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ORIGINAL PAPER

Water shortage management system and challenges in water scarcity area of Haramaya watershed, Eastern Ethiopia

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Abstract: Ethiopia is developing countries which haven't access to better water sources and over 75 to 85% people lack basic sanitation. Transition towards more sustainable urban water management is an urgent need since the scarcity of water has been a major challenge around the world. Supporting such a transition requires the development of alternative methods such as rainwater harvesting (RWH) system, recycling, desalination, wastewater reuse, etc. With the help of a systematic the study critically examined the major developments taken place in Haramaya watershed in the RWH system, measuring the RWH awareness index and identifying the implementation challenges and provides managerial solutions. With the help of an explanatory research design, quantitative analysis was conducted collecting both primary and secondary data. Semi-structured questionnaires were used as research instruments and 403 households (203 users and 200 non-users of the RWH system) of Haramaya watershed were interviewed. Measuring the awareness index in users and the non-users of the RWH system in terms of the four dimensions namely, financial, socio-environmental, technical and institutional, it is found that the user groups are more aware of the issues of climate change than the non-users. Around 70% of the respondent suggested that continuous monitoring, user's self-commitment, cost-friendly technology, pollution control, among others can help to address the RWH system challenges. The current government strategy should be focused on knowledge/capacity building and structural improvements of RWH, and this gap can be fulfilled via an updated RWH system.

Keywords: Water scarcity, sustainable water management, rainwater harvesting.

Introduction

One of the major challenges of the 21st century has been to the problem of water shortage by quality and sanitation; thus, to improve such conditions, government initiatives are needed (Pichel et al., 2019; Phuyal et al., 2019; Phuyal et al., 2020). More than 750 million people in developing countries like Ethiopia do not have access to drinking water sources (Dawit et al., 2020; Roba et al, 2022). In order to mitigate this problem, the sustainable water

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management is needed (Gurung et al., 2019; Gebru et al., 2021).

Major issues with water quality and quantity within the distribution system are particularly serious in middle-income and developing countries (Lufingo, 2019; Emile et al., 2022). Despite the richness in natural water resources, the people in these nations are deprived of water supply because of poor water supply infrastructures. The current knowledge production shows that people are looking for alternative ways for water consumption due to water scarcity and high-water costs (Custódio and Ghisi, 2019). In Haramaya watershed people are switching to processed water bottles and jars for drinking purposes due to less water supply as per demand. The tanker trucks charge the same cost irrespective of dry or rain season; demand for tanker water is higher in the dry season in comparison to the rainy season (Erena et al., 2022). This indicates the requirement of a transition towards more sustainable urban water management and for the cities like Haramaya it seems urgent.

About 65% of economic undertakings of the nation takes place in Haramaya; therefore, the water demand is high. For this research, Haramaya watershed is appropriate because of the increasing urbanization and rapid growth of population every year which has created huge pressure on water demand and, in turn, the supply situation is poor. Dependency on large irrigation practices, bottled water, the demand for tanker truck water, among others, are the particular problems seen in Haramaya watershed in terms of water.

However, empirical studies on people’s preferences on alternative methods such as rainwater harvesting (RWH) system were not carried out in the Haramaya watershed area. In that regard, the objective of this study was to examined major developments taken place RWH system, i.e., measuring the RWH awareness index and identifying the implementation challenges and provides managerial solutions.

Material and Methods

Description of the study area

The study area includes two districts (Haramaya and Kombolcha, Eastern Hararghe Zone), located in the Haramaya watershed, Ethiopia (Figure 1). The watershed lies between 09°23’ and 09°31’ N, between 41°58’ and 42°08’ E (UTM Zone 38) (Sorecha, 2017).

Haramaya is located at 9°26’ N, 42°3’ E, and at a mean altitude of 2006 m above sea level, which puts the area into the category of a highland. The mean annual rainfall received in the district ranges from 600 to 1260 mm. The rainfall is bimodal. The district is representative of a sub-humid mid-altitude agroclimatic zone (Burga et al., 2020). As described by Burga et al. (2020), the short rainy season usually starts in March and ends in May, and the long rainy season occurs between June and September; minimum and maximum annual temperatures range from 6 to 12°C and 17 to 25°C, respectively.

Kombolcha district is situated between 09°25’ N and 42°07’ E, and elevation ranges from 1200 to 2460 m above sea level. The main rainy season starts at the beginning of July and extends up to September, while the short rainy season is from March up to April. Annually, the district receives a mean rainfall of 600 up to 900 mm. The mean annual temperature ranges from 16 to 25°C (Doti, 2017).

Sample size determination and data collection

Purposive sampling has been used in this study according to Paudel and Devkota (2018) and the following formula was used for the determination of sample size (Paudel et al., 2020).

$$n = \frac{z^2 \times p \times q}{e^2} \quad (1)$$

Where: n – sample size needed for the study; z – standard tabulated value for 5% level of significance, in the case of the study was of 1.96; p = prevalence rate of employee satisfaction on merger and acquisition, using the value of 0.5; q = 1 – p; e – allowable error that can be tolerated, using the value of 0.05. The value of "n" resulted in a total of 384.16 respondents. 5% non-response error was added, resulting in ≈ 403 respondents.

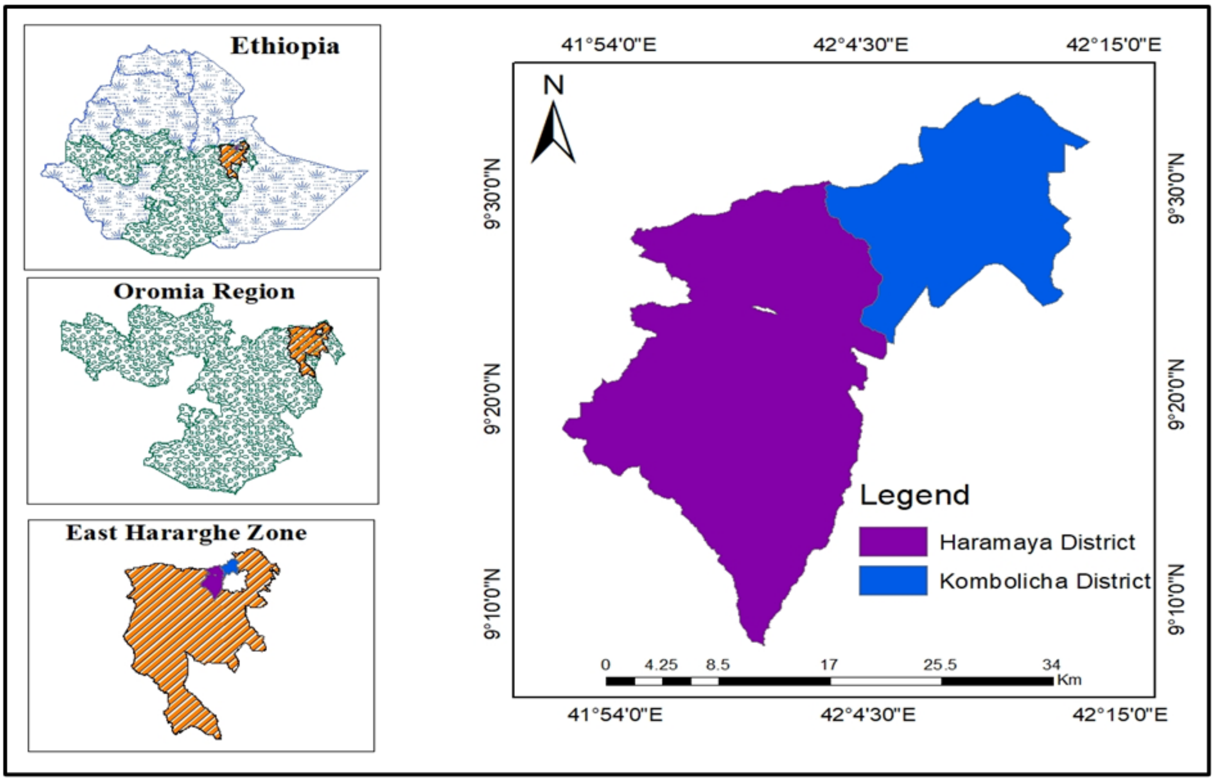

Figure 1: Location map of the study area.

Posteriorly, stratified random sampling was conducted in the 403 households (203 users and 200 non-users of the RWH system of Haramaya watershed). Aiming to measure the RWH awareness index, i.e., identifying implementation challenges and managerial solutions, a household survey questionnaire using Kobo Toolbox, expert opinion and observation during the survey period were used for the data collection. Expert's opinions were taken into consideration before the study commenced in order to understand the relevance of this topic, thinking that it can add some value to the scientific community.

The household survey (HHS) was conducted through a semi-structured questionnaire. Once the questionnaire was set, the Koko Toolbox was used; an easy way of filling up the questionnaire through android mobile. For the most part, the respondents found it easier to work on their devices rather than writing on paper. In sequence, a pre-test with 40 respondents (around 5% of the sample population) was conducted to verify if the given questionnaire set initially provided enough information or needed any modifications. Based on the pre-test, certain changes and some extra questions were added. Observations were also made during the household survey to understand and get knowledge on how the targeted HHs have managed, maintained and operated the RWH system at their household. The data collection lasted about six months. It was not possible reach every location because of the protocols set by the government during COVID-19 pandemic for face-to-face interviews; so, some data (around 100) were collected from telephone interviews and online facilities.

Data analysis

A descriptive analysis was carried out on data. For the purpose of measuring the RWH awareness index, 20 questions were used that contain "yes" and "no" as response options. These questions were administered on the scale of four dimensions of awareness namely, financial, socio-environmental, technical, and institutional (each containing five questions). Both descriptive statistics and econometric models were applied to analyze the data using Stata software version 13.

The questions (in "yes" or "no" format) were: the RWH system is a good alternative; financially viable; consider myself to be environmentally conscious; there is very little health risk connected to the harvested water; stored water could last long for more than one month; harvested rainwater can also be used for potable use if proper filtration is maintained; the government should prioritize rainwater harvesting installment compulsion; among others. For the index, each respondent was first separately measured with the given question responses. As two categories of respondents were available, i.e., user and non-user of rainwater, a comparison on the awareness level between user and non-user groups was maintained considering all dimensions together as well as taking them separately. The general form to identify HH awareness level on the RWH system is presented according to Paudel et al. (2020).

$Y = 0$, *If* $1\% < scale\ score \leq 50\%$
$Y = 1$, *If* $50\% < scale\ score \leq 75\%$
$Y = 2$, *If* $scale\ score > 75\%$

All the questions were given equal weightage. If an HHs received more than 15 questions "yes" or correct (i.e., more than 75% correct), were categorized as 'highly aware' of the RWH system. Similarly, if the respondents receive 5-10 questions "no" or incorrect (i.e., less than 50% incorrect), were understood as 'moderate aware' with the RWH system and 10-15 questions "no" or incorrect (more than 50% incorrect) were labeled as 'less aware' (Paudel et al., 2020).

Results and Discussion

Socio-economic characteristics of the respondents

Around 80% of sampled households are males having little education, approximately two years of schooling (Table 1). The average age of the household was about 50 years. Although non-users of the RWH system are older than the users on average, the mean difference between them is statistically insignificant. The level of education of users of the RWH system is slightly more than that of the non-users; this result is similar with the finding of Staddon et al. (2018).

The awareness of climate change among the users is more than among the non-users (Table 1). A higher proportion of non-users were found to be poor than the users of the RWH system; this demonstrates that because of cost implications, poor people are unable to install this system (Makau et al., 2014; Kimutai and Bwisa, 2015).

Rainwater harvesting awareness index

As presented in Table 2 below, awareness was measured under four dimensions namely, financial (it was evaluated whether the households are well-aware with the economic cost and benefits of RWH system), socio-environmental (it was evaluated whether the households are known with social and environmental issues such as RWH system's connections with their social beliefs, environmental cost of RWH system, among others), technical (it was evaluated whether the respondents know about the technical aspects such as installation, repairing and maintenance), and institutional (it was evaluated whether the respondents are aware with the fact that there are some institutions, governmental and non-governmental, who provide the incentives for the installation of RWH system). It was intended to measure whether the people are aware of the cost implications, socio-environmental issues (because of rapid population growth water is being scarce and because of environmental degradation water sources are drying up). Issues of technical skills and institutional support are also equally important aspects in the usage and maintenance of the RWH system.

Table 1: Socio-demographic characteristic of users and non-users of RWH system

Specifications	Sample size (*n* = 403)	Users of the RWHS (*n* = 203)	Non-users of the RWHS (*n* = 200)	Mean difference (t = test)
Respondent gender (if male = 1)	0.72	0.79	0.64	0.15***
Respondent age (year)	50.17	49.10	51.23	2.13
Level of education	4.11	4.90	3.31	1.59**
Family size	6.39	6.48	6.29	0.19
Economical active age group (15-60 years)	3.09	3.23	2.94	0.29
Technical skill (usage and maintenance)	6.47	7.03	5.91	1.12
Knowledge on water scarcity	2.04	2.09	1.99	0.10
Extension service (if yes = 1)	0.43	0.46	0.40	0.06
Consumption of water greater than 200 L day^{-1} (if yes = 1)	0.5	0.71	0.28	0.43***
Access to credit (if yes = 1)	0.78	0.81	0.74	0.08
Awareness of climate change (if yes = 1)	0.46	0.51	0.41	0.10*
Poor (if yes = 1)	0.57	0.44	0.57	0.13*

RWHS – rainwater harvesting system; *** and * significant at p ≤ 0.01 and p ≤ 0.10, respectively.

Table 2: Rainwater harvesting awareness index

Dimensions	User groups	Level of awareness (%)			Mean difference (t-test)		
		Low	Moderate	High	Low	Moderate	High
Financial	User	1.79	12.71	85.50	0.36	10.9	9.79
	Non-user	1.43	20.80	77.77			
Socio-environmental	User	1.75	8.62	89.63	0.83	14.57	15.10
	Non-user	2.58	23.50	73.50			
Technical	User	3.00	6.36	90.64	0.13	7.86	7.73
	Non-user	2.87	14.22	82.91			
Institution	User	16.8	10.71	72.71	15.00	9.46	5.54
	Non-user	1.58	20.17	78.25			

Both users and non-users of rainwater were asked questions regarding financial aspects of the RWH system to their knowledge on particular statements. The user group’s awareness in the financial dimension was higher (85.5%) than the non-user’s group (77.77%) (Table 2). The results show a greater number of non-users moderately aware than users of RWH system. Very few percent of respondents are less aware of the financial aspects of rainwater. 89.63% of users are highly aware in terms of socio-environmental dimension than non-users (73.50%). Further, the result also shows that under the technical dimension, 90.64% of the users and 82.91% of the non-user are highly aware. Similarly, moderately aware users were 6.36% and non-users were 14.22%. In the institutional dimension, the almost same proportion (72.71%) of users and 78.25% of non-users are highly aware. Similarly, 10.71% of the users and 20.17% of the non-users were moderately aware. Analyzing the mean difference between user and non-user, the results show that financial dimension (moderate), socio-environmental dimension (moderate and high), and institutional dimension (low) were statistically significant.

Was also examined the overall awareness index in order to understand the knowledge of people in total, regardless of any categories. Users are highly aware (84.62%) than non-users (78.10%). In the total 81.36% of the respondents were well aware of the use and implication of the RWH system, whereas only 14.64% of the people are moderately aware. Only a few percentages are less known about the RWH system.

Implementation of RWH challenges

The potentiality of the RWH system in fulfilling household requirements seems good and it offers a set of benefits as well as challenges. It is a matter of perception and responsibility on how people take these issues. Challenges can be overcome based on their degree of impact on rainwater usage this implementation problems as mentioned by other authors (Samaddar and Okada, 2008; Staddon et al., 2018).

Challenge of using RWH system

The study finds that only 8% of the respondents don't have any challenges related to the RWH system, while 92% of the respondents feel different factors constraining the adoption of the RWH system (Table 3). Challenges associated with the RWH system were classified into five parts to know respondent frequency on given constraints. Among these constraints, a majority of respondents (78%) feel the substandard quality of water is a major reason because of which people do not consider rainwater as a source of pure drinking water. The smallest number of respondents (51%) reveal inadequate rainfall trend information is a challenge. Some others, around 60%, had an opinion that inadequate monitoring and maintenance also hamper its optimum utilization. This reveals that a number of challenges are connected with the RWH system and its use in the selected area; similar to that mentioned by other authors (Dile et al., 2013; Roba et al., 2022).

The high cost of the RWH system infrastructure and land ownership/space complexities are the major challenges to be addressed. Other disincentives include quality of harvested rainwater and unreliable rainfall to increase the level of investment/attraction of people in the RWH system (Yohannes, 2004; Kim et al., 2016).

Reason for not having RWH system in Haramaya watershed

Even if people have awareness of the system to a larger extent, there is a very low record of people in Haramaya watershed who have installed RWH system in their houses. Only a few respondents feel health risks as to the reason for not having an RWH system. The variable access to information on in-field RWH appeared positively significant at a 10% level to the adoption of in-field RWH technology. This reveals that the more information people get, the higher is the probability of adopting the RWH system either in their private houses or in public places.

Obstacle faced after implementation of RWH system

The majority of respondents reported that they don't have extremely serious obstacles associated with rainwater use. Besides that, the lack of enough space for optimum utilization was one common obstacle; therefore, these obstacles can be minimized if all the stakeholders perform their part in a responsible manner.

Table 3: Challenges and managerial solutions

Challenges	Responses (%) Yes	No
Pollution is the reason people fear to consume harvested water for potable use	78	22
Poor access to monitoring and maintenance	60	40
Household structure of Haramaya watershed is inappropriate to collect all the rainwater in the tank	50	50
Harvested water quantity is not enough to fulfill the water demand throughout the year	68	32
In adequate trend information	57	49
High cost of RWH system infrastructure	57	43
Lack of enough space/land for tank installation	61	39
Managerial solution		
Continuous monitoring by one person is required while collecting rainwater; checking the valve, water pipes, tank leakages	81	19
Providing knowledge to people/train manpower for effective water management	73	27
Self-commitment to maintain RWH system	70	30
Proper storage system development	66	34
Cost-friendly technology	79	21
Pollution control	55	45
Every house should be able to clean their terrace, pipeline from where water will transfer to tank	68	32
Capacity building programs and subsidized price by government	85	15
Role of government, NGOs and INGOs	78	22
Manage enough space for effective collection	59	49

NGOs – non-governmental organizations; INGOs – international non-governmental organizations.

Actions for mitigating challenge

Respondents provided various suggestions in order to minimize the challenges. The majority of respondents (82%) feel that effective and systematic development of a system is required that provides proper assistance in rainwater collection and filtration. A study conducted by Liuzzo et al. (2016) on the optimize tank size, the results show that the maximum percentage of demand that could be met was 75% with a tank size of 10 m^3. Further, for a tank with storage capacity of 20 m^3, it would be able to ascertain the reliability up to 80%. Because the water demand volumes are higher in comparison to the tank's optimal capacity, i.e., 20 m^3 in the study area, the system's poor performance necessitates the accumulation of more rainwater during the rainy season by expanding the area of collection surfaces. So, the tank size and amount of harvested water matter the most to meet the water demand as mentioned by Tesfai and Stroosnijder (2001) and Yildirim et al. (2022).

Managerial suggestions

In this section, suggestions regarding policies and practices are mentioned.

Concern for RWH implementation

Nearly 50% of the respondents reported that the government (Department of Agriculture Development Office) and/or non-governmental organizations (NGOs) provided a subsidy for them mainly for the materials like plastic, pipe, or cement ranging between 30-50%. The majority of the respondents felt the government and individuals both are responsible more for the proper implementation of the RWH system (Table 3). The government's sole effort does not make any sense if people do not realize the future water requirement and the importance of rainwater for it.

Suggestions on government policy

More than one-fourth of respondents think that capacity building campaigns are needed following a provision of compulsory installation in every house even on a large or small scale in town like Haramaya watershed. If the RWH system is made mandatory and relevant regulations are implemented effectively in the study area, more than 20% of rainwater can be captured and an urban flood can also be mitigated by at least 20%. Considering only from housing units, excluding commercial buildings, industries, or government private office buildings in the area, what to be in agree with Mohamed et al. (2018).

Needed strategies from institution level

The majority of respondents (78%) stated that the institutions play a vital role as a mediator between government and individual in order to make a systematic practice of the RWH system. According to Msuya (2022), different institutions build the capacity and strategic planning management skills for better planning and execution of their goals and for organizational wellbeing improvement.

Mechanism for RWH system compulsion

The majority of the respondents (85%) think providing subsidies will help to install the RWH system in every house. Since cost is an important aspect and most of the respondents mentioned high cost for installation, it is important from the government side to provide assistance through financial support. This is agreement with the findings of Ishaku et al. (2011) Ghosh and Ahmed (2022), sufficient rainwater to supplement the need support of the rural communities for RWH activities should be improved.

Conclusions

With the growing urbanization, people's needs and demands get increased due to rapid population growth. As water is a basic need having social and economic value for humans, its management in the present scenario has been a challenging task all over the world, particularly in the urban areas. Though the facility of clean drinking water and sanitation are taken as the fundamental rights of every human being, many regions around the world critically are suffering from these problems. Measuring the awareness index in users and the non-users of the rainwater harvesting (RWH) system in terms of the four dimensions namely, financial, socio- environmental, technical and institutional, it was found that the user groups are more aware of the issues of climate change than the non-users.

Around 70% of the respondents suggested that continuous monitoring, user's self-commitment, cost-friendly technology, pollution control, among others can help to address the RWH system challenges. It is believed that current governance models reinforce the status quo and a transition necessitates cultural and structural improvements, and this gap can be fulfilled via an updated RWH system. In this context, it is concluded that the RWH system can be an appropriate solution to deal with the growing water scarcity problem in the countries which have similar scenario/challenges.

Identifying RWH management in Haramaya watershed, it is found that the water situation of watershed is dreadful in terms of its availability and quality. Unmanaged urban planning has led to an inadequate and intermittent water supply to the residents of Haramaya watershed. Despite the huge potentiality of the RWH system, enough promotion and policies seem to be lacking from the government side. It is recommended that capacity building programs should be encouraged to install the RWH systems in every house, in the best-case scenario, either on a large or small-scale.

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