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The Influence of Socio-ecological Systems on Sanitation Practices in Slope Settlements of Mwanza City, Tanzania

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Abstract

A socio-ecological system is a multidimensional concept encompassing social relations and society-nature interactions. The concept has been used as a lens to assess various practices, particularly those related to environmental sustainability. However, the use of socio-ecological systems to assess sanitation practices in specific landscapes—such as gentle, sloping, and steep slopes where sanitation practices vary, and affect residents in multidimensional ways—remains unclear. This necessitated the use of socio-ecological systems by this study to examine the social relations and interaction between society and nature that influence sanitation practices. The study employed a cross-sectional explanatory survey design and involved a total of 288 residents who were randomly selected for primary data collection. The methods for data collection included household survey, review of written documents, key informant interviews and focus group discussions. The binary logistic regression was used to determine the association between advocacy and connection to water services, while content analysis was used to analyse qualitative data. Improved sanitation practices showed significant results with reporting inadequate sanitation to representatives, gentle slope and sloping landscape ($p < 0.005$). The construction of latrines was easier on gentle slopes compared to steep slopes. In a way, socio-ecological systems affect communities' efforts to access improved sanitation and their capacity to access better health services. Further progress could be achieved by improving relations among sanitation actors, empowering lower-income individuals to access planned areas for settlement development, and administering regulations for settlement development.

Keywords: *socio-ecological systems, social relations, society-nature interactions, sanitation practices, Mwanza*

1. Introduction

Across the globe, the issue of inadequate sanitation is escalating and significantly impacting public health, mortality rates, and economic stability. Nearly one million people worldwide die each year due to inadequate sanitation (WHO & UNICEF, 2023). Inadequate sanitation also has global economic impacts amounting to $260bn annually (UN, 2023). In Africa, access to sanitation is still low, with 779m people lacking basic sanitation, 418m lacking basic

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drinking water, and 839m still lacking basic hygiene services (UNICEF, 2022). In Tanzania, only 61% of households have access to basic water, 32% have access to basic sanitation, and 48% have access to basic hygiene (World Bank, 2023). Inadequate sanitation causes over 31,000 deaths annually and costs $2.4bn, equivalent to 1% of Tanzania's Gross Domestic Product (GDP), or US$5 per person (World Bank, 2023).

Considering the afore-mentioned negative impacts, particularly on low-income individuals, Tanzania has implemented various measures to improve the situation, including sanitation interventions. However, these interventions have not yielded adequate positive outcomes due to the approaches employed. This is because these approaches have been prescriptive, targeting specific groups, and neglecting locally-developed solutions (Kamara et al., 2017). To address the issue, socio-ecological systems (SESs) were examined to find out the kind of influence they have on sanitation practices.

Socio-ecological systems, encompassing social relations [1] and society-nature interaction, [2] have been employed to assess environmental issues (Herrera-Franco et al., 2018; Holzer et al., 2017; Petrosillo et al., 2015). In the context of sanitation, the increasingly complex nature of individual, social and environmental barriers has been gradually influencing sanitation practices; hence, the need to use SESs to understand the influence of individual, social and environmental factors on sanitation practices (Zimmer, 2010). However, studies that have employed SESs to study sanitation practices have focused on the rural context and the social dimension of SESs (Alemu et al., 2017), ignoring society-environmental interactions in urban areas (Cornea et al., 2017). Focus on the rural context and social aspect of SESs has disregarded the multidimensional influence on sanitation practices in urban settlements on slopes of varying degrees.

While ignoring the contribution of SESs—which could be better understood through the lens of Urban Political Ecology (UPE) as a power relation analytical framework—many scholars have linked inadequate sanitation with inappropriate development planning by political institutions (Mshida et al., 2017). Inappropriate development planning has contributed to uncontrolled population growth, unplanned urbanization, lack of coordination (Kasala et al., 2016; Kamara et al., 2017; Mshida et al., 2017; Safari et al., 2019), inappropriate behaviour and low income among citizens: all of which contribute to inadequate sanitation facilities (Mshida et al., 2017).

Poor analysis and planning have disregarded SESs contribution to sanitation. Eschewed SESs, inappropriate development planning, inappropriate behaviours

[1] Social relations include intrapersonal, interpersonal, community, society/policy level factors (Alemu et al., 2017; Herrera-Franco et al., 2018).

[2] Society nature interaction means human interaction with environments (Herrera-Franco et al., 2018; Herrero-Jáuregui et al., 2018).

and economic issues have been responsible for a sanitation crisis. Such analysis is simplistic and fraught with shortcomings as it solely focuses on human behaviour, while disregarding environmental factors.

In response to inadequate sanitation, Tanzania has implemented numerous interventions to improve the situation. These interventions include *Nyumba ni choo* (a good house is a good toilet), citywide inclusive approach, and national sanitation campaign (USAID, 2021). Tanzania has also declared an SGD roadmap for universal and equitable access to sanitation (Musakwa & Odhiambo, 2020). Despite all such efforts, there are still challenges; which include the lack of focus, top-down approach emphasizing hardware while neglecting software, and wider urban political ecologies (Jewitt, 2011). Furthermore, despite the measures taken, most facilities are in a very bad hygienic conditions in many areas where the interventions have been implemented (Jiménez et al., 2014).

However, despite such unpleasant experiences, in areas where interventions have considered the SESs approach to enhance sanitation, it has been proven to be effective in improving sanitation (Alemu et al., 2017; UN-Habitat, 2018b). Thus, SESs influence communities' access to improved sanitation and better health. Adverse influences, on the other hand, have led to morbidity, mortality, and impoverishment of marginalized people due to impaired social relations.

Inadequate income, morbidity, and the marginalization of low-income individuals contribute to citizens' lack of self-advocacy in seeking sanitation services from government actors. As a result, the disadvantaged groups are faced with inadequate services in their settlements (Sinharoy et al., 2019). This has been the source of diseases among low-income people. While inadequate sanitation persists, efforts to reduce the problem are becoming elusive. The limited success in addressing the sanitation problem may be partially attributed to the minimal consideration given to the influence of SESs. To go beyond such limitations, a deeper exploration on SESs through the UPE framework is crucial.

1.1 Structure of the Article

This article consists of an introduction that highlights the importance of the subject, its connection to current knowledge, and the known and unknown aspects. Furthermore, the literature review encompasses a theoretical review that forms the basis of the study, and a conceptual framework illustrating the relationship between variables. Additionally, the methodology section provides details on the study area, and the techniques employed to gather data. The findings and discussion sections delve into the social relations and interactions between societies that influence sanitation practices. Finally, the conclusion and recommendations section summarizes the major findings, and offers suggestions to enhance sanitation practices.

2. Literature Review

A socio-ecological system as a multidimensional concept has been employed in studying environmental sustainability, especially environmental management issues (Herrera-Franco et al., 2018; Zurlini et al., 2008), and transdisciplinary studies (Herrero-Jáuregui et al., 2018; Holzer et al., 2017). However, studies that have used the SES approach to address sanitation issues have focused on the social aspect of SESs, particularly in rural contexts, disregarding society-environmental interaction in urban settings (Alemu et al., 2017). Therefore, studies on the influence of SESs on sanitation practices in urban mountainous settlements are limited (Kabhele et al., 2018; Uwizeye et al., 2014). Specifically, there has been no study with empirical evidence conducted to examine sanitation practices, by classifying slopes into gentle slopes of 0-5^0, sloping landscape of 6-15^0, and steep slopes of 16-30^0, in Mwanza City.

2.1 Theoretical Review

The urban political ecology (UPE) framework was used to guide this study. UPE has evolved within the discipline of geography to examine the power relations that produce uneven urban space (infrastructure and nature), and unequal access to resources in urban areas (Cornea et al., 2017). Based on UPE, variation in access to urban resources such as surveyed land for developing settlements might lead to uneven access to sanitation. UPE has been used to assess power relations among urban residents in various practices. Unlike previous studies, this study applied UPE to assess sanitation practices by classifying urban landscape into gentle, sloping and steep slopes. This classification is essential for understanding the variation in sanitation practices in the three settlements. However, UPE has been challenged due to its use of the terms 'urban' and 'city' interchangeably, and analysing the production of classes and distributional dimensions of inequalities, rather than informing how multiple social differences are (re)produced in everyday practices (Zimmer et al., 2018). Despite such criticisms, Keil (2020) claims that in contrast to other theories and practical discussions of environments in cities, UPE is a critical urban theory. This study explored how living in varying landscape patterns influences sanitation practices as guided by UPE.

2.2 Conceptual Framework

The conceptual framework for this study shows how the SESs influence sanitation practices. The SESs are divided into two dimensions: social relations, and society-nature interactions. These two dimensions encompass components that influence sanitation practices on sloping landscapes. Social relations refer to intrapersonal, interpersonal, community and society/policy level factors; while the society-nature interactions refer to human-environment interactions (Figure 1). The socio-ecological systems are considered to contribute to uneven access to sanitation practices among social groups.

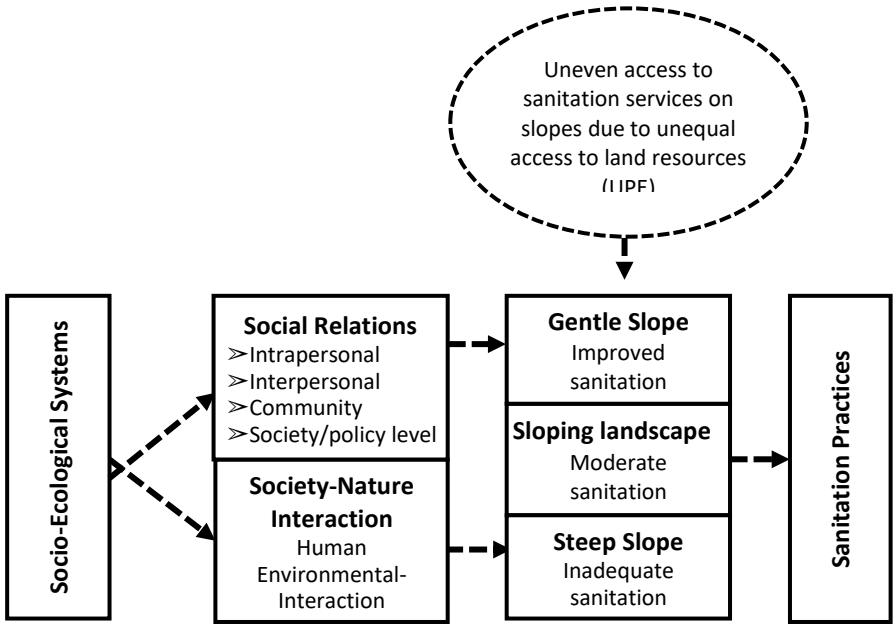

Figure 1: Socio-ecological Systems Shaping Sanitation Practices
Source: Author's own conceptualization

3. Methodology

3.1 Description of the Study Area

This study was conducted in unplanned slope settlements of Mwanza City, Tanzania. Mwanza was chosen because of its physical environmental characteristics, which are dominated by rocks, hence the nickname '*Rocky City*' (Hambati, 2013; URT, 2017a, 2017b; World Bank, 2017; Hambati & Yengoh, 2018). The city was selected because of its population growth of 5–6% per annum normally putting pressure on sanitation facilities (TCLNRT, 2020). Furthermore, the selection was influenced by the share of the population in unplanned slope settlements, which is 75% (Andreasen et al., 2020). The higher proportion of the population in unplanned slope areas is linked to inadequate sanitation. The study covered Butimba, Igogo and Mkuyuni wards. These wards experience an annual growth of 7ha, 3ha, and 3ha, respectively, in unplanned settlements. Furthermore, the wards experience hazardous areas settled by the poor without authorization from the government (Hambati & Yengoh, 2018).

3.2 Research Design, Sampling Procedure and Sample Size

This study applied a cross-sectional explanatory survey design, and the sampling unit was residents of slope settlements located between 0-30 degrees. The slopes were classified into gentle slope (0-5 degrees), sloping landscape (6-15 degrees), and steep slope (16-30 degrees). About 75% of the residents lived in

unplanned slope settlements in the study area (Andreasen et al., 2020). A sample size of 288 households was calculated using $\frac{Z_{1-\alpha/2}2p(1-p)}{d^2}$, a formula suggested by Charan and Biswas (2013); whereby $Z_{1\_}\alpha/2^2$ is the standard normal variate which is 1.96, d is the precision level 0.05 when the study applied 95% of confidence level, and p is the percent of population in steep slopes; which is 75% in Mwanza City (Andreasen et al., 2020). The formula is appropriate because it does not require the total population, rather its proportion. Using the proportion of the population in unplanned slopes settlements, the sample size was: $\frac{1.96^2 0.75(1-0.75)}{0.05^2}$ = 288. The 288-sample involved in this study was randomly selected from street registers. Simple random sampling was used because it creates an equal chance for all units of analysis to be selected. A purposive sampling technique was used to select key informants. The key informants included 7 specialists in water and sanitation, 5 employees in related sectors, and 9 community leaders. These key informants were considered to have knowledge relevant to the study. Purposive sampling enabled getting a representative sample that could provide rich information and an in-depth understanding of the phenomena being studied.

3.3 Data Collection

The primary data for this study was collected through a household survey from 288 households: 129 from Butimba, 88 from Igogo, and 71 from Mkuyuni wards. The location of each household was mapped using a global positioning system (GPS), and the elevations were recorded. The elevations were converted into slopes to determine the slope steepness of each household location. In-depth interviews were conducted with various key informants and FGD participants. During key informant interviews, emphasis was put on how the participants understood the implication of SESs on sanitation practices. Participant observation was conducted to find what types of household sanitation practices exist. The emergent nature of observation enabled the researcher to use a variety of methods, including the observation of human actions and landscape characteristics, informal interviewing and document analysis (Given, 2008). Furthermore, two FGDs were conducted in each ward, making a total of six (6) FGDs. FGDs were essential for harnessing information on the nature of sanitation practices. A review of written documents was also used for data collection. This was essential for unveiling the compliance and discrepancies of sanitation practices with policies and guidelines.

3.4 Data Processing and Analysis

Data was analysed using the IBM SPSS, version 25; and Microsoft Excel software. Both quantitative and qualitative approaches were used in data analysis. Descriptive and binary logistic regression were utilized in the analysis of data. The binary logistic regression was used to analyse household performance of advocacy

activities in demanding water service from the government. The odds ratio was used to interpret the results. This is because the odds ratio is used to show how the independent variables predict which of the two groups of the binary dependent variables people end up falling into. Thus, the odds ratio was an appropriate interpreter under this circumstance. Additionally, the *p*-value was used to indicate the significance of the results of a particular variable. Content analysis was used to analyse qualitative data as it emphasises the context where documents were generated to explain a phenomenon (Bryman, 2012).

4. Findings and Discussion

4.1 The Social Relations Shaping Sanitation Practices

4.1.1 Interaction between Low-income and Government Actors

Interaction between low-income residents and government actors occurred when the former were searching for planned plots for settlements development. Low-income residents failed to access planned plots located in gentle slopes and sloping landscape due to the market price set by the government and private persons. In their effort to interact with the government to emancipate themselves from living in unplanned areas, low-income residents frequently encountered challenges such as the lack of resources and knowledge necessary to build trust to demand services from the government. Government actors, on the other hand, were rarely backed by the low-income residents to ensure access to planned plots on gentle slopes and sloping landscape. The lack of government advocacy for low-income individuals was contrary to the National Human Development Policy of 2000. The policy calls for the allocation of planned plots to low-income individuals, who would be supplied with water and sanitation services at affordable prices for developing settlements.

As a result of the failure to access planned plots on gentle slopes and sloping landscapes, where the environment was favourable for settlements development and installation of infrastructures, people developed settlements along steep slopes, with unfavourable physical conditions. Consequently, there was inadequate sanitation for low-income individuals. This was due to variations in sanitation practices between gentle slopes, sloping landscapes and steep slopes. These variations were observed in latrine depths; with gentle slopes and sloping landscape having an average depth of 150cm, while steep slopes had an average depth of 100cm, and sometimes even less. The shallow depths on steep slopes led to latrines overflow during the rainy season, resulting in the pollution of the environment. Furthermore, the installation of water and sanitation infrastructure, especially pipes, was difficult on steep slopes due to their rocky conditions.

Unplanned slope settlements were located in hazardous areas experiencing conditions like floods, high water table and hard rocks that hindered the construction of more sophisticated sanitation facilities. Additionally, the location of steep slope settlements in the periphery of the city increased the cost of water

connections. Sometimes, the low-income people were required to contribute towards the cost of laying water pipes. These results are similar to findings by other scholars who reported that, in Mwanza City, 75% of the settlements constructed in unplanned areas are located on steep slopes and rocky environmental conditions (Andreasen et al., 2020), resulting in poor sanitation (World Bank, 2017).

Residents of unplanned settlements on slopes have low income because they earn their income mainly through petty trading (61%), and other casual activities (39%). The distribution of income by percentage was 51.9% (low income of TZS<150,000).[3] Sometimes the low income of people on slope settlements was used just to cater for basic needs: it was not enough to purchase surveyed land where they could access social services. The results demonstrate UPEs' assumption on how economic inequalities influence environmental processes, leading to uneven access to sanitation (Tzaninis et al., 2020).

As key informants, urban government officials also revealed the life situations of low-income individuals in steep slope settlements. They admitted that low-income households in Mwanza City developed their settlements in unplanned areas located on steep slopes as they were unable to purchase land in planned areas on gentler slopes. These settlements lacked appropriate sanitation services due to their location in hazardous areas. The key informants offered comprehensive explanations, like in the following excerpt:

> *In Mwanza City, many low-income citizens are living in steep unplanned areas. They do so because they lack adequate income to purchase land in surveyed areas. In addition, they would like to live close to the urban centre where they could undertake petty trading. The government sometimes relocates them and provides areas to develop settlements away from the city; however, in a short period they return to the same unplanned areas close to the urban centre* [Government Officials/Actor].

The responses from government officials were similar to those of household residents in unplanned areas, who admitted that they were living in unplanned areas because of the inability to buy plots in planned areas. Additionally, the results reflect the UPE framework, assuming the contested nature of urban environments where the high-income people live in favourable environments with improved sanitation, while the low-income counterparts live in hazardous areas with inadequate sanitation (Cornea et al., 2017). Furthermore, the results are similar to those of Andreasen (2017, 2020), UN-HABITAT (2018b, 2011), and Hambati and Yengo (2018) who contend that the expansion of informal settlements contribute to inadequate sanitation because these settlements are located in hazardous areas.

The impact of social relations resulting from the interaction between low-income people and government actors were also observed in the provision of water services. This was a result of government prioritizing planned areas

[3]This is according to the country's definition of incomes as follows: TZS113,854 as low; TZS150,000 to 250,000 as middle; and of TZS>250000 as higher income (NBS, 2020).

located on gentle slopes over unplanned steep areas, in the provision of water when funds were available. Government actors disregarded steep slope settlements because of inaccessibility and location in unplanned areas contributing to lack of services in unplanned steep slope settlements.

4.1.2 Implementation of Policies Supporting the Low-Income to Access Planned Plots

The socio-ecological system elucidates that specific behaviour is influenced by factors that exist on society/policy level among others (Alemu et al., 2017). Policy factors involved the interaction of government actors with water and sanitation policies, interpreting them and putting them into practice. The National Human Development Policy calls for the designation of special areas for low-income individuals, which are provided with sanitation and water afforded by them (URT, 2000, p. 26). This study examined the implementation of this policy call, as it could help to improve sanitation. One government official offered this explanation:

> *The plan for designation of special areas for low-income residents was piloted in Mabatini Ward; however, it was unsuccessful. This was because after the allocation of planned plots to the low-income, they in turn sold their plots to higher-income people. Because of their low income, they were easily deceived by the higher-income groups to whom they sold their property* [Government Official].

The results from KIs showed that there were challenges to convince low-income citizens to acquire planned plots. This was because when low-incomes individuals were provided with planned plots in concessional terms, they in turn sold their plots to higher-income individuals. Eventually, the low-income found new places on hazardous areas of cheaper prices, to develop new settlements. This situation contributed to the sprawl of unplanned settlements, resulting into poor sanitation. These results mirrors UPEs' assumptions that urban environments are shaped by multiple actors with diverse interests and knowledge systems. In the aforementioned instance, we observe government actors providing plots to low-income individuals, while higher-income individuals grab the plots intended for low-income individuals. This situation highlights the interaction of multiple actors.

4.1.3 Social Relations between the Low-Income and High-Income Citizens

Regarding social relations between low-income and high-income individuals, the study revealed a kind of impaired relations. Impaired social relations occurred when high-income people deceived low-income individuals to seize their planned plots that were provided by the government at affordable prices. The low-income in turn looked for plots in unplanned areas to develop settlements where they lived with inadequate sanitation. The results demonstrate UPE's assumption about how economic inequalities intersect with the environment, leading to disparities in access to sanitation. Lower-income people are deprived of land in planned areas as a result of their poverty; hence, they lack water and sanitation in these unplanned areas where they develop settlements. The

aforementioned results are similar to the findings by Sinharoy et al. (2019) who reported that even when the government provides subsidy to improve affordability of planned plots for lower-income individuals, the plots are seized by wealthier urban residents who have other plots or better resources. As a result, low-income residents have very little chance of living in planned areas.

Therefore, access to resources in planned plots for settlement development, which is a prerequisite for the provision of services, was influenced by social and economic inequality. Higher-income individuals used their economic power to control land resources in urban areas. Living in planned areas was associated with economic, political, social and cultural power relations, reflecting UPE notions (Zimmer et al., 2018).

Table 1: Summary of Social Relations Indicators Shaping Sanitation Practices in Unplanned Slope Settlements

Factors related to social relations	Descriptions on how the factors contribute to inadequate sanitation
Relations between low-income people and government actors towards access to services and planned plots	• Connection to water service on steep slopes involves unaffordable cost by low income individuals due to location in the periphery • There are no substantial government restrictions on building houses in unplanned areas or on giving relief to low-income citizens in obtaining housing in planned areas • Government actors prioritize planned over unplanned areas in provision of water and sanitation services
Limitation in implementation of land acquisition regulations supporting low-income citizens	• Regulations which require the low income to be provided with affordable planned plots are not accorded priority • Regulations for acquisition of planned land favour higher income rather than low-income individuals who lack collateral, to access credit from financial institutions
Impaired social relations between higher and low-income individuals towards access to planned plots	• Higher income deceives low-income individuals and buy from them land provided by the government at an affordable price

Source: Field survey, 2021

4.1.4 Community Advocacy to Demand Social Services from the Government

This study sheds light on the influence of social relations on the supply and connection to water services. The results show that households/streets that had reported the issue of water and sanitation to their political representatives were more likely to be connected to water services compared to households/streets

that had not presented their issues [OR= 2.052, *p*-value 0.0129] (Table 2). This was because households which had presented their concerns to their representatives had their problem delivered to the government for a solution.

The study assessed the presence of social capital in the community, which could give power to residents to demand water services. The social capital was assessed in terms of the possession of formal education and economic status. The results show that, areas where individuals had formal education and economic capital, people were more likely to be supplied with water services compared to areas where such capital was inexistent [OR=1.564, *p*-value 0.2057] (Table 2). This was because education, as one of the social capitals, gives confidence to individuals to fight for their rights. Individual economic capital enables one to be recognized by others, and to be heard when discussing a particular issue. In terms of cultural capital, places where the community that had a culture of supporting one another, had the potential to develop collective action to demand for their rights. These results are consistent with UPE, which assumes that access to urban services is power-laden and influenced by political, economic and social contexts.

Additionally, this study investigated whether residents ever organized collective actions to demand water in their households or streets. The results show that in areas where residents had taken collective measures as civil societies, they were more likely to be supplied with water compared to areas which lacked community collective measures [OR= 3.089, *p*-value = 0.1550)] (Table 2). This is because where a community had taken collective measures to demand certain rights, it was easily heard by the government as a group, unlike when an individual person went alone.

Furthermore, households located in planned areas were more likely to be supplied with water services compared to households located in unplanned areas [(OR= 1.050, *p*-value, 0.8611)] (Table 2). This was probably because the government actor cherry-picked planned areas over unplanned areas in the provision of water services. These results are consistent with what was reported by Dos Santos (2017): that when the government supplies water, it favours planned over unplanned areas.

As by wards, the results show that households/streets in Butimba Ward were significantly associated with connection to water services ($p < 0.001$). Households/ streets in Butimba were significantly more likely to be connected to water compared to households/streets in Igogo (OR=9.895, $p < 0.001$). Additionally, households/streets in Mkuyuni were significantly associated with connection to water service ($p< 0.005$). Households/streets in Mkuyuni Ward were significantly more likely to be connected to water services compared to households located in Igogo (OR=3.124, p, 0.0006). This was probably because households in Butimba and Mkuyuni wards were supplied with water under the project of Vitens Evides International (VEI), which targeted poor households.

Table 2: Community Advocacy Influencing Connection to Water Service

Variable	Not Connected	Connected	Unadjusted logistic		Adjusted analysis	
Advocacy factor			**OR [95% CI]**	**p-Value**	**AOR [95%CI]**	**p-value**
Does reporting inadequate water and sanitation to political representative?						
No	58(43.61)	75(56.39)	Ref		Ref	
Yes	26(27.37)	69(72.63)	2.052[1.165,3.615]	0.0129	1.254[0.516,3.048]	0.6168
Does lack of social capital and power to organized collective action limit you to access sanitation and water rights?						
No	36(39.56)	55(60.44)	Ref			
Yes	18(29.51)	43(70.49)	1.564[0.782,3.125]	0.2057		
Do residents of this street ever take collective action to influence decisions on sanitation and water?						
No	41(35.96)	73(64.04)	Ref		Ref	
Yes	2(15.38)	11(84.62)	3.089[0.653,14.617]	0.1550	1.950[0.373,10.203]	0.4289
Do you consider representatives prioritizing water and sanitation in elections?						
No	35(34.65)	66(65.35)	Ref			
Yes	74(39.57)	113(60.43)	0.810[0.489,1.340]	0.4118		
Have you built your house in a planned area?						
No	82(38.14)	133(61.86)	Ref			
Yes	27(36.99)	46(63.01)	1.050[0.606,1.819]	0.8611		
Slope						
Gentle slope	8(22.85)	27(77.14)	4.500[1.740,11.636]	0.0019	2.624[0.390,17.657]	0.3214
Sloping landscape	69(35.03)	128(64.97)	2.473[1.351,4.529]	0.0033	3.851[1.236,12.001]	0.0201
Steep slope	32(57.14)	24(42.86)	Ref		Ref	
Ward						
Butimba	22(17.05)	107(82.95)	9.895[5.224,18.742]	<.0001	8.977[2.364,34.095]	0.0013
Mkuyuni	28(39.44)	43(60.56)	3.124[1.629,5.992]	0.0006	3.115[0.898,10.804]	0.0733
Igogo	59(67.05)	29(32.95)	Ref		Ref	

Source: Field survey, 2021

Other reasons might be because of environmental conditions of the wards. Butimba and Mkuyuni wards are located in locations where utilities could easily supply water services. On the other hand, Igogo Ward is located on a steep slope where it was difficult for the utilities to provide water services. The results are similar to the report by UN-HABITAT (2018), which showed that the majority of steep slope environments in Mwanza City lack connection to water services.

Regarding slopes, gentle slopes and sloping landscapes were significantly associated with connection to water services ($p< 0.005$). Households located on gentle slopes were significantly more likely to be connected to water services compared to households on steep slopes (OR=4.500, p-value=0.0019). Households located on sloping landscapes were significantly more likely to be connected to water services compared to households located on steep slopes (OR 2.473, p, 0.0033). Specifically, steep slopes did not have access to water services due to the challenging terrain that made it difficult to install the necessary infrastructure. In contrast, gentle and sloping landscapes had better connectivity to water services. These results are consistent with the UPE's framework, which is premised on the fact that communities living in hazardous environments—in this case steep slopes—usually experience inadequate services compared to communities located in favourable environmental conditions, that is, gentle slopes and sloping landscapes.

4.2 Society-nature Interaction and Access to Sanitation Facilities

The socio-ecological systems that influence sanitation practices under the aspect of society-nature interactions focus on how sanitation practices are exercised when humans interact with the environment. Human interaction with the environment determines the type, quality and durability of water and sanitation infrastructure, to endure the influence of environmental conditions (Table 3).

4.2.1 Latrine Construction and Water Supply by Slope

Gentle Slope Landscape

Through observation, it was noted that slopes influenced the construction of latrines. On gentle slopes, the levelling of site was easy because the landscape consisted of a gentle slope and was covered by less rock. Pit excavation started by digging the upper layer of the soil. On a gentle slope, rocks were reached at a depth of 100cm. From this depth, the rock was heated using wood, used-car-tyres, and/or plastic materials. Heating was essential because it softened the rock to allow continued digging. A normal pit latrine, with a depth of 200cm, could be excavated in a gentle slope. Some latrines had concrete slabs, while others had mud slabs. The materials used for roofing were either iron sheets or thatch (Table 3). The tools used for pit excavation included a spade, hoe, pick axe, bucket, and/or a shovel. As for water supply, many households were connected to water services because gentle slopes were accessed easily by

service providers. Additionally, the flat ground conditions allowed the installation of water supply facilities. Furthermore, laying pipes underground was possible because the digging was easy on gentle slopes.

Table 3: Latrine Construction by Slope

Stages in latrine construction and infrastructure	**Gentle Slope**	**Sloping Landscape**	**Steep Slope**
Site selection	➢ Site is easily obtained as the area is located on a gentle slope ➢ The site is almost flat	➢ To get a site is somehow difficult compared to a gentle slope as the area is covered by rock ➢ The site is in sloping landscape	➢ To get a site is difficult due to pervasiveness of rocks and physical conditions ➢ The site is on a steep slope
Site clearance	➢ Levelling of the site	➢ Levelling of the site is intensive as it involves removing stones	➢ Removing upper rocks ➢ Levelling the site is intensive as it involves removing stones
Pit excavation	➢ Pit excavation starts by removing the upper layer of the soil ➢ Within a depth of 1m the rock is found ➢ Heating of rock to allow digging ➢ A pit may be of 2m	➢ Pit excavation starts by manually removing rocks ➢ Next stage is heating the rock ➢ Heating the rock is followed by digging, before heating the next layer of rock ➢ Pit may reach 150cm depth	➢ Pit excavation stars by manually removing rocks ➢ Heating of rock starts from the next stage ➢ Pit depth may reach 100-150cm
Installation of water and sanitation infrastructure	➢ The installation of infrastructure was feasible because the environment is favourable. Water is constantly flowing from taps ➢ Some households are connected to a sewerage system	➢ The installation of infrastructure was feasible in some areas while others were not because of a mix of a favourable and unfavourable environment ➢ Water flow from taps is intermittent and in small amounts ➢ Very few households are connected to sewerage	➢ Installing water and sanitation infrastructure is challenging due to the prevalence of rocks in the landscape. ➢ Where taps are available, water flows on certain days of the week due to the steep slope that contributes to high cost of pumping water uphill ➢ Very few households are connected to sewerage under a simplified sewer system.

Source: Field Survey, 2021

Sloping Landscape

Through observation and information from FGDs on sloping landscape, latrine construction started with site identification as the normal first stage of latrine construction. Site identification here was more difficult compared to the case of gentle slopes, as the area was covered by rock. The site for latrine construction could

not be further than 6m, which is the standard distance set from a residential house (URT, 2012), because getting more space was difficult due to the rocky surface. Site clearance involved levelling to obtain a flat niche for latrine construction because of the sloping landscape (Table 3). Pit excavation started by removing rocks, and those which could not be removed easily were heated to soften them so that they could be easily removed. The heating involved the use of used-car-tyres, wood and plastic materials, which had to be purchased. This was expensive to low-income people. A maximum pit depth of 150cm could be obtained. Roofing was done by iron sheets. The majority of slabs were made of mud, with a few made of concrete. The tools used for pit excavation included a spade, hoe, pick axe, bucket and a shovel. Many households were not supplied with water because of the difficulty of installing infrastructure on a sloping landscape.

Steep Slope Landscape

Through observation and information from FGDs, site selection on steep slopes was difficult due to inadequate space. Most of the area is covered by rock. Due to the difficulty to obtain space for pit excavation, latrines were located at a distance further than 6m from residential houses, which is beyond the standard distance (URT, 2012). This was because of the lack of space in areas close to houses. Due to inadequate space, two or more households constructed one joint latrine to share. Site clearance started by removing the upper layer of rocks. The next stage was levelling the landscape; an intensive work that involved removing stones. Pit excavation started by manual removal of rocks, and the next stage was heating the rocks so that they could disintegrate for easier removal. A pit of 100–150cm depth could be excavated on this kind of slope. The material used for roofing was iron sheets. The slab was made of concrete and/or mud. The tools used for pit excavation included a spade, hoe, pick axe, bucket, and a shovel (Table 3). As for water supply, steep slopes were supplied with water to a lesser extent because of the difficulty of installing water supply facilities. Even if a house in a steep slope was supplied with water, the availability of this service was intermittent because of the high cost of pumping water. The pipes were laid on/or near the surface because the rocky conditions restricted digging to lay such pipes underground. Due to the laying of these pipes on/or near the surface, there were frequent bursts because of expansion, as a result of high temperatures. Consequently, a lot of water is lost, making the government incur unnecessary costs.

Information from key informants showed that pit latrines in slope settlements were unlined although the soil on steep slope was loose. These types of pit latrines were very risky to community health. Also, they could not withstand disaster conditions such as collapsing soil; and further, they allowed water to seep into pits. Therefore, in hazardous environments, such as in water logged soils, loose soil and hard rock required durable materials for latrine construction.

Based on reactions from key informants, the latrines on steep slopes settlements were of poor quality and less durable, making them susceptible to flooding, soil erosion and subsidence. The pits were shallow and unlined; hence they were against the rules of the National Sanitation Option and Construction Guidelines, 2012; which require that pit latrines be dug in stable soils. In the case of hard rock, the pit depth is required to be at least one metre (1m) (URT, 2012). However, in the steep slopes of the study area, 13% of the pit latrines were between 40–88cm deep, which is below the required standard of one meter. Inadequate sanitation was a result of such conditions.

Additionally, soil stability was a challenge to the construction of improved latrines. As reported by participants during interviews and FGDs, the soil was getting lost from the steep slopes, while at the gentle slopes the soil held too much water during the wet season. This situation resulted into the collapse of latrines located in loose soils, and water-logged conditions during the rainy season.

A few members of the community who were economically better-off built raised pits in water-logged areas, and used stones on steep slopes. The raised pits were more stable in water-logged conditions. These results are consistent with UPE, which assumes that hazardous areas—in this case steep slopes—have poor sanitation compared to gentle slopes where more favourable conditions exist. Thus, latrine construction varied with individual economic and environmental conditions. Previous studies, such as UN-HABITAT (2018b), Hambati (2013), and ODI (2016) found that digging latrines on slopes, especially steep slopes, was difficult; and the majority of latrines in such areas were shallow, resulting in the pollution of the environment.

5. Conclusion and Recommendations

Socio-ecological systems (which are multidimensional), influence sanitation via social relations, and societal-nature interactions contribute to inadequate sanitation. The relations between government actors and low-income individuals contribute to the mushrooming of unplanned slope settlements, which become the source to inadequate sanitation. Additionally, inadequate sanitation is a result of inadequate implementation of policies supporting low-income citizens to access planned plots for developing settlements. Moreover, inadequate sanitation is caused by impaired social relations among sanitation actors. In terms of society-nature interactions, it is the case that residents who live on slope environments rely on rudimentary tools for pit latrine excavation, which prove to be unsuitable, given the rocky nature of the environment. Inadequate sanitation is also caused by the scarcity of water points on steep slopes, the challenge of pumping water, and the frequent bursting of pipes due to being laid on exposed ground under very hot weather conditions. Further progress could be achieved by improving relations among key actors and empowering low-income individuals to access planned plots for settlement

development. Additionally, the implementation of policies supporting low-income groups to develop settlements in planned areas could be one of the best approaches to improving sanitation. Furthermore, the study recommends policymakers should integrate the maximum slope level for settlements development into policy to prevent steep slope settlements from polluting downhill settlements.

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