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ORIGINAL ARTICLE

Determinants for the adoption of residential rainwater harvesting systems on the slopes of Mt. Elgon, East-Africa. How do they perform?

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Abstract

In recent years, the mountainous regions are becoming more susceptible to devastating climatic shocks causing food insecurity and environmental degradation. In response, farmers with small landholding are gaining interest in deploying Residential Rainwater Harvesting Systems (RRWHS) to improve water supplies in homes, though diminutive consideration has been given to the performance evaluation of these systems in a mountainous landscape in the tropics. Our study intended to explicitly understand the determinants for the household adoption of RRWHS and evaluate their performance to improve domestic water supplies in the study area. The study took a cross-sectional design were 444 respondents were selected using a cluster sampling method, and administered with semi-structured questionnaires. The indicators used to assess system performances were: reliability, cost-effectiveness and efficiency. The results of this study showed that system/component price-subsidies, household income-status, landholding-size, availability of technical support and farmer education-level were the most significant determinants for the uptake of RRWHS ($P < = 0.05$). Performance-wise, the most reliable systems were corrugated metallic-tanks and concrete-ferro-cement tanks. The most cost-effective system was plastic jerrycans; while the most-efficient were concrete ferro-cement and plastic tanks. This study reveals that tax exemptions on the manufacture and importation of RRWHS components can increase their acquisition. The high-capacity storage RRWHS systems are preferred by the farmers due to improved water supplies to sustain domestic usage and farming requirements but also safeguard the environment from surface run-off and overexploitation. Plastic-storage facilities are preferred, because they did not react with water compared to metallic systems.

Keywords Residential rainwater harvesting · Farmers · Mt. Elgon · East africa · Uganda

Introduction

Access to safe water is still a burden to many rural households in many developing countries in the tropics (Liang and Van Dijk 2011). This problem highly affects agricultural production, the health of human beings and water resources (Wen et al. 2017). This condition is triggered by the impacts of climate change (drought and erratic rains) which have intensified over the last 2 decades (Mwenge-Kahinda et al. 2008; Auffhammer et al. 2012; Gosnell et al. 2020). The longer duration of low-intensity rainfall events has now been replaced with smaller duration high-intensity rainfall showers (Vashisht and Aggarwal 2016). The magnitude of climate change impacts can vary from very low to very high, depending on regional or geographical location and status of socio-economic development (Pachpute et al. 2009; Ahmed and Diana 2015; Tripathi and Mishra2017

Residential rainwater harvesting systems are often recommended as an alternative water source (Haque et al. 2016) but without considering the nature of the landscape and their performances where there are to be implemented. This technology is economically feasible and has positive effects on individuals and community at large such as increasing water supplies and conserving soil (Su et al. 2009; Parker et al. 2012). Besides, residential rainwater harvesting (RWH) is a model of inducing, collecting, storing, abstracting and

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conserving local run-off for domestic and agricultural production (Button 2017; Amos et al. 2018). A rainwater harvesting system comprises various components such as catchment, conveyance and storage (Mulvaney and Ogale 2012; Kiggundu et al. 2018).

Harvested rainwater can help reduce water-related costs by providing an alternative source of water, in addition to relieving pressure on public water sources and reducing courtyard stormwater runoff (An et al. 2015; Pelak and Porporato 2016). In most homes, harvested water is used for drinking, cooking, washing, watering garden (Steffen et al. 2013; Rahman et al. 2014). To sum up, rainwater harvesting can support and foment sustainable livelihoods, mitigate water insecurity (Bitterman et al. 2016) and promote sustainable development (Ghisi et al. 2009).

The parameters that may influence the adoption of rainwater harvesting system can vary from one ecosystem to another. This variation can be caused by several factors such as capital, institutional support, climate, policies and so forth (Meera and Mansoor-Ahammed 2006; Gwenzi et al. 2015; Kanyi et al. 2016). In Nepal, Adhikari et al. (2018) reported that the major household determinants for the adoption of technologies included the years one had in school, total physical assets and organizational membership of household members. Whereas in Kenya, farmers with smallholdings adopted rainwater harvesting primarily due to the parameters such as cultivatable land size, labour availability and several livelihood options at their disposal (Hatibu et al. 2006; Recha et al. 2015). Consequently, an understanding of parameters that influence the adoption of RRWHS is, therefore, important for the successful uptake of specific rainwater harvesting technologies and design engineering (Baiyegunhi 2015). In this study, the determinants that influenced the uptake of RRWHS were examined in consideration of social-economic environmental, institutional and policy parameters.

The adoption of residential rainwater harvesting technologies is also limited by natural and man-made factors. Rainwater harvesting systems have to cope with the climate change uncertainties (that can cause recurring water scarcities), increase in demand, and ageing infrastructure (Lopes et al. 2017). System usage can also be constrained by the storage capacities of tanks due to the reception of more quantity of water during the advent of any intense storm (Haque et al. 2016). Besides tank storage variations, rainwater harvesting tanks are more reliable to harness rainwater (Kisakye et al. 2018), because there can collect more water during rainfall peaks (Jones and Hunt 2010; Notaro et al. 2016; Angrill et al. 2017). Therefore, rainwater water savings from tanks are strongly correlated with the average annual rainfall received (Rahman et al. 2012).

A review of key literature reveals that most studies on rainwater harvesting have widely investigated its potential to increase water supply (Ishaku et al. 2012; Jung et al. 2015), evaluated performance (Rahman et al. 2012; Ward 2012), water quality (Despins et al. 2009; Mendez et al. 2011; Zhang et al. 2014), assessed the impact of climate change on rainwater (König and Lo 2009; Haque et al. 2016; Kisakye and Van-der-Bruggen 2018), identification of potential sites for harnessing rainwater harvesting (Baguma and Loiskandl 2010) and management (Biazin et al. 2012; Singh et al. 2017). However, little documentation is available on the adoption and performance of residential rainwater harvesting systems by farmers with small landholding found in a mountainous landscape in the tropics. The slopes of Mt. Elgon in Uganda face frequent droughts and farmers suffer from insufficient water supplies to meet irrigation and domestic needs. System performance in this research was investigated using reliability, cost-effectiveness and efficiency indicators that would be easily understood and studied in the scope of smallholders' farming system. The objectives that directed this study were to: (1) assess the determinants for adoption of residential rainwater harvesting systems and (2) evaluate the performance of the systems as perceived by the farmers. This study improves our understanding of RRWHS that perform well in sustaining water supplies on slopes of mountainous landscapes.

Methodology

Location of study site

The study site was Mt. Elgon region found in Eastern Uganda (Fig. 1). Administratively, four districts were selected for further investigation. The major reason for selecting these four districts was that the construction of new residential rainwater harvesting systems was at initial stages. Second, these districts experience prolonged dry spells frequently and the majority of farmers belong to small landholdings category (Jiang et al. 2014). Mt. Elgon is a transboundary natural resource shared between Uganda and Kenya. The largest portion (60%) of the mountain falls on the Kenyan side. The volcanic mountain stands at the height of 4320 metres. The slopes of the mountain can be categorized into steep, moderately steep, and gentle. The mid and low lying slopes are highly settled with farmers with small landholding who are largely engaged in crop and livestock production. These slopes are undercut to create spaces for building homes. The settlements are generally scattered in the region. In terms of vegetation, the slopes are defined by a mountainous vegetation type. The settled landscape is vegetatively characterised by indigenous and exotic tree plantations, bushes and grasslands. The major rivers that originate from the mountain include River Manafwa, Sironko, Sio, Sippi, Namatala among others.

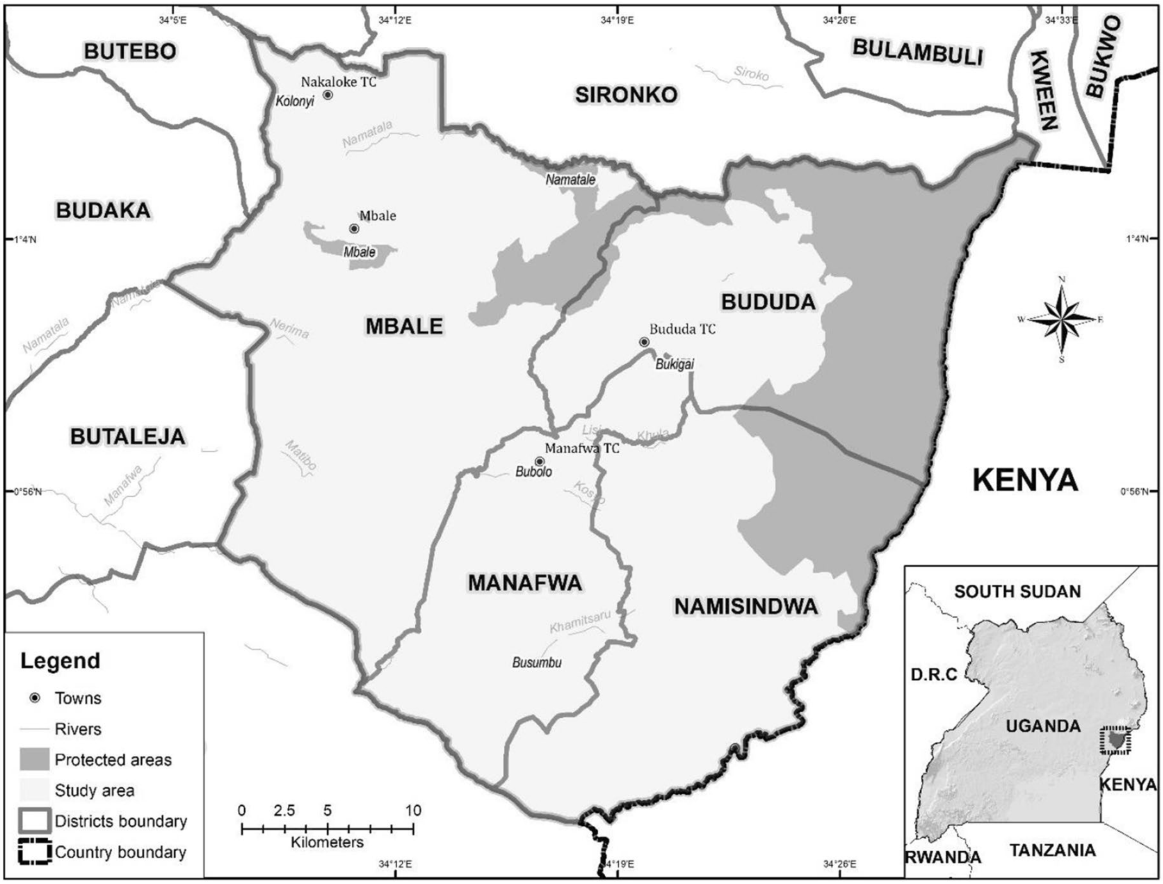

Fig. 1 Study site (source: authors)

The climate can be described as tropical equatorial humid climate. The study experiences a bimodal rainfall pattern. Rains are received in the months of March–May and August–November of each seasonal calendar, though this was reported to be changing, with climate change (Misanya and Oyhus 2015). The mean annual rainfall is about 1400–1800 mm (Fig. 2) and temperature throughout the year remains in the range of 14–25 °C in the region. Droughts remain prominent from December to February and June to July of each year. The study area soils can be characterised as Nitisols (red sandy clay loams), Luvisols (red clay loams), Acric-Ferralsols (red sandy-sandy clay loams). The key crops cultivated here include coffee, banana, maize, beans, millet, Irish and sweet potatoes, while the key livestock

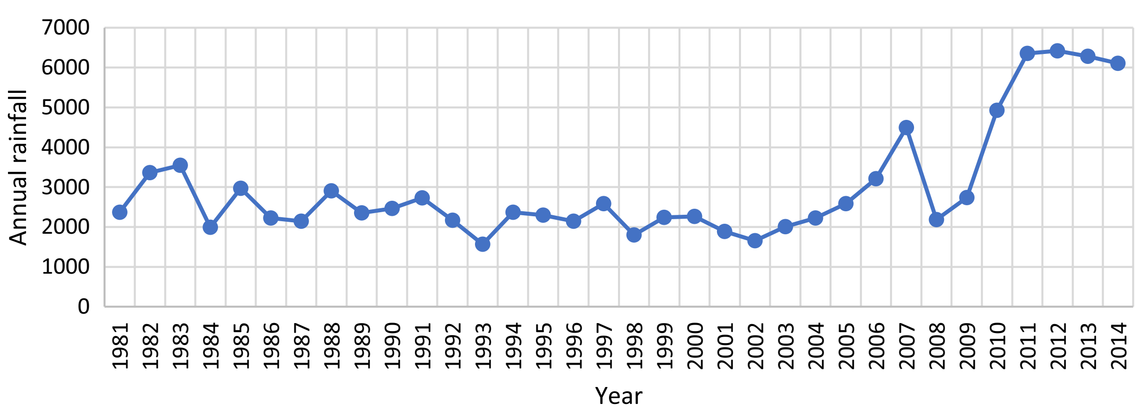

Fig. 2 Annual rainfall received in the study area (source: buginyinya weather station—Uganda national meteorological authority)

(animals and birds) kept include cows, sheep, goats, pigs and poultry. Based on the landscape, agricultural land can be categorized into different categories viz. Coffee-Banana-Agroforestry-Zero grazing Systems, Maize-Beans-Agroforestry-Apiary Systems and Aquaculture (Fish Ponds) Enterprises (van Asten et al. 2011).

Household survey

Household and participatory methods were adopted, because they were robust in gaining a deeper understanding of RRWHS installed by the farmers with small landholding. The utilized socio-economic techniques included key informant interviews, farmer interviews and focus group discussions. This investigation was conducted between July and August of 2018 period which is characterized by torrid conditions.

Key informant interviewing

These were conducted at the district level consisting of officials in charge of water, planning, administration, environment and agricultural production. The district officials are responsible for planning, supervising and budgeting of sector government programmes. In this study, eight key informants were selected and interviewed because of their expertise and knowledge on the extent and distribution of RRWHS in the districts. These were chosen with the guidance of the district chief administrative officers who are responsible for overseeing government programmes and projects in the districts. The researcher engaged with participants by posing questions in a non-offensive manner and listened attentively to participants' responses and then asked follow-up questions and probes based on the responses. The researcher developed a set of interview guide questions, made appointments with the district officers in charge of water, planning, administration, environment and agricultural production and collected the data by engaging them in a one on one discussion. The researcher used both English and the local language which was Lugisu to mostly those rural farmers.

These interviews helped identify farmers and RRWHS characteristics, and neighbourhoods. Insights from held interviews guided the selection of sub-counties that were further investigated for more details. During the interview sessions, questions sought to investigate types of RRWHS adopted and their impact in helping farmers adapt to drought. In the studied districts, the meetings held included at least 8 key informants and these were hosted at the district premises. Furthermore, to confirm the accuracy of key informant data, supplementary data were also collected and collated such as national water sector performance sector reports.

Household interviews and focus group discussions

The criteria to select the beneficiary households to participate in the study was based on not only farmers with small landholding that are engaged in the production of cash crops (coffee), but also food crops on a small scale like banana and rice) and livestock production. Therefore, the local council leaders were contacted to help the study team identify these household farmers. This study targeted farmers who were engaged in both crop and livestock production. This study refers to farmers with small landholding as persons who are entirely involved in rain-fed subsistence farming and own on average 2 acres of land. According to Mukuve and Fenner (2015), 85% of the population in the study area is engaged in rain-fed subsistence agriculture.

The study participants were selected based on multi-stage sampling technique (Oladeebo and Oladeebo 2008) from the district, sub-counties, parishes and village administrative units. This process helped to select the appropriate respondents without bias and met the established study needs. In particular, a multi-cluster sample technique was adopted to select the farmers for oral interviews.

In this research, 444 farmers with small landholding were selected and interviewed from the studied districts, using semi-structured questionnaires. One hundred and eleven respondents were selected in each district at the village level with the guidance of local leaders using registration forms. The village registration list was used to cluster respondents considered for investigations. The validity of our sample was determined using Isreal (1992) procedures (confidence level of 95%, 50% and confidence intervals of 4.65). The study sample size was adequate to detect differences, associations and understand variables under investigation. Data collected included documentation of installed RRWHS system components, determinants for adoption, performance evaluation and parameters to consider in designing and installation of RRWHS. Impacts of RRWHS in this study were related to high crop and livestock yields and household income. Participants interviewed were composed of elders, youths, adults and vulnerable groups who were both male and female. In each district, one focus group discussion was conducted. The members were composed of 12–14 members in consideration of youths, gender, religious and local leaders. This number was not only manageable but also bared a good representation of key informants.

RRWHS performance evaluation

The indicators considered by this study to understand the performance of RRWHS as perceived by the farmers were reliability, efficiency and cost-effective. Efficiency referred to how timely the systems were able to provide water supply; reliability was explained as to how consistent the RRWHS were able to help the farmers cope with water scarcities, and lastly cost-effective was described as how the RRWHS aided the—farmers with small landholding attain their goals and objectives (on-farm and off-farm). The indicators were measured from the perceived performance of the RRWHS using a Likert-scale—5 point (disagree to strongly agree). The scale was used to assess the farmer's perceptions of the performance of the systems. These RRWHS parameter indicators were selected to investigate against their abilities to augment safe water supply—to facilitate potable and non-potable uses. Within each used performance indicator, the intensities were classified as very high, high, moderate and low to classify the measure of RRWHS capability to meet the intended objectives and goals of deployment. While the determinants for the adoption of RRWHS were analysed using a chi-square method in SPSS software (16.0). The most significant systems were determined at the threshold of 0.05 significance level ($P <= 0.05$).

Results

Characteristics of sampled farmers

Describing the socio-economic characteristics of respondents helps provide insights into adoption studies. Table 1 displays the general description of the sampled farmers with small landholding. The specific social-economic features of the farmers investigated included age of participants, education level, weekly household income, land tenure and marital status. These can have significant impacts on the adoption of RRWHS. Generally, the average age of interviewed farmers was 45. The household membership was 7, while the average size of land owned was 2.4 acres. The farmers with small landholding were also interviewed on the amount of the mean weekly earning that they derived from agricultural production and the majority conferred to receive approximately 10 USD ($) a week.

Education-wise, majority of the respondents had attained primary education (53%) followed by those who had completed secondary education (30%). The farmers who obtained tertiary education were 7%, while 10% out of the interviewed respondents had not enrolled for any formal education. Land ownership is a critical element in the deployment of RRWHS. The land tenure system common in the study area was customary (92%) (land acquired through family inheritance), followed by freehold (7%). The remaining farmers (1%) agreed to have obtained land through mailo land and leasehold. Mailo land tenure here refers to the system that came into effect when the Kingdom of Buganda signed an agreement with the British administered Uganda Protectorate in 1900. Nearly all the respondents were married (81%).

Table 1 Demographic and economic characteristics of sampled farmers

Variables	Average ($N = 444$)
Age	44.8
Size of cultivated land	2.4
Household membership size	7.0
Household weekly income	30,579.40 (8USD)
Education level	Frequency (*N*, %)
Primary	230 (52.87)
Secondary	131(30.11)
Tertiary	31(7.13)
No formal education	43(9.89)
Land tenure system	Frequency (*N*, %)
Mailo land	3(0.79)
Freehold	28(7.35)
Customary	349(91.6)
Leasehold	1(0.26)
Marital Status	Frequency (*N*, %)
Married	345(80.99)
Widowed	71(16.67)
Separated	7(1.64)
Divorce	1(0.23)
Single	2(0.47)

Deployment of different residential rainwater harvesting components on different systems

The components of utilized residential rainwater harvesting systems can be broadly categorized as conveyance, storage and abstraction. The typology of systems that have been installed by the farmers includes corrugated, clay pots, plastic tanks, metallic tanks, plastic jerrycans, concrete ferro-cement tanks and industrial metallic/plastic drums. Table 2 shows the components of utilized RRWHS, and this reveals that at the conveyance stage, the most used components to carry water to the storage medium are plastic gutters (70%) and use of sticks/reeds (17%). These are followed by the use of plant stems (pseudo banana stems) (7%), direct rain (4%) and Polyvinyl chloride (PVC) plastic pipes (3%). In the chronology order of conveyance systems, most of these components were installed on concrete ferro-cement tanks (100%), industrial metallic/plastic drums (82%) and plastic tanks (72%). This was followed by plastic jerrycans (68%) and clay plots (64%). Out of the installed conveyance components on the different RRWHS, the mean length was 436.8 m up to the storage facilities (Table 3). This study reveals that the uptake of conveyance components was dependent on durability, accessibility and household income levels. At the storage level, the most utilized RRWHS components were plastic (60%) as per the interviewed farmers. The next constituents used was metal (18%), clay (14%) and cement/

Table 2 Deployment of different rainwater harvesting components on different systems and abstraction

Components	Rainwater harvesting System					
	Plastic tanks	Corrugated metallic tanks	Clay pots	Plastic Jerrycans	Concrete ferro-cement tanks	Industrial metallic/plastic drums
Conveyance	%	%	%	%	%	%
Plastic gutters	72.3	33.3	63.6	68.9	100	82.4
PVC plastic Pipes	9.2	0	0	4.35	0	3.9
Sticks/reeds	7.6	66.6	9.1	9.9	0	7.2
Plant stems (pseudo banana stems)	6.2	0	18.2	9.9	0	5.2
In-situ (Direct) raindrops	4.6	0	9.1	6.8	0	1.3
Storage						
Metallic	0	9.1	0	0	0	76
Plastic	100	0	12	100	0	24
Cement, sand and bricks	0	91	0	0	100	0
Clay	0	0	88	0	0	0
Tank-base						
Concrete floor	5.9	25	16.6	4.3	100	4.5
Wooden table base	81.1	0	8.3	3.1	0	2.8
Earth ground	1.5	0	75	72	0	81.2
Abstraction						
Taps (plastic/metallic)	4.8	100	0	0	100	4
Use of plastic small containers	85.4	0	100	100	0	96

Table 3 Descriptive statistics of components of Residential rainwater harvesting systems

Components	Plastic tanks	Corrugated metalli-tanks	Clay-pots	Plastic Jerrycans	Concrete ferro-cement tanks	Industrial metallic/plastic drums
Conveyance	Length (metres)					
Average	27.2	17	24	16.3	329.2	23.1
Standard deviation	50.8	9.8	36.7	41.5	432.2	54.9
Minimum	0.5	10	1	1	20	1
Maximum	200	24	99	360	1000	379
Coeff. of variation	186.90%	58.20%	152.90%	254.20%	131.30%	238.10%
Tank storage	Litres					
Average	538.8	200	45.5	62.7	6320	230.3
Standard deviation	1284.5	141.4	25.4	97.3	10688.6	804.1
Minimum	30	100	20	1	300	1
Maximum	6000	300	100	1000	25000	6000
Coeff. of variation	238.40%	70.70%	55.90%	155.20%	169.10%	349.10%

sand/bricks with 8%. With the stated component usage, the average litres that they hold are 7,397.3 L (Table 3). The storage units that are made of plastic materials include plastic tanks, jerrycans, and industrial metallic/plastic drums. The bases on which the storage facilities were placed were also investigated astride the utilized RRWHS. Respondents reported that the most utilized bases were ground (48%) and concrete facilities (32%). Bases used to hold facilities were the use of mobile tables and tyres (20%). Facilities directly placed on the ground were industrial metallic/plastic drums, clay pots and plastic jerrycans. Plastic storage facilities were accessible, lighter and perceived by farmers not to react with water compared to metal.

The final stage was the abstraction phase, at this level, the majority of the study participants revealed that they drew rainwater from the deployed RRWHS using mobile containers (63%) such as cups, jars, saucepans and basins; followed by the use of taps (37%). These were mostly placed on the corrugated metallic tanks and concrete ferro-cement tanks; while the containers were largely used to draw water from clay pots, and plastic jerrycans. A synthesis of these results shows that the accessibility highly influences the use of plastic small containers to draw water by the farmers.

One of the systems that were observed to be widely installed/used is plastic rainwater tanks (a), jerrycans (b), Concrete ferro-cement tanks (c), Clay pots (d), Saucepan (e) and industrial metallic/plastic drum (f). Apart from jerrycans and saucepans, the rest are permanently deployed on the houses of farmers (Fig. 3). Second, it is only the plastic tanks and Concrete ferro-cement tanks that are placed on permanent concrete bases with taps to abstract water.

Determinants for the adoption of residential rainwater harvesting systems

The chi-square test findings aboard the adopted technologies show that out of the 13 investigated determinants despite the type of RRWHS implemented; availability of price subsidies, farmer's income status and education levels were the most significant parameters ($P <= 0.05$) (Table 4). This finding was followed by the size of land owned, availability of technical support, accessibility of RRWHS and provisions by the development partners such as non-governmental organizations ($P <= 0.05$). To gain a deeper understanding of determinants, it was important to examine each RRWHS given their adoption and applicability. At the technological level, the most significant determinants for the adoption of plastic tanks by the farmers were household size, accessibility of RRWHS, land ownership, size of land, household income and dwelling type (either permanent or semi-permanent houses) ($P <= 0.05$). The adoption of corrugated metallic tanks was determined by the accessibility of RRWHS, and the uptake of clay pots was due to price subsidies, availability of technical support and household income. The farmers who adopted plastic Jerrycans were influenced by education level, price subsidies and water scarcity ($P <= 0.05$); while those who adopted concrete ferro-cement tanks were largely determined by provision of RRWHS by development partners (Non-governmental organisations).

Performance evaluation of residential rainwater harvesting systems

The performance of RRWHS was evaluated using three key indicators/measures and these were: reliability, efficiency and cost-effectiveness (Table 5). Using a Likert Scale, the farmers revealed that the most reliable tools were plastic tanks, industrial metallic/plastic drums and concrete ferro-cement tanks. Under the efficiency measure, the respondents reported that corrugated metallic tanks (50%) and concrete ferro-cement tanks (78.3%) (very high–high category). Henceforth, the most cost-effective measure were plastic jerrycans (20.8%), clay pots (20.3%) and concrete ferro-cement tanks (50%) (very high–high category). A synthesis of indicators and associated categories reveals a closer relationship between the RRWHS and the costs, multi-benefits and acquisition of intended outcomes (Fig. 4).

The RRWHS that were reported by the farmers to have the highest water demand were plastic tanks, concrete ferro-cement tanks and industrial metallic/plastic drums ($P <= 0.05$) that was required to meet the user needs of the farmers (Table 6). The tools that had the least demands were corrugated metallic tanks, clay pots, and plastic jerrycans. Despite the demands of water by the installed systems, the systems that were observed to provide water supplies as required by the farmers were plastic-jerrycans and industrial metallic/plastic drums. While the least suppliers of water were plastic tanks, corrugated metallic tanks, clay pots and concrete ferro-cement tanks. This result shows that the farmers are highly opting for high-storage capacity tanks to increase water supplies that can meet the user needs.

Discussion

This study demonstrates that residential rainwater harvesting is a fundamental part of sustainable water resources management and coping with extreme weather events. These facts are presented in the form of key findings that this research presents to the scientific body.

The first finding of this assessment is in the form of components that are used to install RRWHS in homesteads. At the conveyance stage, the most utilised components to capture and carry water to the storage medium are plastic gutters and use of sticks/reeds. Gutters are preferred due to their durability and non-collusive with water. This finding is inconsistent with Sturm et al. (2009) who also acknowledged that the installation of gutters prevents water loss and easily screened. The conveyance systems are preferred primarily because of the nature of iron sheet roofed houses (semi-permanent) owned by the farmers. At the storage level, still, the plastic components are most preferred compared to metallic elements such as corrugated tanks. The plastic storage components maintain the quality and quantity of water and do not react with the water. The rainwater tanks have protected inlets that prevent debris from the harvested water. While at the abstraction stage, water is mainly extracted using mobile containers such as cups, jars, saucepans and basins; followed by the use of taps. These facilities were preferred due to their high accessibility, affordability and limited rainwater tank storage.

Fig. 3 Typology of utilized RRWHS


Plastic tank (a)


Plastic jerrycan (b)


Concrete ferro-cement tank (c)


Clay pot (d)


Saucepan usage (e)


Industrial metallic/plastic drum (f)

Table 4 Determinants for the adoption of residential rainwater harvesting Systems by the farmers

Determinants	Plastic tanks	Corrugated metallic tanks	Clay pots	Plastic Jerrycans	Concrete ferro-cement tanks	Industrial metallic/plastic drums
	P values					
Household size	0.002**	0.611	0.91	0.11	0.571	0.65
Provision of RRWHS by development partners	0.588	0.555	0.529	0.182	0.041**	0.042**
Education level	0.731	0.573	0.098	0.001**	0.002**	0.002**
Price subsidies	0.334	0.138	0.005**	0.012**	0.003**	0.373
Accessibility of the RRWH systems	0.012**	0.008**	0.382	0.389	0.251	0.269
Land ownership	0.004**	0.503	0.403	0.784	0.784	0.784
Availability of technical support	0.785	0.554	0.041**	0.214	0.05**	0.87
Household land size	0.028**	0.667	0.338	0.45	0.506	0.011**
Policies/strategies	0.568	0.404	0.604	0.202	0.617	0.032**
Water scarcity	0.653	0.563	0.423	0.021**	0.257	0.631
Household income status	0.002**	0.554	0.012**	0.268	0.824	0.011**
Dwelling type and roofing material	0.003**	0.604	0.837	0.462	0.199	0.517

***Significance level at 0.05

Table 5 Performance indicators of different residential rainwater harvesting systems ($N=444$, %)

Indicators	Residential-rainwater harvesting systems					
	Plastic tanks	Corrugated metallic tanks	Clay pots	Plastic Jerrycans	Concrete ferro-cement tanks	Industrial metallic/Plastic drums
Reliability	%	%	%	%	%	%
Low	4.3	0	53.3	36.3	4.3	26.5
Moderate	34.8	33.3	20	27.9	13	37.6
High	47.8	66.7	13.3	19.6	69.6	22.7
Very high	13	0	13.3	15.1	13	13.3
Efficiency						
Low	9.2	25	62.5	21.3	0	15.1
Moderate	18.5	25	25	39.3	13	55.1
High	58.5	50	12.5	23	78.3	23.2
Very high	13.8	0	0	15.9	8.3	6.8
Cost effective						
Low	16.4	0	46.7	28	0	29.9
Moderate	65.7	100	33.3	36.9	41.7	42.9
High	13.4	0	0	14.7	50	15.3
Very high	4.5	0	20.3	20.8	8.2	11.6

This study secondly presents key findings on the adoption of RRWHS by the farmers. The most significant determinants were price subsidies, farmer's income status and education levels. The subsidies have led to reduced prices in systems repairs/replacements and inexpensive technical support. Farmer's income levels are key on determining the type and storage capacity of RRWHS acquired, while formal education resulted in higher value attachment of the RRWHS, seeking technological support, improved maintenance and report or definition of technological specifications. Similarly, Kimani et al. (2015) also found out that higher household income implied greater incentive for investment in rainwater harvesting by farmers.

The third finding reveals that the most reliable RRWHS were plastic jerrycans and concrete ferro-cement tanks. The jerrycans were agreed to be potable, easily accessible and available in most homes, while the ferro-cement tanks were characterized by high rainwater storage capacity, higher chances of durability and reduced loss of water by evaporation. Efficient RRWHS were plastic jerrycans, corrugated

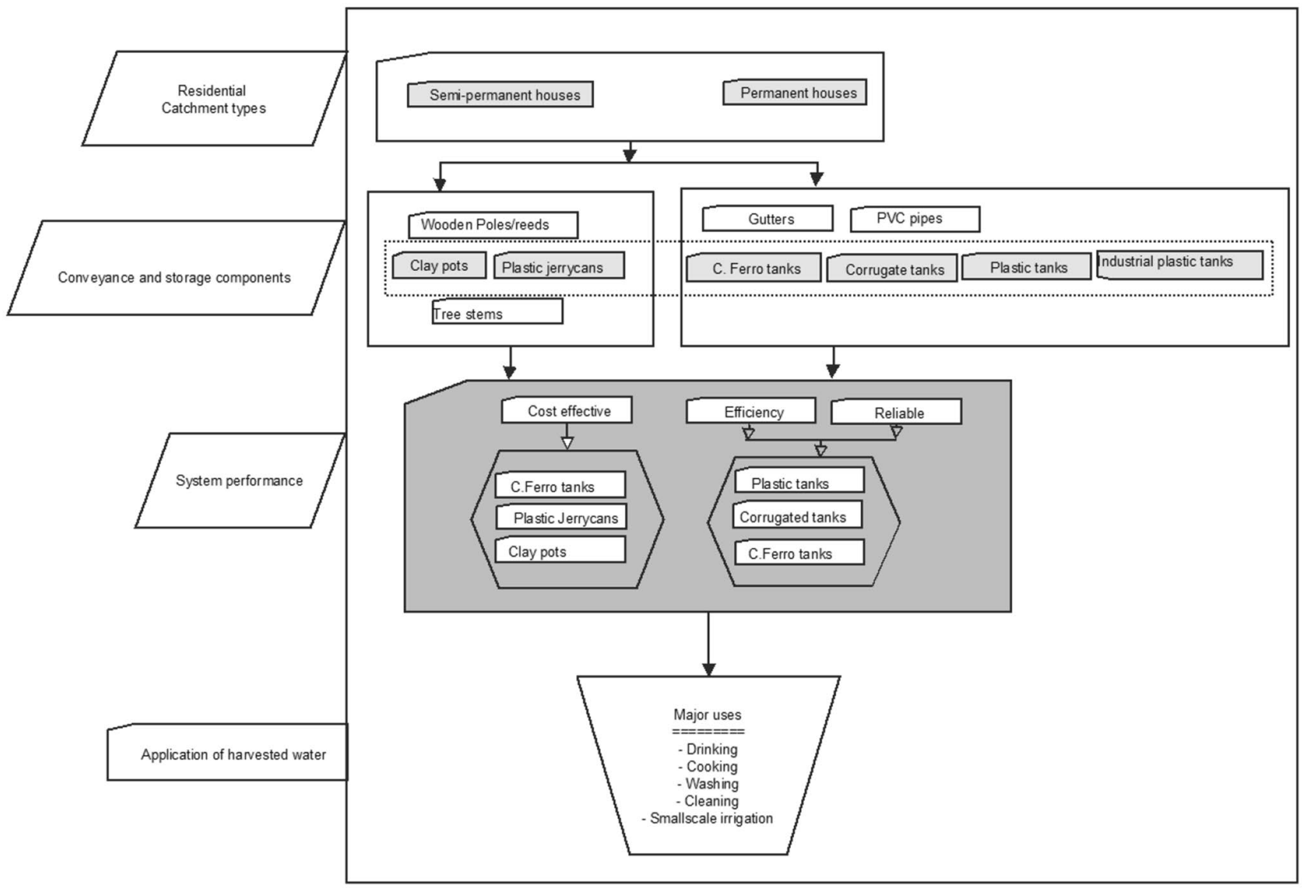

Fig. 4 Residential rainwater harvesting system components, performance and use of harvested water

Table 6 Influence of rainwater harvesting systems by water and supply

Water demand and supply	Residential-rainwater harvesting systems					
	Plastic tanks	Corrugated metallic tanks	Clay pots	Plastic Jerrycans	Concrete ferro-cement tanks	Industrial metallic/plastic drums
Water demand						
Chi squared	87.2	0.33	5.42	408.8	24.5	359.8
P value	0.001**	0.53	0.61	0.43	0.002**	0.001**
Contingency coefficient	0.74	0.316	0.53	0.834	0.726	0.816
Water supply						
Chi squared	45.2	0.41	34	149.9	122	168.2
P value	0.114	0.6	0.83	0.001**	0.24	0.003**
Contingency coefficient	0.629	0.712	0.139	0.67	0.572	0.69

metallic tanks, concrete ferro-cement tanks and plastic tanks. These systems highly facilitated farmers to meet their intended goals and objectives and improved water accessibility during droughts. Lastly, the most cost-effective RRWHS were plastic jerrycans and clay pots due to lower costs of purchasing the tools. Costs affect the economic viability of RRWHS, but it is not clear how great this effect has been translated on the slope of Mt. Elgon. Our findings support the notion that adaptability of rainwater harvesting systems is undertaken to suit local circumstances and budgets (Handia et al. 2003; Silva et al. 2015).

It is worthy to note that much as these findings demonstrate the situation on the slopes of Mt. Elgon at a localized scale, there are of global importance in increasing domestic water supplies, designing and installation of RRWHS meant for mountainous areas in the tropics and igniting reforms in the formulation of national and local strategies geared towards increasing usability and adoption of residential rainwater harvesting technologies.

Conclusions

The percentage of uptake of residential rainwater harvesting by the farmers with small landholding has been gradual but is anticipated to increase in the near future. The uptake of conveyance components was dependent on durability, accessibility and household income levels. Plastic storage facilities were accessible, lighter and perceived by farmers not to react with water compared to metal. The RRWHS accessibility highly influenced use of plastic small containers to draw water by the farmers. The availability of price subsidies and farmer's income status highly influenced the recent adoption of RRWHS. This study also reveals how farmers are increasingly opting for higher capacity storage residential rainwater harvesting facilities. In addition, the mobility of RRWHS technology within the homestead had a significant impact on the supply of water within the study area. A synthesis of indicators and associated categories revealed a closer relationship between the RRWHS and the costs, multi-benefits and acquisition of intended outcomes. Therefore, the cost-effectiveness of the RRWHS is highly associated with what and how the rainwater will be used.

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