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Rooftop Rainwater Harvesting for Sustainable Development of Households in City of Kigali: Case of Niboye Sector in Kicukiro-District

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Abstract

Fresh water is becoming increasingly scarce everywhere around the world especially in developing countries including Rwanda due to population growth. Rooftop rainwater harvesting as the most traditional and sustainable method, could be easily used for potable if well collected and managed. This paper was to analyze how households of the Niboye Sector harvest the rainwater, use it and the challenges they face in this practice. The findings from a survey conducted in the area revealed that RWH is effectively practised by using multiple techniques varying from simple techniques such as jars and pots to more complex techniques like plastic tanks as well as underground cisterns depending on households' financial capacities. Given that this study focused on plastic tanks, it was found that 71 out 108 respondents possess plastic tanks of different sizes (from 1000 litres to more than 10,000 litres) and 71% of respondents use rainwater as sole source of drinking water during rainy season. As expressed by 93% the challenges faced are based on lack of financial means and 82% of respondents emphasized insufficient people's knowledge with regard to RWH and its use while 81% put emphasis on lack of clear policy, etc. Hence, the study recommended local authorities and different civil society organisations operating in the area, support local community initiative in terms of finance and sensitisation for enhancing their knowledge and skills for the sustainable rainwater management.

Subject Areas

Environment Management

Keywords

Rooftop, Rainwater Harvesting, Households, Sustainable Development, Niboye Sector, City of Kigali

1. Introduction

Water is abundant in many countries but due to population growth phenomenon, fresh drinkable water is becoming increasingly scarce especially in developing countries such as Rwanda. In Rwanda the amount of water available is estimated at 9.5 billion m^3 per annum and per capita it is close to 1000 m^3. Fresh water systems consist of 101 lakes (1495 km^2) and 861 rivers totaling 6462 km and ground water with a total renewable (109 m^3/year), all supplied by rainfall [1].

By 2050 [2], the population is projected to double and 70% of people will be in urban areas and by 2032 the total number of households is expected to increase from 2.4 million to 5.3 million with over 100% increase. As Rwandan population is constantly increasing and accordingly so has the water demand. Water is a factor of development. In line with [3], water is at the core of sustainable development and is critical for socio-economic development, healthy ecosystems and for human survival itself. It is vital for reducing the global burden of disease and improving the health, welfare and productivity of populations.

Based on Sustainable Development Goal (SDG No 6) indicators and the 2017 Joint Monitoring Program (JMP) Report quoted in [4], the percentage of households using basic drinking water services was estimated at 57%. Furthermore in 2017, only 13% of households were estimated to use drinking water from improved water source located on premises countrywide while 36% of urban households use drinking water from improved water source located on premises.

To [5], Rainwater Harvesting (RWH) is listed as a source of domestic water supply called domestic rainwater harvesting (DRWH), practiced both in rural and urban areas from ancient times. This is still applied formally and none formally. Formally, it means permanent storage systems while none formally means not to establish a storage, but only to put pots under roof edges while [6] suggests that RWH can help alleviate demands on public water supply sytems and promote better practices in the public.

Harvested rainwater is a renewable source of clean water which can be used for domestic purposes, garden watering and small scale productive activities. It also contributes to increasing the drinking water supply.

1.1. Background and Problem Statement

It is agreed and approved that water is the source of life. Precious resource of environment, water is essential to human activities such as agricultural activities, industrial and domestic activities such as drinking water, and the functioning of terrestrial ecosystems. But there is a fear that water management especially fresh water, is going to become a major concern of the twenty-first century. In this regard Jean-clos quoted in [7] argued that water is strategic weapon in the 21st century. The necessary decisions to manage water and to preserve its quality and quantity must take into account changes in demand but also the state and evolution of the water supply in order to align the needs and water resources.

If water is abundant on earth, 97% of the resource is salt water and 2% is locked in ice. It is about one percent (1%) of fresh water in liquid form [8].

Freshwater comes from different origins: 1) precipitation water its origin is the sky; 2) surface fresh water is found in rivers and lakes; and 3) groundwater comes from the underground (aquifer or reservoir rocks) captured by natural springs or wells.

As [9] argues, rainwater harvesting seems to be a beneficial method for minimizing water scarcity in developing countries. It is a technology where surface runoff is effectively collected during the periods when enough rainfall occurs. To [10], rainwater can be collected and stored from rooftops, land surfaces or rock catchments using simple techniques such as natural and/or artificial ponds and reservoirs. Such technologies are really important for a country like Rwanda where effective rainfall is available for 8 - 9 months of the year, given the short dry seasons that alternate with the rainy season. As [11] emphasised, despite sufficient precipitation that Rwanda has, these cause problems such as the soil erosion, land sliding, floods and other forms of hazards related to rainwater.

Basic premise is that the rainwater falling at a particular location, if not harvested, would flow as surface runoff and may not be available at that location for later use.

According to the Water and Sanitation Corporation (WASAC) cited by [12], the national body for the distribution of water, the quantity of water decreased by losing overall 4,774,172 cubic meters out of 11,840,925 cubic meters of water produced and left to the company, 7,066,753 cubic meters serving its growing number of customers, going from 205,187 customers in the fourth quarter of 2017 to 219,185 at the end of March 2018. According to WASAC, this loss was due mostly to back washing and network flushing.

Besides, this scenario shared with rural water supply operators had a bearing on the water supply services amid a huge unmet demand. This leads some households to collect water from wells or springs as seen in **Figure 1** below.

Figure 1. Photo cyrille ndegeya from http://rwandatoday.africa/news/Demand-for-water-in-Kigali-may-result-in-rationing/4383214-4766176-gjomw7z/index.html.

In Rwanda a feasibility study designed by [11] Rwanda Natural Resources Authority (RNRA, 2016) stipulates that Rainwater harvesting is found wide, covering aspects of rainwater collection from the rooftop of houses for domestic, can meet the households' demand in water. The study suggests that for the effective development of Rainwater harvesting (RWH) in Rwanda, a National Strategy to engage all relevant stakeholders is needed.

Rooftop Rainwater Harvesting as underlined by [11] RNRA (2016), contributes to reducing surface runoff, where for instance, a tank of 5 m^3 can retain up to 60% of the water falling on the roof.

In this sense, the same study emphasizes that at a large scale, the impact could be more significant in the high density area and when the technique is adopted by majority of inhabitants.

Furthermore, the establishment of Sustainable development Goals (SDG 6), Ensure availability and sustainable management of water and sanitation for all, reflects the increased attention on water and sanitation issues in the global political agenda. The 2030 Agenda lists rising inequalities, natural resource depletion, environmental degradation and climate change among the greatest challenges of our time. It recognizes that social development and economic prosperity depend on the sustainable management of freshwater resources and ecosystems and it highlights the integrated nature of SDGs [13].

In line with [14] about RWH, there are challenges, opportunities and barriers that exist to achieve rainwater harvesting objectives which include: 1) lack of a clear policy for RWH, 2) insufficient knowledge and dissemination of RWH techniques, 3) low efficiency of water use, high water losses, 4) lack of integrated management for harvesting run-off water from the road networks, 5) weak coordination, monitoring and evaluation of interventions at different levels, 6) growing water demand amidst high population growth and adverse climate change, 7) limited involvement of research and 8) inadequate and unreliable financing.

After reviewing the existing literature on water harvesting and the way it is done in Rwanda, the researchers realized that there was still a great need to study about the Rooftop Water harvest as one of the factors leading to the contribution of water sufficiency for the residents of Niboye Sector, Kicukiro District in City of Kigali and how households collect and store rainwater from their rooftops manage in their rooftop water.

The paper aims at answering to very important four questions as depicted below.

1.2. Research Questions

1) What is the technology do the households of Niboye Sector use for the Rooftop Rainwater harvesting and its effectiveness?

2) What are the benefits of households practicing Rooftop Rainwater Harvesting to Niboye sector?

3) Are there organisations involved in supporting households in the application of the Rooftop Rainwater Harvesting strategies carried out in Niboye Sector?

4) What are the existing challenges of Rooftop Rainwater Harvesting by some of the households of Niboye Sector?

By answering the above questions, the paper intends to attain the following objectives.

1.3. Objectives of the Study

The general objective of this research is to analyse how households of Niboye Sector harvest the rooftop rain water and challenges they face in this practice that can help to sustain the water management.

Specifically the study intends to attain the following objectives:

1) To analyse the technology in Rooftop Rainwater harvesting used by the households of Niboye Sector and its effectiveness.

2) To find out the benefits of Rooftop Rainwater Harvesting to households of Niboye Sector leading the sustainable development.

3) To find out stakeholders involved in supporting households in the application of the Rooftop Rainwater Harvesting strategies in Niboye Sector.

4) To identify the existing challenges of Rooftop Rainwater Harvesting by some of the households of Niboye Sector.

2. Research Methodology

2.1. Study Area

The study was conducted in Niboye Sector one of 10 sectors (Kigarama, Gikondo, Gatenga, Kicukiro, Kagarama, Niboye, Gahanga, Kanombe, Nyarugunga and Masaka) of Kicukiro District (166.7 km^2) located in south and south East of City of Kigali (730 km^2), the Capital City of Rwanda subdivided into 3 administrative districts (Gasabo, Kicukiro and Nyarugenge) (Figure 2).

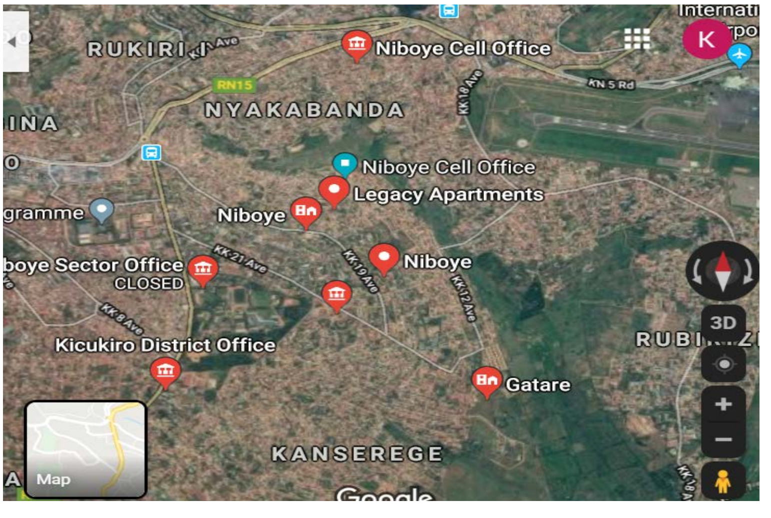

Figure 2. Map of study area.

In 2005, the City of Kigali expanded its WASAC limits by 10 times to 731.24 km^2 leading to the inclusion of large areas of rural and agrarian land [15].

Given the nature of the study (more qualitative than quantitative), data collection for this research was carried out through triangulation approach (combined methods); this means that the information was collected from primary data available both in the households and secondary data from the results of previous studies following the steps below.

2.2. Secondary Data

Secondary data *i.e.* data from physical and e-documents such as books, journals as well as reports helped the researchers to contextualise the findings and to understand how the findings of this study fit into the existing body of knowledge.

2.3. Primary Data

2.3.1. Field Observation

This method has been used to identify the applied technology for rooftop rainwater harvesting in Niboye Sector in order to apprehend the advantages and disadvantages. Direct observation also helped the researchers to envisage other complementary methods of data collection in this study.

2.3.2. Interview

In this study semi-structure interview *i.e.* interview in which the order of the questions can be changed depending on the direction of the interview, was used. Therefore, the researchers, at a gathering with some members of households at Niboye Sector, Agatare Cell in Kigarama Village of Kicukiro District, were able to interview some of them to answer some questions on the rooftop Rainwater harvesting.

2.3.3. Questionnaire

In this research, the questionnaire-survey was administered to sample of 108 people holding water tanks in Niboye Sector. The difference from interview, is that the questionnaire was used for collecting information from a large number of respondents (108 people) to whom a list of written open-ended and closed-end items to which they should respond.

2.4. Sampling Method

The target population for this research was 151 beneficiaries from Niboye Sector who got water tanks whereby Rwanda Natural Resources Authority (RNRA) injected the subsidies and from whom a sample was determined using Yamane formula.

$$n = \frac{N}{1 + N(e)^2} \tag{1}$$

where: n = sample size; N = total population (151) and e = error margin (0.052).

So sample size calculated was $n = 151/1 + 151\ (0.052^2) \rightarrow n = 151/1.4 \rightarrow n = 107.8$ rounded to 108 respondents.

A tanks beneficiaries list taken as sampling frame in Niboye Sector was considered to select respondents to be used in the study.

For selecting respondents, the researchers used the systemic sampling technique where sampling interval calculated was 2 and defined as K, *i.e.* every K^{th} subject on a list of all tanks households, were selected for inclusion in the sample. The calculation of K was done by dividing the total population by sample size (151/108 = 1.4 **rounded to 2 for easy sampling**).

In addition, purposive sampling was used to select some households for interview based on their experience in using RWH pointed by UMURENGE SACCO provider of tanks.

2.5. Data Analysis

This study being more qualitative than quantitative, in the process of data analysis, materials that have been collected were analyzed and highlighted, compiled and grouped into themes especially in accordance with objectives set. Then, data were presented in the form of brief descriptions in tables with connections between categories in order to draw conclusion and the core issues. Qualitative research method does not mean to exclude numbers and statistical techniques for data presentation and analysis [16]. Of course, all primary data which were collected from participants in this study were linked with secondary sources to arrive at factual explanation of the Rooftop Rainwater Harvesting for Sustainable Development of Household in Niboye Sector, Kicukiro District in Kigali City.

3. Results and Discussion

This section presents the results and the interpretation of data gathered out of the methods set in the study, and is represented according to the specific objectives or research questions raised in problem statement.

Profile of respondents

In general the average age of the respondents interviewed is 42.5 years (Minimum 30 and maximum 55). Most of the respondents interviewed have a bachelor degree (39%) followed by a secondary education level (36%). Most of the respondents are married (52%) followed by divorced (20%) and majority of respondents were involved in business.

3.1. Technologies Used for Rooftop Rainwater Harvesting in Niboye Sector

The system used in Niboye Sector for collecting and storing rainwater from rooftops, varies from simple techniques such as jars and pots to more complex techniques such as plastic tanks as well as underground cisterns depending on households' financial capacities.

This paper focused on domestic rainwater harvesting modern system as supported by UMURENGE SACCO.

It has been observed that most of households use plastic water tanks in size of 2 - 5 m^3 because of their costs, availability and ease of installation and maintenance (Figure 3).

Roof

The roof or collection area, also termed catchment or capture area, is the surface upon which the rain falls. Experts suggest that surfaces should be sturdy, durable, impermeable, and non-toxic, as this can have a direct impact on quality of the water and health of the users, if the water is to be for potable uses.

Gutter, Downspout and Pipe

As shown on Figure 1, gutters, downspouts and pipe are the conveyance system linking the roof surface to water tank.

Tank

The tank is where the water conveyed from the collection surface is stored. In many households of Niboye Sector, tanks are in plastic and built above ground for easier maintenance.

3.2. Effectiveness of Rainwater Harvesting in Niboye Sector

Before going into analysis details of the RWH contribution, the researchers deemed necessary to make sure whether households really harvest rainwater from the rooftop. Table 1 provides details.

As displayed in Table 1, there are several sources of water supply in Niboye Sector such as piped water supplied by WASAC (community water, individual and public tap water), wells water and rainwater harvested from the roof. But what is common is that everyone uses rainwater in different proportions. The Rooftop Rainwater harvesting is the main source of water supply of 66% of respondents while 29% use both tap and rainwater. In last position come 5% of households who use at the same time the well water and rainwater. It was noticed that the majority of households of Niboye Sector use RWH as primary source of water supply.

Figure 3. Water Tank in one of the household in Niboye Sector. Source: Photo taken by the Researchers, 2019.

Table 1. Sources of water supply in Niboye Sector during rainy season.

Items	Frequency (n = 108)	(%)
Community Water & RWH	11	10
Public taps & RWH	8	7
Only Rooftop Rainwater harvested	71	66
Individual Tap & RWH	13	12
Wells & RWH	5	5

Source: Field Data, 2019.

What is done in Niboye Sector goes in the same line with the observation of United Nations for Environment Programme (UNEP) which argues that in different countries around the world individuals and groups have developed many varieties of RWH systems for use and this technology adopted in rural and urban areas can serve as a primary or supplementary water source [17]. Similarly to Rwanda, [17] states that due to the hilly or mountainous nature of the terrain in the majority of the British Virgin Islands, combined with dispersed housing patterns, rainfall harvesting appears to be the most practical way of providing a water supply to some residents.

As also confirmed by Jean-Charles (2007) rainwater is harvested everywhere in the world as principal source of supply. He listed some cases like large rural areas of Honduras where RWH is a source for domestic water supply; in Thailand, where is evidence of RWH practice; in Australia where RWH has been used before tenth century, which collected on roofs as primary sources for drinking purpose; in part of India, in Africa and parts of US where RWH system is popular [18].

As stated earlier, RWH in Niboye Sector seems also effective. The issue is storage capacity and conservation for long time but all depends on financial possibilities of each household as stressed by the residents interrogated (**Table 2**).

Capacity of Harvested Water

The residents of Niboye sector practice rooftop rainwater harvesting in their homes and they have water tanks of different capacity depending on the affordability of the payment of the given tanks despite the support by the government of Rwanda.

Table 2 depicted that the respondents have different storage capacity of water harvesting from the roof. The majority of respondents (64%) have capacity of water storage varying from 2000 to 5000 litres. They are followed by 22% of respondents with capacity storage of 2000 litres. Thirdly 8% of respondents with capacity 1000 litres and in forth position come 5% of households with capacity varying between 5000 and 10,000 litres. Those who have the capacity of harvesting water more than 10,000 litres *i.e.* 10 m^3 represent 1%.

Criteria for Selection of Rainwater Harvesting the capacity RWH for domestic use take into consideration notably the size of catchment area (roof), local rainfall data and weather patterns, length of the drought period, alternative water

Table 2. The capacity of water tanks used by respondents.

Capacity of tanks	Number of Respondents	(%)
1000 litres	9	8
2000 litres	24	22
2000 - 5000 litres	69	64
5000 - 10,000 litres	5	5
More than 10,000	1	1
Total	108	100

Source: Field Data, 2019.

sources and cost of the rainwater harvesting system, when rainwater harvesting is mainly considered for irrigation. For Niboye residents, cost and alternative water sources are most determinant factors.

The volume of rainwater that can be harvested from a rooftop is calculated using the formula

$$V = A * R * C, \quad (2)$$

where V is the volume of harvestable water, A is catchment area *i.e.* the roof, R is Total Amount of Annual rainfall, and C is the runoff coefficient. So the capacity of reservoir to avail will depend on the roof area of the house.

The values of 0.8 - 0.85 are often used for the runoff coefficient, however, it may be as high as 0.9 or as low as 0.24, depending on the surface material and other factors which may reduce the efficiency like evaporation, clogging, leakage, infiltration, overspill, and retention [19].

For instance, to optimise the rainwater harvesting (RWH) considering the 1028 mm average amount of rainfall in Niboye [20], a house with 10.75 m^2 and 0.9 of runoff coefficient will require a capacity or size tank of 10,000 litres ($10.75 \times 1028 \times 0.9 = 9945.9$ - 10,000 litres or 10 m^3).

Factors leading to the adoption of using Rooftop Rainwater in Niboye Sector

In general, rooftop rainwater harvesting is used for meeting different demands in Niboye Sector residents. These demands are expressed in terms of Environment, water supply-nexus as well as socio-economic activities.

Table 3 reveals that harvested rooftop rainwater in Niboye Sector is used by the households in different ways depending on the need. Most of the residents (91%) use this water for sanitation purpose like mopping the house, flashing toilettes, cleaning the surroundings of the premises followed by (84%) for bathing bodies and food preparation (81%), drinking (77%), and washing clothes and utensils (72%), etc.

From factors raised above, it is noticed that Rainwater Harvesting can provide an independent water source in areas where other water sources are unavailable, or where water quality is unacceptable or too difficult to obtain. The use rooftop rainwater harvesting provides many advantages as detailed in **Table 4**.

Table 3. The use of harvested rooftop rainwater by the respondents.

Different use ways of Rainwater harvested in Niboye Sector households	Frequency (n = 108)	(%)
Used for Drinking	77	71
Used of Cooking (food preparation)	87	81
Used of washing clothes, utensils and other domestic assets/material	78	72
Used of bathing	95	84
Used of general sanitation of the house like mopping, flushing toilets, etc.	98	91
Others ways	75	69

Source: Field Data, 2019.

Table 4. Advantages of Niboye Sector households to harvesting Rooftop Rainwater.

Advantages Niboye Sector residents to harvesting Rooftop Rainwater	Frequency (n = 108)	(%)
it is easy to maintain	71	66
It reduces water bills	107	99
It reduces water demand	88	81
It is used for watering the Kitchen garden	11	13
It generates income for supporting the domestic needs	10	9
It reduces Flooding and Erosion	108	100

Source: Field Data, 2019.

3.3. Advantages' Rainwater Harvesting

The importance of RWH is becoming nowadays increasingly uncontourable due to its easy management. This meets the view of Cowden who states that RWH is described as a lid that saves money and time, because there are no monetary costs or travel to the dweller [5]. It serves also to empower slum household even if there was no enhancing of the availability and willing of government.

Table 4 presents the respondents' perceptions on RWH advantages among them are mentioned:

1) Easy to maintain has been expressed by 66% of respondents.

As seen earlier, the systems for the collection of rainwater are based on simple technology.

The factors such as easy installation, low energy requirement and cheap maintenance serve as motivation for urban and rural inhabitants to install rainwater harvesting systems (RWHS) [21] [22]. Whereas other studies support that rainwater harvesting has been identified as one of the best means for promoting sustainable water supply in urban areas [23] [24]. In this sense Rainwater can provide an independent and free water supply that offers several advantages of its usage.

2) Reduces Flooding and Erosion has been pointed out by all respondents (100%).

Harvesting rainwater can help the environment in a number of ways. For starters, it can reduce erosion and control storm water run-off. The collection of rainwater may reduce flooding in certain areas as wells. In the same vein [25] and [26] argue that rainwater prevents flooding, helps in controlling climate change impacts and contribute to the storm water management, and so forth.

3) Reduces Water Bills has been stated by 99% of respondents.

Rainwater harvesting helps not only individuals save on their water bills but can cut costs for entire communities. The cost to supply mains and overall water services can be substantially reduced when many people in one community use rainwater. Having a source of water reduces also dependence on WASAC sources especially in case the tap water is interrupted and other water sources are contaminated. Similar studies emphasise that in areas where domestic water source are contaminated, RWH has been proven to fill the gap as an alternative water source [27] [28] [29].

4) Reducing water demand scored by 81% of respondents.

Different scholars confirm that the increase in population invariably leads to an increase in water demand and that water scarcity and the limited capacity of conventional sources in urban areas promote RWH as an easily accessible source [30] [31] [32]. Where water is scarce rainwater properly harvested is for drinking, bathing and other domestic activities as seen in **Table 3**.

World Health Organisation (WHO) estimates that drinking water per day and per capita is 20 litres while water for cleaning although it is difficult to determine the consumption required [33] while [34] estimates it at 50 litres per day and per capita. In Niboye where the average size of a household is 5 people, for reaching these estimations, it will take an optimum of 20 liters + 50 liters × 5 people = 350 litres or 0.35 m^3

The demand for the household with a size 5 people can be estimated on a month by month basis, or averaged for simpler calculations. The following formula is used for calculating the required water each month for meeting the household's need of the whole year [35].

$$V_t = V_{t-1} \text{ (Runoff-Demand)} \tag{3}$$

V_t = theoretical volume of water remaining in the tank at the end of the month.

V_{t-1} = volume of water left in the tank from the previous month.

If V_t is negative it means that demand is greater than supply; if it is greater than zero it means the demand is met every month.

Assume 350 litres for 5 peoples a day; Total annual rainfall 1028 mm; Catchment efficiency 90%; Catchment area 10.75 m^2 and tank size 10,000 litres.

Table 5 is the calculations' example of monthly Catchment.

It is assumed that the demand is constant. The V_{t-1} is the reflection of the previous month's V_t. Based on these calculations, it is proven that where rainfall is spread throughout the year as in Niboye Sector and if the collection of rainwater is optimized, household water demand will always be satisfied along the whole year without shortage.

Table 5. Monthly catchment calculation.

Months	Precipitations	V_t litres	V_{t-1} litres	Runoff litres	Demand litres
January	69	317.575	317.575	667.575	350 litres
February	100	935.05	317.575	967.5	350 litres
March	106	1610.6	935.05	1025.55	350 litres
April	183	3031.125	1610.6	1770.525	350 litres
May	92	3571.225	3031.125	890.1	350 litres
June	20	3414.625	3571.225	193.5	350 litres
July	9	3151.7	3414.625	87.075	350 litres
August	34	3130.65	3151.7	328.95	350 litres
September	86	3612.7	3130.65	822.05	350 litres
October	102	4249.55	3612.7	986.85	350 litres
November	127	5.128.275	4249.55	1228.725	350 litres
December	100	5745.775	5128.275	967.5	350 litres

5) Watering kitchen garden has been underscored by 13% of respondents.

Rainwater harvesting is also used to improve plants and gardens. Using rainwater harvesting that is this clean and healthy for plants and trees can save money on overall property maintenance and landscaping needs.

6) Generating income for the households has been rated by 9% of respondents. One resident from Niboye interviewed stated: **"*I sell the harvested rooftop Rain water during the rainy season from my water tank and get some money to buy the basics of my family and this has improved the family economic status. I sell a jerrycan at* 200 *FRW and this has created a job for my wife as she is the one who sells this water at home*".**

3.4. Organisations Involved in Rooftop Rainwater Harvesting Project

In Kicukiro District, there are many stakeholders (Multilateral, bilateral, NGOs, the Civil Society and the Private Sector) and donor commitments to support RWH activities. Among the existing INGOs, some have developed the water distribution to Niboye Sector households by giving water tanks and the accessories to harvest water from the rooftops of their houses.

As depicted in Table 6, the majority of respondents (97%) stated that organisations involved in RWH are less than ten (10) in Niboye Sector. Only 3% reported that more than ten (10) organisations assisted them.

According to RNRA [11] (2016), the existence of RWH based International and neighboring organizations (SEARNET; RAIN Foundation; GWP; IRHA; UN-FAO; ERHA; KRA; URHA) further augment the success of rain water harvesting. The Rwandan Financial institutions have been a strong backbone to facilitate the households to buy water tanks which they wouldn't afford without the loans especially granted by UMURENGE SACCO and GTBANK which have immensely involved for supporting RWH activities.

Table 6. Respondents perceptions on involvement of organization to support Rooftop Rainwater Harvesting in Niboye Sector.

Number of organization supporting Rooftop Rainwater Harvesting	Number of Respondents	(%)
Below 10 Organisations	105	97
10 - 12 Organisations	2	2
12 - 15 Organisations	1	1
Total	108	100

Source: Field data 2019.

3.5. Challenges Faced by Rooftop Rainwater Harvesting

Even if RWH presents benefits of being near to households, there are some challenges hindering its effective implementation.

In Table 7, it is displayed the following majors challenges which seem common to RWH's users everywhere the technology is applied.

Lack of financing

The respondents from Niboye Sector urge that the greatest challenge they are facing in RWH is the lack of financing as pointed out by 93% of respondents. One of respondents interviewed stated: ***to buy the water tanks and the accessories for Rooftop rainwater harvesting, the residents of Niboye Sector acquire loans in terms of Rwanda Francs from the financial institutions such as Umurenge*** **SACCO and GTBANK**. ***But for enough water quantity that can cover a household's demand, it requires at least an amount of*** **500,000** ***RWF adequate size of tank that has been only granted to*** **3%** ***of households***.

Insufficient people's knowledge in RWH and use

The lack of people's knowledge regarding RWH and its use was second challenge as raised by 82% respondents in Niboye Sector.

Lack clear policy

In third position come 81% of respondents who argued that the challenge faced is lack clear policy. In line with this issue, RNRA [11] revealed that the National Policy on water and sanitation in Rwanda exists and it focuses on Water Supply and Sanitation services with a bit emphasis on RWH but it does not indicate how the option of rain water can be tapped to augment water resources.

Inaccessibility to adequate technology

Another important category of Respondents (66%) underscored inaccessibility of households to adequate technology. This aspect is linked to inadequate financial support.

Poor quality of rain water harvesting

The penultimate category of respondents (21%) emphasised the RWH poor quality. Rainwater is pure and drinkable if it is collected in the disinfected containers. But their only drawback is that they do not contain mineral salts and other elements essential to good health that are found in waters that have passed through the different layers of the soil. On the other hand, the meteorological water can be polluted by the discharge into the atmosphere including chemical compounds emanating from industries by sulfur which even decimate plants. Under these conditions the water is not pure and drinkable. Another issue is that rainwater cannot be conserved for long time without being deteriorated. So it requires the treatment.

Methods of treating harvested rooftop rain water

As displayed in Table 8, there are different methods of rain water treatment used by respondents especially for those who use it as unique drinking water source.

Referencing to Table 8, it was observed that most of the respondents (71%) boil water before drinking, % of respondents use filtering method and 2% apply chlorination methods because the ones are chemical products which are expensive while 29% do not use any method either by ignorance of consequence or due to the fact that rain water is not used as drinking water source.

A resident from Agatare cell in Kigarama Sector stated: "*We are happy to have rooftop rainwater harvesting system but treatment methods such as chlorination* (*chemical products expensive*) *and boiling* (*required charcoal*) *are costly. The most method we use to treat water is the boiling water but this is not permanently done due to lack of money for buying charcoal.*"

So this water is being drunk untreated by those householders can cause to them water borne diseases which require great attention.

Table 7. Challenges rooftop rainwater harvesting.

Challenges	Frequency (n = 100)	(%)
Continuation of paying exorbitant bill to WASAC	10	9
People's inaccessibility to adequate technology	71	66
Lack of a clear policy for RWH	87	81
Insufficient people's knowledge with regard to RWH and its use	88	82
Lack of financing	100	93
Poor Rain Water Harvesting Quality	23	21

Source: Field Data 2019.

Table 8. Different methods applied for water treatment used by respondents.

The methods of water treatment	Frequency (n = 108)	(%)
Boiling	77	71
Filtering	7	4
Chlorination	2	2
No water treatment adopted	31	29

Source: Field Data 2019.

4. Conclusion

Rooftop rainwater harvesting is one of the optimistic and economically viable methods of rainwater harvesting. Respondents acknowledge the positive and negative impact of this practice of Rooftop Rainwater harvest that contributes to their well-being of households and for the adequate solution to reduce challenges of water demand and its management within Niboye Sector, Kicukiro District in Kigali City. For preventing the challenges, this requires the close collaboration and a collective engagement among stakeholders *i.e.* residents, Government bodies, Civil Society organisations such as Non-Government Organizations (NGOs) so as to enhance the citizens' perceptions in regards to practicing Rooftop Rainwater harvesting and for a financial and educational support in this trend in order to comply with the SDG6 goal of Water and Sanitation for all.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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