.3	TNTC	TNTC
HT2306	6.98	4460	3010	384.4	2510	970	388.7	374.22	16.4	350	1190.0	45.0	TNTC	0
HT2105	7.00	9060	6300	259.2	3570	1460	585.1	512.73	6.30	850	2615.6	61.7	TNTC	16
HT2104	7.05	4340	2970	296.4	2000	940	376.7	257.58	29.7	325	1070.6	33.6	TNTC	1
HT2103	6.93	4290	3000	300.4	2030	1280	513.0	182.25	47.9	425	765.16	34.4	32	2
HT2102	7.57	540	148	12.26	500	380	152.3	29.160	9.20	40	59.423	5.30	44	0
HT0801	7.00	580	153	16.70	960	420	168.3	131.22	UR[1]	4	37.693	3.49	6	0
HT0901	7.07	3510	2440	308.0	1860	960	384.7	218.70	48.1	325	668.38	24.0	23	2
MoE standards	*6.5-8.5*	*500*	*200*	----	*500*	----			*50*	*250*	*150*	----	*0*	*0*
WHO guidelines	*6.5-8.5*	*600*	*250*	----	*500*	*300*			*50*	*250*	*200*	*300*	*0*	*0*

[1]UR: under range
[2] TNTC: Too numerous to count
Shadowed cells show values above MoE standards and WHO guidelines

The pH of the rainwater collected from the rooftops in Saida, Beirut, and Hazmieh ranged between 5.26 and 6.83 (Table 8). The lowest pH of 5.26 was recorded in Beirut on March 25, 2015. On the same day, the pH registered values of 6.38 and 6.49 in Saida and Hazmieh respectively. The low pH values can be attributed to the fact that rainfall was collected after a period of no rain which might have led to the accumulation of pollutants. The pH values of harvested rainwater in Italy and Spain are reported to vary between 5.8 and 8.8 (Villarreal & Dixon, 2005; Sazakli *et al.*, 2007; Schriewer *et al.,* 2008). Chlorides, nitrates, and sulfate concentrations were all within the WHO guidelines. According to Halstead *et al*. (2000), the concentration of sulfates, chlorides, potassium, calcium, and magnesium increases with proximity to coastal areas due to sea salt aerosol containing these ions. The average hardness as $CaCO_3$ was 7.2 mg/L; thus the rainwater is considered to be very soft which offer the benefits of preserving household fixtures (faucets, dishwashers, sink tops, and washing machines), decreasing scum formation, and reducing detergent consumption in case the rainwater is used to meet the laundry demand (Farreny *et al.* 2011b). Roof rainwater showed the presence of total coliform bacteria in most samples and fecal coliform in 60% of samples. Microbiological contamination of rooftop runoff can be attributed to the presence of microorganisms in bird droppings such as *Salmonella* and *Campylobacter*; in addition to the presence of insects, mammals, and reptiles (Appendix 6). *Salmonella* was reported in rainwater samples collected in California (Shroeder *et al*. 2002; Kinde *et al.* 1997). Note that samples collected on March 24, 2015 showed the highest levels of microbial contamination across the three areas because the rainfall event on that day occurred following a long dry period; thus rooftops were not clean and bacteria were not washed off prior to sampling. In contrast, samples collected on April 14 and 23, when precipitation occurred on previous days, exhibited no bacterial contamination. Although many types of coliform bacteria are harmless, some can cause health problems which include diarrhea, cramps, nausea and vomiting. According to Clary *et al.* (2014) the level of *E. coli* and enterococci in roof runoff vary depending on the presence of animals, especially if the roofs are shaded by trees. Such bacteria pose a health risk for infants, elderly and compromised immune systems (EPA, 1989). Thus, chlorination is imperative to ensure that collected rainwater is safe. Cleaning the catchment area and removing possible sources of

contamination is equally essential before the rainy season. Nevertheless, industrial areas should probably be avoided; unless water treatment is practiced to treat the harvested rainwater.

Table 8: Results of rainwater collected from rooftops and gutters in Saida, Beirut and Hazmieh

Sample ID	pH	Total dissolved solids TDS mg/l	Total hardness as $CaCO_3$ mg/l	Total alkalinity as $CaCO_3$ mg/l	Bicarbonate HCO_3 mg/l	Chloride Cl- mg/l	SO^{2-}_4 mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Nitrate as NO^{-}_3 mg/l	Total Coliform CFU/100 ml	Fecal Coliform CFU/100 ml
SR1	6.24	75	7.05	38	34.34	36.75	4.10	2.31	0.31	2.78	TNTC	TNTC
SG1	6.22	88	11.9	41	51.00	38.50	3.10	4.22	0.34	3.84	TNTC	TNTC
SR2	6.57	33	1.10	34	12.87	21.00	1.00	0.36	0.05	2.01	63	39
SG2	6.38	39	1.69	42	44.00	24.50	1.13	0.51	0.10	2.12	59	21
SR3	6.77	88	14.0	57	42.94	38.50	4.99	5.14	0.28	2.09	14	2
SG3	6.53	92	14.2	52	39.18	38.20	5.01	5.25	0.27	3.67	18	6
SR4	6.71	48	5.14	61	11.91	22.03	5.32	1.78	0.17	1.12	0	0
SG4	6.83	43	3.53	46	11.76	21.19	6.48	1.12	0.18	1.35	12	4
BR1	6.13	67	8.26	33	12.87	42.00	2.49	2.20	0.67	1.29	4	0
BG1	6.09	72	8.42	29	13.18	42.00	2.59	2.25	0.68	3.32	10	0
BR2	5.64	31	3.31	35	19.02	2.620	13.00	1.14	0.11	2.84	0	0
BG2	5.26	37	2.93	39	17.20	2.330	14.21	1.12	0.03	3.19	3	0
BR3	6.59	47	1.64	61	4.270	19.07	7.77	0.32	0.20	1.42	0	0
BG3	6.51	56	2.27	54	4.060	21.03	8.68	0.38	0.32	2.58	8	1
BR4	6.11	77	9.61	32	21.77	38.50	3.55	2.78	0.65	1.24	0	0
BG4	6.08	79	8.89	45	21.16	40.25	3.55	2.71	0.52	1.48	27	0
HZR1	6.23	51	6.36	32	4.270	21.00	3.51	2.21	0.20	1.24	32	12
HZG1	6.18	59	7.61	39	12.40	22.07	4.23	2.44	0.37	2.94	41	17
HZR2	6.55	47	6.10	54	12.87	45.50	3.50	1.16	0.78	0.24	22	10
HZG2	6.49	62	8.83	36	13.91	45.93	3.63	2.27	0.77	1.78	38	9
HZR3	6.72	14	0.70	42	12.54	24.50	6.01	0.04	0.13	UR*	0	0
HZG3	6.69	17	0.89	31	13.47	24.50	6.19	0.05	0.19	UR	5	0
HZR4	6.65	76	13.7	63	36.23	29.07	2.88	4.22	0.78	0.19	0	0
HZG4	6.58	84	14.8	67	34.67	31.50	2.49	4.68	0.77	1.04	0	0
MoE standards	*6.5-8.5*	*500*	-----	-----	-----	*200*	*250*	-----	-----	*50*	*0*	*0*
WHO guidelines	*6.5-8.5*	*600*	-----	-----	-----	*250*	*250*	-----	-----	*50*	*0*	*0*

*UR: Under range
S: Saida; B: Beirut; HZ: Hazmieh
R: Rainwater; G:Gutter
Samples (1) collected on 24/03/15; Samples (2) collected on 25/03/15;
Samples (3) collected on 14/04/15; Samples (4) collected on 23/04/15.
Shadowed cells show values not compatible with MoE standards and WHO guidelines

3.2 Potential Rainwater Supply and Demand

According to Ferrera (2010) the amount of rainwater that can be harvested depends on four major aspects: 1) the amount of precipitation in the area, 2) the area of the rooftops, 3) water losses due to evaporation and runoff, and 4) the volume of the storage tanks. Rainfall data from a 10-year period show that the highest amount of rainfall is received during November, December, January and February, as shown in Figures 2 and 6. Similar to other Mediterranean countries, the dry summer months (June through August) coincide with the peak water demand due to increase in water consumption highlighting the importance of using large storage tanks to store rainwater for the dry months.

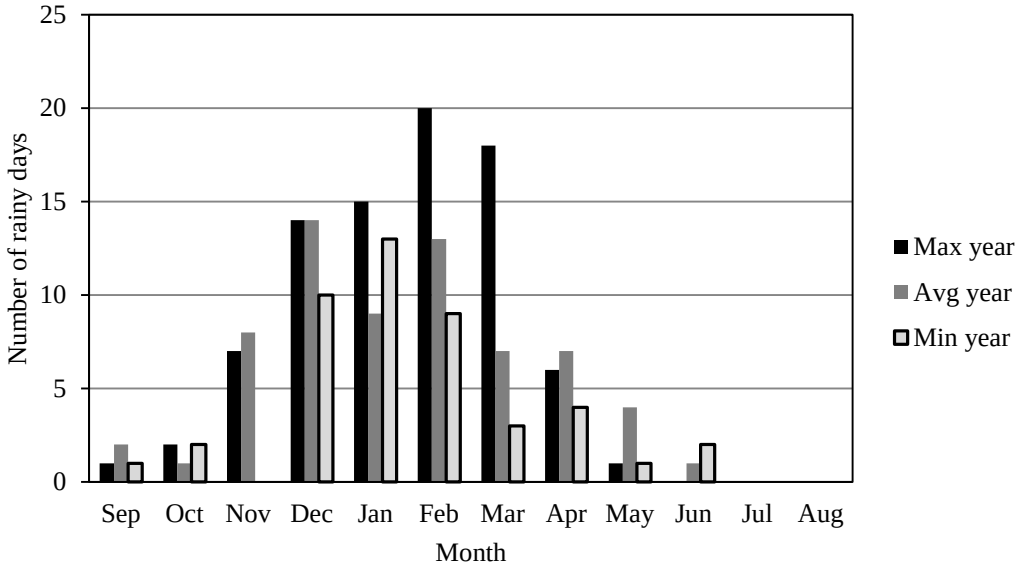


Figure 6: Number of rainy days during minimum, average and maximum rainfall years

The potential amount of rainwater that can be harvested from a rooftop area was calculated, considering the average monthly rainfall during the three hydrological years (Figure 7). An estimated 128.5, 135.7, and 182.5 m^3 can be harvested annually during the dry, average, and wet years respectively, assuming a 300 m^2 roof area. The harvested volumes can cover exclusively the daily water demand of a building with 50 inhabitants for 20 days. For a single household, the volume of harvested rainwater can serve for 203 days. The ability to meet domestic demands showed large variability by month as shown in Figure 8.

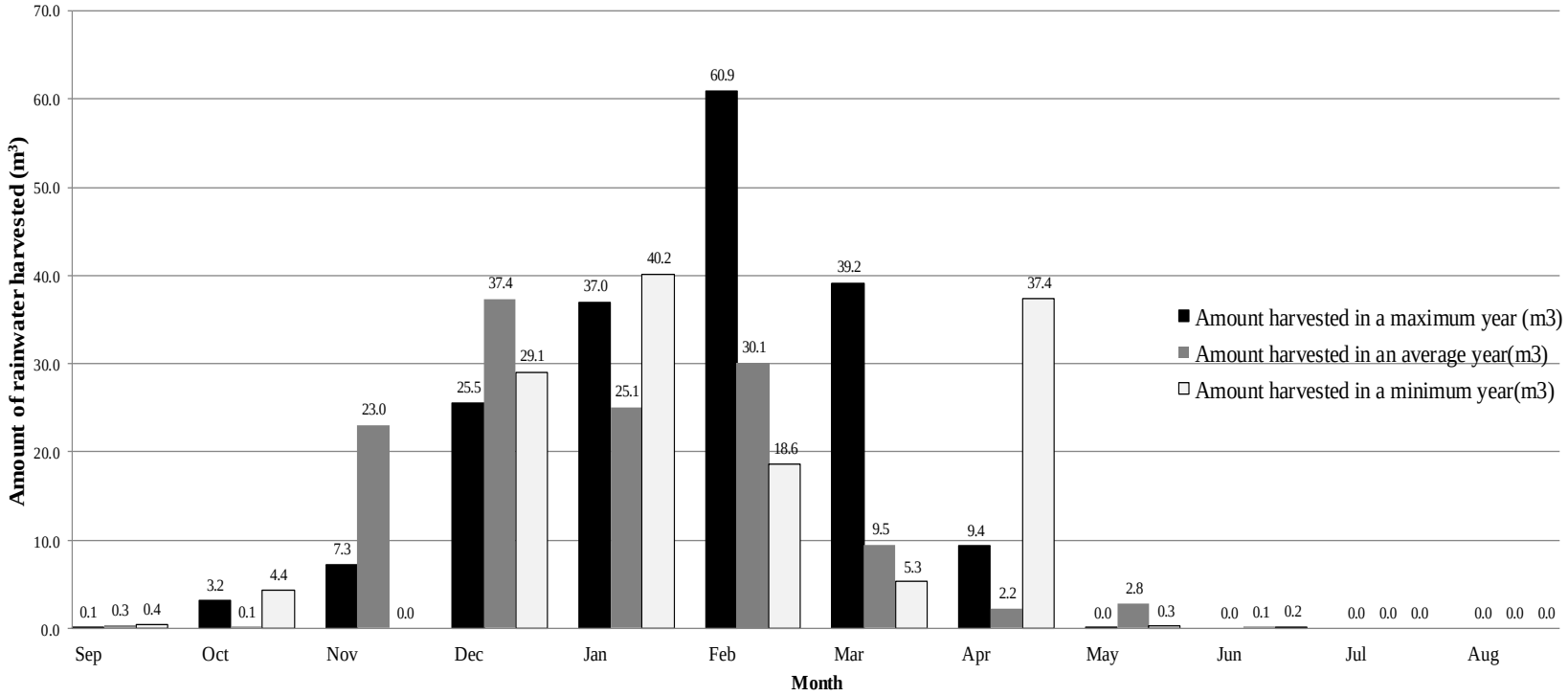


Figure 7: Monthly volume of rainwater (m^3) that can be harvested in three hydrological years

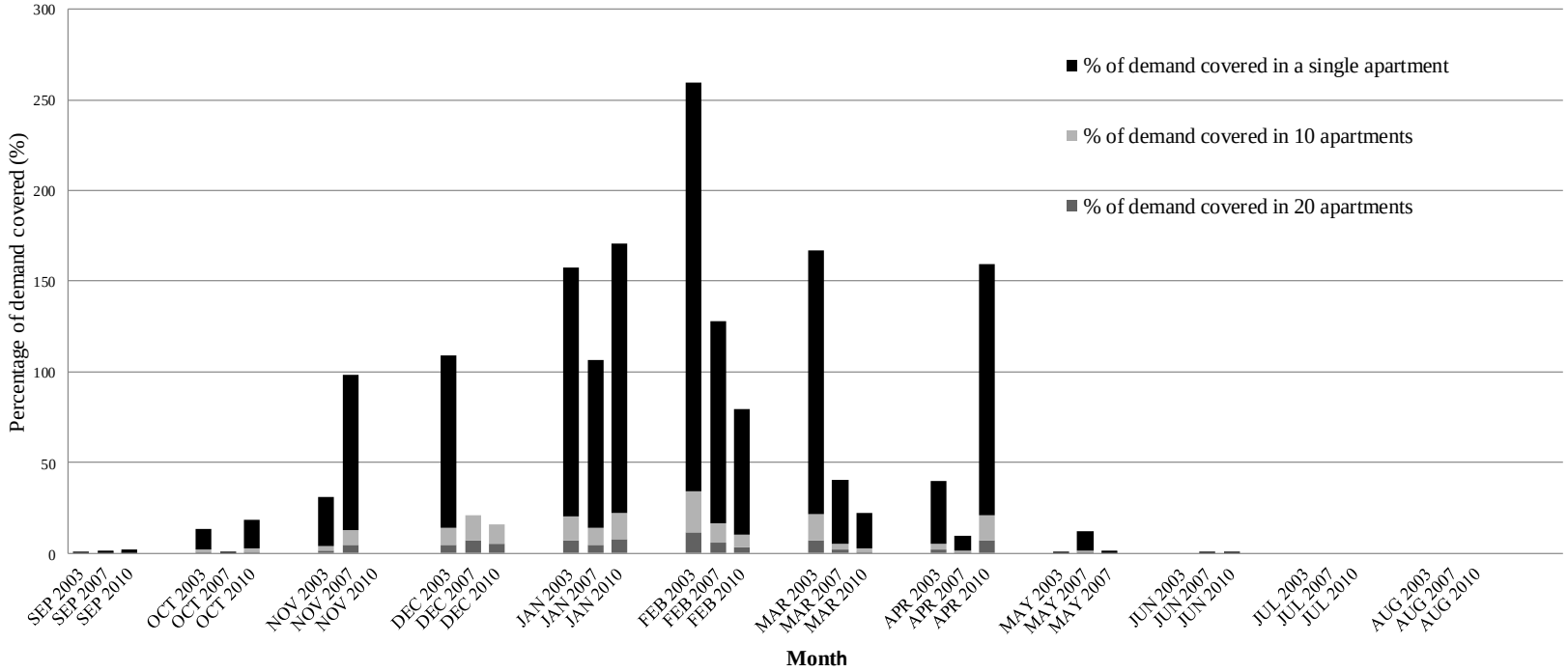


Figure 8: Percentage of demand covered by rainwater in a single apartment, 10 apartments and 20 apartments building

The results showed that during the wettest year (2003), the amount of rainwater that can be harvested exceeded the demand of a single household of 5 inhabitants. During an average year, (2007), the rainwater supply was estimated to cover up to 100% of the demand. As for the driest year, the amount of rainfall received was estimated to cover up to 60% of the demand. For multi-story buildings, the percentage of demand covered by rainwater is minimal irrespective of the hydrological year. While the volume harvested may be minimal with respect to total demand, its contribution towards reducing the deficit between demand and supply is promising. Figure 9 shows that the water deficit can be reduced between 4.6% and 92.2% for buildings with 5 and 20 apartments with a maximum rooftop area of 217 m^2.

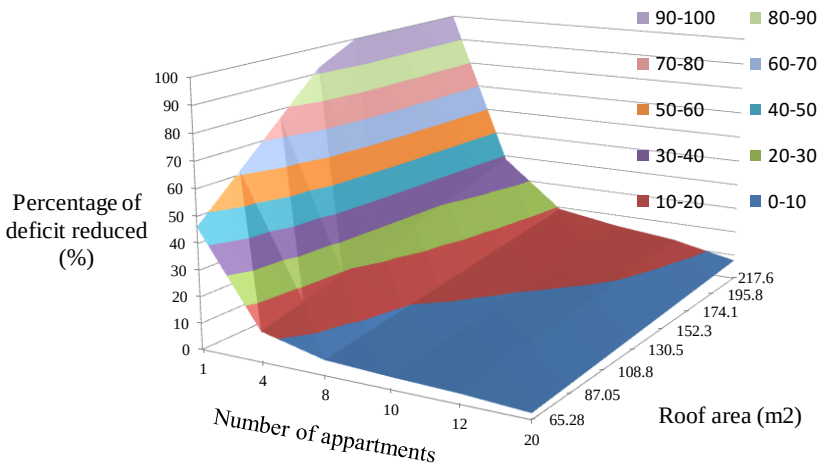


Figure 9: Percentage of deficit reduced as a function of rooftop area and number of apartments

The sizing of the storage tank depends on local conditions such as average rainfall, water demand, catchment area, space area availability, and budget. The most common types of storage tanks used in the area, are concrete and polyvinyl chloride (PVC). Appendix 7 shows the various types of storage tanks options. Underground concrete storage tanks are the most preferable for aesthetic reasons; however, they might be too expensive or difficult to retrofit into constructed buildings. The needed storage tank sizes for buildings with four apartments or more are reasonable since the estimated amount of collected rainwater will

often not carry over from month to month due to the high daily demand and the limited supply. Whereas for a single apartment-household, a surplus in excess of 22 m^3 is expected in the month of February, requiring a 25 m^3 storage tank to prevent the overflow of rainwater. Figure 10 shows the percentage of days per year when precipitation can be captured for different roof areas of a single residence (5 occupants) as a function of water tank volume.

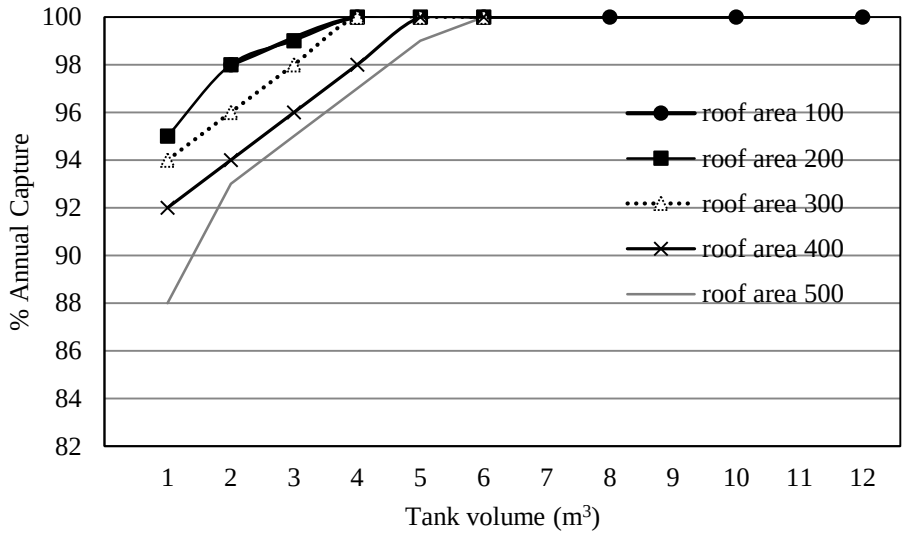


Figure 10: Percentage of days per year when total precipitation can be captured

Note that due to the intermittent supply of water, many households already have one or several water storage tanks that can be used to collect harvested rainwater in a building after treatment. This option can overcome limitations such as the availability of space for installing storage tanks or the difficulty of re-plumbing an entire building to create dedicated water supply lines to link harvested rainwater directly to toilets or washing machines. Most new buildings in the area have an underground storage tank with a capacity ranging from 20 to 40 m^3 intended to store water received from the network.

3.3 Socioeconomic Assessment

3.3.1 Economic Analysis

The RWHS can help reduce water shortages in the study area. Yet, the associated costs with these systems will primarily drive their market penetration. The capital investment needed for a RWHS was estimated to vary between $2,100 and $9,500 depending on the capacity of the installed storage tank (between 5 and 40 m^3). These costs include the price of the storage tank, the pump, pipes, gutters, and excavation (Appendix E). The price of the storage tank represents the largest portion for installing a RWHS, reaching 30 to 45% of the total cost of the system depending on the tank's material and size. The installation of a RWHS during construction will generally cost less than retrofitting a system in an existing building because of the extra costs associated with the plumbing changes needed as well as the installation of downpipes to deliver rainwater from the roof into the storage tanks located at the ground level.

Accounting for operation and maintenance costs as well as energy costs needed to pump water from the storage tank to the household, the total cost of rainwater (amortized capital cost plus annual operation and maintenance costs) harvested in a 5 m^3 storage tank is estimated at $125 per year, considering a 5% interest rate and a 40 year life span of the system. Thus, the cost of harvested rainwater per cubic meter is $0.28 assuming a 300 m^2 rooftop area. The cost drops to $0.16/$m^3$ when the storage tank's capacity is increased to 40 m^3, which is comparable to current tariff on network water. Moreover, rainwater harvesting competes favorably with the adaptation measures that people are resorting to in an effort to overcome chronic water shortages whereby residents are reported to pay $1.36/$m^3$ for water from a reverse osmosis system and up to $10/$m^3$ for water delivered by tankers according to the household survey.

Examining the feasibility of rooftop rainwater harvesting in the area at different scales revealed that detached single households are most suitable technically in terms of supply since the potential amount of rainwater which can be harvested can cover almost 100% of the demand in a wet year. However, economically such an option will involve relatively large investments in constructing storage tanks. Morales-Pinzon *et al.* (2012b) concluded

that a neighborhood scale rainwater harvesting system applied to collect rainwater is a more economically attractive option than a single household ($242 as compared to $5703 for a single family household). Another study by Rahman *et al.* (2010) showed that it could be possible to achieve a cost-benefit ratio of 1.39 for a domestic RWHS with a capacity of 75 m^3 installed at a multistory residential building with a roof area of 1,600 m^2, having 72 to 96 water users.

3.3.2 *Household Survey*

Nearly 77% of household interviewees expressed interest in participating in a rainwater harvesting program. A number of interviewees viewed rainwater as a complementary water supply source that can contribute in alleviating scarcity and reduce the demand on aquifers. When it comes to their preferred uses for the harvested rainwater, 64.4% of respondents stated their willingness to use rainwater for all household usages except drinking; 31.1% believed that rainwater was suitable for potable purposes if properly treated. The remaining 4.5% believed that rainwater was only good for outdoor usages such as car washing and landscaping.

3.3.3 Willingness to Participate

Several factors proved to be significant factors explaining respondents' willingness to participate in a rainwater harvesting program (Table 9). The four most significant determinants of interviewees' willingness to participate were found to be: age, presence of outdoor space area, highest level of education, and number of floors in the building.

Table 9: Results of the willingness to participate logistic regression model

Predictor	Estimate	Standard Error	Z-value	Significance
Intercept	7.1874	2.7819	2.584	0.00978
$\frac{Age - 50}{10}$	-0.6625	0.3267	-2.028	0.04257
Absence of outdoor space area	-7.0841	2.1566	-3.285	0.00102
Holder of university degree	1.7316	1.0017	1.729	0.08386
$Building\ Floors - 2$	-0.6710	0.3474	-1.931	0.05342

To provide a meaningful intercept to the model, age was reported in decades after centering on 50 years. Similarly, the number of floors in buildings was centered on a two-story building. As such, a respondent aged 50, with no university degree, and living in a two story building with access to an outdoor area is almost certainly willing to participate with a probability > 99.99 %. When lacking access to an outdoor space, the probability of participation dropped down to 52.6%. In the event that the respondent had a university degree, the probability of participation increased by five folds. For every additional floor, the odds of participation dropped by half. Older respondents were less likely to adopt rainwater harvesting. With every ten years of age, the odds of adopting a RWHS dropped by 51.6%. The multivariate model accounted for 0.2 (McFadden's pseudo R^2) and 0.3 (Cragg and Uhler's pseudo R^2) of the proportion of the total variability of the outcome depending on the pseudo R^2 equation used (Long 1997).

3.3.4 Willingness to Pay

Given that the only significant predictor was the monthly household income, an ANOVA test was used to predict the variability within a particular income group while testing for inter-income group variability. In other words, people's willingness to pay (WTP) for a RWHS was only found to significantly vary as a function of the income of the household (p-value< 0.05). Note that a log transformation was applied on all the monthly income groups in an effort to normalize the data. Monthly incomes were divided into 4 groups: < \$1500, \$1500 to \$ 4000, \$4000 to \$6000, and > \$6000. The ANOVA analysis showed that household income was a significant predictor of WTP for all 4 income groups. On average, a household with a monthly income < \$1500 was willing to pay 0.54 \$ /m^3 to install a RWHS in case the current source of water is no longer available as compared to 2.34 \$/m^3 for those with an income > \$6000/month. A comparison between the price a family of 5 occupants is currently paying for 1 m^3 of water delivered by water tankers (\$5.64/m^3), network water (\$1.4/m^3), and municipal water in Hadath (\$0.37/m^3) to account for water shortage, reveals that the residents' WTP closely related to the high costs they incur by purchasing water from other sources.

3.4 SWOT Analysis

The SWOT analysis for the adoption of a RWHS can help towards the development of a strategy-plan and to prioritize actions needed to be taken in the short, medium, and long term (Dyson, 2004). Literature based indicators coupled with social, economic, and environmental considerations were analyzed to generate the SWOT analysis for the implementation of a rainwater harvesting project (Table 10). Utilizing a RWHS have many strengths starting from providing an onsite source of water for homeowners at a reasonable price, especially for households that already have storage tanks, to providing a substitute for water tankers and network water mainly during the wet season. The results demonstrated that rainwater can allow for 4 months of water supply for a single household. However, the major weaknesses for the applicability of the system include the absence of legislation/regulations and the low priority given to RWHS by the central government and municipalities. Nevertheless, the study area is an urbanized suburb with little or no outdoor space area; thus, making it difficult to construct or retrofit storage tanks. The absence of network water meters, low prices of network water and absence of a tariff system on wastewater generated are inhibitors for the adoption of a RWHS. From a technical perspective, the amount of rainwater that can be harvested is highly dependent on the rooftop area and consumption patterns. Hence, the harvested amounts might be insufficient to meet the demands in multi-story residential buildings. However, even under these conditions, rainwater is a sustainable resource that offers an opportunity for urban municipalities to reduce water deficits, runoff, and non-point source pollution. On the other hand, external factors pose a threat on the viability of the system such as: fluctuating prices of material and equipment needed to construct a RWHS, prolonged dry periods and inadequate monitoring and treatment of harvested water; thus, posing a health risk for the household users. Based on the SWOT analysis, the main challenge to the application of a RWHS in the study area pertains to the lack of legislations and political will to regulate the use of this technology and the absence of subsidies.

Table 10: SWOT analysis of rainwater harvesting systems in the study area

STRENGTHS	WEAKNESSES
– Provide an onsite source of water for homeowners – Supply water at a reasonable cost with minimal investment for households that have storage tanks – Reduce the centralization of water distribution – Reduce dependence on water tankers especially in the wet season – Provide water with a relatively good quality to meet non-potable household demand- – Improve water security – Allow for four months of water supply for a single household with 5 inhabitants	– Absence of laws and regulations pertaining to the harvesting of rainwater – Low priority given to RWHS by donors, central government, and municipalities – High initial investment required in case of excavation or retrofitting – Increased sizes of storage tanks will add to the construction and operating costs which may not be economically feasible, especially for single households – Insufficient area for placing storage tanks – Highly dependable on rainfall amounts – Lack of building codes for rainwater harvesting – Might not be cost efficient since the amount harvested water is dependent on roof size and demand – Insufficient amount of rainfall to meet the demand especially in multi-story residential buildings – Absence of a tariff system on wastewater generated – Treatment and disinfection of rainwater is necessary depending on the intended use of the effluent water – Absence of network water meters and its considerably low rates make the system cost effective only for households with large roof areas or not connected to the public water system
OPPORTUNITIES	THREATS
– Offers an opportunity for municipalities to invest at a larger scale to supply households within their boundaries or for landscaping – Municipalities can construct rainwater harvesting systems on municipal properties to capture rainwater to be used for watering public gardens and landscapes – Can decrease water deficit – Can help raise users awareness on water use – The system can be installed in residences which already have water storage tanks – Reduce runoff and non-point source pollution	– Fluctuating prices of construction material, storage tanks, and treatment systems – Expected climate change impacts on precipitation levels and potential prolonged dry periods – Absence of water meters to charge users according to their consumption of network water makes the price of rainwater difficult to compete with network water – Inadequate monitoring and treatment of captured rainwater poses health risks for the end user – Water quality is threatened by surrounding environment, animal feces, and other contaminants which might be present

– Can decrease combined sewer overflows and the associated pollution of surface water with pathogens, organic material, and nutrients	

4 CONCLUSION AND RECOMMENDATIONS

Water shortage is one of the critical problems facing the study area. Based on the study results, it is clear that rainwater harvesting will not be the sole solution that will solve the water scarcity problems in the Hazmieh/Hadath/Baabda area; yet it can be used as a complementary source to current public and private water systems. Rainwater provides an important water resource for developing a sustainable urban future for the Hadath/Hazmieh/Baabda area in light of increased demand and limited supply from conventional water sources. It is recommended that new buildings adopt this technology and make use of the harvested water for non-potable uses as has been done in Spain, Italy, Australia, and Taiwan (Farreny et al., 2011b; Liaw & Tsai, 2004). While roof-collected rainwater, in general, meets the classical parameters for drinking water in terms of physico-chemistry, microbiological properties of tested samples (coliforms) exceeded acceptable limits. As a result, it is recommended to use a system equipped with disinfection especially that the contamination persisted after the first-flush. The cost of common types of disinfection methods are presented in Appendix F. Continuous water quality monitoring should also be performed to ensure that rainwater is safe for use, especially if it is stored in a common water tank with network water. The installation of first flow diverters are also recommended to prevent household users from using low quality water due to the accumulation of dirt or debris.

The ability to capture rainwater on a large scale has not been investigated in this study and should be further examined. However, this is faced with many limitations such as the availability of space to construct a catchment area to store rainwater harvested from rooftops, pavements, roads, and parking. Moreover, poor water quality and social acceptability or willingness to cooperate/invest in such a plan may present additional constraints. The household survey showed that residents have a lack of trust in large projects adopted at the central level and tend to favor projects where they can operate and maintain the system themselves.

The need for a management framework for rainwater harvesting systems is imperative given the lack of policy statements on nonconventional sources of water. Moreover, the absence of regulations and guidelines pertaining to the use of rainwater leaves homeowners and local decision makers uncertain about the benefits, safety and level of treatment necessary for the safe use of harvested water. Such guidelines can be devised through a collaborative work between local municipalities and the Directorate General of Urban Planning and several ministries including the Ministry of Environment (MoE), Ministry of Energy and Water (MoEW), and Ministry of Public Health (MoPH). Thus, it is imperative to promote urban rainwater harvesting through a series of policies and legislations, which encompass a mixture of incentives and penalties. A regulatory framework is equally critical to avoid adverse effects of poor water quality and diffusion of inefficient technology. Therefore, promoting and sustaining rainwater harvesting practices in Lebanon is a shared responsibility between various regulatory, enforcement and protection stakeholders. Table 11 outlines an institutional framework for rainwater harvesting comprised of key ministries and local municipalities along with respective responsibilities.

Table 11: Main responsible authorities in the rainwater harvesting plan

Authority	*Responsibility*
Ministry of Energy and Water (MoEW)	– Identify, plan, execute, and supervise large scale rainwater harvesting projects. – Provide incentives in the form of tax credits for homeowners that install a RWHS. – Subsidize RWHS and offer 0% interest rate 5-year loans (similar to the subsidies given for solar water heaters)[1] – Restructure the flat tariff water system based on consumption. – Implement a wastewater discharge fee
Ministry of Public Health (MoPH)	– Establish a program for the protection, monitoring and treatment of a RWHS. – Ensure that water quality standards and public health concerns are met.
Ministry of Interior and Municipalities (MoIM)	– Provide permits for homeowners who wish to implement a RWHS. – Offer a rebate on property tax as an incentive for implementing a RWHS. – Apply laws related to necessitating new buildings with a roof area > 200 m^2 to adopt RWHS to obtain permission for construction. – Ensure that the slab or the roof of new buildings is equipped with a proper spout or gutter for the collection of rainwater – Educate contractors about building codes set by the Order of Engineers so that installed RWHS meet the requirements.

Directorate General of Urban Planning (DGU)	– Establish building codes to ensure that the slab or the roof of new buildings is equipped with a proper spout or gutter for the collection of rainwater.

[1]: (Lebanese Center for Energy Conservation, 2011)

An enabling regulatory and institutional framework is equally imperative to organize the implementation and use of a RWHS including the establishment of monitoring requirements and providing consumers with a "safe" water source at a reasonable cost. The implementation of such a framework will require the involvement of various regulatory, protection and enforcement bodies. A general management framework including regulatory measures, guidelines and practices and institutions is outlined in Table 12.

Table 12: Management Framework for a RWHS

			Institution Responsible					
			MoEW[1]	MoIM[2]	MoE[3]	MoPH[4]	DGU[5]	MoF[6]
System Design and Water Quality	Regulatory Measures Permits/License	-Provide permits for households who wish to use rooftops only as a collection surface	x	x				
		-Establish building codes which address the design and installation of rooftop RWHS[7]					x	
		-Adopt rainwater permits requiring on-site retention and use of rainwater technologies for new buildings[8]	x	x			x	
		-Provide technical assistance for homeowners to ensure that the appropriate – sized storage tanks are built.	x					
		-Ensure that RWHS components (pipes, storage tanks) are not placed where service lines are located (telephone, electricity, cable lines and sewer).		x			x	
		-Ensure proper drainage of rainwater from the storage tank to a nearby sewage discharge channel in case of overflow or potential leaks in the system		x				
	Materials	-Specify approved rooftop material, storage tank and pipe materials used for the provision of rainwater.	x		x			
		-Recommend the use of PVC storage tanks for small and medium tank sizes, concrete storage tanks for medium and large tanks sizes, and fiberglass for large tank sizes	x					
		-Subsidize the prices of the components and materials needed to construct a RWHS	x					x
	Water Quality	-Develop quality standards for different uses of rainwater (irrigation, toilet flushing, laundry…) including physical, chemical and microbiological parameters	x		x	x		
		-Provide data on human pathogens present in rainwater and risks associated with various uses	x		x	x		
		-Provide an overview of treatment devices available in the market such as screens and filters to reduce the risk of contamination with suspended solids and debris	x			x		
		-Offer treatment recommendations to remove microorganisms and pathogens such as the use of ultraviolet (UV) lamps or chlorination	x			x		
	Inspection	-Conduct rainwater sampling campaigns on a weekly and/or monthly basis during the wet period.			x	x		
		- Ensure that rainwater storage tanks are easily accessible for inspection and maintenance		x				
	Training	-Train household owners on the best hygienic practices to ensure a good quality of harvested water	x		x	x		

		-Educate the homeowners about the safe use of a chlorine kit to eliminate the risk of posing a health hazard		x	x	x		
	Incentives	-Offer tax credits for RWHS	x					x
		-Implement rainwater harvesting rebate programs to encourage rainwater harvesting at the household level	x	x				x
	Tariff/Penalties	-Implement sewer tariff and metering regulations to charge homeowners for the amount of rainwater lost in the sewer system	x	x				
		-Set fines and penalties on the property owners who fail to implement a RWHS and subsequently contribute to water wastage		x				
		-Handle overflows from rainwater storage tanks through allowing rainwater to exit the storage tank at the same flow rate it enters the storage tank. This can be done by using an overflow exit pipe of a 25-50mm height lower than that of the entry pipe[9]	x	x				
Operation	Water Quantity	-Predict domestic water use of harvested rainwater in an effort to estimate potable water savings.	x		x			
	Water Quality	-Analyze runoff contaminant loading (physical, chemical, microbiological)			x	x		
		-Remove trees and other contaminant sources that might hinder the quality of harvested water		x				
Maintenance	Treatment and disinfection	-Specify chlorination frequency and acceptable chlorination dose to protect human health				x		
	Maintenance programs	-Periodic inspection to ensure robust maintenance for any treatment systems or mechanical systems by homeowners	x	x	x			
	Record keeping	-Maintain a record book including dates of site visits, sample analysis, outbreaks, fines, and recommendations.			x			
Monitoring	Sampling frequency	-Conduct sampling campaigns on a monthly and annual basis (analysis of physical, chemical and microbiological parameters)	x	x	x			
		-Submit water quality results to the MoPH	x	x	x			
	Risk Assessment	-Assess possible health risks associated with the use of harvested rainwater				x		
		-Select best remediation/treatment technologies to reduce the risk of contaminants			x	x		
Public Awareness Campaigns	Proactive public outreach initiatives	-Conduct publications, public announcements and door-to-door visits in order to promote awareness about the benefits of the implementation of a RWHS and secure public acceptance and support	x	x				

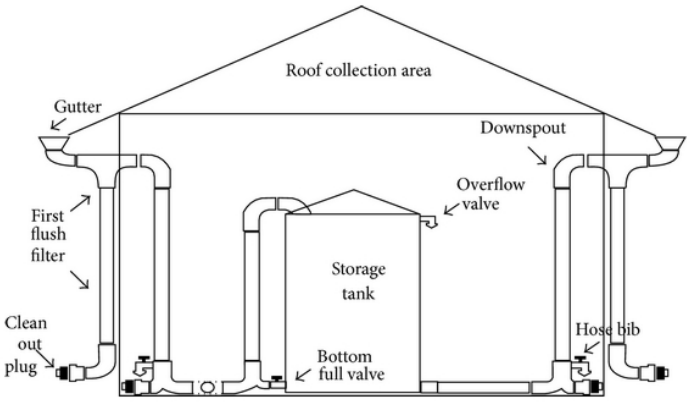
[1]: Ministry of Energy and Water, [2]: Ministry of Interior and Municipalities, [3]: Ministry of Environment, [4]: Ministry of Public Health, [5]: Directorate General of Urban Planning, [6]: Ministry of Finance, [7]: Building codes should outline system and permitting requirements for various applications such as toilet flushing, irrigations, laundry… [8]: (Stecker and Poresky, 2010), [9]: (City of Guelph Water Services, 2014).

5 FUTURE PERSPECTIVES

For a sustainable urban future, it is vital to continue integrating unconventional water resource management such rainwater harvesting and gray water reuse in urban planning. Nevertheless, future work should strive to explore the dynamics of urban environmental changes in terms of urban density, homogeneity of construction and networks, and space distribution for their effect on the management of water resources. Moreover, research should be expanded to examine harvesting potential at larger urban scales including parking lots, public spaces, department stores and the like, and to integrate the results of rainwater with gray water in the system.

Appendix 1

Typical rainwater harvesting installation
(Texas Water Development Board, 2005)



Appendix 2

Household Survey

ID |___|___|-|___|___|-|___|___|

Potential use of rainwater harvesting systems in the Hazmieh/Hadath/Baabda Area

Questionnaire Identification					
AI1	**Zone**	|___||___|	AI5	**Floor no.**	|___|___|
AI2	**Street**	_____	AI6	**Housing unit no.**	(Start from right side) |___|
AI3	**Neighbourhood**		AI7	**GPS coordinates**	N: _____
AI4	**Building**	_____	AI8		E: _____
Well water Sampling					
WWS1	Do we have access to the first discharge of the artesian well to take sample?	_____			
WWS2	Can we measure the water level in the well? (drop meter to touch water level)?	_____			
Schedule					
AV1	First Visit	DD.MM.YY |___|___|.|___|___|.|___|___|	AT1	Start of interview (time)	hh:mm |___|___|:|___|___|
			AT2	End of Interview (time)	hh:mm |___|___|:|___|___|
AV2	Second Visit	DD.MM.YY |___|___|.|___|___|.|___|___|	AT3	Start of interview	hh:mm |___|___|:|___|___|
			AT4	End of Interview	hh:mm |___|___|:|___|___|
AV٣	**Total visits carried out** |___|				
AV٤	**Editing Date**			DD.MM.YY	|___|___|.|___|___|.|___|___|
AV٥	**Coding Date**			DD.MM.YY	|___|___|.|___|___|.|___|___|
AV٦	**Data Entry Date**			DD.MM.YY	|___|___|.|___|___|.|___|___|
Staff					
AS1	**Interviewer**	|___|___|	AS4	**Coder**	|___|___|
AS2	**Supervisor**	|___|___|	AS5	**Data entry operator**	|___|___|
AS3	**Editor**	|___|___|			
Respondent					
AH1	**Name of household head (optional) _____**				
AH2	**Name of main Respondent (optional) _____**				
AH3	**Gender of Respondent**				

AH4	**Marital status of respondent**		
AR1	**Interview status**		
	1	Interview completed	**COMMENTS:**
	2	Refusal converted	
	3	Partly completed	
	4	No usable information	
	5	Household unit is vacant	
	6	No contact	
	7	Refusal	

Additional comments

_____

_____

سوف أبدأ بالسؤال عن المبنى الذي تسكن فيه

معلومات حول المبنى (Building Information)		
BI1	ما هو عدد الطوابق التي فيها شقق؟	_____ طابق
BI2	ما هو العدد الإجمالي للشقق المسكونة ؟	_____ شقة
BI3	ما هو العدد الإجمالي للشقق الغير مسكونة؟ (تبقى فارغة لأكثر من ٣ أشهر)	_____ شقة
BI4	كم عمر المبنى ككلّ؟	_____ سنة
BI5	منذ متى وأنتم تسكنون هذه الشقة؟	_____
BI6	هل تم إعادة تأهيل شبكة المياه ومياه الصرف الصحي و متى؟	_____ ١ لا إعادة تأهيل 98 لا جواب 99 لا أعلم
BI7	من المسؤول عن لجنة المبنى إذا وجدت؟	_____ ١ لا لجنة ٩٨ لا جواب ٩٩ لا أعلم
BI8	مساحة سطح	_____ مساحة مسطحة المبنى _____ مساحة منحدرة ٩٨ لا جواب 99 لا اعلم

BI9	نوع السطح	١ اسمنت مسطح ٢ طين ٣ اسفلت ٤ خشب ٥ الواح ٦ قرميد ٩٨ لا جواب
BI10	من لديه القدرة على الوصول إلى السطح	
BI11	متى تقوم بتنظيف السطح ؟ الاولى	١ لا نقوم بتنظيف السطح ٢ قبل هطول الامطار للمرة ٣ كل ٣ اشهر ٤ مرة في السنة ٩٨ لا جواب ٩٩ لا اعلم
BI12	هل يوجد خزان مشترك لسكان البناية؟	١ نعم ٢ كلا
BI12A	اين يوجد هذا الخزان؟ (على السطح)	١ فوق ٢ تحت
BI١٢B	اذا نعم, ما هو حجم الخزان؟ _____ لتر	
BI11C	ما هي استخدامات المياه في هذا الخزان؟	
BI11D	هل لديك موتور على سطح المبنى؟	1 نعم 2 كلا
BI11E	هل تقوم بتخزين المواد الكميائية أو الفيول على السطح؟	1 نعم 2 كلا
BI11F	هل لديكم خزان خاص على سطح المبنى؟ ما هو حجم الخزان؟	1نعم 2كلا
BI11G		

الآن سوف أسأل عن المياه في المنزل:

مصادر المياه (Water Sources)

WS1	ما هي مصادر المياه التي تصل الى المنزل؟		
WS1A1	شبكة المياه العامة	١	نعم
		٢	كلا
		٩٩	لا أعلم
WS١A٢	مياه المشروع)البلدية	١	نعم
		2	كلا
			لا أعلم
		99	
WS1B	بئر أرتوازي	١	نعم
		٢	كلا
		٩٩	لا أعلم
WS1C	صهريج مياه	١	نعم
		٢	كلا
		٩٩	لا أعلم
WS1D	مياه معبأة (bottled)	١	نعم
		٢	كلا
		٩٩	لا أعلم

WS1E	مياه منقولة باليد	١	نعم
		٢	كلا
		٩٩	لا أعلم
WS1F	مياه الأمطار	١	نعم
		2	كلا
		٩٩	لا أعلم

إذا كنت تحصل على المياه من الشبكة العامّة

مياه الشبكة العامة (Network Water)				
NW1	هل تصل إليك مياه الشبكة العامة مباشرةً (من خلال حنفية خاصة للشرب في المطبخ مثلاً)؟		١	نعم
			٢	كلا
			٩٨	لا جواب
			99	لا أعلم
NW2	هل لديك عيار بالمتر المكعب؟		١	نعم، خاص بالشقة
			٢	نعم، مشترك للبناية
			3	كلا
			٩٨	لا جواب
			٩٩	لا أعلم
NW3A	إذا كان لديك عيار بالمتر المكعب:	ما قيمة **فاتورتك** السنويّة؟	|___|___|___|,|___|___|___| ليرة	
			97	N/A
			٩٩	لا أعلم
NW3B		ما قياس عيار الشقة؟	|___|___|.|___|___| م^3	
			97	N/A
			٩٩	لا أعلم
NW4	ما هي استخدامات المياه التي تحصل عليها من شبكة المياه العامة		١	للشرب
			٢	لغسل الأيدي
			٣	للاستحمام
			٤	لغسل الطعام
			٥	للطبخ
			٦	لغسل الصحون
			٧	لتنظيف البيت
			٨	في غرفة الغسيل

NW5A	ما وتيرة تزويد المياه عبر الشبكة العامّة في الصيف ؟		|____| مرة في الأسبوع
		١	متقطّع لكن لا يمكن تحديد الوتيرة
		٢	بشكل مستمر
		٩٨	لا جواب
		٩٩	لا أعلم
NW٥B	كم تبقى المياه مزوّدة حين تأتي في الصيف		|___|___| ساعة
		١	لا يمكن تحديد المدّة
		٩٨	لا جواب
		٩٩	لا أعلم
NW٦A	ما وتيرة تزويد المياه عبر الشبكة العامة في الشتاء ؟	_____	مرة في الأسبوع
		١	متقطع لكن لا يمكن تحديد الوتيرة
		٢	بشكل مستمر
		٩٨	لا جواب
		٩٩	لا أعلم
NW6B	كم تبقى المياه مزوّدة حين تأتي؟		|___|___| ساعة
		١	لا يمكن تحديد المدّة
		٩٨	لا جواب
		٩٩	لا أعلم
NW7	هل أنت راضٍ عن نوعيّة مياه الشبكة التي تصل الى منزلك في فصل الصيف؟	١	نعم
		٢	لا
		٩٧	N/A
		٩٨	لا جواب
		٩٩	لا أعلم

NW8	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	١	المياه ليست صافية
		٢	هناك رائحة كلور في المياه
		٣	هناك طعم للمياه
		٤	المياه كلسيّة
		٥	المياه تترك بقعاً على التجهيزات (المطبخ، الحمام)
		٦	المياه ملوّثة
			المياه ذات طعمة ملوحة
		٧	
		٨	غير ذلك، حدد _____
		97	N/A
		٩٨	لا جواب
		٩٩	لا أعلم
NW9	هل أنت راضٍ عن نوعيّة مياه الشبكة التي تصل الى منزلك في فصل الشتاء؟	١	نعم Go To NW11
		٢	لا
		97	N/A
		٩٨	لا جواب
		٩٩	لا أعلم
NW10	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	١	المياه ليست صافية
		٢	هناك رائحة كلور في المياه
		٣	هناك طعم للمياه
		٤	المياه كلسيّة
		٥	المياه تترك بقعاً على التجهيزات (المطبخ، الحمام)
		٦	المياه ملوّثة
		٧	المياه ذات طعمة ملوحة
		٨	غير ذلك، حد _____
		97	N/A
		٩٨	لا جواب
		٩٩	لا أعلم
NW11	كيف تصنّف نوعية هذه المياه عموماً؟	١	جيدة (دون لون، طعم، رائحة، ورواسب)
		٢	متوسطة (بعض اللون، طعم، رائحة، ورواسب)
		٣	سيئة (ذات لون، طعم، رائحة، ورواسب)

		٩٨ لا جواب
		٩٩ لا أعلم

اذا كنت تحصل على المياه من الآبار

مياه الآبار (Well Water)					
WW1	عدد الآبار التي تصل منها المياه الى المنزل	|___|			
WW2	هل كان لديك بئر قديم لم تعد تستخدمه؟ لماذا؟	١ نعم، لأنّ البئر القديم جفّ			
WW2A		٢ نعم، لسبب آخر حدّد _____			
		٣ كلا			
		٩٨ لا جواب			
		٩٩ لا أعلم			
		١ **البئر ١**	٢ **البئر ٢**	٣ **البئر ٣**	٤ **البئر ٤**
WW3A					
WW3B	نوع البئر	١ خاص للمبنى ٢ مشترك لعدة مبان 3 مشترك للحي ٩٨ لا جواب ٩٩ لا أعلم	١ خاص للمبنى ٢ مشترك لعدة مبان 3 مشترك للحي ٩٨ لا جواب ٩٩ لا أعلم	١ خاص للمبنى ٢ مشترك لعدة مبان 3 مشترك للحي ٩٨ لا جواب ٩٩ لا أعلم	١ خاص للمبنى ٢ مشترك لعدة مبان 3 مشترك للحي ٩٨ لا جواب ٩٩ لا أعلم
WW3C	عمق البئر	|___|___| م |___|___| قسطل ٩٨ لا جواب ٩٩ لا أعلم	|___|___| م |___|___| قسطل ٩٨ لا جواب ٩٩ لا أعلم	|___|___| م |___|___| قسطل ٩٨ لا جواب ٩٩ لا أعلم	|___|___| م |___|___| قسطل ٩٨ لا جواب ٩٩ لا أعلم
WW3D	سنة الحفر	|___|___|___|___| ٩٨ لا جواب ٩٩ لا أعلم	|___|___|___|___| ٩٨ لا جواب ٩٩ لا أعلم	|___|___|___|___| ٩٨ لا جواب ٩٩ لا أعلم	|___|___|___|___| ٩٨ لا جواب ٩٩ لا أعلم

WW4A	ما هي استخدامات المياه التي تحصل عليها من البئر	١ ٢ ٣ ٤ ٥ ٦ ٧ ٨	للشرب لغسل الأيدي للاستحمام لغسل الطعام للطبخ لغسل الصحون لتنظيف البيت في غرفة الغسيل
WW5	لماذا اخترت استخدام مياه الآبار؟	١ ٢ ٩٨ ٩٩	الحاجة إلى كمية أكبر من المياه سبب آخر، حدد _____ لا جواب لا أعلم
WW6	ماذا تدفع مقابل مياه الآبار او خدمة تأمين مياه البئر؟ لمن تدفع هذا المبلغ؟	1 |___|___|___|,|___|___|___| ٩٨ ٩٩	لا شيء ألف ليرة شهرياً لا جواب لا أعلم
WW6A	هل هناك عيار للبئر الذي تستخدمه؟	١ ٢ ٩٨ ٩٩	نعم كلا لا جواب لا أعلم
WW7A	هل أنت راضٍ عن نوعيّة مياه الآبار التي تصل الى منزلك في فصل الصيف؟	١ ٢ 97 ٩٨ ٩٩	نعم لا N/A لا جواب لا أعلم

WW7 B	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	١	المياه مالحة	
		٢	المياه كلسيّة	
		3	للمياه لون، حدد_____	
		٤	للمياه رائحة غريبة غير رائحة الكلور، حدد_____	
		٥	للمياه رائحة معدنيّة	
		٦	المياه تترك بقعاً \ طبقة على الأواني والتجهيزات	
		٧	المياه ملوّثة جرثوميّاً	
		٨	غير ذلك، حدد_____	
		97	N/A	
		٩٨	لا جواب	
		٩٩	لا أعلم	
WW8 A	هل أنت راضٍ عن نوعيّة مياه الآبار التي تصل الى منزلك في فصل الشتاء؟	١	نعم	Go To WW9
		٢	لا	
		٣	لا أستخدم مياه البئر في الشتاء	
		97	N/A	
		٩٨	لا جواب	
		٩٩	لا أعلم	

WW8 B	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	١	المياه مالحة
		٢	المياه كلسيّة
		3	للمياه لون، حدد_____
		٤	للمياه رائحة غريبة غير رائحة الكلور
			حدد_____
		٥	للمياه رائحة معدنيّة
		٦	المياه تترك بقعاً \ طبقة على الآواني والتجهيزات
		٧	المياه ملوّثة جرثوميّاً
		٨	غير ذلك، حدد _____
		97	N/A
		٩٨	لا جواب
		٩٩	لا أعلم
WW10	إذا كان الطعم مالحاً، منذ متى هذا الوضع؟		سنة ___|___|___|__|
		97	N/A
		٩٨	لا جواب
		٩٩	لا اعلم
WW11	هل للمبنى خزان خاص بمياه الآبار	١	نعم
		٢	لا
		٩٨	لا جواب
		٩٩	لا أعلم
WW١ ١A	ما هو حجم الخزان ؟	____	لتر
WW12	هل تتم معالجة مياه البئر قبل استعمالها؟	١	نعم، يدويّاً بواسطة أدوية كيمياويّة Go to WW13
		٢	نعم، بواسطة فلتر Go to WW14
		3	نعم، بواسطة نظام معالجة Go to WW18
		4	كلا Go to WT1A
		٩٨	لا جواب
		٩٩	لا اعلم

WW13	إذا تستعمل أدوية كيمياويّة ما هي هذه المواد؟			
	إسم المادّة	ماذا يعالج؟	الكلفة السنوية بالليرة اللبنانية	
WW13A	_____1_	_____2_	_____3__	
WW13B	_____1_	_____2_	_____3__	
WW13C	_____1_	_____2_	_____3__	
WW14	إذا كنت تستعمل فلتر، أين تضعه؟	١	على حنفيّة واحدة في المنزل، حدّد _____	
		٢	على عدّة حنفيّات في المنزل	
		٣	على خزان مياه البئر	
		٤	غير ذلك، حدّد _____ __	
		٩٨	لا جواب	
		٩٩	لا أعلم	
WW15	ماذا يعالج هذا الفلتر؟	١	ملوحة	
		٢	لون	
		٣	تلوّث ميكروبي	
		٤	تكلّس	
		٥	رواسب	
		٦	غير ذلك، حدد _____	
		٩٨	لا جواب	
		٩٩	لا اعلم	
WW16A	ما كلفة شراء وتركيب الفلتر الواحد؟		شراء وتركيب _____ ليرة	
		٩٧	N/A	
		٩٨	لا جواب	
		٩٩	لا اعلم	
WW18	ما هي وتيرة تغيير الفلتر؟	___		
	اذا كنت تستعمل نظام معالجة، ماذا يتضمن من وحدات معالجة؟			
WW19	هل يتضمن:	A محلي للمياه المالحة Reverse) (Osmosis	B تخفيف عسر المياه (الاملاح المعدنية) (Water softener)	C نظام آخر، حدد _____ أو مجموعة وحدات

		١ نعم ٢ كلا ٩٨ لا جواب ٩٩ لا أعلم	١ نعم ٢ كلا ٩٨ لا جواب ٩٩ لا أعلم	١ نعم ٢ كلا ٩٨ لا جواب ٩٩ لا أعلم
WW20	سنة الشراء	|__|__|__|__| 97 N/A ٩٨ لا جواب ٩٩ لا أعلم	|__|__|__|__| 97 N/A ٩٨ لا جواب ٩٩ لا أعلم	|__|__|__|__| 97 N/A ٩٨ لا جواب ٩٩ لا أعلم
WW21	ماذا تعالج هذه الوحدة؟	١ ملوحة ٢ لون ٣ تلوّث ميكروبي ٤ تكلّس ٥ غير ذلك، حدد ____________ ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	١ ملوحة ٢ لون ٣ تلوّث ميكروبي ٤ تكلّس ٥ غير ذلك، حدد ____________ ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	١ ملوحة ٢ لون ٣ تلوّث ميكروبي ٤ تكلّس ٥ غير ذلك، حدد ____________ ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
WW22	أين توجد هذه الوحدة؟	١ قبل الخزان الخاص بالبئر ٢ بعد الخزان الخاص بالبئر ٣ قبل الخزان المشترك للمبنى ٤ بعد الخزان المشترك للمبنى قبل الخزانات الخاصة لكل شقّة ٥ للشقّة، قبل الخزّان الخاص	١ قبل الخزان الخاص بالبئر ٢ بعد الخزان الخاص بالبئر ٣ قبل الخزان المشترك للمبنى ٤ بعد الخزان المشترك للمبنى قبل الخزانات الخاصة لكل شقّة ٥ للشقّة، قبل الخزّان الخاص	١ قبل الخزان الخاص بالبئر ٢ بعد الخزان الخاص بالبئر ٣ قبل الخزان المشترك للمبنى ٤ بعد الخزان المشترك للمبنى قبل الخزانات الخاصة لكل شقّة ٥ للشقّة، قبل الخزّان الخاص

		٦ للشقّة، بعد الخزّان الخاص ٧ على حنفيّة المطبخ ٨ غير ذلك ٩٧ N/A ٩ لا جواب ٨ ٩ لا اعلم ٩	٦ للشقّة، بعد الخزّان الخاص ٧ على حنفيّة المطبخ ٨ غير ذلك ٩٧ N/A ٩ لا جواب ٨ ٩ لا اعلم ٩	٦ للشقّة، بعد الخزّان الخاص ٧ على حنفيّة المطبخ ٨ غير ذلك ٩٧ N/A ٩ لا جواب ٨ ٩ لا اعلم ٩
		B محلي للمياه المالحة Reverse) (Osmosis	C تخفيف عسر المياه (الاملاح المعدنية) (Water softener)	D نظام آخر، حدد _____ أو مجموعة وحدات
WW23	ما كانت كلفة شراء وتركيب هذه الوحدة؟	•سعر إجمالي: _____ ليرة •لكل شقّة: _____ ليرة ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	• سعر إجمالي: _____ ليرة • لكل شقّة: _____ ليرة ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	• سعر إجمالي: _____ ليرة • لكل شقّة: _____ ليرة ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
WW24	ما كلفة تشغيل وصيانة هذه الوحدة: أدوية، كهرباء، فلاتر.	_____ ليرة لكل شقّة في السنة ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	_____ ليرة لكل شقّة في السنة ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم	_____ ليرة لكل شقّة في السنة ٩٧ N/A ٩٨ لا جواب ٩٩ لا اعلم
WW25	هل حصل أن استبدلت هذه الوحدة؟	١ نعم ٢ كلا ٩٨ لا جواب	١ نعم ٢ كلا ٩٨ لا جواب	١ نعم ٢ كلا ٩٨ لا جواب

		٩٩ لا اعلم	٩٩ لا اعلم	٩ لا أعلم ٩
WW26	كم كان عمر الوحدة القديمة عند الاستبدال؟	_____ سنة 97 N/A 98 لا جواب ٩٩ لا أعلم	_____ سنة 97 N/A 98 لا جواب ٩٩ لا أعلم	_____ سنة 97 N/A 98 لا جواب ٩٩ لا أعلم
WW27	كلفة الاستبدال لكل شقة:	_____ ليرة 97 N/A 98 لا جواب ٩٩ لا أعلم	_____ ليرة 97 N/A 98 لا جواب ٩٩ لا أعلم	_____ ليرة 97 N/A 98 لا جواب ٩٩ لا أعلم

اذا كنت تحصل على المياه من الصهاريج

صهاريج المياه (Water Tankers)		
WT1	ما هي استخدامات المياه التي تحصل عليها من صهاريج المياه	١ للشرب ٢ لغسل الأيدي للاستحمام ٣ ٤ لغسل الطعام ٥ للطبخ ٦ غسل الصحون ٧ تنظيف البيت ٨ في غرفة الغسيل

WT2	في أي شهر من السنة تبدأون عادةً بشراء المياه في الصهاريج؟	_____ ٢ على مدار السنة ٣ أحياناً عند الحاجة ٩٨ لا جواب

		٩٩ لا أعلم	
WT3	عادةً، هل يطلب الصهريج للمبنى ككلّ؟	١ نعم ٢ كلا ، للشقة فقط ٩٨ لا جواب ٩٩ لا أعلم	
WT4	أين يتم تخزين مياه الصهاريج؟	١ خزان مياه الشبكة المشترك للمبنى ٢ خزان مياه الشبكة الخاص بالشقة ٣ الخزان الخاص بالبئر ٩٨ لا جواب ٩٩ لا أعلم	
	أسئلة حول استهلاك مياه الصهاريج	**A** في الصيف	**B** في الشتاء
WT5	ما هي وتيرة طلب الصهاريج؟	____| ___| مرة في الشهر 97 N/A ٩٩ لا أعلم	____| ___| مرة في الشهر 97 N/A ٩٩ لا أعلم
WT6	ما هو حجم الصهريج الذي تطلبه؟ **(حدّد الوحدة)**	_____ 97 N/A ٩٩ لا أعلم	_____ 97 N/A ٩٩ لا أعلم
WT7	كم تدفع مقابل مياه الصهاريج؟ **(حدد الوحدة)**	_____ 97 N/A ٩٩ لا أعلم	_____ 97 N/A ٩٩ لا أعلم
WT8	ملاحظات	_____ _____ _____	_____ _____ _____
WT9 WT9A	لماذا اخترت استخدام مياه الصهاريج؟	١ الحاجة الى كمية أكبر من المياه ٢ مشكلة في مصادر المياه الأخرى ٣ سبب آخر، _____ ٩٨ لا جواب 99 لا أعلم	

WT10A	هل أنت راضٍ عن نوعيّة مياه الصهاريج التي تصل الى منزلك في فصل الصيف؟	١	نعم	
		٢	لا	Go to WT10B
		97	N/A	
		٩٨	لا جواب	
		٩٩	لا أعلم	
WT10B	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	١	المياه مالحة	
		٢	المياه كلسيّة	
		3	للمياه لون، حدد_____	
		٤	للمياه رائحة، حدد_____	
		٥	المياه تترك بقعاً \ طبقة على الأواني والتجهيزات	
		٦	المياه ملوّثة جرثوميّاً	
		٧	غير ذلك، حدد_____	
		97	N/A	
		٩٨	لا جواب	
		٩٩	لا أعلم	
WT11A	هل أنت راضٍ عن نوعيّة مياه الصهاريج التي تصل الى منزلك في فصل الشتاء؟	١	نعم	
		٢	لا	Go to WT11B
		97	N/A	
		٩٨	لا جواب	
		٩٩	لا أعلم	
WT11B	لماذا أنت غير راضٍ؟ (ممكن أكثر من جواب)	١	المياه مالحة	
		٢	المياه كلسيّة	
		3	للمياه لون، حدد_____	
		٤	للمياه رائحة، حدد_____	
		٥	المياه تترك بقعاً \ طبقة على الأواني والتجهيزات	
		٦	المياه ملوّثة جرثوميّاً	
		٧	غير ذلك، حدد_____	
		97	N/A	
		٩٨	لا جواب	
		٩٩	لا أعلم	
WT13	هل حصل وكانت المياه مالحة؟	١	نعم، دائماً	
		٢	نعم، أحياناً	
		٣	نعم، في الصيف فقط	

		٤	كلا، أبداً
		٩٨	لا جواب
		٩٩	لا أعلم
WT14	ما هو مصدر مياه الصهاريج؟	١	نبع
		٢	بئر
		٣	شركة
		٩٨	لا جواب
		٩٩	لا أعلم
WT15	حدّد اسم المصدر ورقم التلفون إذا أمكن		_____ /___|___| |___|___||___|___|___|___|
		٩٨	لا جواب
		٩٩	لا أعلم
WT16	هل تعالج مياه الصهريج قبل استعمالها؟	١	نعم، دائماً
		٢	نعم، أحياناً
		٣	نعم، في الصيف فقط
		٤	كلا، أبداً
		٩٨	لا جواب
		٩٩	لا أعلم
WT17	ما هي طرق المعالجة المتّبعة؟		_____ _____ _____ _____ _____
		97	N/A
		٩٨	لا جواب
		٩٩	لا أعلم

إذا كنت تشتري المياه المعبأة:

المياه المعبأة (Bottled Water)			
BW1	ما هي استخدامات المياه المعبّأة؟	١	للشرب
		٢	لغسل الأيدي
		٣	للاستحمام
		٤	للطبخ

BW2	عدّد أنواع العبوات التي يستهلكها منزلك؟	**A** نوع ١ _____	**B** نوع ٢ _____	**C** نوع ٣ _____
BW3	ما هي سعة العبوة؟	|___|___| ليتر ٩٩ لا أعلم	|___|___| ليتر ٩٩ لا أعلم	|___|___| ليتر ٩٩ لا أعلم
BW4	كم عبوة يستهلك المنزل في الأسبوع؟	|___|___| ٩٩ لا أعلم	|___|___| ٩٩ لا أعلم	|___|___| ٩٩ لا أعلم
BW5	كم تدفع عن كل عبوة؟	|___|___||___|___| ليرة ٩٩ لا أعلم	|___|___|___|___| ليرة ٩٩ لا أعلم	|___|___||___|___| ليرة ٩٩ لا أعلم
BW6	لماذا اخترت استخدام المياه المعبأة؟ (ممكن اكثر من جواب)	١ طعمها أفضل ٢ أسباب صحية ٣ مشكلة في مصادر المياه الأخرى	١ طعمها أفضل ٢ أسباب صحية ٣ مشكلة في مصادر المياه الأخرى	١ طعمها أفضل ٢ أسباب صحية ٣ مشكلة في مصادر المياه الأخرى
BW61		٤ سبب آخر _____ ٩٨ لا جواب	٤ سبب آخر _____ ٩٨ لا جواب	٤ سبب آخر _____ ٩٨ لا جواب
BW7	كيف تصنّف نوعية هذه المياه؟	1 جيدة 2 متوسطة 3 سيئة 98 لا جواب	1 جيدة 2 متوسطة 3 سيئة 98 لا جواب	1 جيدة 2 متوسطة 3 سيئة 98 لا جواب

الآن سوف أسأل عن تخزين المياه في منزلك:

خزانات المياه (Storage Tanks)								
ST1	**عدد خزانات المياه** المستخدمة لتأمين المياه الى منزلك **(مشتركة وخاصة)** |___|							
ST2		**١ الخزان ١**		**٢ الخزان ٢**		**٣ الخزان ٣**	**٤ الخزان ٤**	
ST2A	لمن الخزان؟	١ خاص للمنزل	١	خاص للمنزل	١	خاص للمنزل	١	خاص للمنزل
		٢ مشترك للمبنى	٢	مشترك للمبنى	٢	مشترك للمبنى	٢	مشترك للمبنى
		٩٨ لا جواب	٩٨	لا جواب	٩٨	لا جواب	٩٨	لا جواب
		٩٩ لا أعلم	٩٩	لا أعلم	٩٩	لا أعلم	٩٩	لا أعلم

ST2B	موقع الخزان:	١	الطابق الأرضي	١	الطابق الأرضي	١	الطابق الأرضي	١	الطابق الأرضي
		2	تحت الأرض	2	تحت الأرض	2	تحت الأرض	2	تحت الأرض
		٣	سطح المبنى	٣	سطح المبنى	٣	سطح المبنى	٣	سطح المبنى
		٤	تختيّة الشقة	٤	تختيّة الشقة	٤	تختيّة الشقة	٤	تختيّة الشقة
		٩٩	لا أعلم	٩٩	لا أعلم	٩ ٩	لا أعلم	٩٩	لا أعلم
ST2C	المادة المكوّنة للخزان:	١	معدن	١	معدن	١	معدن	١	معدن
		٢	إسمنت	٢	إسمنت	٢	إسمنت	٢	إسمنت
		٣	بلاستيك	٣	بلاستيك	٣	بلاستيك	٣	بلاستيك
		4	إتيرنيت	4	إتيرنيت	4	إتيرنيت	4	إتيرنيت
ST2C1		5	غير ذلك، حدد: _____	5	غير ذلك، حدد: _____	5	غير ذلك، حدد: _____	5	غير ذلك، حدد: _____
		٩٩	لا أعلم	٩٩	لا أعلم	٩ ٩	لا أعلم	٩٩	لا أعلم
ST2D	هل الخزان:	١	مغطّى	١	مغطّى	١	مغطّى	١	مغطّى
		٢	مفتوح	٢	مفتوح	٢	مفتوح	٢	مفتوح
		٣	مقفل	٣	مقفل	٣	مقفل	٣	مقفل
		٩٩	لا أعلم	٩٩	لا أعلم	٩ ٩	لا أعلم	٩٩	لا أعلم
ST2E	سعة الخزان:	|___|___|.___|___| _ م^3 برميل		|___|___|.___|___| م^3 برميل		|___|___|.___| ___ م^3 برميل		|___|___|.___|___| _ م^3 برميل	
		٩٨	لا جواب	٩٨	لا جواب	٩ ٨	لا جواب	٩٨	لا جواب
		٩٩	لا أعلم	٩٩	لا أعلم	٩ ٩	لا أعلم	٩٩	لا أعلم

		١ الخزان ١	٢ الخزان ٢	٣ الخزان ٣	٤ الخزان ٤
ST2F	مصادر مياه الخزان (ممكن أكثر من جواب):	١ مياه الشبكة ٢ مياه البئر ٣ مياه الصهاريج ٤ مياه الشتاء ٩٨ لا جواب ٩٩ لا أعلم	١ مياه الشبكة ٢ مياه البئر ٣ مياه الصهاريج ٤ مياه الشتاء ٩٨ لا جواب ٩٩ لا أعلم	١ مياه الشبكة ٢ مياه البئر ٣ مياه الصهاريج ٤ مياه الشتاء ٩٨ لا جواب ٩٩ لا أعلم	١ مياه الشبكة ٢ مياه البئر ٣ مياه الصهاريج ٤ مياه الشتاء ٩٨ لا جواب ٩٩ لا أعلم
ST2G ST2G1	وتيرة تنظيف الخزان:	١ ولا مرة ٢ عند الحاجة ٣ سنوياً ٤ كل ستة أشهر ٥ غير ذلك، حدد ___________ 97 N/A ٩٨ لا جواب ٩٩ لا أعلم	١ ولا مرة ٢ عند الحاجة ٣ سنوياً ٤ كل ستة أشهر ٥ غير ذلك، حدد ___________ 97 N/A ٩٨ لا جواب ٩٩ لا أعلم	١ ولا مرة ٢ عند الحاجة ٣ سنوياً ٤ كل ستة أشهر ٥ غير ذلك، حدد ___________ 97 N/A ٩٨ لا جواب ٩٩ لا أعلم	١ ولا مرة ٢ عند الحاجة ٣ سنوياً ٤ كل ستة أشهر ٥ غير ذلك، حدد ___________ 97 N/A ٩٨ لا جواب ٩٩ لا أعلم
ST2H	حدد الأسباب التي تدفعك إلى تنظيف الخزان	___________ ___________ ___________ ___________ ٩٧ N/A ٩٨ لا جواب ٩٩ لا أعلم	___________ ___________ ___________ 97 N/A ٩٨ لا جواب ٩٩ لا أعلم	___________ ___________ ___________ ___________ ___________ 97 N/A ٩٨ لا جواب ٩٩ لا أعلم	___________ ___________ ___________ ___________ 97 N/A ٩٨ لا جواب ٩٩ لا أعلم

ST2I	هل تتم معالجة مياه الخزان قبل استعماله ؟ا	١	نعم، يدويّا بواسطة أدوية كيمياويّة	١	نعم، يدويّا بواسطة أدوية كيمياويّة	١ نعم، يدويّا بواسطة أدوية كيمياويّة	١	نعم، يدويّا بواسطة أدوية كيمياويّة
		2	نعم، بواسطة فلتر	2	نعم، بواسطة فلتر	2 نعم، بواسطة فلتر	2	نعم، بواسطة فلتر
		3	نعم، بواسطة نظام معالجة	3	نعم، بواسطة نظام معالجة	3 نعم، بواسطة نظام معالجة	3	نعم، بواسطة نظام معالجة
		٤	معالج سابقا	٤	معالج سابقا	٤ معالج سابقا	٤	معالج سابقا
		٥	كلا	٥	كلا	٥ كلا	٥	كلا
		٩٨	لا جواب	٩٨	لا جواب	٩ ٨ لا جواب	٩٨	لا جواب
		٩٩	لا أعلم	٩٩	لا أعلم	٩ ٩ لا أعلم	٩٩	لا أعلم

			١ الخزان ١	٢ الخزان ٢	٣ الخزان ٣	٤ الخزان ٤
ST2LA	ما هي المادة المكوّنة للخزان القديم؟	١	معدن	١ معدن	١ معدن	١ معدن
		٢	إسمنت	٢ إسمنت	٢ إسمنت	٢ إسمنت
		٣	بلاستيك	٣ بلاستيك	٣ بلاستيك	٣ بلاستيك
		4	إتيرنيت	4 إتيرنيت	4 إتيرنيت	4 إتيرنيت
ST2LA1		5	غير ذلك، حدد: _____	5 غير ذلك، حدد: _____	5 غير ذلك، حدد: _____	5 غير ذلك، حدد: _____
		٩٨	لا جواب	٩٨ لا جواب	٩٨ لا جواب	٩٨ لا جواب
		٩٩	لا أعلم	٩٩ لا أعلم	٩٩ لا أعلم	٩٩ لا أعلم
ST3	**إذا كنت تستخدم مياه الشتاء، إشرح عن كيفية حصاد مياه الشتاء:**			_____ _____ _____ _____ _____ _____		
				97 N/A		
				٩٨ لا جواب		
				٩٩ لا اعلم		

الآن سوف أسألك عن تجميع مياه الأمطار

مياه الشتاء

RW1	إذا كنت تستخدم مياه الشتاء ، متى تم تركيب نظام تجميع مياه الأمطار	سنة_____
RW2	لماذا قررت إستخدام تقنية تجميع مياه الأمطار ؟	1 لا يوجد مصدر مياه أخر 2 للتوفير من كلفة شراء مياه من مصدر أخر 3 جيد للمحافظة على البيئة 4 لتوفير مياه لري الحديقة/المزروعات 5 لتوفير مياه لتنظيف البيت 6 النظام كان مركب قبل سكننا في هذه الشقة 7 غير ذلك؛ حدد 98 لا جواب 99 لا اعلم
RW3	ما هي سعة الخزان المستخدم لتجميع مياه الأمطار ؟	1 خزان واحد أو أكثر <١٠٠٠ لتر 2 خزان واحد أو أكثر بين ١٠٠٠ و-١٠٠٠٠ لتر 3 خزان واحد أو أكثر> ١٠٠٠٠ لتر 4 غير ذلك؛ حدد 98 لا جواب 99 لاأعلم
RW4	ما هي نوعية الخزان المستخدم لتجميع مياه الأمطار ؟	1 حديد 2 بلاستيك 3 اسمنت 4 غير ذلك ، حدد 98 لا جواب 99 لا اعلم
RW5	إذا عندك نظام لتجميع مياه الأمطار لكنك لا تستخدمه ما هو السبب ؟	1 عملية بناء هذا النظام ليست مكتملة 2 النظام غير فعال 3 كمية الأمطار التي يمكن حصادها ليست كافية 4 لا أحب أن استخدم مياه الأمطار 5 لون مياه الأمطار التي تم حصدها ليس مقبول 6 وجود أوساخ وحشرات 7 غير ذلك؛ حدد 98 لا جواب 99 لاأعلم
RW6	إذا لا يوجد عندك نظام لتجميع مياه الأمطار؛ ما هو السبب؟	1 لا يوجد مساحة خارجية للشقة لتثبيت خزانات مياه 2 هذه الشقة مستأجرة لا يوجد قساطل مياه مناسبة لنقل المياه من السطح إلى 3الخزان 4 لا أعرف/لم أسمع عن هذه التقنية كلفة 5تركيب 6 لا أعتقد أن هذه التقنية ستوفر علي مادياً 7 نوعية مياه الامطار ليست جيدة 8 لا أعتقد أن هناك أي أثر ايجابي على البيئة 9 لا يوجد لدي مدخل إلى السطح

		10 غير ذلك؛ حدد
RW7	هل تعتقد أن تجميع مياه الأمطار تقنية جيدة يمكن استخدامها إضافة إلى مصادر المياه الأخرى؟	1 نعم 2 كلا 98 لا جواب 99 لاأعلم
RW8	إذا لا، ما هو السبب ؟	1 كمية المياه التي يمكن الحصول عليها ليست كافية 2 أعتقد أن نوعية مياه الأمطار ليست جيدة للاستخدام لأنها ملوثة كلفة الحصول على مياه الأمطار هي أكثر من كلفة أي مصادر 3 أخرى 4 غير ذلك؛ حدد
RW9	برأيك، ما هي الوسيلة الأفضل للحصول على معلومات حول تقنية حصاد مياه الأمطار؟	1 وسائل الإعلام راديو تليفزيون جريدة 2 مراكز العمل والمدارس 3 الإجتماعات العامة والمعارض 4 رسائل نصية 5 على فاتورة المياه 6 على الإنترنت (مواقع التواصل الإجتماعي، مواقع الوزارات
RW١٠	هل يوجد مساحة خاصة للشقة لوضع خزان المياه؟	1 نعم 2 كلا
RW١١	ما هي المساحة التي يمكن استخدامها لوضع خزان المياه؟	_____m^2 في كاراج المبنى أو تحت الأرض _____m^2 فوق الأرض
RW١٢	لأي اغراض برأيك يمكن أن تستخدم مياه الأمطار ؟	1 لجميع الاستخدامات المنزليه 2 لجميع الاستخدامات المنزلية ما عدا الشرب 3 للتنظيف والغسيل 4 لري المزروعات ٥ لجميع الاستخدامات المنزلية والشرب في حال إستخدام نظام معالجة 6 غير ذلك حدد
RW13	في حال إقامة مشاريع حصاد مياه الأمطار عن أسطح المنازل، هل لديك رغبة للمساهمة في مثل هذه المشاريع؟	1 المساهمة بالمال 2 المساهمة بالعمل 3 لا ارغب 4 غير ذلك، حدد
RW14	ما هي الملوثات التي تتوقع وجودها في مياه الأمطار ؟	
RW15	ما هي القيمة المادية التي أنت مستعد لدفعها للحصول على نظام معالجة لهذه الملوثات	_____ليرة

الآن سوف أسألك بعض الأسئلة عن استعدادك للمساهمة في بناء شبكة لتجميع مياه الأمطار

Willingness to pay for a rainwater harvesting system		
WTPRW1	ما هو الحد المالي الأقصى الذي أنت مستعد لدفعه لبناء شبكة لتجميع مياه الأمطار ؟	---------- 98 لا جواب 99 لا أعلم

	في حال المصدر الحالي الذي تستخدمه لم يعد موجوداً		
WTPRW2	هل أنت مهتم بمشاركة نظام تجميع الأمطار مع جيرانك في المبنى ؟	1 2 98 99	نعم كلا لا جواب لا أعلم
WTPRW3	إذا كان هناك خطة من قبل البلدية لتجميع مياه الأمطار هل أنت مستعد لدفع أي مبلغ؟	1 2 98 99	نعم كلا لا جواب لا أعلم
WTPRW4	ما هو المبلغ الشهري (الليرة اللبنانيّة) الذي تستعدّ لدفعه للمساهمة في الخطّة؟	_____ 98 99	 لا جواب لا أعلم

سوف أطرح عليك بعض الأسئلة حول الإستعداد للدفع

الإستعداد للدفع (Willingness to Pay)			
WTP1	بالنسبة لملوحة المياه في منزلك، هل ترى وجوب اتخاذ اجراءات لتخفيض نسبة الملوحة؟	1 ٢ ٩٨ ٩٩	نعم كلا لا جواب لا أعلم
WTP2A	إذا تمّ وضع **خطة لحماية الآبار الجوفيّة من ارتفاع نسبة الملوحة في مياهها**، هل أنت مستعدّ لدفع أيّ مبلغ للمساهمة في الخطّة؟	١ ٢ ٩٧ ٩٨ 99	نعم Go to WTP2B كلا، لست مستعدّاً لدفع أيّ مبلغ Go to WTP2C N/A لا جواب لا أعلم
WTP2B WTP2C	ما هو المبلغ الشهري (الليرة اللبنانيّة) الذي تستعدّ لدفعه للمساهمة في الخطّة؟ حدد أول مبلغ تقترحه على المجيب:_____ ل ل	 N/A 98 99	|___|___|___|,|___|___|___| ليرة Go to WTP ٩٧ لا جواب لا أعلم
WTP2C	لماذا أنت غير مستعدّ؟	١	لا أملك الإمكانية لتحمّل أي كلفة إضافية

WTP2C1		٢	أرفض فكرة المساهمة في حماية الآبار
		3	أرفض فكرة وضع قيمة نقدية لنوعية المياه
		4	لا أثق بالجهة المنفذة (الدولة)
		٥	غيره، حدد _____
		97	N/A
		٩٨	لا جواب
		٩٩	لا أعلم
WTP3A	إذا هناك **إجراءات أو معالجات للحدّ أو تخفيض نسبة الملوحة في مياه البئر الإرتوازي الذي تستخدمه،** هل أنت مستعدّ لدفع أيّ مبلغ للمساهمة في ذلك؟	١	نعم Go to WTP3B
		٢	كلا، لست مستعدّاً لدفع أي مبلغ Go to WTP3C
		٩٧	N/A
		٩٨	لا جواب
		٩٩	لا أعلم
WTP3B	ما هو المبلغ **<u>الشهري</u>** (الليرة اللبنانيّة) الذي تستعدّ لدفعه لذلك؟		|___|___|___|,|___|___|___| ليرة Go to SD1
WTP3C	حدد أوّل مبلغ تقترحه على المجيب:_____ ل ل	٩٧	N/A
		98	لا جواب
		99	لا أعلم
WTP3C1	لماذا أنت غير مستعدّ؟	١	لا أملك الإمكانية لتحمّل أي كلفة إضافية
		٢	أرفض فكرة المساهمة في معالجة ملوحة مياه الآبار
		3	أرفض فكرة وضع قيمة نقدية لنوعية المياه
		٤	غيره، حدد _____

		N/A 97 ٩٨ لا جواب ٩٩ لا أعلم

Factors affecting the possibility of installing the water reuse system			
WTPWR1	ماذا يحصل لمياه الصرف الصحي في المبنى ؟	1 2 ٣ ..... 98 99	موصولة بشبكة التصريف العامة هناك جورة صحية جواب آخر لا جواب لا أعلم
WTPWR2	ما رأيك بفكرة تكرير وإعادة إستخدام مياه الصرف الصحي لأغراض منزلية كدافق المرحاض ، وتنظيف الأرضيات، وتنظيف المرآب، وغسيل السيارات وري النباتات؟	1 2 98 99	فكرة جيدة ليست فكرة جيدة. السبب: لا جواب لا أعلم
WTPWR3	ما رأيك بفكرة تكرير وإعادة إستخدام المياه الرمادية (غسيل اليدين، الإستحمام، و غسيل الثياب) لأغراض منزلية كدافق المرحاض ، وتنظيف الأرضيات، وتنظيف المرآب، وغسيل السيارات وري النباتات؟	1 2 98 99	فكرة جيدة ليست فكرة جيدة. السبب: لا جواب لا أعلم
WTPWR4	هل تمانع تعديل شبكة القساطل في منزلك لتركيب قساطل خاصة بالمياه المكررة إن كان ذلك يوفر عليك مادياً؟	1 2 98 99	نعم كلا لا جواب لا أعلم
WTPWR5	هل بنظرك أن سكان المبنى قد يدعمون مادياً مشروع كهذا إن كان يؤدي إلى خفض مصروف المياه وبالتالي يحول دون مواجهة مشكلة إنقطاع وشراء المياه في الصيف؟	1 2 98 99	نعم كلا لا جواب لا أعلم
WTPR٦	ما هو الحد المالي الأقصى الذي أنت مستعد لدفعه لتركيب نظام إعادة إستعمال للمياه	98 لا 99	لا جواب أعلم

WTPR7	هل أنت مهتم بمشاركة نظام إعادة إستعمال المياه مع جيرانك في المبنى	1 2 98 99	نعم كلا لا جواب لا أعلم

WTPR8	إذا كان هناك خطة من قبل البلدية لإعادة إستعمال المياه هل أنت مستعد للمشاركة؟	1نعم 2 كلا 98 لا جواب 99 لا أعلم
WTPR9	الذي تستعد لدفعه للمشاركة في (الليرة اللبنانية)ما هو المبلغ الشهري الخطة ؟	_____ 98 لا جواب 99 لا أعلم

سوف أطرح الآن بعض الاسئلة عن العائلة والعمل:

معلومات اجتماعية وديموغرافية (Socio-Demographic and Work Information)																
	SD1	ما هو عدد الأفراد الذين يسكنون في المنزل؟ _____														
		SD2		SD3	SD4	SD5		SD6		SD7		WI1		WI2		
		علاقته برب المنزل:		الجنس:	سنة الولادة:	هل هذا الفرد:		أين يتعلّم حاليا؟		أعلى مستوى علمي حصّله:		هل يعمل حاليا، ما العمل الحالي:		في أيّ قطاع يعمل؟		
	إسم الفرد الذي يسكن في المنزل:	١	رب المنزل	١ ذكر	سنة	١	لم يتعلّم	١	مدرسة خاصّة	١	لا يقرأ ويكتب	١	لا يعمل	١	مؤسّسة خاصة	
		٢	زوجة	٢ أنثى	____	**Go to SD7**		٢	مدرسة رسميّة	٢	يقرأ ويكتب	2	صاحب مؤسسة	٢	مؤسّسة عامة	
		٣	إبن \ إبنة			٢	تعلم/ تخرج	٣	الجامعة اللبنانية	٣	إبتدائي	3	موظّف	٣	جمعيّة	
		٤	أب \ أم			**Go to SD7**		٤	جامعة خاصّة	٤	متوسّط	4	ربّ عمل \ مدير			
		٥	أخ \ أخت			٣	يتعلم حالياً	٥	معهد	٥	ثانوي	5	ربة منزل			
		٦	حفيد \ حفيدة			**Go to SD6**				٦	تقني	٦	متقاعد			
		٧	الصهر\ الكنة							٧	جامعي					
		٨	غيره							٨	دراسات عليا					
		٩٧	N/A			٩٧	N/A	٩٧	N/A	٩٧	N/A	٩٧	N/A	٩٧	N/A	
		٩٨	لا جواب			٩٨	لا جواب	٩٨	لا جواب	٩٨	لا جواب	٩٨	لا جواب	٩٨	لا جواب	
		٩٩	لا أعلم			٩٩	لا أعلم	٩٩	لا أعلم	٩٩	لا أعلم	٩٩	لا أعلم	٩٩	لا أعلم	
A		____		____	____	____		____		____		____		____		
B		____		____	____	____		____		____		____		____		
C		____		____	____	____		____		____		____		____		
D		____		____	____	____		____		____		____		____		
E		____		____	____	____		____		____		____		____		
F		____		____	____	____		____		____		____		____		
G		____		____	____	____		____		____		____		____		
H		____		____	____	____		____		____		____		____		

سوف أطرح عليك بعض الأسئلة حول الوضع المالي العام لمنزلك:

الوضع المالي (Financial Status)			
FS1	عدد الغرف في المنزل: **فقط النوم والصالونات** (دون المطبخ، الحمام، الشرفة والمخزن/موقف السيارة)		|___|___|
FS2	هل تملك المنزل الذي تسكن فيه؟	١	نعم، ملك
		٢	كلا، إيجار
		٣	كلا،
			حدد_____
		٩٨	لا جواب
		٩٩	لا أعلم
FS3	ما هو المصروف الشهري الإجمالي للعائلة؟		|___|___|,|___|___|___|,|___|___| ليرة
		٩٨	لا جواب
		٩٩	لا اعلم
FS5	ما هو الدخل الشهري الإجمالي للمنزل؟	1	٥٠٠ دولار وما دون
		٢	٥٠٠-١٥٠٠ دولار
		٣	١٥٠٠-٤٠٠٠ دولار
		٤	٤٠٠٠ – ٦٠٠٠ دولار
		٥	أكثر من ٦٠٠٠ دولار
		٩٨	لا جواب
		٩٩	لا أعلم
FS6	ما عدد السيّارات التي يملكها سكّان المنزل؟		|___|___|
		98	لا جواب
		99	لا اعلم

Appendix 3

Setup used to collect rooftop rainwater

Setup used to collect rainwater for physicochemical testing

Setup used to collect rainwater for microbiological testing

Appendix 4

Rainfall Coefficient

Rainfall Coefficient respective to types of surface
(Texas Water Development Board. 2005)

Type	*Runoff coefficient*
Galvanized iron sheets	>0.9
Tiles (glazed)	0.6-0.9
Aluminum sheets	0.8-0.9
Flat cement roof	0.6-0.7
organic	0.2

Appendix 5
Estimates of material and labor costs

Estimates of material and labor costs ($) required for the construction of a rainwater harvesting system

Input description		*units*	*Material cost ($)*	*Labor cost ($)*	*Total cost ($)*	*Life span*
Plastic storage tanks (cylindrical poly tanks)	6 m^3	m^3	675	-	675	40
	8 m^3	m^3	720	-	720	40
	10 m^3	m^3	1200	-	1200	
Prefabricated concrete storage tanks	5 m^3	unit	3500	-	3500	40
	10 m^3	unit	5500	-	5500	40
	25 m^3	unit	8000	-	8000	40
	40 m^3	unit	12000	-	12000	40
Pavement		m^2	75	50	125	40
Sand backfilling		m^2	20	50	70	40
Brick		m^2	0.75	50		40
Concrete material		Kg	2.0	-		
Construction services		h	-	750	750	40
PVC pipes	120 – 160 mm diameter	unit	20.6	-	200	25
pump	-	unit	533	-	533	15
Filter screen	-	unit	400	-	400	5
Level control	-	unit	166	-	166	15

Appendix 6
Types of contaminants typically found in RWHS

Types of contaminants typically found in rainwater systems and their associated mitigation measures (Mosley, 2005)

Contaminant	*Source*	*Mitigation measure*
Dust and ash	Surrounding dirt and vegetation Volcanic activity Car exhausts and generators	Use of first flush system Regular maintenance of roof and gutters
Pathogenic bacteria	Bird and other animal droppings on the roof	Use of first flush system Regular maintenance of roof and storage tanks
Heavy metals	Dust, particularly in industrialized areas	
Mosquito Larvae	Mosquitoes laying eggs in gutters and tanks	

Appendix 7
Types and characteristics of storage tanks

Types and Characteristics of Storage Tanks Used for Storage of Rainwater

Type of Storage tank	*Location*	*Capacity (m^3)*	*Characteristics*
Fiberglass	Above ground	0.2 - 57	Vertical and low-horizontal cylinder shaped Relatively expensive for sizes < 4 m^3 Easily repaired
Polypropylene	Above ground	0.2 - 38	Relatively inexpensive, durable, and light weight Bulkhead fittings might be subject to leakage Do not retain paint well UV-degradable
Wood	Above ground	2.6 - 140	For aesthetic appeal; made up of cedar, pine, or cypress trees Easily dismantled and reassembled at different locations Relatively expensive

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