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ORIGINAL ARTICLE

Factors influencing community's adoption of domestic water conservation measures in Moshi Rural District, Tanzania

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Abstract
Water conservation is necessary to minimize water losses and meet the needs of the growing population. While several domestic water conservation measures (WCMs) have been developed and promoted among households in Africa, the extent of adoption and factors associated with their adoption are not well understood. We conducted an analysis to assess the current level of adoption and identify factors associated with household adoption of domestic WCMs through interviews with 150 randomly selected household heads from six villages in northern Tanzania. On average, 60% of the respondents reported implementing various WCMs whereas 40% did not implement any measures. The most adopted WCM was rainwater harvesting in water tanks, followed by wastewater reuse and the utilization of alternative cleaning methods such as brooms and towels. The likelihood of adopting WCMs was found to be higher among single heads of household compared to married heads of household. Additionally, adoption was negatively correlated with age but positively correlated with the distance between the household's residence and alternative water sources. We recommend targeting water conservation education at elderly individuals, married couples, and those residing near water sources to improve domestic water conservation practices within local communities.

Keywords Water conservation · Water efficiency · Domestic water use · Socio-economic factors

Introduction

Water is an essential resource crucial for sustainable development and maintaining the health of ecosystems (WSSD 2002). However, the ever-growing human population, climate change, drought, and unsustainable land management practices are exerting immense pressure on water sources, resulting in water scarcity for both domestic and agricultural purposes (Koop and Van Leeuwen 2017). Globally, approximately 2 billion people still lack access to safely managed drinking water (UN DESA 2023), and it is projected that 40% of the world's population will face water shortages by 2030 (WRG 2009). In Sub-Saharan Africa alone, around 319 million people do not have adequate access to safe water supplies (Dos Santos et al. 2017), posing a significant threat to public health.

Improved water resource management is essential to meet the increasing water demands of the growing population. Water conservation can be achieved through saving water for later use, or using as little as possible, through manipulation of flow rate in the households (Herr et al. 1979; Postel 2000; Jeffrey and Gearey 2006). The latter approach, although older, is more commonly employed and efficient in rural areas of Africa particularly in Tanzania (Dungumaro and Madulu 2003). Several domestic WCMs have been developed and promoted in Africa (Thiam et al. 2021; Aina et al. 2023); however, the extent of their adoption and the factors influencing the choice of WCMs is not known. Among the commonly promoted domestic WCMs are rainwater harvesting in tanks and in wells, water storage in containers, and the reuse of wastewater. In rural Africa, the utilization of water-efficient technologies to minimize water wastage in taps or showers is practiced by only a small proportion of the population.

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The adoption of domestic WCMs can be influenced by various factors, including water scarcity, the average distance to a water source, the time spent on water collection, and the availability of water daily (Garcia et al. 2013; Meta et al. 2016., Onyenankeya et al. 2021). Some studies suggest that individuals who have personally experienced drought are more likely to adopt WCMs, as they already feel a moral obligation to conserve water (Tong et al. 2017; Garcia et al. 2013). Additionally, household, and socio-economic characteristics have been found to impact domestic water usage habits (Fielding et al. 2012; Garcia et al. 2013; Fan et al. 2014; Aprile and Fiorillo 2017; Xue et al. 2017). However, factors influencing the adoption of WCMs can vary across different locations, among individuals, and may change over time (Fielding et al. 2012; Garcia et al. 2013; Koop et al. 2019).

The objective of this study was twofold: (1) to analyse the domestic water conservation measures implemented by households, and (2) to identify the factors associated with the adoption of WCMs by households. Understanding the knowledge and practices related to water conservation is crucial for water suppliers and policymakers in developing and implementing effective behaviour change policies.

Methodology

Description of the study area

The study was conducted in six villages in East Old-Moshi and Kimochi Wards located in Moshi Rural District. Moshi Rural District is at the base of Mt. Kilimanjaro in the nnorthern part of Tanzania (Fig. 1). The district is divided into

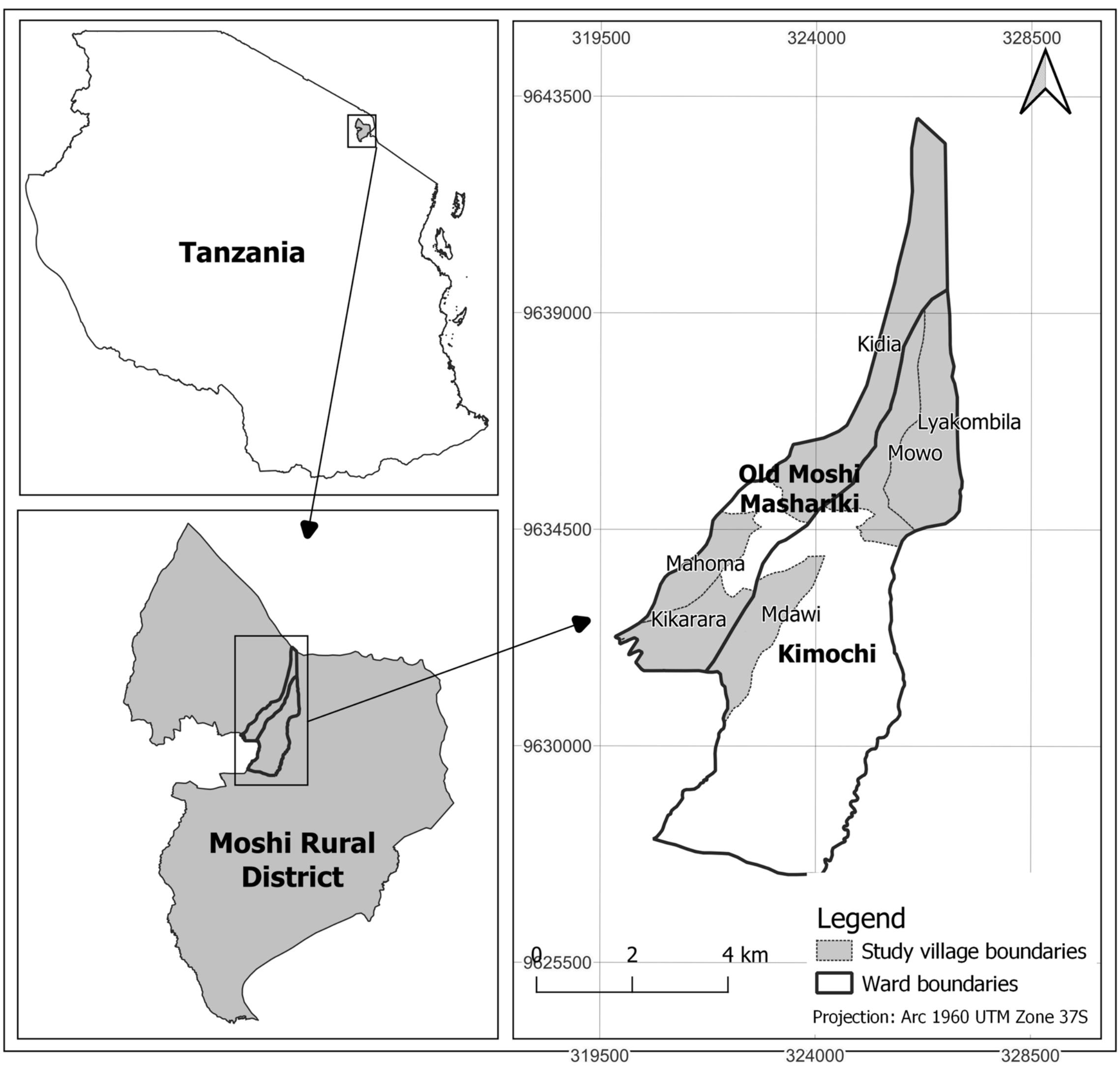

Fig. 1 Location map of the study area showing the position of the study villages. The map was created by Omega Emmanuel Kaaya

4 divisions, 31 wards, and 145 villages. According to the Tanzania National Census (2012), the district has 466,737 people with an average household size of 4.2, mostly composed of the *Chagga* ethnic group.

Land use in Moshi Rural District is influenced by the altitudinal gradient. The lower area is dominated by maize mono-cropping and pastoralism (Misana et al. 2012). The mid-altitude zones are dominated by mixed farming of trees and crops (home garden agroforestry practice). Some of the tree crops cultivated are Coffee (*Coffea arabica*), Avocado (*Persea americana*), Java Plum (*syzygium cumini*), Banana (*Musa acuminata*), Yams (*Dioscorea spp*), Taro plants (*Colocasia esculeta*), and Sweet Potatoes (*Ipomea batatas*). Cereal crops such as Maize (*Zea mays*) were also grown and animals such as cattle, goats, pigs and poultry like chickens, ducks, and pigeons were raised. Cattle are kept for milk, while goats and pigs are reared for meat, either for sale or for home consumption (Kimaro et al. 2019).

Two different rainy seasons occur in the study area: the long rains that start from mid-March to the end of May, and the short rains that start in October and end in December. The driest period is July through the end of September. The mean annual rainfall is 1000–1200 mm in the lower and mid areas, and 1800–2000 mm in the upper areas (Misana et al. 2012).

Domestic water supply in Moshi Rural District is currently vulnerable to drought, climatic change, an increase in the human population, old infrastructure, and unsustainable water management practices which have increased pressure on water resources leading to its scarcity of domestic water and water for agricultural uses (Kimaro et al. 2019; de Haas and Borst 2012). Villages in the study area have a centralized piped water system being captured from several springs and streams in the higher parts of the area and flow by gravity to the lower parts of the village but the system is poorly maintained. There is no regular maintenance, only repairs in case there is a problem. Repairs are also difficult due to inadequate funds (Mokiwa 2015; de Haas and Borst 2012). In many parts of the district, especially in the lower areas, there is either no or only very little water available in the system. Water supply to most parts of the villages is not available all day of the week, most people try to extract and use or store as much water as they can.

Sampling design

The study employed purposive and simple random sampling approaches. Moshi Rural District was purposely selected due to the existence of information on unsustainable water use, and promotion of WCMs (Misana et al. 2012; Kimaro et al. 2019). Within the district, two wards East Old-Moshi and Kimochi were randomly selected out of 31 wards. Within each ward, three villages were randomly selected. The selected villages are Kidia, Kikarara and Mahoma from East Old Moshi Ward; and Mdawi, Lyakombila, and Mowo from Kimochi Ward. In each village, 25 households were randomly selected making a total of 150 households (Fig. 1).

Data collection

Data collection was conducted between October 2019 and March 2020. Questionnaire copies were administered to 150 households in the six villages as specified earlier. The questionnaire comprised information about respondents' characteristics, livelihood strategies, domestic water use, and WCMs. The questionnaire was prepared in Kiswahili to avoid language barriers, as most of the community members do not understand English. One Focus Group Discussion (FGD) was held in each ward to supplement the information obtained from the households. The FGD was composed of one village chairman, one member of domestic water project committee, and six community members selected based on balancing equality on age, sex, and educational level.

Data analysis

The Statistical Package for Social Sciences (SPSS) for Windows version 12 (SPSS Inc., Chicago, Ill., USA) was used in the analysis. The Binary Logistic Regression was used to determine the factors associated with the community's adoption of water conservation measures. The probability that a WCM measure would be adopted was defined as:

$$\mathrm{Logit}(Y) = \alpha + \Sigma\beta_1 x_1 + \Sigma\beta_2 x_2 \ldots + \Sigma\beta_n x_n + \varepsilon i,$$

where: Y = dependent variable (choice of WCMs), with 1 = adopters of WCMs, and 0 = non-adopters; α = intercept; β_1, β_n = coefficients of the independent variables indicating the influence of these variables on the likelihood of choice; $x_1, \ldots, x_{11}$ = the independent variables.

Collinearity between independent variables was tested. Independent variables with variance inflation factors (VIF) less than 10 suggested a lack of multi-collinearity. However, O'Brien (2007) suggests consideration of other factors beyond VIF. Such consideration was the justification from theories if the variables that show collinearity measure the same underlying concept.

Following the procedures above, we found and selected 10 independent variables that might affect respondents' decision to adopt WCMs. The variables are described below.

1. *Age of household head*: A positive relationship is expected between the age of the household head and the adoption of WCMs. Older heads of households possess traditional knowledge, experience, and a better understanding of water flow systems, making them

more inclined to adopt WCMs (Grafton et al. 2011; Malila et al. 2023; Worthington and Hoffman 2008).

2. *Household size*: A positive relationship is expected between household size and the adoption of WCMs. As family size increases, individual water consumption also tends to increase (Willis et al. 2013).
3. S*ex*: The odds of adoption of WCMs are expected to be higher for women than men. Women generally consume considerably less water than men (Tong et al. 2017; Kirenga et al. 2018).
4. *Marital status*: The odds of adopting WCMs are expected to be higher for single heads of households than for married individuals. Single people tend to use more water than married ones (Fan et al. 2014).
5. *Income*: A negative relationship is expected between income and the choice of WCMs was expected. Higher income levels are typically associated with higher water consumption rates, indicating a potential resistance to water conservation (Willis et al. 2013; Xue et al. 2017)
6. *Distance to the household's source of water*: A positive relationship is expected between distance and the adoption of WCMs. The farther the distance to the water source, the higher the expected number of WCMs applied, to reduce the need for multiple trips to collect water (Garcia et al. 2013).
7. *Education level*: A positive relationship between years of schooling and the choice of WCMs was expected. Educated individuals are generally more likely to use water efficiently and be committed to water conservation due to their increased awareness and understanding of the importance of conservation practices (Fan et al. 2014; Aprile and Fiorillo 2017).
8. *Duration of water availability*: A negative relationship between the duration of water availability and the choice of WCMs was expected. Respondents who receive tap water often are less likely to adopt WCMs due to the perception of continuous water availability (Meta et al. 2016).
9. *Awareness of environmental protection laws*: A positive relationship is expected between awareness of environmental protection rules and regulations as WCMs are also environmentally friendly (Garcia et al. 2013).
10. *Participation in water management meetings:* Respondents' adherence to their roles and responsibilities is expected to facilitate the implementation of WCMs, as these meetings serve as reminders to conserve water and reinforce the importance of water conservation practices.

Results

The existing WCMs in Moshi Rural

The results revealed that, on average, 90 respondents (60%) applied various water conservation measures (WCMs), whereas 60 respondents (40%) did not use any WCMs. The results revealed further that respondent from East Old Moshi Ward had the highest average adoption rate of WCMs compared to those from Kimochi Ward (Table 1). The most preferred WCM in the study area was rainwater harvesting in tanks, used by 41% of the respondents. The other top three WCMs were the reuse of wastewater (34%), the use of alternative cleaning sources such as brooms, towels, and other dry materials (33%), and performing cleaning activities only when there are full loads of laundry or kitchen tools and pans (32%). The adoption rate for rainwater harvesting using tanks was significantly higher compared to the adoption rates for the installation of water-efficient devices and for rainwater harvesting in wells (Fig. 2). Additionally, respondents in villages situated at lower elevations, namely Kikarara, Mahoma, and Mdawi, demonstrated a significantly higher adoption rate of WCMs than those in villages located at higher altitudes, such as Kidia, Mowo, and Lyakombile (Fig. 3).

Factors influencing the community's adoption of water conservation measures

The results indicated that the choice of WCMs was significantly associated with the age of the respondent ($p = 0.004$), marital status of the respondent ($p = 0.006$), and the distance to the alternative source of water ($p = 0.008$) (Table 2). The odds of adopting WCMs increased by 11 times for every decrease in the age of the household head by 10 years, and it increased by 3 times if the respondent was single. Additionally, the odds of adopting WCMs were found to increase by 10 for every 10 km increase in distance to the alternative source of water.

Discussion

The existing water conservation measures

The findings of the study revealed that most households preferred rainwater harvesting in tanks over other domestic WCMs, specifically water harvested in wells, installation of water efficient devices, and water saving garden. According to the focus group discussions (FGDs), rainwater harvesting in tanks was favoured because it was relatively cheaper

Table 1 The adoption rate (%) of water conservation measures in Moshi Rural District

S/N	WCMs	East Old Moshi ward			Kimochi ward			Average ($N=150$)	Villages χ^2	*df*	*P* value
		Kikarara ($n=25$)	Mahoma ($n=25$)	Kidia ($n=25$)	Mdawi ($n=25$)	Mowo ($n=25$)	Lyakombila ($n=25$)				
1	Rainwater harvested in tanks	76	60	40	44	12	16	41.33	31.562	5	0.000
2	Reuse of wastewater	60	36	36	40	20	12	34	15.597	5	0.008
3	Use of alternative sources of cleaning	36	32	36	28	32	32	33	15.143	5	0.010
4	Start cleanness for only full loads	48	52	20	40	16	16	32	15.809	5	0.007
5	Use vessels to tap water when performing cleanness	52	40	12	36	12	28	30	0.515	5	0.992
6	Application of water saving gardens	60	20	24	36	20	8	28	20.238	5	0.001
7	Installation of water efficient devices	20	4	0	12	16	8	10	7.778	5	0.169
8	Rainwater harvested in wells	12	12	8	8	4	4	8	2.174	5	0.825
	Average	45.5	32	22	30.5	16.5	15.5	27			

and effective. The FGDs also highlighted that there are various types of water tanks available with different capacities, allowing each respondent to choose a tank that suited their needs and budget. These findings are consistent with the research conducted by Suresh et al. (2017), who found that local communities in India preferred Taankas, a traditional indigenous rainwater harvesting technique for water storage. On the other hand, rainwater harvesting through wells was the least preferred method due to its high establishment cost. Respondents cited financial constraints as the primary reason for not adopting this water harvesting technique. One participant in an FGD in Kikarara village stated, *"We would like to apply water harvesting in well but due to their expensiveness we fail"*. There was poor installation of water efficient devices in the study area. The main limitation was limited availability of the devices and high costs.

Regarding water-saving gardens, field observations revealed that most respondents used 100 or 50-kg bags filled with soil and manure to grow vegetables for household and commercial purposes. In an FGD conducted in Kikarara Village, the participants agreed that the education provided by a project namely Rural Initiatives for Participatory Agricultural Transformation (RIPAT) had a positive impact on the choice of water-saving gardens. However, one participant in the FGD mentioned that despite the information being shared with every group, the adoption of water-saving gardens remains low due to the laziness of some members. These individuals perceive the preparation of such gardens as more labour-intensive compared to traditional gardens, leading to reluctance in adopting the water-saving gardening approach. During a key informant interview, it was revealed that water-saving gardens not only involve the preparation of the gardens but also the watering practices. People can adopt watering techniques that help conserve water. For example, before the RIPAT project, community members were unaware that watering gardens in the midday, when sunlight is intense, leads to higher evaporation. However, after learning about this, gardeners started irrigating their gardens in the evening when temperatures were lower. The findings align with the research conducted by Melbourne, Kneebone et al. (2018), who reported that a combination of media campaigns, price incentives, water use restrictions, and knowledge transfer resulted in water savings of approximately 10% to 25% in lawns and gardens. However, it is worth noting that while these findings suggest positive impacts of water-saving practices in gardens, the effectiveness may vary depending on local conditions and the specific approaches implemented.

Kikarara, Mahoma, and Mdawi Villages had higher rates of adoption of WCMs, scoring an average of 47%, 39%, and 33%, respectively. In contrast, Mowo and Lyakombila Villages were the lowest adopters of WCMs, with mean adoption rates of 16% and 18%, respectively,

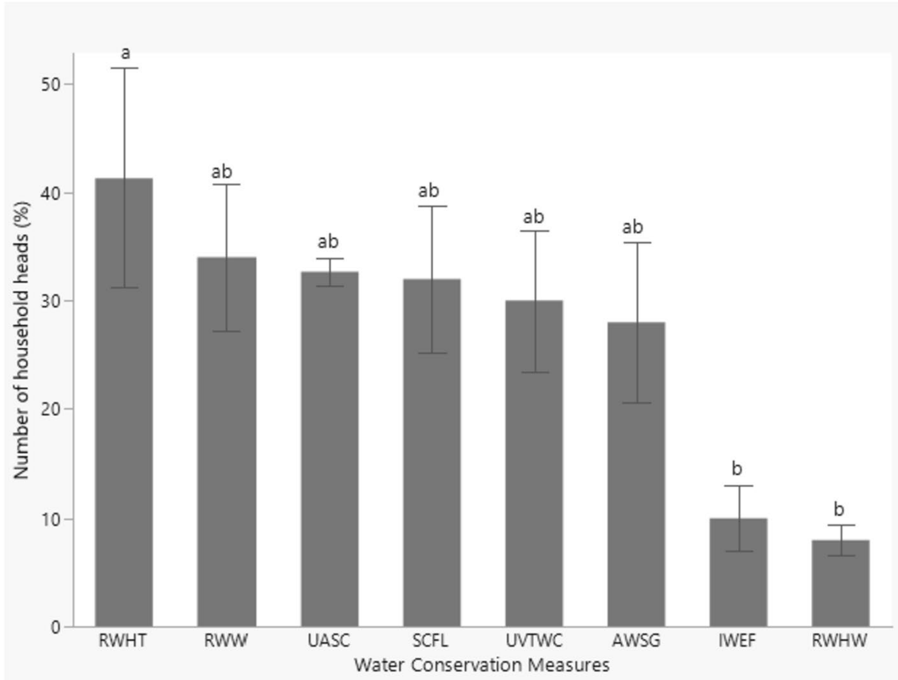

Fig. 2 The adoption rate of water conservation measures in the study area. Where RWHT = Rainwater harvested in tanks; RWW = Reuse of wastewater; UASC = Use of alternative sources of cleaning; SCFL = Start cleanness for only full loads; UVTWC = Use vessels to tap water when performing cleanness; AWSG = Application of water saving gardens; IWEF = Installation of water efficient devices; RWHW = Rainwater harvested in wells. Different letters above error bars '*a*–*b*' indicate significant differences ($P < 0.05$) in the adoption rate among water conservation measures

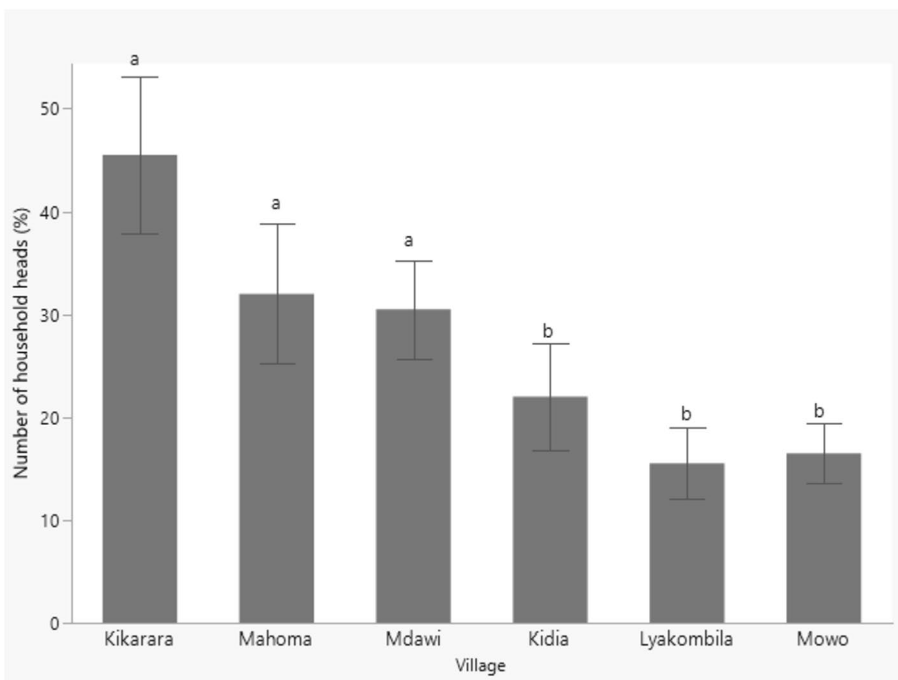

Fig. 3 The rate of adoption of water conservation measures across study villages. Different letters above error bars '*a*–*b*' indicate significant differences ($P < 0.05$) in the adoption rate of water conservation measures between villages

followed by Kidia (25%). These findings suggest that respondents in villages located at higher altitudes practice fewer or no WCMs, possibly due to higher stream and tap water availability in those areas compared to respondents located downstream. In the lowlands, water availability is scarce, particularly during dry seasons. These findings also support previous research by Mihayo (2008) conducted in the same district, which revealed that different storage facilities have been adopted by residents living in lowland areas to store water.

East Old Moshi Ward had the highest average adoption rate of WCMs (33%) compared to Kimochi Ward (21%). According to a key informant (KI) from East Old Moshi Ward, the area experiences more severe water shortages compared to Kimochi Ward. This fact has prompted people in East Old Moshi Ward to adopt various WCMs to address

Table 2 Summary results of Binary Logistic Regression examining factors associated with the community's adoption of WCMs

S/N	Independent variables	Estimate (*B*)	S. E	Wald	*df*	Sig	Odds (Exp(*B*))
1	Age of respondent (years)	− .051	.018	8.397	1	.004**	1.05
2	Marital status of respondent (1 married, 0 = single)	.919	.538	2.920	1	.006*	3.105
3	Distance to household's alternative source of water (km)	.037	.014	7.119	1	.008**	1.038
4	Participation in water project's meetings (1 = participate, 0 do not participate)	.629	.417	2.277	1	.131	1.876
5	Duration to water availability per week	− .187	.136	1.892	1	.169	.829
6	Income (TZS/year)	.000	.000	1.075	1	.300	1.000
7	Sex of respondent (1 male, 0 = female)	− .490	.514	.908	1	.341	.613
8	Years of school (years)	.060	.092	.419	1	.517	1.062
9	Awareness of village's by-laws on water protection (1 aware, 0 = not aware)	− .275	.432	.404	1	.525	.760
10	Household size	− .072	.119	.365	1	.546	.931
	Constant	1.600	1.568	1.042	1	.307	4.953

Overall Wald statistic = 5.918 (P = 0.015); Omnibus tests of model coefficients Chi-square = 46.236 (P = 0.000); Hosmer and Lemeshow test Chi-square = 5.177 (P = 0.739); Cox and Snell R^2 = 0.265; Nagelkerke R^2 = 0.359

**Significant at $P < 0.01$, *Significant at $P < 0.05$

the water scarcity issue. Additionally, the presence of fewer water sources in East Old Moshi Ward has influenced community members to apply WCMs. A KI from Kimochi Ward reported that despite having five water sources compared to the three in East Old Moshi Ward, various initiatives have been implemented in the ward to address water problems. Specifically, the presence of a donor-funded project called SamSam water has helped alleviate water shortages and water-related issues in Mdawi Village, which is in Kimochi Ward.

Factors influencing the community's adoption of water conservation measure

The binary logistic regression analysis indicated that the choice of WCMs was significantly associated with the respondent's age, marital status, and distance to the alternative source of water. Surprisingly, the results showed that older respondents were less likely to choose WCMs. These findings contradict the results reported by Worthington and Hoffman (2008), who conducted a survey on residential water demand modelling in Australia and found that older individuals possessed traditional knowledge, experience, and a better understanding of water flow systems, making them more prepared to adopt WCMs. Furthermore, other studies such as Davies et al. (2014) and Clark and Finley (2007), have suggested that families with young children and older individuals are more likely to engage in water conservation practices, while adolescents tend to consume more water. It is important to consider that the findings of this study might reflect specific contextual factors or variations in cultural and socio-economic factors that differ from the previous cited research.

Results further revealed that the odds of adopting WCMs were higher for single heads of households than for married individuals as expected (Grafton et al. 2011). Single individuals living alone may not use more water than married individuals, but they lack sufficient labour to assist with water collection. It is widely known in Africa that children are involved in fetching water (Kamya et al. 2021).

Regarding the distance to the alternative source of water, the results of the study align with the findings reported by Garcia et al. (2013). Their study focused on attitudes and behaviours towards water conservation on the Mediterranean coast and found that as the distance to the water source increased, there was a higher likelihood of implementing water conservation measures (WCMs) to save time and energy. The similarity in findings suggests a consistent pattern that can be observed across different regions and contexts, emphasizing the relationship between distance to water sources and the adoption of WCMs.

Conclusions

The study findings indicate that approximately 60% of the respondents in the study areas adopted various water conservation measures (WCMs). Among the different options, rainwater harvesting in water tanks was the most preferred choice, followed by the reuse of wastewater and the utilization of alternative cleaning methods such as brooms and towels. The adoption of WCMs was significantly associated with the respondent's age, marital status, and distance to the household's alternative water source. Based on these findings, it is recommended to focus on awareness creation and education initiatives to improve water conservation practices in local communities. Specifically, targeting education efforts towards older individuals and those residing in highland areas can help increase their understanding and engagement in water conservation. By providing education on water conservation, users can be encouraged to integrate multiple uses and users of water, promoting more sustainable practices.

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Data availability The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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