Resources, Conservation and Recycling 73 (2013) 72–77

Contents lists available at SciVerse ScienceDirect

Resources, Conservation and Recycling

journal homepage: www.elsevier.com/locate/resconrec

On-site rainwater harvesting to achieve household water security among rural and peri-urban communities in Jordan

Almoayied Assayed*, Zaid Hatokay, Rania Al-Zoubi, Shadi Azzam, Mohammad Qbailat, Ahmad Al-Ulayyan, Ma'ab Abu Saleem, Shadi Bushnaq, Robert Maroni

Mercy Corps Organization, Amman 11183, P.O. Box 830684, Jordan

ARTICLE INFO

Article history:
Received 26 December 2011
Received in revised form 13 January 2013
Accepted 17 January 2013

Keywords:
Rainwater harvesting
Water demand management
Community based organization
Household water security
Revolving loans

ABSTRACT

This paper presents the experience of Mercy Corps' "Community Based Initiatives for Water Demand Management" project, a five year project (2006–2011), in terms of community-based initiatives for water management. This project was designed to build the capacity of local community-based organizations (CBOs) to raise the awareness level around water demand management (WDM) and engage community members in water management measures. It showed how local solutions decrease the reliance on public water systems and ultimately help in facing the water shortage on a national level. This paper also showed that on-site rainwater harvesting Cisterns funded through this project have been able to harvest 88,335 m^3 annually. The paper found that rainwater harvesting at household level was able to save an average of 24% in potable water per year.

1. Background

Jordan is one of the ten most water-deprived countries in the world. Available per capita fresh water lags far behind that available in most other countries. In the year 2008 the renewable freshwater resources available per capita in Jordan were about 145 m^3/year. This is less than one third of the widely recognized "water poverty line" of 500 cubic meters per capita per year (Jordan's Water Strategy, 2008)

Jordan is located in an arid to semi-arid part of the world where water resources are limited and scarce. Water resources are highly dependent on rainfall, which varies in quantity, intensity and distribution from year to year. Surface water supplies contribute approximately 37% of Jordan's total water supply. Groundwater contributes 54% of the total water supply. The unsustainable abstraction of groundwater due to population growth, rainfall shortage and agricultural expansion is a major problem today. Ten out of 12 water basins are over pumped and groundwater is used at twice the recharge rate (Nortcliff et al., 2008).

Demand for water far exceeds supply and the deficit is increasing. The future challenges on water demand are enormous. Any unexpected population growth due to regional instability, as was the case during the past decades, would further increase water demand and impact the country's plans to reach a balanced demand and supply (Annual report, 2007).

The Jordanian government has realized this alarming water status. The ministry of water and irrigation (the official body dealing with all water-related issues in the country) has identified several measures to reduce the stress on available water resources and to ensure that water is allocated wisely for all sectors. In Jordan's water strategy for 2008–2022, rainwater harvesting has been considered a potential measure to reduce water demand and a significant alternative resource for domestic and irrigation water supply. Jordan's water strategy states: "*Jordan will encourage regulations to encourage rainwater harvesting*". In water supply section, the strategy stipulates "*we will look to maximizing the use of alternative water resources including the use of greywater and rainwater harvesting*".

In May 2006, Mercy Corps Organization (MC), with a financial support from the United States Agency for International Development (USAID), began implementing the project entitled "Community Based Initiatives for Water Demand Management in Jordan (CBIWDM)". This five-year project was designed to enable communities in Jordan to improve water use efficiency through building the local CBOs' capacity to take the lead in promoting and raising the awareness of their constituents around Water Demand Management. The whole project is based on the concept of revolving loans, in which each CBO received a specific amount of

Abbreviations: MC, Mercy Corps Organization; WDM, Water Demand Management; CBOs, Community Based Organizations; CBIWDM, Community Based Initiative for Water Demand Management; USAID, United States Agency for International Development; FF, Filling Frequency; CV, Cistern Volume; nC, number of Cisterns; VR, volume of rainfall that could be harvested; AR, average rainfall; A, catchment area.

* Corresponding author. Tel.: +962 777 726 716; fax: +962 554 85 73.
E-mail addresses: almoayied.assayed@gmail.com, moayed1948@yahoo.com (A. Assayed).

0921-3449/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.resconrec.2013.01.010

money as a grant. These grants are managed by the selected CBOs and operated as revolving loan funds to support households and small farms to develop and implement water saving and efficiency projects.

This paper tackles rainwater harvesting revolving projects implemented through the "Community Based Initiatives for Water Demand Management in Jordan CIBIWDM" project. The aim of this paper is to evaluate the role of rainwater harvesting projects in household water security and estimate how much on-site rainwater harvesting contributes in Jordan's water budget.

2. Method

2.1. Selection of eligible Community Based Organizations

Throughout the project's life span, 135 Community Based Organizations (CBOs) have been awarded averaging 10,000 JDs ($ 14,114 USD). The selection of participating CBOs was done through a highly-competitive and transparent process involving all relevant stakeholders. Evaluation process started with an invitation of all CBOs to a "Project Awareness Session", in which general objectives of the project were explained and discussed. Afterwards, all interested CBOs were asked to attend a "Proposal Orientation Workshop", where proposal template was discussed and then distributed. All proposals that had been received before the deadline were considered and evaluated. The evaluation of proposals went through the following subsequent steps:

(1) Site visits to all CBOs who submitted proposals: the purpose of site visits was to discuss the proposal items and to ensure that all information mentioned in the proposal is accurate. The site visit report was attached with the original proposal to be considered in later steps.
(2) All information gathered through the field visit and mentioned in the proposal was summarized by using an evaluation matrix, developed by the project team.
(3) All proposals, in addition to the field visit reports and evaluation matrix, were thoroughly studied and discussed by the project's steering committee, which is comprised of representatives of relevant governmental bodies, international donors and experts in Water Demand Management. Depending on the proposals, field visit reports as well as the evaluation matrix, the steering committee was able to finally select the eligible CBOs for funding.

2.2. Building the managerial and technical capacity of granted CBOs

The CBIWDM started out by building the leadership capacity of the local CBOs in project management and technical aspects related to Water Demand Management projects. The managerial training includes: 1 day of revolving loan management and 2 days of business management training. The technical training is comprised of: estimating the Cistern Volume required for rainwater harvesting, health aspects related to rainwater harvesting, gray water management at household level, best management practices to manage irrigation water at farm level including drip irrigation techniques, springs rehabilitation, and residential network maintenance. In addition to the formal training listed above, CBOs received on-the-job training during supervision and monitoring visits by project team members to reinforce learning and insure smooth implementation of the Water Demand Management projects.

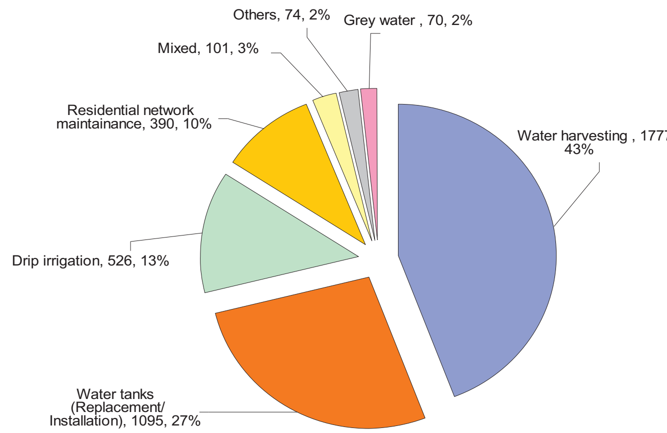

Fig. 1. The distribution of beneficiaries within CBIWDM.

2.3. Disbursing loans and starting implementation

After acquiring the required technical and managerial knowledge, CBOs began disbursing loans to beneficiaries in order to implement Water Demand Management projects. The types of projects funded by CBOs are varied due to several factors, such as: average rainfall, land topography and community interest. Examples of such projects are rainwater harvesting Cisterns and reservoirs, roman Cistern rehabilitation, residential network maintenance, drip irrigation, small agricultural canal maintenance, spring improvement, gray water treatment and other small-scale high impact water efficiency investments. Fig. 1 shows the distribution of individual beneficiaries according to the type of project.

As shown in the figure above, rainwater harvesting projects have been the most dominant project within CBIWDM. Granted CBOs have given 1777 revolving loans for rainwater harvesting to local beneficiaries (average of 1200 $ for each loan), which constitutes 43% of all projects. This can be attributed to three main factors: firstly, people in rural and peri-urban areas in Jordan look at rainwater harvesting as a conventional and indigenous technique to save water. This technique has been used in Jordan for thousands of years, in particular during the Roman Empire. Although modern services have reduced reliance on such age-old traditions, abundant of ancient roman rainwater harvesting is still in use since then. The second factor is that, the know-how of establishing a rainwater harvesting system among rural communities is well-known. Households who obtained the loans have been able to design and construct the rainwater harvesting system without any external assistance. The last factor is that the impact of rainwater harvesting on household water supply is direct and tangible, in contrary to other projects where the impacts are indirect or require more time to be evaluated.

2.4. Rainwater harvesting: salient revolving project in CBIWDM

Rainwater harvesting is a technology best described as the collection and storage of rainwater runoff from rooftops, land surfaces, road surfaces or rock catchments (Abdulla and Al-Shareef, 2009; Kahinda et al., 2007). Every rainwater harvesting system consists of a catchment surface for collecting rainwater (i.e. roof or ground surface) and a delivery system for transporting rainwater into a storage tank (Zimmermann et al., 2009; Hanida et al., 2003).

More than 1777 rainwater harvesting Cisterns have been implemented through the project of CBIWDM. Two structures have been adopted for rainwater storage. An underground pear-shape storage Cistern has been the preferred structure as this structure does not need concrete and steel. This structure can only be installed in

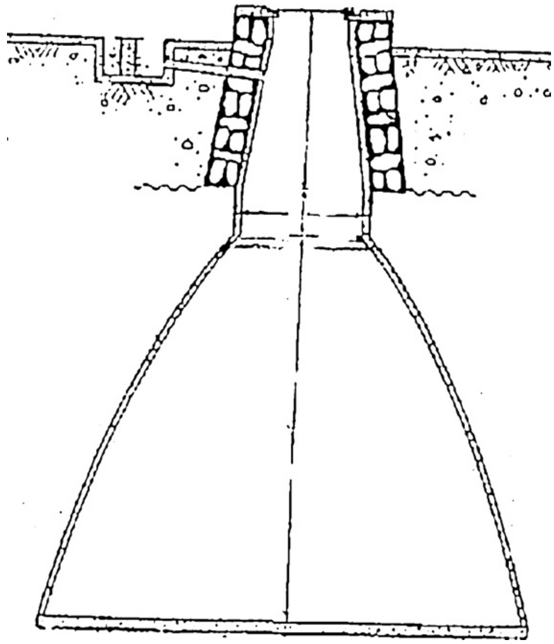

Fig. 2. Pear-shape storage Cistern.

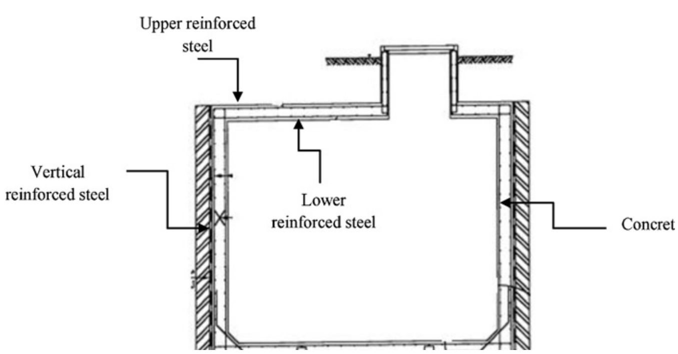

Fig. 3. Square-shape reinforced Cistern.

rocky soil where the round underground structure does not collapse due to the hard rock formations. The walls are then lined by 3 layers of plastering of which the final layer may consist of a waterproofing material (Fig. 2). In locations where land topography and soil structures are not suitable for the pear-shape Cistern (i.e., extremely steep land or sandy soil), a square-shape reinforced Cistern is used. This structure requires steel and concrete and can be built underground, above ground, or semi-underground (Fig. 3).

The catchment area can be either from the top of a house roof, where water can be used for drinking if best management practices are followed (such as, distance from any pollution source and clean-up of the roof from any pollutants), or from the ground or street runoff, where water can be used for supplementary irrigation or livestock watering. However, most of rainwater harvesting projects implemented within CBIWDM have been utilized for potable purposes.

2.5. Cistern capacity calculation

To find out the storage capacity for the rainwater harvesting system, the annual quantity of rainwater that could be harvested is calculated. The volume of rainwater that could be harvested at household is determined by using the equation below:

$$\mathrm{VR} = \mathrm{AR} \times A \times C$$

Table 1
Filling Frequency in Jordanian governorates.

Governorate	Average rainfall (mm)	The annual water that could be harvested (m^3)[a]	The minimum storage capacity for Cistern	Filling Frequency
Ajloun	582.2	63	30	2.1
Amman	480.6	52	30	1.7
Balqa	530.4	57	30	1.9
Irbid	470.8	51	30	1.7
Jarash	436.7	47	30	1.6
Karak	349.7	38	30	1.3
Ma'an	42.8	5	30	0.2
Madaba	320.3	35	30	1.2
Mafraq	161.3	17	30	0.6
Tafaileh	242.3	26	30	0.9

[a] Based on department of statistics annual report, the average area of housing unit in Jordan is estimated 120 m^2. The runoff coefficient is 0.9 as most of catchment surfaces are made from cement.

where VR is the volume of rainwater that could be harvested; AR is the local average rainfall; *A* is the total area of catchment surface (m^2); *C* is the run-off coefficient (estimated 0.9 for cement roofs that means a loss of 10% of the rainwater via evaporation and to the drainage system, including the first flush).

Given that the average area of housing unit in Jordan is 120 m^2 (Department of Statistics, Annual Report, 2004) and the average of annual rainfall for all governorates is 362 mm (see Table 2), the minimum storage capacity for rainwater harvesting Cistern was identified 30 m^3. This storage capacity was commensurate with the maximum average loan for each beneficiary (1200 $) and normally covers 20–40% of water demand for rural household in Jordan (see Table 3). This percentage of saving (20–40%) was sufficient to fulfill the demand during disruption periods and significantly minimize the demand on private water tankers.However, in locations where rainfall is high and the average surface area of roofs is relatively large, beneficiaries built storage Cisterns larger than this volume. On the other hand, due to difficulties in excavation, some beneficiaries were obliged to build small storage Cisterns, sometimes not exceeding 20 m^3.

2.6. Filling Frequency

Filling Frequency is how many times the Cistern becomes full by rainwater each year. Filling Frequency mainly depends on the average local rainfall and the storage capacity of Cistern. Table 1 shows estimations of Filling Frequencies for all governorates in Jordan.

3. Results

3.1. The amount of rainwater harvested within CBIWDM

In order to estimate the amount of rainwater harvested through CBIWDM each year, the total number of Cisterns at each governorate are counted and multiplied by the average Cistern Volume (30 m^3) and Filling Frequency. The equation below has been used to estimate the amount of harvested water in each governorate.

$$\text{Amount of water harvested} = nC \times \mathrm{CV} \times \mathrm{FF}$$

where *nC* is the number of Cistern, CV is the average Cistern Volume (30 m^3) and FF is the Filling Frequency.

3.2. On-site rainwater harvesting vs. household water security

Mercy Corps-granted CBOs have given about 1777 revolving loans for water harvesting projects. Each loan represents a

Table 2
Amount of rainwater harvested per year in each governorate within CBIWDM.

Governorate	Annual average rainfall (mm)	Number of Cisterns funded within CBIWDM	Average volume of Cistern (m^3)	Filling Frequency	The amount of water harvested per year (m^3)
Ajloun	582.2	305	30	2.1	19,215
Amman	480.6	176	30	1.7	8976
Balqa	530.4	169	30	1.9	9633
Irbid	470.8	407	30	1.7	20,757
Jarash	436.7	219	30	1.6	10,512
Karak	349.7	222	30	1.3	8658
Ma'an	42.8	27	30	0.2	162
Madaba	320.3	167	30	1.2	6012
Mafraq	161.3	89	30	0.6	1602
Tafaileh	242.3	104	30	0.9	2808
Total	Average = 362 mm				88,335

Table 3
Annual amount of water saved for each household via CBIWDM.

Governorate	Average family size (*Source*: Department of Statistics, 2009)	Daily water requirement (L/capita) (*Source*: WHO)[a]	Water demand for each household/year (Family size × daily water requirement × 365 days) m^3	Filling Frequency	The annual amount of water harvested per household (m^3)	Annual water savings for each household (%)
Ajloun	5.8	80	169.36	2.1	63	37
Amman	5	80	146	1.7	52	35
Balqa	5.5	80	160.6	1.9	57	35
Irbid	5.5	80	160.6	1.7	51	32
Jarash	5.9	80	172.28	1.6	47	27
Karak	5.6	80	163.52	1.3	38	23
Maan	5.9	80	172.28	0.2	5	2
Madaba	5.7	80	166.44	1.2	35	21
Mafraq	6.1	80	178.120	0.6	17	10
Tafaileh	5.7	80	166.440	0.9	26	15

[a] Estimated according to water service levels adopted by WHO (the average of intermediate access and optimal access).

household of 5–6 members. Table 3 shows the annual amount of water that could be saved for each household.

3.3. Microbial and chemical characterization of harvested rainwater

In order to assess the quality of harvested water, samples were taken from 21 Cisterns located at different locations. The results are shown in Table 4.

4. Discussion

Rainwater harvesting systems can provide a supply of potable water, in addition to non-potable use i.e. toilet flushing, vehicle washing and irrigation. Based on Filling Frequency and minimum storage Cistern capacity adopted by CBIWDM project, rainwater harvesting reduces annual household main water consumption by (2–37%). This is quite similar to the findings of Ghisi and Oliveira (2007) research conducted in Brazil which reported 35.5% of potable water saving when rainwater is harvested and utilized. Also, the potential for potable water savings by harvesting

Table 4
chemical and microbial characteristics of harvested rainwater.

Cistern	pH	TDS	NO_3	SO_4	Pb	*E. coli*	Algae
1	8.9	239	6.3	19.3	<0.01	<1.1	Not seen
2	10.6	124	2.7	7.3	<0.01	<1.1	Not seen
3	8.14	365	25.2	30.4	<0.01	>23	Not seen
4	8.17	224	12.2	24.6	<0.01	>23	Not seen
5	8.51	534	20.1	83.2	<0.01	<1.1	Not seen
6	8.11	561	21.9	93.4	<0.01	<1.1	Not seen
7	8.11	508	20.3	92.7	<0.01	<1.1	Not seen
8	8.15	606	22.9	97.9	<0.01	<1.1	Not seen
9	8.29	545	22.8	102	<0.01	9.2	Not seen
10	8.09	584	23.1	98.6	<0.01	<1.1	Not seen
11	9.04	112	6.3	15.2	<0.01	<1.1	Not seen
12	7.84	605	22.2	95.7	<0.01	<1.1	Not seen
13	8.74	154	9.8	33.5	<0.01	<1.1	Not seen
14	9.4	151	3.4	28.1	<0.01	<1.1	Not seen
15	8.67	113	3.9	11.5	<0.01	1.1	Not seen
16	8.43	137	4.6	15.5	<0.01	<1.1	Not seen
17	9.03	88	3.1	11.9	<0.01	<1.1	Not seen
18	8.88	312	9.9	15.9	<0.01	<1.1	Not seen
19	8.3	251	18.8	40.3	<0.01	<1.1	Not seen
20	8.45	238	29.6	17.9	<0.01	<1.1	Not seen
21	8.76	132	4.3	17.9	<0.01	<1.1	Not seen

rainwater was estimated for Jordan by Abdulla and Al-Shareef (2009), and it ranged from 0.27–19.7%.

The amount of water that could be harvested per year varies among the governorates, ranging from 162 m^3 for Ma'an governorate to 20,757 $m^3$for Irbid governorate. The variations in rainwater quantity being harvested are mainly attributed to fluctuations in rainfall rates between governorates and the number of Cisterns constructed.

The chemical and biological characteristics of harvested rainwater through the CBIWDM project were in compliance with Jordanian Standards for potable water. However, *E. coli* was detected in three locations at levels exceeding the permeable limit (Table 4). Further investigation was conducted to find out the sources of *E. coli*. The microbial contamination was attributed to the seepage pit, which was located nearby the rainwater Cistern. In addition, feacal deposits from birds that accumulated on rooftop (catchment area) contributed in the contamination of harvested rainwater. The way of retrieving water stored in the Cistern also played a role in contamination. Some of the households used a rope and a bucket instead of using an electrical pump, which increased the risk of contamination. Lee et al. (2010) conducted a piece of research on microbial and chemical characteristics of harvested rainwater in South Korea. In this study, *E. coli* was detected in 72% of harvested rainwater samples at levels exceeding the national guidelines. According to Lee et al. (2010), the most likely source of *E. coli* was feacal matter that enters the storage tank via the catchment or from dead animals and insects on the rooftop (Simmons et al., 2001; Lee et al., 2010). However, redirecting the first-flush water out of storage cistern is essential to get rid of most of pollutants (Gikas and Tsihrintzis, 2012).

Household water security can be defined as: improving families' access to safe and affordable water sources at reasonable distance from the home (Bandara et al., 2010) Although the level of services in the water supply sector in Jordan is fairly high covering 97% of the population in urban areas and 83% in the rural areas (Jordan's Water Strategy, 2008), the components of water security at the household level i.e. safe, sustainable and affordable, are still far from the optimal status. Since 1987, the supply of water to households has been rationed. For most parts of Jordan, water is supplied once or twice a week. However, in many cases, especially in the summer, people are obliged to buy water from private tankers in order to offset the insufficiencies in water supplied by the municipal network. According to Table 3, the average savings in household water demand each year through revolving rainwater

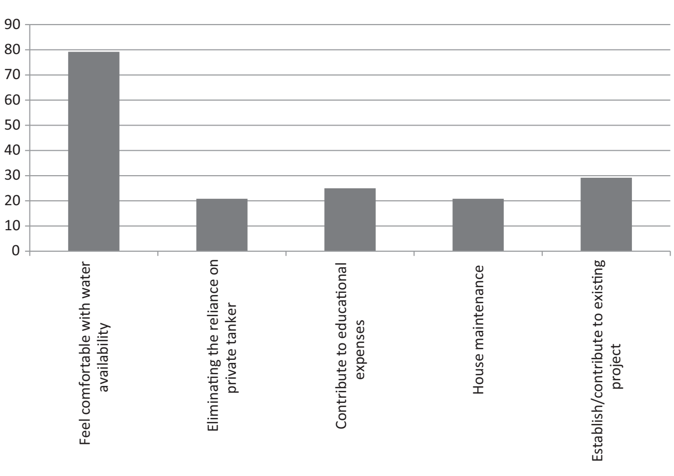

Fig. 4. Social and economic impacts of on-site water harvesting Cisterns on beneficiaries in *Jerash* governorate (one out of the 10 governorates implementing rainwater harvesting projects through CBIWDM).

harvesting projects ranged between (2–37%). This water saving has eliminated the need of buying water from private tankers for many households, which, in turn, improves their economic and social status. This finding was revealed by using a field survey and direct interviews with beneficiaries to assess the social and economic impact of rainwater harvesting Cisterns. The survey indicated that 80% of households feel more comfortable since water has become available and accessible through rainfall harvesting. Consequently, beneficiaries have been less vulnerable to water cut-offs during the hottest days of the year. The surveyed households also stated that they were able to save 50–240 JD every year by either reducing or eliminating the demand on private tankers, which in turn enable them to direct these savings toward investments in a new business/project or contribute in the existing ones (Fig. 4).

5. Conclusion

(1) Jordan is and will be facing a chronic water crisis. Rainwater harvesting is a traditional practice in Jordan and a potential solution for the chronic water shortage in Jordan. It is sustainable, cost-effective and environmental-friendly. When rainwater harvesting is coupled with micro-finance and socio-economic benefits, it gives outstanding results, on both individual level, as well as national level.
(2) The annual rainwater harvested via CBIWDM varies among the governorates, ranging from 162 m^3 for the Ma'an governorate to 20,757 m^3 for the Irbid governorates. This variation is attributed to different rainfall rates, numbers of beneficiaries, and Cistern storage sizes.
(3) Through CBIWDM, there was an average saving of (2–37%) in potable water for each household per year.
(4) The quality of harvested rainwater through the project of CBIWDM was compatible with Jordanian Standards for potable uses. However, best management practices must be considered to ensure harvested rainwater pathogen-free.
(5) Beneficiaries of the CBIWDM project have been able to save 50–240 JD per year, which was previously used to purchase water before practicing rainwater harvesting. This saving has enabled many households to afford family and social activities they were not able to afford previously.
(6) On-site rainwater harvesting does not only provide a source of water to increase water supplies, but also can play an important role in public involvement and make water management everybody's concern.
(7) On-site rainwater harvesting at household levels should be encouraged and fostered by government. Incentives and government support are essential to spread rainwater harvesting practices.

Acknowledgements

The authors would like to express their gratitude to the United States Agency for International Development (USAID) for the financial support given to Mercy Corps in Jordan to implement this project. Authors would also like to acknowledge the great support and significant contribution of Royal Scientific Society (RSS) and Jordan River Foundation (JRF) in implementing this project. Many thanks to all Mercy Corps' staff for the hard and sincere work they have done throughout the project lifespan. Special thanks go to the CBOs' project management committees, without which the whole project could not have been accomplished.

References

Abdulla F, Al-Shareef AW. Roof rainwater harvesting systems for household water supply in Jordan. Desalination 2009;243:195–207.

Annual report, Ministry of Water and Irrigation. Jordan; 2007.

Bandara M, Ranjith Premalal De S, Dayawansa NDK. Household Water Security through stored rainwater and consumer acceptability: A Case Study of the Anuradhapura District (2010). Available on: http://ideas.repec.org/p/iwt/conppr/h042862.html

Department of Statistics, Population and Housing census. Jordan; 2004.

Ghisi E, Oliveira S. 'Potential for potable water saving by combining the use of rainwater and greywater in houses in southern Brazil'. Building and Environment 2007;42:1731–42.

Gikas G, Tsihrintzis V. Assessment of water quality of first-flush roof runoff and harvested rainwater. Journal of Hydrology 2012;466/467:115–26.

Hanida L, Tembo J, Nwiindwa C. Potential of rainwater harvesting in urban Zambia. Physics and Chemistry of the Earth 2003;28:893–6.

Jordan's Water Strategy, Ministry of Water and Irrigation. Jordan; 2008.

Kahinda J, Taigbenu A, Boroto J. Domestic rainwater harvesting to improve water supply in South Africa. Physics and Chemistry of the Earth 2007;32:1050–7.

Lee J, Yang J, Han M, Choi J. Comparison of the microbiological and chemical characterization of harvested rainwater and reservoir water as alternative water resources. Science of the Total Environment 2010;408:896–905.

Nortcliff S, Carr G, Potter R, Darmame K. Jordan's Water Resources: Challenges for the Future". UK: School of Human and Environmental Sciences, University of Reading; 2008.

Simmons G, Hope V, Lewis G, Whitmore J, Gao W. Contamination of potable roof-collected rainwater in Auckland, New Zealand. Water Research 2001;6(35):1518–24.

Zimmermann M, Sturm M, Schutz K, Urban W, Hartung H. Rainwater harvesting as an alternative water resource in rural sites in central northern Namibia. Physics and chemistry of the Earth 2009(34):776–85.