

Topographic Influences on Household Distance to Water Points in Mountainous Lake Victoria Settlements, Tanzania

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abstract

Limited access to water services in urban areas has focused primarily on infrastructural deficits, with comparatively little attention to environmental factors, especially topography, and their relationship to household distance from water points. Consequently, empirical evidence on the role of environmental conditions in shaping household distance to water points remains limited. However, understanding the relationship between topography and household distance to water points can inform context-sensitive planning strategies aimed at improving access to water services. This study examines the association between topography classified as gentle slope (0-5°), sloping landscape (6-15°), and steep slope (16-30°) and household distance to water points, drawing on Urban Political Ecology as a theoretical framework for analysing power relations. A mixed method approach was adopted, integrating household survey and key informant interviews to explore this relationship. Data analysis was conducted using descriptive statistics, chi-square tests, GIS and content analysis. The findings indicated that residents located in gentle slope areas tended to access water points at comparatively shorter distances, followed by those in sloping landscapes, while residents in steep slope areas were more likely to access water points located beyond 400 metres from their households. The distances in steep slope settlements are inconsistent with the standards outlined in the Tanzania National Water Policy. The proportion of households located beyond 400 metres from water points was 14.72% in sloping landscape and 26.79% in steep slope, whereas no such cases were observed in gentle slope areas. The findings underscore a significant association between topography and household distance to water points. In light of these findings, I conclude that addressing disparities in water access may require greater consideration of terrain-specific conditions, strengthened regulatory enforcement, and improved policy implementation mechanisms.

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1. Introduction

Considerable efforts have been made globally to address challenges related to inadequate water supply (Munamati et al., 2016). However, approximately, 2.2 billion people continue to lack access to safe drinking water worldwide (Bachwenkizi et al., 2023; Dickin & Gabrielsson, 2023; Salehi, 2022; UNICEF, 2024). Inadequate water supply is commonly associated with low-income economies. Consequently, the majority of countries with limited access to improved water services are located in low-and middle-income countries (LMICs), particularly those in Sub-Saharan Africa (Bachwenkizi et al., 2023). Nevertheless, the role of environmental conditions, particularly topography, in shaping variations in household access to water services remains insufficiently examined.

Numerous studies examining water access and household distances to water sources have focused on various dimensions of service availability and accessibility. Yu et al. (2017) integrated population census data and water point mapping techniques to examine spatial patterns of water accessibility, while Anthonj et al. (2018) examined community water points, their functionality, and associated distances from households. These studies demonstrate persistent challenges related to the availability and accessibility

of water services. Importantly, Bachwenkizi et al.(2023) highlight the implications of inadequate water access for women's well-being, noting that longer distances to water sources are associated with delayed return times, reduced capacity to fulfil other responsibilities, and potential household tensions. Existing evidence therefore, suggests that extended distances to water sources may have implications for household well-being. Consequently, assessing household distances to water sources across different slope environments is important for generating context-specific evidence to support improved water service planning. Consequently, an assessment of household distance to water sources across different slope environments is important for generating context-specific evidence to support improved water service planning. A closely related study by Hambati (2013) and Hambati and Yengo (2018) classified landscapes into valley bottoms, gentle slopes, steep slopes, and interfluvies to assess community vulnerability to disaster risks and resilience. However, their landscape classification was primarily designed for disaster vulnerability, offering limited insight into the relationship between landscape characteristics and access to essential services such as water. This study therefore, extends the application of landscape classification by categorising landscapes into gentle slopes, sloping landscapes, and steep slopes to examine the association between topography and household distance to water sources.

In Tanzania, access to water services has improved although coverage has not yet reached all urban residents. Current estimates place urban water-service coverage at 90.1% at the regional level. and 74.5% in districts and small towns (URT, 2024). These figures suggest that a substantial proportion of

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urban residents still lack adequate access to water supply services. While previous studies have explored water service coverage in urban areas, they have not examined the variations in coverage across specific environmental contexts, particularly in settlements located on slopes. The 1991 Tanzania National Water Policy (NAWAPO) established a target of ensuring access to clean and safe water within 400 metres of households (Smiley, 2013; URT, 2002). However, this target has not yet been fully achieved. Existing evidence indicates that urban water services provision is associated with inequalities in access and distribution (Mapunda et al., 2018). This pattern of uneven access underscores the need for further investigation, particularly through analytical lenses that emphasise inequality, such as Urban Political Ecology (Cornea et al., 2017), to better appreciate how social, political, economic, and spatial processes are associated with uneven access to water services.

Inadequate water supply is associated with poor health, low quality of life and economic loss as suggested by previous scholars (Ba et al., 2023; Behera et al., 2020; Munamati et al., 2016). These water-related challenges, in turn, are associated with increased levels of poverty among the population (Anthonj, 2021; Poague et al., 2023). The diseases associated with inadequate access to water include COVID 19 (Poague et al., 2023) and diarrhoea, especially among children under five years of age (Gaiffe et al., 2023; Munamati et al., 2016; Priya et al., 2023), as well as typhoid (Priya et al., 2023). These diseases are among the major causes of illness worldwide (Anghileri et al., 2024; Gaiffe et al., 2023). These studies highlight an association between inadequate water services and diseases burden. However, the severity of water scarcity is context-specific. In vulnerable environments such as slope settlements (UN-Habitat, 2018b), where water coverage is inadequate (UN-Habitat, 2018a), water-related diseases may be more prevalent. Low-income people living in vulnerable environments are more likely to be affected by water related diseases than higher-income individuals. This inequality in access to water services can be appropriately examined through the lens of the Urban Political Ecology theoretical framework.

Water scarcity literature has consistently linked inadequate water supply with infrastructural coverage (Kayaga et al., 2020), poverty (WHO/UNICEF, 2019), and contextual factors, specifically, rural and urban settings (Anthonj et al., 2019; Dickin & Gabrielsson, 2023). In urban contexts, poor infrastructural service coverage is associated with rapid urbanisation, physical and technical factors, economic and financial limitations, and institutional, structural/legal, and socio-cultural constraints (Kayaga et al., 2020; Sinharoy et al., 2019). Furthermore, evidence suggests that, in many urban settlements, particularly in developing countries, where infrastructure has not kept pace with rapid population growth (Kayaga et al., 2020).

Poverty has been widely examined, with studies indicating that poorer households are substantially more likely to have inadequate WASH services. Regarding contextual factors, studies have also shown that rural areas are more affected by inadequate WASH services than urban areas (Dickin & Gabrielsson, 2023). This is exemplified by the fact that eight out of ten people who lacked access to basic drinking water services in 2020 lived in rural areas (Dickin & Gabrielsson, 2023). While the aforementioned issues have been extensively discussed in the literature, limited attention has been given to how environmental conditions, particularly topography, are associated with access to water services.

In response to inadequate water supply, efforts have been made since the colonial period to improve water services, especially in Dar es salaam, the principal city in Tanzania. These efforts began during the German colonial rule, when early development of infrastructure was initiated; however, World War I limited the full implementation of urban planning schemes. Following the German rule, Tanzania came under British colonial administration, during which water services were provided to limited area of Dar es salaam, primarily serving European residential areas (Smiley, 2013). After independence, Tanzania made several efforts to address inadequate water supply, including the introduction of the National Water Policy of 1991. Due to identified limitations, this policy was subsequently replaced by the National Water Policy of 2002 (URT, 2025). Other efforts have included the launch of the National Water Sector Development Programme of 2006, the Water Supply and Sanitation Act of 2009, and the Water Resources Management Act of 2009. Collectively, these policies and Acts provide an institutional framework for the development of the water sector (URT, 2015). Specifically, the National Water Policy provides a guideline stating that water service

should be available within 400 metres of households. However, this target has not yet been achieved since its introduction in the 1990s. At the international level, Tanzania has adopted global development frameworks, including the Millennium Development Goals (MDGs) and the Sustainable Development Goals (SDGs), as benchmarks for monitoring and evaluating progress. For example, SDG Target 6.3 emphasises improving water quality by reducing pollution, minimising the discharge of untreated wastewater, and promoting recycling and safe reuse (Munamati et al., 2016).

Despite the efforts made to address and understand the root causes of inadequate water supply, the challenge remains persistent. To address this limitation, this study adopts a more differentiated classification of topography to examine how household distance to water points is associated with specific landscape patterns. The study posits that household distance to water points may vary across these landscape patterns. Urban Political Ecology theory is employed as a theoretical framework to examine the inequalities in access to water services across different landscape patterns, and this understanding may inform context-specific interventions aimed at addressing inadequate water supply by considering the distinct challenges associated with particular landscape patterns.

1.1 Urban Political Ecology Theoretical Framework

The Urban Political Ecology (UPE) was originally articulated by Erik Swyngedouw in 1996 according to (Keil, 2020), and has since evolved within the field of geography to examine the power relations that are associated with the production of uneven urban spaces (including infrastructures and nature) and differential access to resources (Cornea et al., 2017). This framework is particularly relevant for examining the relationship between topography and household distance to water sources in mountainous settlements, because it emphasizes the socio-spatial inequalities observed in such contexts. The UPE has been employed by earlier scholars to explore how power dynamics are associated with variations in access to resources (Cornea et al., 2016). In this study, the resource of interest is conceptualized as land located in topographically favourable areas for settlement development. Unequal access to such favourable landscapes is associated with disparities in access to water services. Specifically, favourable land is defined as areas characterized by gentle and moderately sloping terrain, whereas steep slopes are considered less suitable for settlement development.

The premises that underpin the theory and analytical approach in the UPE include the interconnectedness of socio-ecological systems (SESs), power relations and politics, and unequal access to urban development. SESs focus on society–nature interactions and social relations (Holzer et al., 2017). In this study, utilities are described as lacking the capacity to interact effectively with nature, particularly steep-slope landscapes to install water supply infrastructure. The social-relations aspect focuses on how social, economic, and cultural characteristics are associated with differences in access to water services. Power relations and politics denote the dynamics of power among residents, which are associated with unequal access to favourable land for settlement development. Unequal access to urban development refers to disparities in living conditions that are associated with differences in the level of urban development.

The UPE is relevant for this study because it explains how variations in settlement landscapes, which are associated with differences in the economic positions of urban residents, are in turn associated with variations in access to water services. Unlike previous UPE studies that examined unequal access to social services at the urban scale, this study does not treat the city as a homogeneous space; rather, it differentiates urban areas into spatial patterns to examine unequal access to water services. This application of UPE is important for developing its theoretical body across multiple geographical contexts and diverse positions (Zimmer et al., 2018). Therefore, this study applies UPE to understand access to water services by classifying landscapes into gentle, moderately sloping, and steeply sloping terrains.

2. Methodology

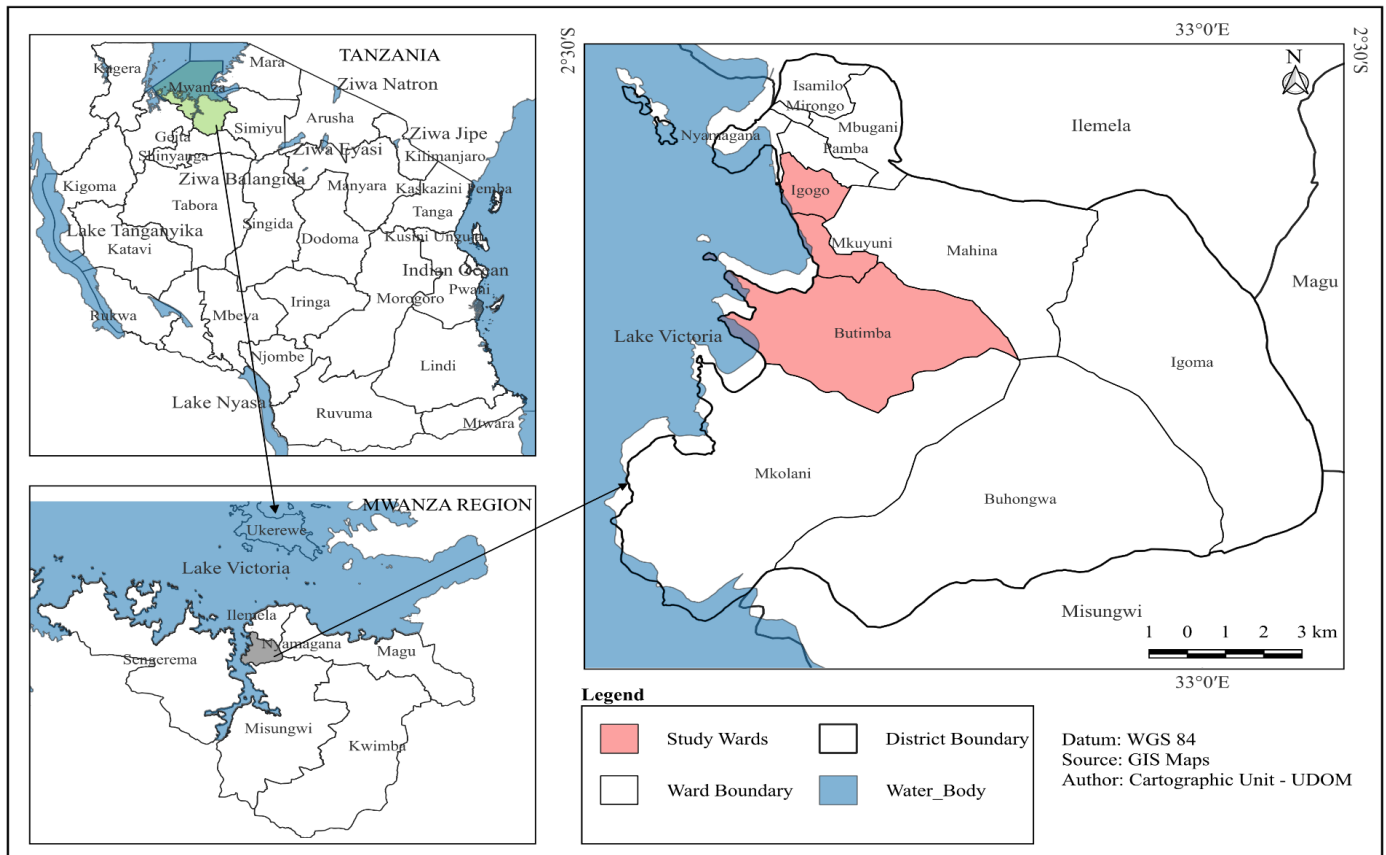
2.1 Study Design

This study applied a cross-sectional explanatory survey design to examine the association between topography and distance to water points in slope settlements. This design was adopted because it enables the examination of relationships at a single point in time. A mixed-methods approach was employed in data collection, involving the integration of both quantitative and qualitative data. This approach is considered appropriate for reducing potential sources of error, as the two forms of data complement each other. Data were collected using a structured questionnaire administered to residents of slope settlements ranging from 0° to 30°. The slope landscape was classified into three patterns: gentle slope (0°–5°), sloping landscape (6°–15°), and steep slope (16°–30°) (FAO, 1977, 2010). This classification was important in highlighting the similarities and differences in household distance to water points across landscapes. The distance to water points was examined in relation to the landscape patterns in which the households were located.

2.2 Study Area and Population

This study was conducted in the Nyamagana District in Mwanza City (Figure 1). Mwanza was selected purposively because of its landscape characteristics,

which are characterised by rocky terrain and sloping topography (Hambati & Yengoh, 2018; URT, 2017a, 2017b; World Bank, 2017). The study was carried out in three purposively selected wards: Butimba, Igogo, and Mkuyuni (Figure 1). These wards were selected because of their ecological placement in a contiguous landscape and because they are situated across heterogeneous elevations and slope gradients (Fig. 1). The wards were also characterised by a hazardous ecosystem that has been settled and developed without formal government authorisation (Mwesongo, 2025b). The total population of households in the three wards was 21,249, with 9,548 households in Butimba, 6,500 in Igogo, and 5,201 in Mkuyuni (URT, 2022). Two streets were purposively selected from each ward: Bohari and Kambarage in Butimba; Azimio and Malulu in Igogo; and Shede and Mkuyuni Sokoni in Mkuyuni. These streets were sampled because they are located on heterogeneous slopes and are ecologically juxtaposed within a connected landscape. The target population was adults aged 18 years and above from the three selected wards residing in slope settlements, including both males and females. This target population was selected because they are primarily responsible for household water access and management and reside within the targeted landscape.



Sampling Frame and Techniques

The sampling process was conducted in two stages: the selection of study wards and the selection of respondents. The wards were selected purposively based on their placement on a heterogeneous slope. Within these wards, the sampling frame consisted of lists of registered households and professionals eligible as key informants. A sample size was calculated using

$$\frac{Z_{1-\alpha/2}^2 P(1-P)}{d^2}$$

formula (Charan & Biswas, 2013). In this formula,

$Z_{1-\alpha/2}$ is the standard normal variate, taken as 1.96. d represents the precision level 0.05 at a 95% confidence level, and p denotes the proportion of the population in the respective study area. This formula was adopted because it does not require the total population size but rather relies on population proportion. Approximately 75% of the residents in Mwanza City lived in informal slope settlements (Andreasen et al., 2020; World Bank, 2017). Using this proportion, the sample size was calculated as

$$\frac{1.96^2 0.75(1-0.75)}{0.05^2}$$

follows: $\frac{0.05^2}{0.05^2} = 288$. A proportion of 75% was used because according to Charan and Biswas (2013), sample size estimation can be based on a known population proportion when studying a specific subpopulation. The sample size was determined based on the population size of each ward, with the aim of ensuring adequate representation at the ward level. However, although the sample provides good representation of the wards, the distribution of respondents across slope categories may be associated with potential representation bias. This sample size was deemed both statistically adequate and logistically feasible, thereby supporting reliable analysis within a manageable scope of fieldwork. The proportion of the sub-sample from

selected wards was calculated using $n_h = \frac{N_h n}{N}$ formula, whereby:

n_h The proportional sample of each ward (1, 2, 3, 4,.....)

N_h The number of households of each ward;

N Total number of households;

n Sample size of households;

Therefore, the households from each ward were calculated as follows:

- i. Butimba $\frac{9548}{21249} \times 288 = 129$
- ii. Igogo $\frac{6500}{21249} \times 288 = 88$
- iii. Mkuyuni $\frac{5201}{21249} \times 288 = 71$

$$\text{iii. Mkuyuni } \frac{5201}{21249} \times 288 = 71$$

Furthermore, Table 1 and Table 2 show how the proportion of households in wards and streets were obtained.

Table 1: Sample Size and Household Distribution at Ward Level

Ward name	Wards Population	Ward HH size	Number of Households	Sample size	(%)
Butimba	44876	4.7	9548	129	45
Igogo	27303	4.2	6500	88	30.5
Mkuyuni	21324	4.1	5201	71	24.5
Total	93503	4.3	21249	288	100

Source: (URT, 2013)

2.4 Data Collection

2.4.1 Household Survey

The researcher used household surveys to collect both quantitative and qualitative data through a structured household questionnaire and GPS measurements. The survey instruments consisted of interview questions for the household survey (see Table 3), particularly those used to generate indicators of access to water supply for this study. The main data sources comprised residents from 288 slope-settlement households and key informants from relevant city offices. Among the 288 participants, 129 were from Butimba, 88 from Igogo, and 71 from Mkuyuni wards (Table 1). The questionnaire covered participants' demographic characteristics and the types of water points accessed by each household. The questionnaire was administered face-to-face by the researcher to the selected 288 households. The GPS was used to capture household locations and record their elevations. The recorded elevations were subsequently converted into slope gradients to determine the steepness of each household location. Data were collected within these landscape patterns to assess variations in household distance to water points. Furthermore, the GPS was used to record the household and water point coordinates. The euclidean distance between households and water points was then calculated using GIS software. However, while euclidean distance provides an objective estimate of spatial proximity, it may underestimate the actual walking distance because it measures straight-line distance rather than routes determined by existing paths and landscape configurations. This limitation is particularly relevant in the study area, where sloping terrain and settlement patterns may constrain mobility and require residents to travel longer distances to access water points.

Table 2: Sample Size and Household Distribution at Street Level

Ward	Street	Street population	Ward HH size	Number of HH	Sample size	(%)
Butimba	Bohari	5570	4.7	1185	60	47
	Kambarage	6406	4.7	1363	69	53
Total		11976	4.7	2548	129	100
Igogo	Azimio	3402	4.2	810	46	52
	Malulu	3108	4.2	740	42	48
Total		6510	4.2	1550	88	100
Mkuyuni	M/Sokoni	2091	4.1	510	39	55
	Shede	1714	4.1	418	32	45
Total		3805	4.1	928	71	100
Grand total		22291	4.3	5026	288	100

Source: URT, 2013 and Mwanza City, 2025

Table 3: Survey, key informant interviews used to generate access to water services indicators

Water supply indicator	Question	Question type	Data collection instrument/Tool	Coded response
Household access to water services defined by landscape location and the technical feasibility of pumping water to the area.	What is the location of the household in terms of landscape pattern?	Measurement of elevation/slope in degrees	GPS	Gentle slope (0-5°) Sloping landscape (6-15°) Steep slope (16-30°)
Household access to water services is defined as to collect water at a distance of 400 metres from household	Please show the water source/points you commonly collect water.	Measurement of household distance to the nearest water point	GPS	<100m 100-199m 200-299m 300-399m Beyond 400m
Household access to water is defined as connected to water service	Is your household connected to water service?	Reported; select one	Household questionnaire	Yes No
Collection of water in defined points/sources	Which water supply point/source are you commonly collect/get water?	Reported; select all that apply	Household questionnaire	Tap at neighbour Piped water to yard Piped water into dwelling Public tap Tanker truck
Reporting adequate water supply in settlements	What are your opinions on the situation of water supply in slope settlements?	Reported; general explanations	Interview Guide	General explanations
Reporting equality in access to water supply among landscape patterns	Which area of settlements between, lower slope, mid slope and higher slope is more experiencing inadequate water supply?	Reported; general explanations	Interview Guide	General explanations
Availability of projects for provision water supply in the slope settlements	Are there any project engaging in water supply in these settlements	Reported; general explanations	Interview Guide	General explanations

Source: Researcher construction, 2022

2.4.2 Key Informant Interviews

The data used were collected using key informant interviews to complement and provide contextual understanding of the household survey findings. Data collection was guided by a set of interview questions presented in the interview guide (Table 3). The pre-developed questions were used to structure the interviews. The study involved four key informants, specifically three Ward Executive Officers (WEOs) from Butimba, Igogo, and Mkuyuni, and one district official from the water sector. The key informants were recruited based on their specialised knowledge of water supply issues and their institutional roles within the study area. These recruitment criteria were used because the selected participants represented key stakeholders with relevant knowledge and perspectives on water service provision. Specific data collected from key informants included the types of water points used by residents in slope settlements and the availability of water services within these settlements. Key informant interviews were preferred because they provided additional contextual insights, supported the interpretation of survey findings, and helped minimise potential misinterpretation of information collected from the community.

2.5 Data Analysis

Data analysis was conducted according to the nature of the collected data. Quantitative data were cleaned, coded, and analysed using the Statistical Package for the Social Sciences (SPSS) version 25. Descriptive statistics, including frequencies and percentages, were computed to summarise household characteristics and patterns related to water access. In addition, Chi-square tests of independence were employed to examine the association between landscape characteristics and selected household water access indicators, including household distance from water points and household connection status to water services. The tests were conducted at a 5% significance level to determine whether observed associations between landscape patterns and water access variables were statistically significant. Qualitative data obtained from key informant interviews were analysed using

content analysis. This approach facilitated the systematic identification and interpretation of themes emerging from participants' accounts while considering the social and contextual meanings embedded within the data.

Spatial data analysis involved the processing and analysis of Digital Elevation Model (DEM) data using Geographic Information System (GIS) techniques. High-resolution DEM data with a spatial resolution of 30 metres were obtained from the USGS Earth Explorer platform in 2024. The DEM was processed in ArcGIS 10.4.1, where the spatial reference system was defined using the Geographic Coordinate System based on the WGS 84 datum. The Spatial Analyst Mask tool was applied to extract elevation data corresponding to the study area by clipping the DEM to the study boundary. Subsequently, surface analysis tools were used to derive slope raster data from the DEM. The generated slope values ranged from 0° to 30° and were classified into three categories based on the FAO slope classification standards: gentle slopes (0°–5°), sloping landscapes (6°–15°), and steep slopes (16°–30°) (FAO, 1977, 2006). This classification enabled the assessment of variations in landscape conditions and their association with household water access patterns across different slope categories.

3. Results and Discussion

3.1 Water Points used by Households in Slope Settlements

Table 4 presents the type of water points used by households for water collection. The most frequently used water points were neighbours' taps, yard taps, piped water connections within dwellings, public taps, and water tankers. Households on gentle slopes, sloping landscapes, and steep slopes collected water from neighbours' taps, accounting for 57.4%, 39.09%, and 46.43%, respectively. These results indicate that a high proportion of households collecting water from neighbours' taps were located in the gentle slope areas. This is interpreted to mean that households in gentle slope areas may have experienced limited access to individual water connections and therefore, relied on neighbours' water connections compared to households on steep slopes and sloping landscapes. Households without direct water

connections may therefore, have depended on neighbours as an alternative source of water. In the sloping landscape, the proportion of households collecting water from neighbours was moderate, which may reflect limited availability of household water connections. Thus, some households relied on public taps as alternative water sources. A similar pattern was observed on steep slopes, where households collected water from neighbours' taps in moderate proportions, possibly reflecting limited access to formal water services. Consequently, households depended on the nearest available water sources to meet their water needs.

The observed variations in household water access across slope categories may reflect a combination of environmental and socioeconomic factors. The limited proportion of households connected to water services in sloping and steep slope areas may be associated with environmental conditions, particularly, the slope steepness. However, other factors such as household income and potential challenges faced by authorities in extending infrastructure to steep-slope areas, may also contribute to this situation. In addition, settlements located in environmentally constrained areas, including those established without formal approval, may experience additional challenges in accessing water infrastructure. Furthermore, the technical difficulties associated with extending water networks across sloping and steep-slope landscapes may also influence patterns of household water access. A previous study examining household water collection patterns showed that piped water systems and private household taps reduce the distance to water points and time spent in fetching water (Winter et al., 2021).

In addition, 34.29%, 43.15%, and 32.14% of households located on gentle slopes, sloping landscapes, and steep slopes, respectively, collected water from piped water connections in their yards (Table 4). These households were connected to the water supply network operated by MWAUWASA. However, variations were observed in the proportion of households with yard connections across the three slope categories. On gentle slopes, a moderate proportion of households were connected to water points, which may reflect the relatively greater accessibility of these areas for water infrastructure development and service provision. Accessibility may partly explain this pattern; however, socioeconomic conditions also appear to be relevant, as gentle slope settlements were inhabited by relatively higher-income households who may have had greater financial capacity to establish household water connections. In sloping landscapes, the proportion of households connected to the water grid was higher than that observed in both gentle and steep slopes. This pattern appears to be associated with the implementation of the VEI water supply project, which supported low-income households in slope settlements that had previously faced financial barriers to accessing formal water connections.

The VEI projects focused on households that were not connected to the government-managed water network due to financial constraints. A water official interviewed as a key informant reported that "The VEI project operates in Butimba and Mkuyuni wards and has to some extent reduced water scarcity among residents." Despite this intervention, a considerable number of low-income households remain unconnected because project coverage depends on available financial resources and implementation capacity. The proportion of households connected to water in yards on steep slopes was comparatively lower, which may be related to the technical and logistical challenges associated with extending water infrastructure to steep terrains. Even where households had connections, water supply was often intermittent. Respondents reported that households on steep slopes sometimes received water at night only once or twice per week. This pattern is likely associated with the operational challenges of pumping water to higher elevations, which may increase the complexity and cost of water distribution.

Another source of water used by residents of slope settlements was piped water into dwellings. There were no households with piped water into dwellings on gentle slopes. Only a small proportion of households in sloping landscapes (7.61%) and steep slopes (1.79%) had piped water inside their dwellings. This finding suggests that direct household water connections remain limited across all slope categories. Households that collected water from public taps accounted for 6.60% on the gentle slope, 8.57% on the

sloping landscape, and 19.64% on the steep slope (Table 4). The relatively higher proportion of households relying on public taps on steep slopes indicates greater dependence on communal water sources in these areas.

This pattern is consistent with the lower proportion of households connected to formal water services on steep slopes. In contrast, fewer households in sloping landscapes and gentle slopes relied on public taps, possibly because a greater proportion of households in these areas had access to yard connections. Thus, residents tended to collect water from the nearest available source, including public taps and neighbouring households. The distribution of public tap use across slope categories reflects differences in household water access arrangements associated with both landscape characteristics and socioeconomic conditions. Gentle slopes, where physical accessibility is relatively favourable, had a lower proportion of households depending on public taps, whereas steep slopes, where infrastructure expansion is more challenging, showed greater reliance on communal sources. These findings highlight spatial inequalities in water access, although the observed relationships should be interpreted as associations rather than direct causal effects given the cross-sectional design of the study.

Tanker trucks represented another source of water access among households in the study area. The findings indicate that no households on gentle slopes reported collecting water from tanker trucks, which may reflect the relatively higher availability of alternative water sources in these areas. In the sloping landscapes, 3.55% of households reported purchasing water from tanker trucks (Table 4). The use of tanker trucks in these areas appears to be associated with limited household connections to formal water services, creating a demand for privately supplied water among some residents. In contrast, no households on steep slopes reported accessing water from tanker trucks. This pattern may be linked to the limited accessibility of these areas, particularly where inadequate road infrastructure constrains the movement of water delivery vehicles. Previous studies have similarly identified a range of household water sources, including piped water, boreholes, protected dug wells, protected springs, and surface water, among others (Pullan et al., 2014; Roche et al., 2017; Tesha et al., 2019).

3.1.1 Households Connected to Water Services by Slope and Ward

Household access to water services was examined according to the slope categories and wards with the goal of identifying spatial variations in water service coverage. The analysis considers whether settlement location is associated with differences in household connectivity to formal water services across the study area.

3.1.1.1 Household Connected to Water Services by Slope

Households connected to water services were assessed by slope and ward. Regarding slope categories, the findings indicate that an overall 62.15% of households were connected to water services, although variations were observed across different slope conditions. The distribution of households connected to water services by slope was 77.1%, 65%, and 42.9% in gentle slopes, sloping landscapes, and steep slopes, respectively (Table 4). Conversely, households without connections to water services accounted for 35.85% overall, with proportions of 22.9%, 35%, and 57.1% recorded in gentle slopes, sloping landscapes, and steep slopes, respectively (Table 4). These results indicate that the highest proportion of households without water service connections was observed in steep slope areas (57.1%), followed by sloping landscapes (35%) and gentle slopes (22.9%). The observed variation suggests that slope conditions are associated with differences in household access to formal water services.

The relatively lower proportion of connected households on steep slopes may be linked to the challenges associated with extending water infrastructure to physically constrained terrains. It may also be associated with the continued expansion of informal settlements in the study area (Hambati, 2013), which has increased demand for urban services and may have created challenges for existing water supply systems to meet growing needs. Local leaders, as key informants, reported persistent challenges related to inadequate water supply in steep slope settlements. These findings imply that households in steep slope areas may experience greater difficulties in accessing reliable water

services, which could increase the burden of water collection and affect household sanitation practices. The findings differ slightly from those reported by MWAUWASA (2019), which indicated that 50% of households in Mwanza City were connected to the water network. The 12.15 percentage-point difference between the current study and MWAUWASA's report may partly reflect differences in study periods, as the current study was conducted in 2021. The observed pattern supports the Urban Political Ecology (UPE) perspective, which highlights how unequal access to urban services is associated with the spatial organisation of settlements. From this perspective, water infrastructure provision may be more concentrated in areas where extension of services is relatively feasible, while settlements located in physically challenging environments may experience comparatively limited access.

3.1.1.2 Households Connected to Water Services by Ward

The overall proportion of households connected to water services across the study wards was 62.15%, although substantial variation was observed at the ward level. Butimba has the highest connection rates (82.95%), followed by Mkuyuni (60.56%), and the lowest was in Igogo (32.95%). Conversely, 37.85% of households were not connected to water services overall, with the highest proportion of unconnected households recorded in Igogo (65.05%), followed by Mkuyuni (39.44%) and Butimba (17.05%) (Table 4). The

relatively higher levels of connectivity in Butimba and Mkuyuni may be associated with the presence of the VEI International Water Project, which has supported water supply infrastructure in these wards, whereas Igogo was not covered by this initiative and appears to have comparatively limited access. Qualitative evidence from a key informant further indicates spatial disparities linked to topography, noting that households located at lower elevations were more likely to be connected to water services, while those at higher elevations had limited access. These findings suggest that access to water services is associated with environmental conditions, particularly elevation. Limited access in steep-slope areas may also be related to infrastructural constraints, including poor road accessibility, as well as the relatively low socioeconomic status of residents. In such contexts, households often rely on alternative coping strategies, such as collecting water from distant sources or purchasing it at relatively high prices from vendors, a burden that appears to disproportionately affect women, who are primarily responsible for domestic water collection. These results are consistent with previous studies, including MWAUWASA (2019) and UN-Habitat (2018), which reported inadequate water service coverage in steep-slope settlements due to inaccessibility and limited financial capacity among residents; however, these studies provide limited insight into specific government strategies aimed at improving water service provision in such geographically constrained areas.

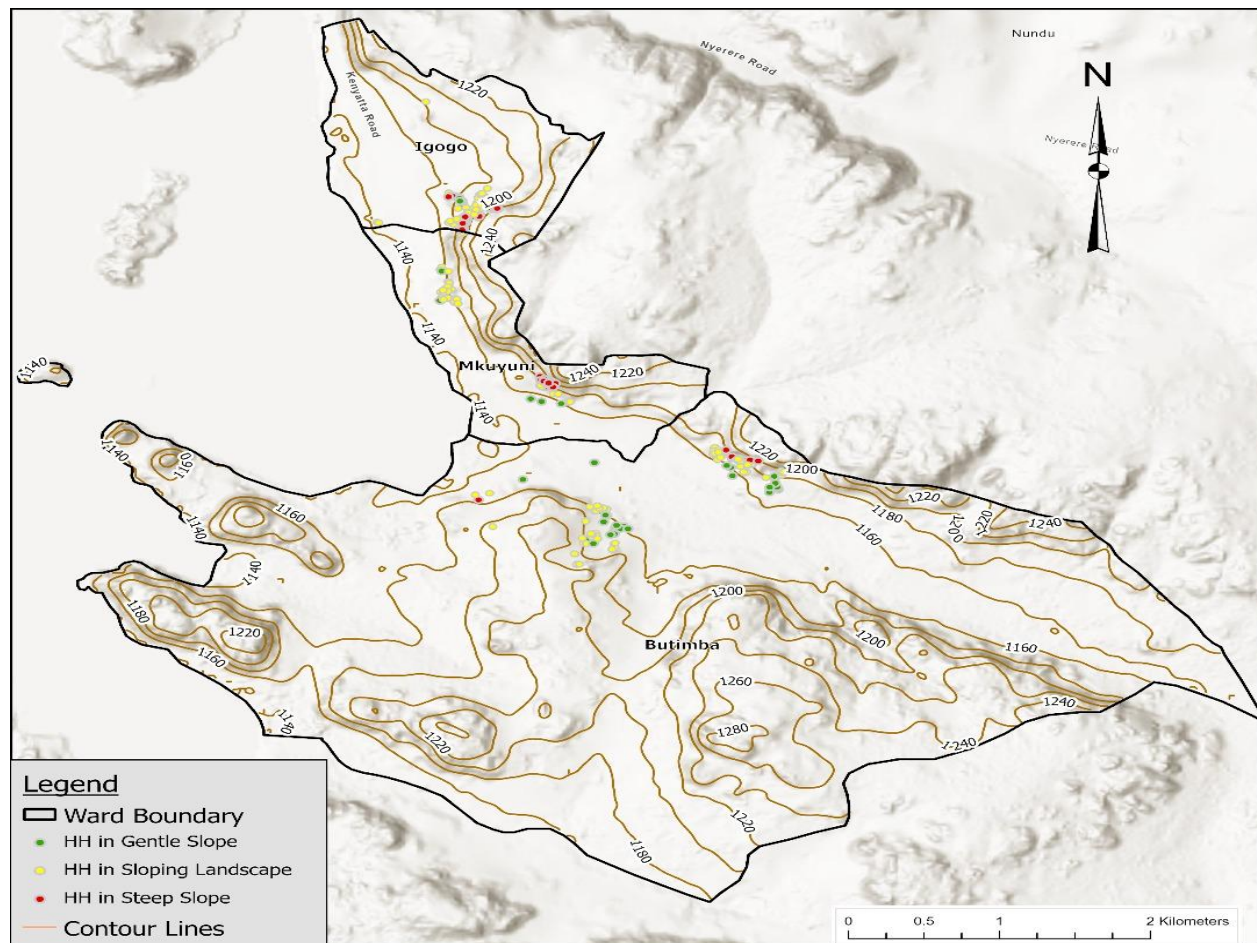


Figure 2: Spatial distribution of settlements on slopes

Source: Prepared by the author based on Tanzania administrative area boundary map, 2026

Table 4: Access to water services

Access and type of water point	Access to water service by slope				Access to water services by ward		
Variable	All	Gentle slope	Sloping landscape	Steep slope	Butimba	Igogo	Mkuyuni
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
HH connected to water services in yard							
Not connected	109(37.85)	8(22.9)	69(35)	32 (57.1)	22(17.05)	59(67.05)	28(39.44)
Connected	179(62.15)	27 (77.1)	128(65)	24(42.9)	107(82.95)	29(32.95)	43(60.56)
Water supply points/ sources							
Tap at neighbour	123(42.71)	20(57.14)	77(39.09)	26(46.43)	46(35.66)	45(51.14)	32(45.07)
Piped water to yard	115(39.93)	12(34.29)	85(43.15)	18(32.14)	63(48.84)	22(25.00)	30(42.25)
Piped water into dwelling	16(5.56)	0(0.00)	15(7.61)	1(1.79)	14(10.85)	2(2.27)	0(0.000)
Public tap	27(9.38)	3(8.57)	13(6.60)	11(19.64)	6(4.65)	12(13.64)	9(12.68)
Tanker truck	7(2.42)	0(0.00)	7(3.55)	0(0.00)	0(0.00)	7(7.95)	0(0.00)

Source: Field survey, 2022

3.2 The Impacts of Topography on Household Distance to Water Point

3.2.1 Distance from Water Point by Slope

This study also sought to understand the relationship between household distance to water points and landscape patterns, with the goal of indicating how far each household was located from the nearest water point. Table 5 presents the association between landscape patterns and distance to water points by slope and ward using the chi-square technique. The Chi-square test of independence was used to examine the association between landscape pattern and household distance to the water point at a 5% significance level ($\alpha = 0.05$). The results indicated a statistically significant association between the variables, $\chi^2 (10, N = 288) = 40.79, p < 0.001$. The assumptions of the Chi-square test were satisfied because all expected cell frequencies were greater than five.

Households located within 100 metres of a water point were 68.57%, 59.90%, and 39.29% on gentle slopes, sloping landscapes, and steep slopes, respectively (Table 5). These households accessed water at relatively shorter and more reasonable distances. Generally, households collecting water at a distance of less than 400 metres are considered to have adequate water supply as per NAWAPO (URT, 2002). These results imply that a higher proportion of households collecting water at distances of less than 100 metres were located on gentle slopes, followed by sloping landscapes, and finally steep slopes. This is because of greater accessibility for service provision in gentle slope areas, relatively higher income levels among residents, and smoother water flow conditions compared to other slopes. Thus, more water points were constructed in these areas. Regarding sloping landscapes, households were moderately supplied with water due to a mixture of favourable and unfavourable environmental conditions, where water infrastructure was installed only in areas suitable for water flow. On steep slopes, households were less adequately supplied with water services because a large portion of the terrain was inaccessible for service provision. This situation aligns with the Urban Political Ecology (UPE) theoretical framework, which suggests that limited capacity to interact with nature can reduce access to essential services, representing a key dimension of socio-ecological systems. Therefore, environmental conditions contribute to variations in access to water services across different landscape patterns. Nevertheless, access is also shaped by socio-political factors, including the expansion of informal settlements, weak governance structures, and limited government capacity to invest in water supply infrastructure. Inadequate water supply on steep slopes has adverse implications for sanitation practices, as water is essential for maintaining cleanliness.

The distribution of households located at distances of 100–199 metres from water points varied across slope categories. The proportion of households within this distance range was 14.29% on gentle slopes, 12.69% on sloping landscapes, and 5.36% on steep slopes (Table 5). These findings suggest that household distance from water points was associated with the landscape characteristics of the settlement location. A higher proportion of households on gentle slopes and sloping landscapes were located closer to water sources

compared with those on steep slopes; thus, access to domestic water in gentle and sloping landscapes appears relatively easier.

Moreover, the distribution of households located at distances between 200 and 299 metres from water points was 5.71% on gentle slopes, 5.58% on sloping landscapes, and 1.79% on steep slopes. Regarding distances between 300 and 399 metres, 11.43% of households were located on gentle slopes, 7.11% on sloping landscapes, and 26.79% on steep slopes (Table 5). The results indicate that households within the 200–299 metre range were more concentrated on gentle slopes and sloping landscapes, whereas those within the 300–399 metre range were predominantly located on steep slopes. These patterns suggest that increasing distance from water points is associated with a higher proportion of households located on steep slopes and a lower proportion located on gentle slopes and sloping landscapes. Therefore, households located on gentle slopes and sloping landscapes were generally able to access water within 400 metres, which is the distance threshold stipulated in the Tanzania National Water Policy.

In connection with households located beyond 400 metres from water points, the results show that no households on gentle slopes were located beyond this distance, whereas 14.72% of households on sloping landscapes and 26.79% of households on steep slopes were located beyond 400 metres (Table 5). These findings indicate that longer distances to water points are more prevalent among households located on steeper terrains. According to NAWAPO, households should be located within 400 metres of water points; beyond this distance, households are considered to experience inadequate access to water services. Such conditions may be associated with challenges including limited water availability for hygiene practices, increased walking distances for water collection, and heightened social vulnerabilities, including risks of intimate partner violence. Based on the 400-metre criterion, many households located on steep slopes experience inadequate access to water services. Drawing on the Urban Political Ecology perspective, this pattern suggests that households located on steep slopes, which are often situated in peripheral and environmentally constrained areas, may face greater challenges in accessing water infrastructure.

3.2.2 Distance from Water Point by Ward

This sub-section examined household distance to water points by ward. A high proportion of households in Butimba Ward (93.02%) were located at distances between 100 and 399 metres from water points, indicating that these households collected water within a relatively reasonable distance. This pattern may be associated with the Vitens Evides International (VEI) project, which supported low-income households in accessing water services. In contrast, 6.98% of households in Butimba Ward collected water from distances beyond 400 metres, suggesting inadequate access to water services. In Igogo Ward, households collecting water from distances between 100 and 399 metres accounted for 71.60%, whereas those collecting water beyond 400 metres accounted for 28.41%. In Mkuyuni Ward, 85.92% of households

Table 5: Distance from water point by slope and ward

Variable	Distance from water point by slope				p-value	Chi-square			Distance from water point by ward		
	All n (%)	Gentle slope n (%)	Sloping landscape n (%)	Steep slope n (%)		by slope	by ward	df	Butimba n (%)	Igogo n (%)	Mkuyuni n (%)
Distance from water point					<0.001	40.79	35.926	10			
<100m	164(56.94)	24(68.57)	118(59.90)	22(39.29)					83(64.34)	49(55.68)	32(45.07)
100-199m	33(11.46)	5(14.29)	25(12.69)	3(5.36)					17(13.18)	4(4.55)	12(16.90)
200-299m	14(4.86)	2(5.71)	11(5.58)	1(1.79)					8(6.20)	4(4.55)	2(2.82)
300-399m	33(11.46)	4(11.43)	14(7.11)	15(26.78)					12(9.30)	6(6.82)	15(21.13)
Beyond 400m	44(15.28)	0(0.00)	29(14.72)	15(26.78)					9(6.98)	25(28.40)	10(14.08)

Source: Field Survey, 2022

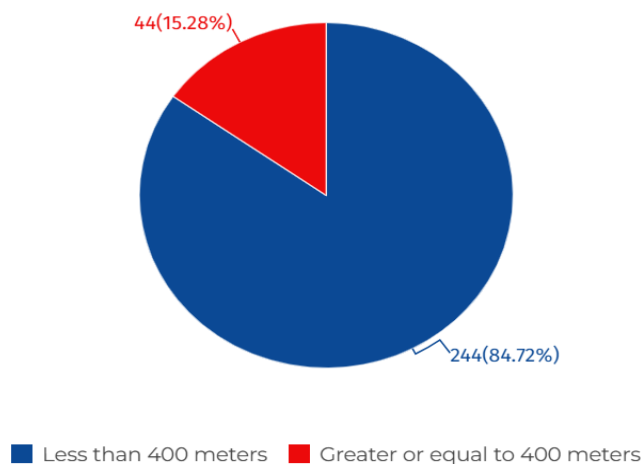


Figure 3: Distribution of households by distance from water source

collected water from distances between 100 and 399 metres, while 14.08% collected water beyond 400 metres from water points (Table 5).

The results show an association between access to water services and spatial settlement location. However, access to water services is also shaped by broader socio-political factors, including governance, income inequalities, informality, and limited institutional capacity to invest in water supply infrastructure. Long distances travelled to collect water may result in time loss that could otherwise be used for income-generating activities. Previous studies, including Masanyiwa et al. (2015) and Nganyanyuka et al. (2018) have reported that Tanzanian citizens walk long distances from households to water points. However, these studies considered the environment generally without classifying it according to landscape patterns to understand context-specific challenges. A key informant reported that “*Water supply on steep slopes was inadequate.*” This persistent challenge of water scarcity on steep slopes highlights the need for context-specific strategies for settlement development and water supply improvement, in line with the National Human Settlements Development Policy in Tanzania.

3.3 Distribution of Households by Distance from Water Source

According to the National Water Policy of Tanzania, the standard distance between a household and a water source is 400 metres. A household collecting water at this distance is considered to have adequate access to water services. The assessment of household distance to water sources in Mwanza City was compared with the policy standard. The results show that 15.28% of the households collect water from distances beyond 400 metres, while 84.72% of households collect water from distances less than 400 metres from water sources (Figure 3). The findings suggest that access to water services in slope settlements remains limited despite government efforts to improve water service provision. This situation may be associated with increased time spent collecting water among residents of slope settlements. In particular, residents of steep slope areas appear to be more affected, as they may spend more time collecting water that could otherwise be used for income-generating activities. However, they often collect limited quantities of water, which may be insufficient for

domestic purposes, including bathing. Consequently, residents of slope settlements may be more vulnerable to water-borne and water-washed diseases.

Conclusion

The study has established that the provision of water services is associated with environmental conditions such as topography. Classifying topography into three landscape patterns, the results showed varying levels of access to water services. Due to topographical constraints, residents in slope settlements are often required to walk long distances to fetch water for domestic purposes. The findings show that residents of gentle slopes and sloping landscapes travel distances between 100 and 399 metres, which is consistent with the NAWAPO. In contrast, residents on steep slopes travel distances beyond 400 metres to access water points, which may be associated with the location of their settlements in steeper terrain. Distances exceeding 400 metres among households on steep slopes suggest comparatively limited access to water services relative to the other two landscape patterns. These results align with the UPE theoretical framework, which suggests that access to urban services is shaped by environmental conditions and broader socio-political factors. Households with higher income levels may have better access to services due to their greater capacity to obtain land in more favourable locations for settlement development. The effects of walking long distances may include the collection of limited quantities of water, which may be insufficient for domestic needs, as well as loss of time that could otherwise be used for income-generating activities. Based on these findings, the study recommends that settlement development should consider environmental conditions and their suitability for water service provision. Furthermore, the study recommends improving power supply to facilitate water pumping from lower to higher elevations. From a governance perspective, strengthening regulatory enforcement and improving policy implementation are also recommended. Beyond settlement development monitoring, the findings of this study highlight the need for further research on the impacts of socio-political factors on access to water services in slope settlements in Mwanza City.

Declaration of interests

The authors declare that they have no known competing financial interests or Personal relationships that could have appeared to influence the work reported in this paper.

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