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Factors Affecting Borehole Water Project Sustainability in Dodoma, Tanzania: A case of Nghong'onha ward

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Abstract

Access to a clean, safe, and affordable water supply for domestic use is a fundamental human right. However, in many urban areas in sub-Saharan African countries, including Tanzania, not all people have access to water due to the operation, maintenance, and sustainability challenges of the built infrastructure. This study assessed factors affecting the sustainability of the Borehole water project in Dodoma Region, taking a case of Nghong'onha ward in the City Council of Dodoma. Specifically, the study focused on household water use practices and examined the factors affecting the sustainability of borehole water projects. The study used both primary and secondary data of a quantitative and qualitative nature collected through interviews, observations, and a documentary review. This study employed probability and non-probability sampling techniques to select a sample of respondents and key informants. The collected data were analysed for descriptive statistics such as frequencies and means and binary logistic regression analysis, whereas qualitative data were analysed using the qualitative content analysis technique. The study found that, on average, households consumed 82.27 litres of water daily, and 47.5% of respondents had to wait for 31–45 minutes to fetch water at the water point. Furthermore, findings revealed that community meetings (0.000), distance to water points (0.000), water facility spare parts availability (0.054), payment modality (0.023), and annual maintenance (0.011) significantly affected borehole water project sustainability. The study recommends that interventions to improve access to domestic water supply in the study area should focus on improving water supply infrastructure and the built infrastructure's operation, maintenance, and sustainability.

Keywords: Borehole water project, household practices, sustainability, Tanzania

1. Introduction

Water is a fundamental necessity for life, and its availability and quality are paramount. The percentage of the global population with access to safely managed drinking water has increased from 62% in 2000 to 74% in 2020 (Girmay *et al.,* 2023). Although there is progress, 2 billion people worldwide still have no access to safely managed drinking water services (Bhattacharya *et al.,* 2022). Among them, 771 million people cannot access water from improved sources, with a roundtrip collection time of less than 30 minutes (Wangari and Minja, 2021). Furthermore, 8 out of 10 people lacking essential drinking water services live in rural areas, half of which are in least-developed countries (Bhattacharya *et al.,* 2022). Water demand is increasing rapidly due to population growth in both urban and rural areas.

Additionally, the unequal distribution of freshwater resources and climate change exacerbate water-related issues (Wangari and Minja, 2021). By 2025, over 3 billion individuals will reside in countries with water scarcity, and 14 countries will transition from water-stressed to water-scarce (Chumbula and Massawe, 2018). Around the world, various stakeholders have initiated water projects to improve safe water supply and sanitation in both rural and urban areas. In 2015, the United Nations acknowledged access to safe and clean water as a fundamental human right, and these efforts align with the global Sustainable Development Goals. As part of this initiative, each member country committed to establishing a target to achieve universal access to safe drinking water and basic sanitation by 2030 (United Nations, 2015).

Despite various stakeholders offering continued support for water-related projects to address the rising demand for water resources, many projects have failed to operate sustainably (Chumbula and Massawe, 2018; Hassan *et al.,* 2020). Okeniyi (2015) highlights that over a third of global water projects fail to achieve their goals, raising concerns about sustainability. Borehole water projects are an essential protected water source in Africa's rural areas, providing almost half the total supply. However, their functionality rate is estimated to be only around 66% (Oberlin and Kassim, 2018). In some countries, the number of non-operational Borehole water projects can be as high as 60% (Chumbula and Massawe, 2018).

The Tanzanian government has set a target of providing clean water access to 95% and 85% of the urban and rural populations by 2025 (URT, 2020a). This ambitious goal is being pursued by prioritizing water infrastructure projects, with significant investments in this area. These efforts have improved drinking water sources from 68.9% to 79.2% during the rainy season and from 58.5% to 66.8% during the dry season between 2014/15 and 2020/21 (World Bank, 2023).

Despite the government's efforts, most of the focus has been on the quantity of built infrastructure, while little attention has been given to the infrastructure's operation and maintenance. It has been found that from 2014 to 2019, around 30% of the constructed water points were non-functional (URT, 2020a). Furthermore, in Nghong'onha ward in Dodoma, the sustainability of the borehole water project is questionable, as out of 15 water points, only seven were functional and the remaining eight water domestics were dysfunctional (URT 2020b). The failure of water infrastructure has led to a decrease in the reliability of water supply systems and an increase in their risk of failure.

The concept of sustainability is not easily expressed concretely, despite being intuitively understood. Oino *et al.* (2015) argue that sustainability is critical for the success of community-based projects. Abraham (1998) defines the sustainability of water projects as the continuous provision of water at the same quantity and quality level as when the supply system was designed. Furthermore, Amjad *et al.* (2015) suggest evaluating sustainability based on functionality, goal achievement, and efficient financing and management. In this study, sustainability is defined as the ability of a water project to continue functioning beyond government financing.

Water projects' sustainability is influenced by several factors, including financial, technical, community support, and spare parts availability, as evidenced by studies conducted by Oberlin and Kassim (2018) and Hassan *et al.* (2020). In recent research conducted by Ntuku (2021) on water projects in Tanzania's Bunda district, it was found that water production falls short of demand, and inadequate contributions from beneficiaries cause operational inefficiencies. Additionally, the study revealed high electricity costs for pumping water, water loss due to leakages and pipe breakages, insufficient funds for maintenance, a lack of technical expertise, and water source invasion as some of the challenges faced by these projects. The sustainability of water from the project can also be influenced by the presence of an efficient water user committee, frequency monitoring, annual spare parts maintenance, and the number of meetings held annually by water users Chumbula and Massawe (2018), Ong'wen (2014), and Wangari and Minja (2021).

Additionally, a community-based water initiative struggled due to inadequate technical expertise and limited use of technology in its administration (Tafara, 2013; Achieno and Mwangangi, 2018). As a result, this project faced higher operational costs, reduced effectiveness, and a shorter lifespan. Therefore, this study aimed to assess factors affecting borehole water project sustainability in Nghong'onha ward, Dodoma, Tanzania.

2.0. Methodology

The study was conducted in Nghong'onha ward in the City Council of Dodoma. The study was conducted in this ward because there was little information on the factors affecting the sustainability of the borehole water point projects, as out of 15 domestic water points in the area, only seven were functional. The study used a cross-sectional research design to collect data from a representative sample at a single point in time (Kothari, 2004). This design permits the descriptive analysis, interpretation, and determination of relationships between variables. Primary data were collected directly from the head of the household in the area via an open-ended questionnaire. In contrast, secondary data were obtained from published and unpublished documents related to the study using a checklist.

The selected key informants were the Ward Executive Officer (WEO), the Community Development Officer (CDO) at the ward level, hamlet leaders, and water user association leaders due to their expertise in water availability (including water sources, sustainability challenges, distance, and time), participation in water project development, gender issues in water management, and resource allocation for project infrastructure maintenance. Key informants provided valuable information to supplement the data collected through observation and structured questionnaires.

The study employed a sample size of 139 heads of households using the Cochran formula for an unknown population. The formula used was: $n = [Z^2 * p * q] / e^2$, where Z is the z score (1.96), n is the sample size, p is the precision level (5%), q is the confidence level (95%), and e is the error term (10%) (Cochran, 1963). The study employed simple random and purposive sampling techniques to select individual households and key informants.

The study employed descriptive and inferential statistics to analyse the data. In descriptive statistics, frequencies, percentages, and mean values were employed, while in inferential statistics, a binary probit model with marginal effect was used. The binary probit model was used since the dependent variable (sustainability) was a dichotomous decision of being sustainable with a value of 1 or not with a value of 0. Modelling a dichotomous dependent variable may use a binary logit or probit model, and both approaches arrive at the same result and conclusions. Binary probit was used because of the normal distribution of error term assumptions. Also, it allows random taste variation, correlated error terms, and unequal error variance and

captures any substitution pattern (Tundui, 2012).
The model is presented in the following equation:

$Y_i = \beta X_i + \mu_i$ ....(i)

Where by:

Y_i = 1, if a water project is functioning

Y_i =0, if a water project is not functioning

μ_i = Error term

Equation one represents a model with a binary choice (binary probit model) involving an estimation of the probability of a water project being sustainable (Y_i) given a set of factors (X_i) which are independent variables

The mathematical representation of the model is represented below;

$P(Y_i = 1) = F(\beta_i X_i)$..............................(ii)

$P(Y_i = 0) = 1 - F(\beta_i X_i)$........................ (iii)

Whereby;

Y_i = Is the observed response of ith water project sustainable or not

Y_i =1, if a water project is sustainable

Y_i =0, if a water project is not sustainable

Table 1: Description of the explanatory variables

Variable	Descriptions
	Dependent variable
Water sustainability	1= Functioning, 0 = Otherwise
	Independent variables
Household size	Continuous variable (Number of individuals in the house)
Household water consumption	Continuous variable (Average liters of water consumed by household members per day)
Price of water	Continuous variable (Amount of money set to pay for water service per container)
Maintenance per annum	1 = if done, 0 = if not done
Community meetings per annum	1 = if done, 0 = if not done
Water management training per annum	1 = if done, 0 = if not done
Distance to water point (measured in meters)	1= within 400 meters, 0 = above 400 meters
Payment model system	1 = Pre-paid system, 0 = Otherwise
Water spare parts availability in the area	1 = Yes, 0 = No

3.0. Results and Discussions

3.1. Characteristics of the respondents

The findings in Table 2 reveal that most of the respondents, 76 (54.7%), were female, and 63 (45.3%) were male. This result indicated that at the household level, women are responsible for performing most of the domestic activities related to water use such as washing, gardening and cooking just to mention a few. These findings conform to those obtained by (Mcheka, 2015), who urged that females were more likely to provide information regarding water availability and accessibility in the Mufindi district than males.

The study's findings in Table 2 revealed that 57 (41%) of the respondents in the study area were married, 55 (39.6%) were single, 20 (14.4%) were divorced, and only 7 (5%) were widows. Additionally, most participants (72 out of 139 respondents) fell within the age bracket of 18 to 35, making up 52.6% of the total respondents. The data also shows that only 6.4% (9) of the respondents were over 55. This suggests that the study participants were mature enough to provide valuable insights into the topic. Moreover, the findings show that 66 (47.5%) had a secondary education, 51 (36.7%) had a primary education, and 15 (10.8%) held a university degree. This highlights the success of the national and global drive towards providing education for all, with more individuals enrolling in educational programmes.

Based on the data presented in Table 2, it can be observed that the majority of respondents (51.1%) had a household containing less than four individuals. Additionally, 30.2% of respondents reported having a household size of 4-6 individuals, while 18.7% had more than six people. The results indicate that only a small proportion of study participants have many individuals in their households who require a significant amount of water for daily use. This finding is consistent with the URT (2022) report, which stated that Nghong'onha ward has an average household size of 3.8.

Table 2: Demographic characteristics

Variables	Category	Frequency	Percent
Gender	Male	63	45.3
	Female	76	54.7
Marital status	Married	57	41.0
	Single	55	39.6
	Divorced	20	14.4
	Widow	7	5.0
Respondents Age	18-35	73	52.6
	36-55	57	41.0
	Above 55	9	6.4
Respondents education level	Primary	51	36.7
	Secondary	66	47.5
	Tertiary	7	5.0
	College/University	15	10.8
Household size	Less than four	71	51.1
	4 to 6	42	30.2
	Above 6	26	18.7

3.2. Household Water Use Practices

3.2.1. Household water consumption per day

The results in Table 3 reveal that the average water consumption per household is 82.27 litres per day. With an average household size of 3.8 in the study area, the findings indicate that every person consumes 21.65 litres of water daily. This result implies that most households meet the minimum water consumption standard of the World Health Organization (WHO). WHO recommends a minimum of 20-25 litres of safe water per day to ensure basic living standards, including cooking, drinking, personal hygiene, laundering, cleaning, and other domestic activities (WHO, 2019). These findings align with earlier research conducted by Beyene (2012), who reported that households in Ethiopia typically consume an average of 25 litres of water per day.

3.2.2. Water price in the area

The findings revealed that the average price for 20 litres of water is TShs 223, with a minimum price of TShs 100 at public water points and a maximum price of TShs 500 at individual water vendors. The findings imply that households in the study area pay more for water than the stipulated price of TShs 100, as per the Energy and Water Utilities Regulatory Agency (EWURA) (URT, 2020). The findings imply that, although community members are responsible for making decisions on the price of water for community-based water projects through general meetings, the infrequent flow of water tends to raise the price of water as the demand becomes higher than the water supply in the area.

In an interview, one respondent argued, "*The cost of water in our area fluctuates based on the season. At times, the price can increase up to 500 Tanzanian shillings for a 20-litre bucket, which poses a significant challenge to low-income individuals as they struggle to access sufficient water in line with their budgets." (*Woman interview in Nghong'onha ward, August. 2023).

3.2.3. Waiting time at the domestic water point

The study aimed to gauge the waiting time of respondents at the water source to fetch water, which is an essential indicator of water accessibility. Table 5 presents the results, which indicate that 47.5% of respondents had to wait for 31-45 minutes to fetch water, while only 7.2% had to wait for more than 60 minutes. These findings suggest that there is a water accessibility problem in the area, as the majority of respondents exceeded the 30-minute target set by the National Water Policy of 2002. Additionally, this means that people spend more time fetching water, impacting their ability to carry out other tasks. These results align with another study by Masanyiwa *et al.* (2017), which found that over half of water users in Magu and 44% in Lamadi had to wait for over 60 minutes. Long queues at water points may be due to limited domestic water points and inconsistent water supply.

Table 3: Waiting time at the domestic water point

Variable	Category	Frequency	Per cent
Time spent fetching water (minutes)	0-30	45	32.4
	31-45	66	47.5
	46-60	18	12.9
	Above 60	10	7.2

3.3. Factors affecting the sustainability of water projects

The study highlights the factors that impact the sustainability of water projects in the study area. A binary probit model was used to evaluate the model's accuracy, and Pseudo (R^2) was estimated. The test results using this model indicate that the Pseudo (R^2) was 0.7629, demonstrating that the model could explain the change in the dependent variable by 76.29% due to the change in the independent variables.

Maintenance per annum

Table 8 results indicate that maintenance of the borehole water project had a significant positive impact at a one percent level. Specifically, water projects that received annual maintenance were more sustainable than those that did not. Water projects maintained annually had a 40.7% higher likelihood of being sustainable than those not maintained. The maintenance included replacing water corks at the water point using the water user fees collected by the water committee in the area. The finding highlights the importance of regular maintenance to ensure the longevity of domestic water points. These findings support Aarseth *et al.* (2017), who suggested that incorporating sustainability into project design and technical systems through maintenance practices is crucial for ensuring project longevity.

Community meetings per annum

Table 8 results indicate that community meetings had a positive sign and were statistically significant at the one percent level. The results show that those project implementers who held regular meetings with the community about their water project were more likely to be sustainable by 83.8% compared to those who did not hold a regular community meeting. The findings imply that conducting regular community meetings facilitates community ownership of the project while at the same time promoting a willingness to contribute to the cost of the project operations, thereby ensuring sustainability. These findings align with those of Mwangangi *et al.* (2016), who found that a unit increase in community participation leads to a 0.812 increase in the sustainability of borehole water projects in Kenya. Also, Mrangu (2018) argued that most water projects fail to achieve their goals due to ineffective community participation.

In an interview with the Ward Community Development Officer (CDO), who used to facilitate awareness creation about water issues with the communities in the study area, the interviewee insisted that *"The key focus of any project's sustainability is information sharing. Meetings between the various water resource governing committees and water users improve project ownership and, ultimately, project survival over the long term"* (CDO at Nghong'onha ward, August 2023).

Payment modality system

The results in Table 8 indicate that the payment modality system had a negative sign and was statistically significant at the five percent level. The results show that those projects with a prepaid model system were less likely to be sustainable by 50.4% compared to those domestic water points that used a post-paid model payment system, which required water users to pay for water buckets at the domestic water point. The prepaid payment model system required water users to pay for the water system electronically before going to the water point to fetch water. The findings imply that the prepaid model was not preferred by the respondents in the study area because respondents lacked knowledge on how to use the payment system and because the infrequent flow of water at the domestic water points made water users prefer paying for water at the water point after fetching the water. These findings align with those of Masanyiwa *et al.* (2017), who found that non-metered customers in Magu preferred a monthly post-paid flat rate payment system of TZS 4500.

In an interview, one key informant said, "Payment modality matters to ensure the sustainability of water projects. *For instance, a water project on this street funded by the Coca-Cola Company used a prepaid payment modality (metered). Unfortunately, the project failed, and all the domestic water points were dysfunctional because people lacked knowledge of the system. Also, the infrequent water flow at the water point made water users prefer post-paid modality rather than post-paid modality"* (key informants' interview in Nghong'onha ward, August. 2023).

Spare parts availability

The results in Table 8 indicate that the area's availability of spare parts for regular maintenance had a negative sign and was statistically significant at the five percent level. The results show an inverse relationship between spare parts availability and borehole water projects in the area. The findings imply that the unavailability of spare parts in the area does not affect the adequate provision of water in the study area as the area is near the city, where it took only half an hour to access the spare parts even if they are inaccessible in the project area. These findings contradict those of Oberlin and Kassim (2018), who reported that sustainable spare parts availability in the project area is required to facilitate regular maintenance and repair. This contradiction can be attributed to the fact that the Oberlin and Kassim (2018) study was conducted in rural areas where project implementers travelled a long distance to access spare parts.

Distance to the water collection point

The results in Table 8 indicate that time taken from the household to the domestic water point had a positive sign and was statistically significant at the one percent level. The results show that the shorter the distance to the water point, the more likely the project will be sustainable. Those domestic water points found within 400 meters were more likely to be sustainable by 57.4% compared to those found above 400 meters by the household's residents. The findings imply that a short distance to the water points enables the frequency of maintenance and repair of the water points easily in case of any breakage. These findings align with those of Kyamani (2013), who found that community-based water projects in Rufiji were not sustainable due to the high distance from the household's residence to the domestic water point, making the maintenance and protection of water projects difficult.

Table 4: Probit regression results

Variables	df/dx	Std. Err.	Z	P>|Z|	X-bar	95% C.I.	
						Lower	Upper
Household size	.0134469	.04735	0.28	0.776	4.23022	-.079349	.106243
Water Consumption	-.0847051	.23349	-0.36	0.717	1.63309	-.542344	.372934
Spare parts availability	-.3761952	.19551	-1.92	0.054	.618705	-.75939	.007
Maintenance	.4070086	.15932	2.55	0.011	.47482	.094738	.71928
Community meetings	.8385189	.09906	8.46	0.000	.496403	.644363	1.03267
Water management training	.2956564	.17481	1.69	0.091	.431655	-.046958	.638271
Payment modality system	-.5042178	.22248	-2.27	0.023	.683453	-.94028	-.068155
Distance to the water collection point	.5747869	.10365	5.55	0.000	.76259	.371637	.777937

Number of obs = 139
LR chi2(8) = 146.07
Prob > chi2 = 0.0000
Log-likelihood = -22.703193; Pseudo R^2 = 0.7629

4.0. Conclusions and Recommendations

This study has assessed factors affecting borehole water project sustainability in Dodoma using the case of the Nghong'onha ward. The main conclusion emerging from the findings is that although the present water consumption levels meet the recommended minimum thresholds, most households can only meet the basic access requirement, which does not enable them to consume enough water in quantity to guarantee healthy conditions. Further, most households spent more time fetching water, impacting their ability to carry out other economic activities. Also, regular maintenance of domestic water points, community meetings, payment modality, spare parts availability in the study area, and distance to the water points were predictors of water project sustainability in the study area.

Based on the findings, the study recommends that interventions aimed at improving access to domestic water supply in the study area should focus on improving water supply infrastructure and maintaining the built infrastructure. The study further recommends that more local technicians be trained on the operation and maintenance of domestic water points and that water tariffs commensurate with the economic status of the households in the study area be introduced. Also, the study recommends the establishment of a gender-sensitive water management committee to avoid gender discrepancies. This will ensure that everyone in the community is involved in managing water projects in the area.

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