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Prevalence of rooftop rainwater harvesting to Replenish Accessibility of Clean and Safe Water among Community Households of Nyarugenge District, Rwanda

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Abstract: **Access to clean and safe water remains a major public health challenge globally, regionally, and locally, particularly in Nyarugenge District, Rwanda. Rooftop Rainwater Harvesting (RRWH) offers a sustainable and cost-effective alternative to supplement the water supply, yet its adoption remains limited. In Kigali, only 4.5% of households utilize a complete RRWH system, and there is limited documentation on its uptake in Nyarugenge. This study aimed to assess the prevalence of RRWH among community households in Nyarugenge District and examine how knowledge, attitudes, and practices (KAP) influence its adoption. A mixed-methods approach was employed, using both quantitative and qualitative data within a descriptive cross-sectional design. Stratified purposive sampling targeted households with RRWH systems in Kimisagara and Kigali sectors. Data were analyzed using SPSS, with findings presented through descriptive and inferential statistics, including graphs and charts. The results showed that 67.1% of RRWH users were male and 32.9% female. Most households (91.0%) still rely on piped water, with only 5.4% using rainwater for domestic consumption. Among those with RRWH systems, 38.5% used containers with a capacity between 501 and 1000 liters. The overall uptake of RRWH in the community was 49.9%. KAP showed statistically significant influence on adoption, with a p-value of 0.0123 at a 95% confidence interval. This study highlights the need for increased awareness, technical support, and incentives to promote RRWH as a complementary water source in urban settings.**

Keywords: **Rooftop Rainwater Harvesting, community household, Access, clean, safe, replenish.**

1. INTRODUCTION

Access to clean and safe water is a fundamental human right and a key pillar of public health and sustainable development. Despite global efforts, over 2 billion people still lack access to safely managed drinking water services. In sub-Saharan Africa, more than 400 million people depend on unsafe water sources, a crisis worsened by environmental degradation, inadequate infrastructure, and socio-economic disparities (WHO, 2022).

In East Africa, rapid population growth and urbanization are intensifying pressure on limited water resources. Only 62% of the population has access to basic drinking water, and just 35% benefit from safely managed sources (UNICEF, 2021). These conditions demand innovative and sustainable water supply strategies.

Rwanda, though receiving significant annual rainfall of 1,200 mm, is classified as water-scarce, with only 670 cubic meters of water available per person per year (Rwanda Natural Resources Authority [RNRA], 2016). Nationwide, 55% of the population has basic drinking water services, while 25% experience limited access. In Kigali, access is higher at 82%, but only 52% of households treat water before consumption, compared to 43% in rural areas (DHS, 2020; UNICEF WASH Program, 2020). These figures reveal continued gaps in achieving reliable and safe water access.

Rooftop rainwater harvesting (RRWH) presents a practical and sustainable solution to alleviate water shortages, particularly in urban areas where infrastructure struggles to meet rising demand. RRWH involves collecting and storing rainwater from rooftops for domestic uses such as drinking, cooking, and sanitation (Pande, 2020; Zhou et al., 2021). It has proven successful in various global contexts, including England, Malaysia, and South Africa, where it contributes significantly to household water conservation (Malaysian Water Association, 2019; Baiyegunhi, 2015). It is also increasingly adopted in East African countries such as Kenya and Uganda, where government support and subsidies have improved water availability (Ministry of Water and Environment, Uganda, 2019).

In Rwanda, 17% of the population uses some form of RRWH, but only 2% utilize a complete system (EICV4, 2016/2017). In Kigali, 35% of households have implemented RRWH, yet only 4.5% use a complete system (National Institute of Statistics of Rwanda [NISR], 2016). In Nyarugenge District, the adoption, functionality, and community engagement in RRWH remain underexplored. There is limited documentation on its prevalence and the factors influencing its uptake.

This study addresses that gap by determining the prevalence of rooftop rainwater harvesting to replenish clean and safe water access among community households in Nyarugenge District. It also explores how knowledge, attitudes, and practices influence adoption. The findings aim to inform policymakers and stakeholders seeking to enhance urban water security, public health outcomes, and sustainable development.

2. ROOFTOP RAINWATER HARVESTING

2.1. Prevalence of Rooftop Rainwater Harvesting (RRWH) To Enhance Clean and Safe Water Accessibility in Nyarugenge Community Households

Rooftop rainwater harvesting (RRWH) is defined as the collection and storage of rainwater from rooftops for use in various domestic applications, such as drinking, cooking, and irrigation. This sustainable water management practice has gained prominence due to its potential to alleviate water scarcity, reduce dependence on municipal water supplies, and enhance water security. The prevalence and uptake of RRWH are influenced by various factors, including socio-economic conditions, public awareness, technical feasibility, and environmental considerations. (Staddon et al., 2018)

The components of RRWH systems are integral to their functionality and effectiveness in collecting and utilizing rainwater for domestic purposes. The primary component is the catchment area, which is typically the rooftop of a building. The surface area and material of the roof significantly influence the quantity and quality of water collected. Rooftops made of non-toxic materials, such as metal or tile, are preferable as they reduce the risk of water contamination (TamilNadu Water Supply and Drainage Board, 2024). Rainwater is funneled from the roof into gutters and downspouts, which direct the flow towards storage systems. The design and maintenance of these gutters are crucial as they must efficiently handle heavy rainfall and prevent blockages caused by debris. The effectiveness of RRWH systems in providing a reliable supplementary water source hinges on the proper integration and maintenance of these components, ensuring that households can maximize the benefits of rainwater harvesting (Kagabika et al., 2021).

Globally, RRWH has been increasingly adopted as a supplementary water source. In regions experiencing significant variability in rainfall and rapid urbanization, such as in Ethiopia, Jordan, and Nigeria, RRWH has proven to be an indispensable component of the urban water mix. Demeke and Amali (2023) reveal that RRWH can augment water demand by up to 70% and provide annual savings of up to USD$56 million in municipal energy costs. At the household level, financial returns can range from $12 to $48 annually. This evidence underscores the urgent need for governments and households to promote RRWH adoption and carefully monitor compliance with standards in decentralized water distribution systems.

In Europe, a study in Germany found that 25% of households have implemented RRWH systems, reducing their municipal water consumption by up to 50% (Schaefer, 2018. In Malaysia, 35% of households in urban areas like Kuala Lumpur have adopted RRWH, primarily for non-potable uses, contributing to a reduction in urban flooding by up to 50% (Malaysian Water Association, 2019). These figures highlight the effectiveness of RRWH in managing water resources in densely populated urban areas. In Africa, a study in Nigeria found that 20% of urban households use RRWH systems, which meet 25% of their water needs during the rainy season (Adewumi et al., 2014). In South Africa, particularly in the KwaZulu-

Natal region, 30% of households have adopted RRWH, contributing to a 20% increase in crop yields for small-scale farmers (Baiyegunhi, 2015). These studies illustrate the potential benefits of RRWH in enhancing water security and supporting agricultural productivity in African contexts. In Kenya, about 25% of urban households in Nairobi use RRWH systems to supplement their water needs, leading to a 20% reduction in water expenses during dry seasons (Mbogo, 2020). Similarly, in Uganda, 30% of households use RRWH to supplement their water supply, particularly in rural areas where access to municipal water is limited (Ministry of Water and Environment, 2019). These findings underscore the role of RRWH in improving water accessibility in East African countries.

In Rwanda, despite its significant annual rainfall of 1,200 mm, as of the 2016/2017 EICV survey, 17.4% of households have implemented some form of rainwater management system, reflecting a growing recognition of rainwater harvesting (RWH) as an essential aspect of water management. Among these, ditches are the most common method, used by 13.4% of households to guide rainwater either into underground storage or away from living areas. While this method is practical and cost-effective, it does not necessarily ensure that the stored water is readily accessible for household use. In contrast, 2.1% of households have installed rainwater tanks, representing those with a complete RRWH system that actively replenishes water accessibility by storing it for future use. Additionally, **1.8%** of households have systems that pipe rainwater away from their homes, and **0.3%** use other unspecified methods.

In Kigali, the capital of Rwanda where rapid urbanization puts more pressure on water accessibility, 35.2% of households have implemented some form of rainwater management system. Among these, ditches are the most common method, used by 27.8% of households to guide rainwater either into underground storage or away from living areas. In contrast, 4.5% of households have installed rainwater tanks, representing those with a complete RRWH system. Additionally, 2.9% of households have systems that pipe rainwater away from their homes. A study conducted by Kagabika et al. (2021) in Niboye Sector, which surveyed 108 respondents with a complete RRWH system, found that 66% rely on rainwater as their primary water source. The research highlighted the potential for RRWH to improve water security, particularly during dry seasons, but noted significant barriers such as financial constraints and technical challenges. Government incentives and public awareness campaigns were suggested as strategies to boost adoption rates in the region.

Empirical studies from various countries provide insights into the prevalence and uptake of RRWH and how it has impacted water accessibility. In England, a study conducted by DEFRA (2016) assessed the adoption of RRWH systems in London. Using a mixed-methods approach, the research included surveys and interviews with 300 households. The findings revealed that 20% of the households had RRWH systems, primarily used for gardening and toilet flushing. The study highlighted that 70% of these households reduced their water bills by up to 40%. Despite these benefits, concerns about water quality and the complexity of maintenance were significant deterrents for wider adoption.

In Malaysia, the experience with RRWH was examined by the Malaysian Water Association (2019), which focused on urban households in Kuala Lumpur. The study employed a quantitative research design, using structured questionnaires to collect data from 400 households. Findings showed that 35% of households had adopted RRWH, primarily for non-potable uses. The study found a strong correlation between income levels and RRWH adoption, with higher-income households more likely to invest in these systems. Additionally, 25% of respondents reported that RRWH helped mitigate urban flooding.

In Africa, a study by Baiyegunhi (2015) in South Africa's KwaZulu-Natal region assessed the adoption of RRWH among small-scale farmers. Using a mixed-methods design, the research surveyed 600 households. Results indicated that 30% of the households used RRWH, which contributed to a 20% increase in crop yields. However, financial constraints and lack of technical knowledge were significant barriers to broader adoption. The study recommended increased government support and training programs to enhance RRWH uptake. In Rwanda, the baseline survey carried out for the RNRA project1 in 2014 interviewed 1200 users in 6 districts in Rwanda (Gasabo, Kicukiro, Nyarugenge, Musanze, Nyabihu, and Rubavu) and found that 28.6% of the population uses RWH as their source of water. But the survey also mentions that over 60% of those use jerry cans for storage. The harvested water is insufficient for the majority of people interviewed (about 72%).

2.2 Knowledge, Attitude, and Practices (KAP) on Utilization of Rooftop Rainwater Harvesting

Rooftop rainwater harvesting (RRWH) is an increasingly recognized method for addressing water scarcity, yet its adoption is significantly influenced by the knowledge, attitudes, and practices (KAP) of households. Understanding these factors is crucial for designing effective interventions to promote RRWH and ensure its sustainability.

Globally, awareness and knowledge about RRWH vary widely. In the United States, a study by the United States Environmental Protection Agency (EPA) found that 70% of households in regions prone to water scarcity are aware of RRWH, and 50% express a positive attitude towards its adoption (EPA, 2018). In Canada, a survey revealed that 65% of households in British Columbia are aware of the benefits of RRWH, with 40% having implemented the systems primarily for non-potable uses such as gardening and toilet flushing (Environment Canada, 2017). These figures indicate significant awareness but highlight that further efforts are needed to translate awareness into widespread adoption.

In Europe, particularly in Germany, public knowledge and attitudes towards RRWH are shaped by extensive government and community initiatives. A study by the Federal Environment Agency (UBA) found that 80% of households are aware of RRWH, and 60% have a positive attitude towards its implementation (UBA, 2016). Despite high awareness, only 35% of households have installed RRWH systems, suggesting that practical barriers such as cost and maintenance still play a significant role in adoption rates. In Asia, awareness and adoption of RRWH vary significantly between countries. In Japan, a survey conducted by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) found that 55% of urban households are aware of RRWH, and 30% have implemented it for non-potable uses, contributing to a 40% reduction in municipal water usage (MLIT, 2015). In Thailand, knowledge and attitudes towards RRWH are influenced by both government policies and community practices. A study by the Thai Ministry of Public Health found that 60% of households are aware of RRWH, with 35% adopting it, primarily to manage water shortages during dry seasons (Thailand Ministry of Public Health, 2019).

In Africa, knowledge and awareness about RRWH vary across different regions. In Senegal, a study by the National Agency for Statistics and Demography (ANSD) found that 45% of households are aware of RRWH, and 25% have a positive attitude towards its adoption (ANSD, 2018). The study emphasized the need for more public awareness campaigns and educational programs to promote RRWH. In South Africa, awareness and attitudes towards RRWH are influenced by socio-economic factors.

In East Africa, the level of knowledge and awareness about RRWH is influenced by government initiatives and community-based programs. In Kenya, a study by Irungu et al. (2024) found that 45% of households were aware of RRWH, and 30% had a positive attitude towards its adoption. The study highlighted the importance of educational programs and community engagement in promoting RRWH. Similarly, in Uganda, awareness and attitudes towards RRWH are influenced by public awareness campaigns and educational programs. According to the Ministry of Water and Environment (2019), 40% of households are aware of RRWH, and 25% have a positive attitude towards its adoption. In Rwanda, the level of knowledge and awareness about RRWH is relatively low, particularly in urban areas like Nyarugenge District, as highlighted by its adoption, where only 35% implement any form of RRWH, with only 4.5% using a complete RRWH system. (EICV, 2016/2017). However, the data on how KAP influences RRWH in Rwanda, Kigali, and Nyarugenge remains very limited.

Empirical reviews from various countries highlight the importance of knowledge, attitudes, and practices in influencing the adoption of RRWH. In the United States, a study by the EPA (2018) found that public awareness campaigns significantly increased knowledge and positive attitudes towards RRWH, leading to a 30% increase in adoption rates. In Canada, research by Environment Canada (2017) showed that educational programs and public awareness campaigns increased knowledge and positive attitudes towards RRWH, resulting in a 25% increase in adoption rates.

In Germany, a study by the Federal Environment Agency (UBA, 2016) assessed the impact of public awareness campaigns and educational programs on RRWH adoption. The research included a sample of 800 households and found that public awareness campaigns and incentives significantly increased knowledge and positive attitudes towards RRWH, leading to a 25% increase in adoption rates. The study concluded that continuous government support and public awareness campaigns are essential for promoting RRWH. A study in Thailand by the Thai Ministry of Public Health (2019) assessed the impact of public awareness campaigns on the adoption of RRWH in urban areas. The research included a sample of 700 households and found that public awareness campaigns significantly increased knowledge and positive attitudes towards RRWH, leading to a 30% increase in adoption rates. In Africa, a study by the Water Research Commission (WRC, 2017) assessed the impact of public awareness campaigns on the adoption of RRWH in South Africa. The study surveyed 600 households and found that public awareness campaigns significantly increased knowledge and positive attitudes towards RRWH, leading to a 20% increase in adoption rates. The research highlighted the importance of continuous public awareness campaigns and educational programs to enhance knowledge and attitudes towards RRWH.

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2.3. Conceptual framework

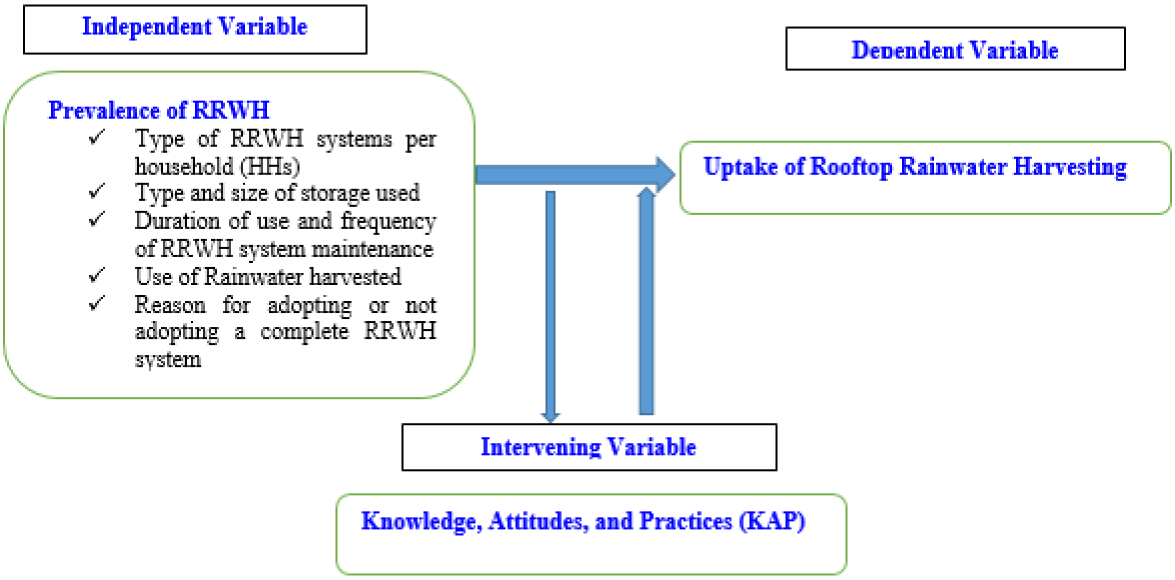

Figure 2.1: Conceptual framework Silali (2024)

3. METHODS AND METHODOLOGY

3.1 Methods

This study employed a descriptive cross-sectional design with a triangulated mixed-method approach. The cross-sectional design enabled data collection at a single point in time, offering a snapshot of rooftop rainwater harvesting (RRWH) uptake and related factors in Nyarugenge District. The design was appropriate for efficient data collection within a limited timeframe. The triangulation involved combining quantitative methods, such as structured household questionnaires, with qualitative methods, including in-depth interviews and focus group discussions. This integration enhanced the credibility and depth of the findings by allowing for the validation of results across multiple data sources.

The quantitative component involved the use of structured questionnaires to collect numerical data from households in the selected sectors. This data was analyzed statistically to identify patterns, correlations, and trends related to RRWH adoption and its effectiveness. The qualitative component involved in-depth interviews and focus group discussions with key informants, including local authorities, sector representatives, and selected household heads. These interviews and discussions provided detailed insights into the personal experiences, perceptions, and motivations behind RRWH adoption.

The study population consisted of all households in the Kimisagara and Kigali sectors that have implemented any form of rooftop rainwater harvesting (RRWH) system, which includes a catchment area with a gutter, a downspout, whether connected or not to a storage tank. These sectors were selected to ensure comprehensive representation of both the central and peripheral areas of Nyarugenge District. According to the 2022 Rwanda Population and Housing Census, Kimisagara is the most densely populated sector in the central area of Nyarugenge, with 16,434 households, while Kigali sector is the most populated in the peripheral areas, with 17,911 households. Based on previous research, it is estimated that approximately 35% of households in Nyarugenge District have implemented some form of RRWH system. Therefore, the study population within these sectors is estimated to comprise around 12,020.

The target population for this study includes all households in the Nyarugenge district that have implemented any form of rooftop rainwater harvesting (RRWH) system, which includes a catchment area with a gutter, a downspout, whether connected or not to a storage tank. According to the Fifth Rwanda Population and Housing Census, 2022 (NISR), Nyarugenge District comprises 103,985 households spread across its ten sectors: Gitega, Kanyinya, Kigali, Kimisagara, Mageregere, Muhima, Nyakabanda, Nyamirambo, Nyarugenge, and Rwezamenyo. The target population is specifically those households among the 103,985 that have implemented any form of RRWH system.

To determine the appropriate sample size for this study, Yamane's formula was used. Yamane (1967) provides a simplified formula to calculate sample sizes:

$$\mathbf{n} = \frac{N}{1+N(e)2},$$

Where: **n** is the sample size, **N** is the population size, and e is the marginal error (0.05)

Substituting, given that the target population (households with RRWH systems) in the selected sectors is 12020:

$$\mathbf{n} = \frac{12020}{1+12020(0.05)2} = \mathbf{387}$$

Thus, the sample size for this study was 387 participants at 95% CI with a 5% margin of error.

Data collected was managed by SPSS Version 27, analysis by cross-tabulating descriptive and inferential statistics; data was presented using pie charts and bar graphs. Ethical clearance was sought at Mount Kenya School of Postgraduate and its ethical clearance from Nyarugenge district office.

4. RESULTS AND FINDINGS

4.1 Demographic Profile

The data shows that the majority of the respondents, 248 (63.8%) are male, while 139 (36.2%) are female, demonstrating a significant chance of sustainability program with P values of 0.023 95%CIm highlighting notable gender participation in rooftop rainwater harvesting to ensure year-round water supply for community households, recognizing water as a fundamental element of life.

The majority of respondents were aged between 35 and 44 years (40.6%), followed by those in the 25 to 34 age group (34.4%). A smaller proportion, 6.2%, fell within other age ranges, while the least represented group was those aged 55 to 64, accounting for only 21% of the respondents.

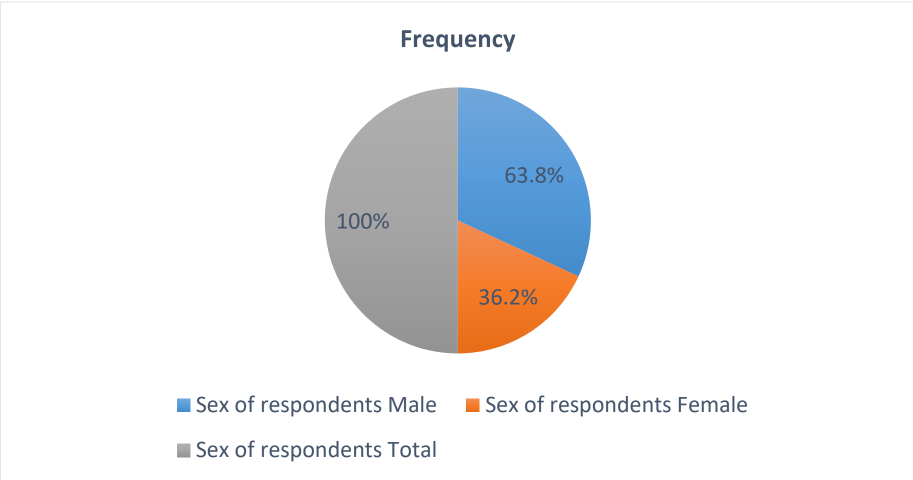

Figure 4.1: Shows the Distribution of Sex Participation in Rooftop Rainwater Harvesting

4.2 Prevalence of Rooftop Rainwater Harvesting in Nyarugenge Community Households

The study opined a prevalence of 151 respondents (38.5%) use containers with a capacity between 501 and 1000 liters, reflecting a preference for mid-sized systems that balance cost and water storage. And least respondents had containers with capacities, between 100 to 500 liters, 15 (3.9%), suggesting that most households prioritize larger systems for a more reliable water supply, and the range of respondents with water containers for rainwater harvesting was 136 (34) %. This data underscores the growing trend toward adopting larger, more efficient storage systems for rainwater harvesting to meet household needs throughout the year. This was also discussed in the FGD saturation interview held in the district:

"I decided to install a storage tank because I was tired of relying on an unpredictable WASAC city water supply, and my family needed a backup solution", FGD held on February 28, 2025.

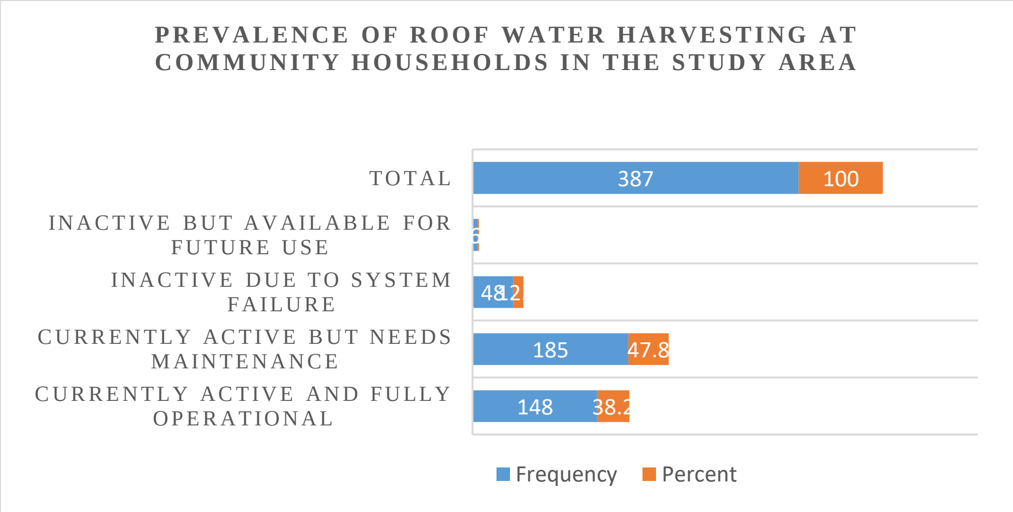

Figure 4.2: Prevalence of Roof Water harvesting at Community households in the study area

The status of rooftop rainwater harvesting systems in Nyarugenge District reveals a range of operational conditions. The largest proportion of respondents, 190 (47.8%), reported that their systems are currently active but require maintenance, indicating that while rainwater harvesting is widely practiced, many systems are not functioning optimally. Additionally, (147) 38.2% of systems are fully operational and actively providing water, showcasing a significant adoption of functioning systems. However, a smaller percentage, 48 (12.4%), reported that their systems are inactive due to failure, highlighting potential challenges in system durability and reliability. Only 1.6% of respondents indicated that their systems are inactive but available for future use, suggesting that a very small number of households have opted out of using their systems temporarily but may resume once maintenance or improvements are made. Overall, the data emphasizes the need for regular maintenance and support to ensure the long-term functionality of rainwater harvesting systems in the community.

4.3 Knowledge, Attitude, and Practices KAP on *Rooftop Rainwater Harvesting to Contribute to Municipal Water Supplies in the Study Area*

The study found that residents in Nyarugenge generally hold a high level of awareness and positive attitudes toward rooftop rainwater harvesting (RRWH), especially in recognizing its sustainability and health benefits. A majority understood the health risks of untreated water (77.8%) and reported consistent treatment practices (78.3%). However, knowledge gaps remain, with 23.5% unaware of rainwater harvesting methods and 16.8% lacking knowledge of treatment techniques. While 59.4% practiced safe storage and 58.4% were motivated to conserve water, only 2.1% always treated rainwater, and 3.1% never did, posing potential public health risks. Behavioral inconsistencies suggest the need for ongoing education and practical training. As one participant noted, “Some people are still doubtful. They think the water is dirty or not safe to drink” (FGD, February 28, 2025). Another shared, “I first heard about rainwater harvesting during a community meeting, and I learned that it can help save on water bills and provide a backup during shortages” (FGD, February 18, 2025), highlighting the impact of awareness efforts.

Despite enthusiasm, adoption is hindered by technical and financial barriers. One respondent explained, “Even though we see the benefits of RRWH, many people are still hesitant because they don’t know how to install the systems or can’t afford the upfront costs” (FGD, February 28, 2025). These findings underscore the importance of targeted interventions, including technical training and financial support, to convert positive attitudes into widespread, safe, and effective RRWH practices contributing to municipal water supply resilience.

5. CONCLUSIONS AND RECOMMENDATIONS

The Gutter and Downspout System is the most commonly used method, demonstrating its affordability and ease of installation. Key drivers of adoption include financial savings, unreliable water supply, environmental benefits, government incentives, and community programs. However, despite these motivating factors, reliance on rainwater as a primary source remains low, with most households still depending on piped water. Accessibility to water sources varies, with some households traveling significant distances, though the majority perceive their supply as reliable.

The study recommends implementing gender-inclusive awareness and training programs in Nyarugenge District, with a particular focus on empowering women to reduce the gender gap in adopting rooftop rainwater harvesting systems. Households should invest in larger storage tanks and perform regular maintenance to ensure system efficiency and longevity.

To support sustainable use, affordable and accessible system maintenance and technical support services should be established in the district. Promoting consistent water treatment methods, such as boiling or filtration through targeted community education, will enhance safe water use.

The district government should expand financial incentives and community engagement programs to encourage wider adoption of rooftop rainwater harvesting. Collaboration with partners to provide technical training and establish monitoring mechanisms will strengthen the effectiveness and sustainability of these systems.

Further research is recommended to explore the role of government incentives in enhancing rainwater harvesting practices and to assess the socio-economic benefits of rooftop rainwater harvesting in water-scarce communities.

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