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Drivers of Undesirable Land Use Practices in Nzovwe River Catchment, Mbeya-Tanzania

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ABSTRACT

Despite the presence of laws, guidelines and policies regulating riparian land use, the Nzovwe River catchment is facing rampant undesirable land use within 60m of the buffer zone. This study was set to investigate the drivers of undesirable land use in the catchment. Questionnaires and key informant checklists were used to collect primary data from heads of households and key informants respectively. Statistical Package for Social Sciences was used to perform descriptive and inferential analyses of data. A content analysis was used to analyse key informants' data. The Geographical Information System (GIS) was used to obtain and analyse land use images of the study area. Results as per key informants' perspective revealed that lack of political will, administrative fragmentation, limited reallocation compensation funds, law ambiguities and poor land use planning are the drivers of undesirable land use in the catchment. The heads of households argued that undesirable land use in catchment is driven by poor governance (69.4%), negligence (52.4%), ignorance (35.3%), increased demand for land (52.9%), lack of LUP (15.1%), poverty (36.7%), law ambiguities (2.4%) and lack of political will (8.3%). We recommend that the government should emphasize the enhancement of social learning, participatory LUP and research-based policies

1. Introduction

Regardless of the complex relationship existing between land and water, their co-existence is necessary to human life (Bakure *et al.*, 2020; Camara *et al.*, 2019; Katusiime and Schütt, 2023). In the prehistoric era, the relationship between spatial land distribution and water quality was reported to be positive due to non-existence of anthropogenic activities in water catchments (Aghsaei *et al.*, 2020; Cheng *et al.*, 2022; Mello *et al.*, 2020). Human activities are the key drivers of land use land cover changes causing major variations in the components of social-economic and environmental factors such as ecosystem and water quality (Rodrigues *et al.*, 2018). Land uses such as agriculture, settlements, and industrialization comprising the development of infrastructures and technologies in riparian lands trigger the amplification of nutrients transfer into water sources in the catchments (Gobry *et al.*, 2023).

Globally, the population growth in cities has exacerbated the demand for natural resource use on the environment, including land resources (Mwalwiba *et al.*, 2025; Weiner *et al.*, 2022). With the rapid global increase in population, there has been an increase in land demand for community development which in turn has led to the intensification of land use near water sources, (Camara *et al.*, 2019; Mcgrane, 2016; Tahiru *et al.*, 2020). The competition for land resource accessibility has increased the price of the resource, making it hard for some of the community members to access land easily (World Bank, 2021).

In Africa, human induced degradation and pollution in river catchments is a major source of water quality deterioration which is a serious and increasing problem (Chen *et al.,* 2022). The need for agricultural and settlement land has led to the migration of people from their allowed economic and residential zones to catchment areas in search for pasture, water and fertile land (Hellar-Kihampa and Ndunguru, 2021; Uisso *et al.*, 2023). To accommodate this demand, riverine vegetation has been cleared to allow space for human land uses (Mello *et al.*, 2018). Following riparian land use intensification, the natural mechanism of water

quality protection is minimized thus an increased water pollution is prominent (Mwasenga and Mjemah, 2023; Njue *et al*., 2016; Valera *et al*., 2019). In Tanzania, undesirable land uses in riparian areas have led to continuous change of land use patterns and decline of water quality of the particular water sources (Alphayo and Sharma, 2018; Antwi-agyei *et al.,* 2019). Clearing natural vegetation along river banks for agricultural activities and urban developments has been reported to increase bare lands, runoff and sediment loads into water streams (Gobry *et al.*, 2023; Mwasenga and Mjemah, 2023; Song *et al*., 2020). In the struggle to control the influx of undesirable land uses in catchment areas, the Tanzanian government has enacted various policies and regulations. For instance, *"No human activities of a permanent nature or which may, by their nature, likely to compromise or adversely affect conservation and or protection of oceans or natural take, shorelines, river banks, water dams or reservoirs shall be conducted within 60m"* (URT, 2004 and URT, 2009). Despite the presence of these laws and regulations, their enforcement has still proven to be ineffective (Hellar-Kihampa and Ndunguru, 2021; Mwasenga and Mjemah, 2023).

Tanzanian government authorities have made efforts to control the intensification of land uses in catchment areas through policies, laws and regulations, however these efforts have failed (Mello *et al*., 2020). The challenges constraining the struggle for land use control in riparian zones are possibly caused by the failure of the authorities to involve local stakeholders in managing ' river catchments (Weiner *et al.*, 2022). Furthermore, failure to incorporate traditional knowledge and community initiatives in urban land use planning has been reported to be one of the reasons for community negligence in adhering to the guidelines pertaining to the riparian zones (Ioki *et al.*, 2019; Markkula *et al.*, 2019).

Nzovwe river catchment pours its water into Songwe sub-basin which ultimately pours its water into Lake Rukwa basin. The Nzovwe River catchment passes through Itende, Kalobe, Nzovwe, Iyela, Mabatini, Ghana, Iganzo, Ilomba, Isanga, Itiji, Iwambi, Maendeleo, Majengo, Nsoho, Nonde, Ruanda, Sinde and Sisimba wards in Mbeya city. The catchment is specifically on the upstream of Lake Rukwa basin which is vulnerable to pollutant flow from adjacent households, farms and commercial premises (Ojija, 2016). Following the extension of irrigation agriculture and settlements in the catchment, water level and quality have decreased (Elisa *et al*., 2021; Mapenzi *et al.*, 2020; Sumari *et al.*, 2023). Furthermore, it has been reported that the pollution from the catchment has led to vulnerability to death of aquatic organisms in Lake Rukwa, such as catfish and tilapia (Mapenzi *et al*., 2020). The influx of community members into prohibited riparian zones of the Nzovwe River catchment has been observed to be increasing with time which is contrary to the law (Mwalwiba *et al.*, 2025).

While several studies have documented physicochemical and biological pollution, hydrological degradation and land use change in the Nzovwe River catchment, there is a limited understanding of the underlying drivers behind persistent illegal and undesirable land use practices, particularly in riparian zones. Existing research has emphasized on the outcomes of environmental degradation and aquatic mortality rather than the social, economic, institutional, and governance dimensions that sustain these practices. There is insufficient evidence on the level of community awareness and compliance with riparian regulations, the effectiveness and challenges in institutional enforcement of land use policies, livelihood pressures, and informal urban growth in promoting encroachment and how policy and legal frameworks are perceived and applied at the local level. This gap limits the ability of planners, regulators, and local authorities to develop responsive interventions tailored to local realities. Thus, this study seeks to fill this critical knowledge gap by investigating the underlying drivers that sustain or exacerbate undesirable land uses within the Nzovwe River catchment. In doing so, it aims to offer context-specific insights that can inform more effective catchment governance and land use planning in Tanzania's urban rivers.

2. Materials and Methods

2.1. Description of the study area

Nzovwe River catchment (Figure 1) is an upstream of Songwe River catchment found in Mbeya. The Songwe River catchment is a sub-basin of Lake Rukwa basin, thus putting Nzovwe River catchment under the administration of Lake Rukwa Basin Water Board. Nzovwe River catchment passes through 18 wards of Mbeya city with a total population of 541,603 people, a land area of 250,219 km^2 and 0.140 km^2 covered by water (URT, 2022). The climate of the study area is subtropical, with a unimodal rainy pattern (October to early May) that amounts to 885 mm per year (Batho *et al.*, 2019; Kimambo and Ndeto, 2022). Water of the Nzovwe River catchment is used for industrial processes, irrigation agriculture, domestic

activities and watering livestock. The catchment is faced with rampant encroachment of different land uses that collectively pose a potential threat of catchment degradation.

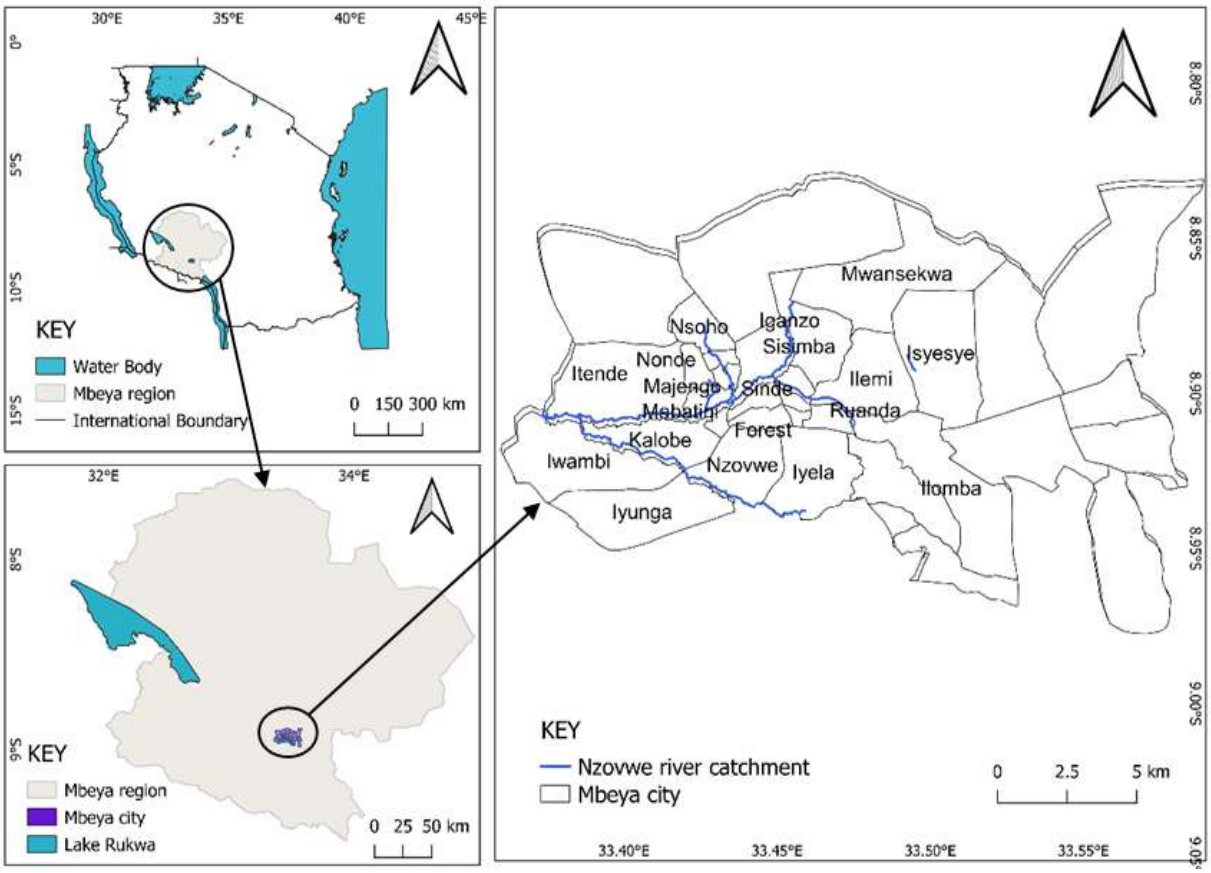

Figure 1: Map of Nzovwe river catchment

2.2. Research design

A cross-sectional social survey design was adopted in this study. The study area was divided into two groups: the upper-middle stream (U-M) and middle-downstream (M-D) with a total of 11 selected wards (Table1). The wards were categorized according to the Strahlers stream order number theory (Chhetri, 2023; Kant *et al.*, 2022; Singh and Singh, 2022), whereby first to second orders were grouped into the U-M and from second to third stream order, they were grouped into the M-D stream. Distance of the ward from the river was the criterion used to select the wards in both U-M and M-D streams. The Cochran sample size formula was used to obtain the sample size for each stream (Nanjundeswaraswamy and Divakar, 2021, Equation 1). An overall sample size for this study was 252 household respondents. The stratum sample size formula (Equation 2) was used to obtain the sample size of respondents in each ward as indicated in Table 1 (Miah, 2016).

Formula:

$$n = \frac{(Z^2)pq}{e^2} \quad \text{.....Equation 1}$$

$$nh = \left(\frac{N_h}{N}\right) n \quad \text{.....Equation 2}$$

Where by n= sample size, z= acceptance region at 95% confidence interval, p= estimated population proportion (0.05), q= 1-p, n_h= sample size for h stratum, N= total population of wards, N_h= Population size for h stratum and e^2 = error at 95% confidence interval

Table 1: Number of households sampled from each ward in Nzovwe catchment

S/N	Ward	Number of households (n= 252)	Location in the catchment	
1	Sisimba	15	Upper-middle stream	
2	Ghana	20	Upper-middle stream	
3	Iganzo	25	Upper-middle stream	
4	Sinde	25	Upper-middle stream	(U-M) stream
5	Ruanda	15	Upper-middle stream	
6	Iyela	26	Upper-middle stream	
7	Kalobe	30	Middle-downstream	
8	Itende	20	Middle-downstream	
9	Nzovwe	30	Middle-downstream	(M-D) stream
10	Mabatini	26	Middle-downstream	
11	Itiji	20	Middle-downstream	

Furthermore, a total of 40 respondents from commercial premises were selected from both middle upper stream and middle downstream, with 20 respondents from each stream. The industrial zone in Mbeya city is located far downstream and only 1 industry was found within the catchment downstream; thus, it was selected for data collection in this study. A total of 14 key informants were interviewed,which included 11 WEOs, 1 town planner, 1 environmental officer and 1 retired public servant.

2.3. Data collection and analysis

2.3.1. Data collection

Primary data were gathered from household respondents living in communities inside the 11 wards using a questionnaire. Household heads or in some cases their representatives responded to a set of open-ended and closed questions. The key informants involved in secondary and primary data collection were ward Executive Officers, retired public servant, town planner and an environmental officer. All participants provided informed consent prior to their involvement in the study.

Geographical Information System (GIS) was used to collect land use land cover (LULC) satellite images. The Landsat 8 images (with seven bands) were used in the classification of Nzovwe River catchment land uses. Image date and cloud cover criteria were considered when downloading the land sat images from USGS Earth explorer. Images taken from November, 2022 to January 2023 were considered in this case with a cloud cover of less than 30%.

2.3.2. Data analysis

SPSS software version 20 was used to perform descriptive and inferential analysis of primary data. With descriptive analysis, frequency and measures of central tendency were obtained. Using the inferential analysis method, t-test for independent sample and chi-square analysis were involved in the analysis. A t-test for independent mean was used to compare the means of the U-M stream and M-D stream, while chi-square was used to test the homogeneity of variables between the U-M and M-D stream groups. Content analysis was used to analyse key informants' data according to themes and concepts of the subject matter.

Using QGIS software version 3.20 and Google Earth Pro, data were analysed to produce the desired land use classification map of the Nzovwe River catchment. The supervised land use classification method was used in analysing the data where by the land use/land cover was categorized into four classes (Table 2). These land use classes were obtained from the level I land use classification system and its components at level II in the description (Antwi-agyei et al., 2019).

Table 2: Description of Land use/Land cover (LU/LC) as used in the map classification

LU/LC class/ level I	LU/LC description (level II)
Built-up area	Residential areas, built-up premises, infrastructures, construction sites
Water	Water sources including ponds, rivers, lakes and dams
Agricultural land	Crop land and pasture land
Bare soil	Barren/fallow land, prepared farms for cultivation/uncultivated croplands
Vegetation	Farms, natural vegetation such as forests, grass lands and shrubs

Source: (El-zeiny and El-kafrawy, 2016)

3. Results and Discussion

3.. Demographic and social economic status

There is a significant difference ($p < 0.05$) between respondents in the Upper-Middle (U-M) stream and Middle-Down (M-D) stream with respect to age groups. The majority proportion (63.5%) of respondents in the U-M stream were youth and 60.5% of respondents in the M-D stream were adults (Table 3). The difference in annual income of respondents in the U-M and M-D streams was significant ($p<0.05$, Table 3). Most of the respondents (57%) in the M-D stream have low income while 52% of respondents in the U-M stream have a high income. The observed significant difference is attributed by more availability of business opportunities influencing the majority of the respondents (61.6%) to be involved in business. Moreover, there was a significant difference in the duration of stay among respondents in the U-M and M-D streams. Most of the respondents (53.2%) in the U-M had a shorter stay period in the catchment compared to the long stay of 50% of respondents in the M-D stream. The recent high influx of people into U-M stream is partly contributed to by attraction to emerging business opportunities. The observed significance could partly be explained by the inequality in the opportunities found in these areas, which includes business and social interactions.

Table 3: Characteristics of respondents in the study area

Variables	Categories	Respondents' percentage proportions (%)			Chi-square	p- value
		U-M *(n=126)*	M-D *(n=126)*	Total *(N=252)*		
Age (Years)	Youth (18-35)	63.5	25.2	44.3	9.60	0.008
	Adults (36-60)	30.2	60.5	45.4	(df=2)	
	Elders (>60)	6.3	14.3	10.3		
Gender	Male	31	39	34.92	1.746	0.234
	Female	69	61	65.08	(df=1)	
Marital status	Single	27	24	25.5	1.779	0.619
	Married	61	61	61	(df=3)	
	Widow	5	9	6.3		
	Separated	7	6	7.2		
Education level	Informal	3	7	5.2	9.212	0.56
	Primary	14	26	20.2	(df=3)	
	Secondary	48	37	42.86		
	Tertiary	35	30	31.74		
Occupation	Farming	24.9	36.5	35.7	1.484	0.829
	Business	61.6	46	48.8	(df=2)	
	Employed	13.5	17.5	15.5		
Annual income (TZS $\times 10^6$)	Low (<0.925)	18	57	37.5	57.3	0.01
	Moderate (0.925-1.5)	30	23.8	26.9	(df=2)	
	High (>1.5)	52	19.2	35.6		
Duration of stay (Years)	Short stay (< 3)	53.2	34.9	44	35.6	0.04
	Moderate stay (3-5)	19.8	15.1	17.5	(df= 2)	
	Long stay (> 5)	27	50	38.5		

3.2. Land ownership

Significant proportions of respondents (64.3% in the U-M stream and 54.9% in the M-D stream) obtained the right to use/acquire land through rental and purchase methods, respectively (Table 4). In the U-M stream, it is mostly dominated by residential land use while in the M-D stream, it is dominated by agricultural activities. There are no respondents who occupied land through government allocation in the study area; however, in other places of Tanzania, it is an applicable method (Aikaeli and Markussen, 2022; Erneus, 2022). Only 32.1% of the overall respondents owned land by title deeds (Table 4). Possession of title deeds was significant ($p < 0.001$) when considered with respect to eras before and after the enactment of the Environmental Management Act (EMA) of 2004. Majority of title deed holders (96.8%) obtained them after the enactment of the EMA, 2004.

Table 4: Land acquisition methods and possession of title deeds in the study area

Variable (s)	Category	Respondents' percentage proportions (%)			Chi-square	p- value
		U-M *(n=126)*	M-D *(n=126)*	Total *(N=252)*		
Land acquisition method	Inheritance	1.6	15.1	8.3	16.023 (df=2)	0.000
	Purchase	34.1	54.9	44.5		
	Rental	64.3	30	47.2		
		Respondents' percentage proportions (%)				
		After EMA *(n= 62)*	Before EMA *(n= 64)*	Total *(N=126)*		
Title deed	Possess	96.8	23	32.1	67.7 (df=1)	0.000
	Do not possess	3.2	77	67.9		

It was expected that after the enactment of the EMA 2004, no individual could have been given land rights (title deed) in the riparian zones but instead a significant number of people were provided with the same (Mwasenga and Mjemah, 2023). This suggests that the encroachment into the riparian zones of the Nzovwe River catchment started and continued after the enactment of the EMA, 2004. This is a serious ineffective enforcement of EMA, 2004 and its subsequent regulations that came later, such as the Water Resources Management Act of 2009 and its Amendment Act of 2022.

3.3. Land uses along the riparian zones of Nzovwe river catchment

The U-M stream is dominated by built-up areas while the M-D stream is characterized by bare soils and agricultural land (Figure 2). This difference in the land uses along the catchment is qualified by differences in the potentiality of the land, whereby in the M-D stream land is more fertile and suitable for agricultural activities. The U-M stream land is less fertile and has a steep slope compared to the M-D stream thus potentially suitable for residential purposes. Antwi-agyei *et al*. (2019) and Tahiru *et al.* (2020) noted that the increase in bare soil land around the catchment areas was caused by extensive clearance of forest and natural vegetation for crop farming and grazing activities. According to Camara *et al*. (2019), the built-up area comprising the settlements, agricultural lands and commercial premises contributes to approximately 87% of pollutants in catchment areas.

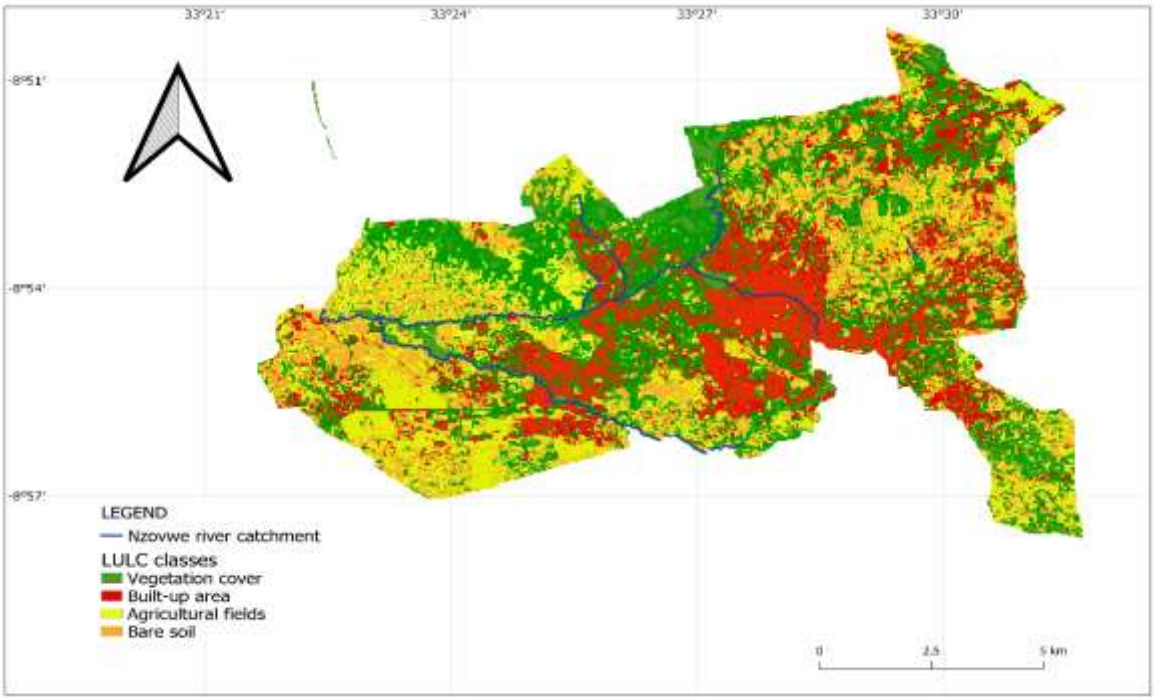

Figure 2: Land use Land cover classification map of Nzovwe river catchment
Source: Researchers' GIS work

3.3.1. Residential land use

There is a significant difference ($p < 0.05$) in the distribution of settlements in the study area, whereby most of the residential areas are located in the U-M stream of the catchment (Table 5, Figure 2). Furthermore, the mean land size of U-M stream dwellers using the land for residential purposes is 0.05 hectares greater than the land size of M-D stream dwellers (Table 5). This inequality in the distribution of residential land use across the catchment can probably be caused by the difference in potentiality of land and available social services. This difference may also partly be contributed to by the land availability and affordability for individuals, whereby in some cases it is possible that land in the U-M is cheaper than the land in the M-D stream. This is consistent with a study conducted by Gobry *et al*. (2023) and Uisso *et al*. (2023) who noted that the need for cheap land for accommodation among the community members drove unplanned urban cities, leading to catchment degradation.

Table 5: Land sizes under different land uses in Nzovwe river catchment area

Land use	Location	Mean (hectares)	Std Dev.	Levene's test for equality of variance		t-test for equality of means		
				F	p-value	t	df	p-value
Residential	U-M stream	0.14 ±0.01	0.11	1.071	0.0302	0.47	250	0.041
	M-D stream	0.09 ±0.01	0.03					
Crop farming	U-M stream	0.03 ±0.01	0.07	20.96	0.000	-2.7	250	0.008
	M-D stream	0.06 ± 0.01	0.12					
Livestock keeping	U-M stream	0.004±0.001	0.012	3.684	0.5	0.98	250	0.37
	M-D stream	0.002±0.001	0.01					
Commercial premises	U-M stream	2.0±0.000	0.00	1.216	0.047	0.48	39	0.0335
	M-D stream	1.05±0.04	0.02					
Industrial	U-M stream	-	-	-	-	-	-	-
	M-D stream	1.00 ± 0.00	-					

Residential areas are associated with the presence of sanitation facilities, whereby in this study these facilities were taken into consideration (Table 6). There is a significant difference ($p < 0.05$, Table 6) existing between U-M stream and M-D stream in the materials used to constructthe pit latrine. Most of the respondents (82.5%) in the U-M stream have pit latrines constructed by cement, while 42.1% of respondents in the M-D have earth material pit latrines.

Table 6: Materials used in the construction of sanitary facilities and their distances from the river bank

Variable (s)	Category	Respondents' percentage proportions (%)			Chi- square	p- value
		U-M *(n=126)*	M-D *(n=126)*	Total *(N=252)*		
Materials used in pit latrines	Earth	17.5	42.1	29.8	18.2	0.000
	Cement	82.5	57.9	70.2	(df=1)	
Distance of pit latrine from river bank	< 60m	63.5	67.5	65.5	0.44	0.5
	≥ 60m	36.5	32.5	34.5	(df=1)	
		Respondents' percentage proportions (%)				
		U-M (n= 62)	M-D (n= 64)	Total (N=126)		
Materials used in septic tanks	Earth	1.6	12.5	7.2	5.6	0.01
	Cement	98.4	87.5	92.8	(df=1)	
Distance of septic tank from river bank	< 60m	23.6	69.9	52.4	3.81	0.04
	≥ 60m	76.5	30.1	47.6	(df=1)	

Furthermore, there is a significant difference existing between U-M stream and M-D stream in the materials used to construct septic tanks whereby 98.4% of respondents in U-M stream have cemented septic tanks while 12.5% of the M-D dwellers have earth material septic tanks (Table 6). Additionally, there is a significant difference ($p < 0.001$) between U-M stream and M-D stream in the distance of septic tanks from river banks. Most of the septic tanks (69.9%) in the M-D stream are within 60 m and only 23.6% in the U-M stream are within 60m.

Results suggest that most of the respondents within the riparian zones have poor consideration of the potential implications of earth constructed sanitary facilities on the catchment water quality. This was also found to be a problem in a study conducted by *Massawe et al.* (2019) in the Uluguru forest catchment area of Morogoro, Tanzania. According to Zhang *et al*. (2021), the location and design of sanitary facilities have an impact on water quality, whereby earth material designs located in the near proximity from river banks tend to have low filtration rates, causing possible nitrate and faecal pollution. This was also reported in the study conducted in Kilombero Valley, whereby the sanitary facilities with earth material and located in closer proximity to river banks were proved to be a problem in the catchment (Alavaisha *et al.*, 2019). In a study conducted in the Volta basin Ghana, a positive correlation between settlement increases and water pollution in the catchment was reported (Alphayoand Sharma, 2018; Tahiru *et al*., 2020). This finding suggests the same possibilities of occurrence in the study area if the settlements within riparian zones are not controlled.

3.3.2. Crop farming

There is a significant difference ($p < 0.05$) in the distribution of crop farming between U-M stream and M-D stream, whereby this land use dominates more in the M-D stream (Table 5, Figure 2). The mean land size of M-D stream dwellers using the land for crop farming purposes is 0.03 hectares greater than the land size of U-M stream dwellers (Table 5). This difference is attributed by the difference in community income levels. This is because in most developing countries, crop farming agriculture is the last resort for low-income individuals which leads to marginal and riparian land invasion. This variation was also revealed in a study conducted by Tahiru *et al*. (2020), whereby people invaded riparian lands for crop farming activities due to poverty. Moreover, the need for agricultural land exacerbates clearing of riverine vegetation and promotes the growth of undesirable land uses in the riparian zones of river catchments (Camara et al., 2019; Kalfas et al., 2024; Mello et al., 2018). The observed effects of crop farming in Nzovwe river catchment are soil erosion, sedimentation, river diversion, eutrophication and riparian vegetation loss. This variation was also observed in a study conducted in the Mindu catchment in Morogoro, whereby the effects of crop farming included significant nitrate and phosphate pollution, eutrophication, sedimentation and river diversion (Gobry *et al*., 2023; Massawe *et al.*, 2019; Melchioly, 2021). Likewise, in a study conducted in the Kilombero Valley and Ruvu River Basin, irrigation agriculture was found to affect the natural ecosystem and water quality of the catchments (Alavaisha *et al*., 2019; Alphayo and Sharma, 2018).

3.3.3. Livestock keeping/ Grazing

The distribution of livestock keeping and/or grazing is not statistically significantly different ($p > 0.05$) between U-M stream and M-D stream (Table 5). The livestock kept are predominantly cows, pigs, chickens, goats, donkeys and ducks, whereby the mean of the number of livestock kept in both streams is equally distributed (Table 7). The observed effects following the growth of livestock keeping and/or grazing in the Nzovwe River catchment are eutrophication, faecal pollution and loss of riparian vegetation. Njue *et al*. (2016) documented thatpoorly managed livestock grazing exerts pressures on water quality and its associated ecosystem. Unrestricted livestock access to riverbanks leads to trampling of vegetation which increases surface runoff and erosion (National Special Committee, 2022; Silangwa, 2021). Moreover, livestock keeping exacerbates nutrient loading into near water sources, introducing phosphorous and nitrogen levels (Martin *et al.*, 2017; Moe *et al*., 2019; Saviato *et al.*, 2022; Zhang *et al*., 2021).

Table 7: Number of animals in the U-M stream and M-D stream of Nzovwe river catchment area

Animal/ poultry	Location	Mean	Std Dev.	Levene's test for equality of variance		t-test for independent mean		
				F	p-value	t	df	p-value
Cows	U-M stream	5.27 ± 0.66	2.2	6.7	0.017	-0.18	1	0.86
	M-D stream	5.58 ± 1.55	5.4					
Pigs	U-M stream	2.0 ± 1.24	4.1	0.12	0.736	-0.33	1	0.74
	M-D stream	2.5 ± 0.93	3.2					
Chicken	U-M stream	14.5 ± 6.5	21.6	0.9	0.330	0.78	1	0.44
	M-D stream	8.5 ± 4.41	15.3					
Goats	U-M stream	2.27 ± 0.82	2.7	4.49	0.046	-0.65	1	0.52
	M-D stream	3.42 ± 1.52	5.3					
Donkeys	U-M stream	0.36 ± 0.36	1.2	1.69	0.208	0.54	1	0.59
	M-D stream	0.17 ± 0.11	0.4					
Ducks	U-M stream	0.45 ± 0.46	1.5	0.78	0.387	0.4	1	0.69
	M-D stream	0.25 ± 0.25	2.2					

3.3.4. Commercial and/or business premises

There is a significant difference ($p < 0.05$) existing between M-D and U-M streams in the distribution of commercial activities in the study area (Table 5). The mean land size of U-M stream dwellers using the land for commercial purposes is 0.95 hectares greater than the land size of M-D stream dwellers (Table 5). The commercial and business activities are dominant in the U-M stream which suggests the need for the particular land use despite its implications in the catchment. Wastes generated from commercial premises include food scraps, oil and grease, wasted grains, and waste water. These wastes block river flow and also create an oily layer blocking sun rays and oxygen from entering river water, causing water pollution and subsequent deaths of aquatic organisms (Njue *et al*., 2016). According to Naidu *et al.* (2023) and Ismail *et al.* (2023), commercial premises near river catchments are the source of polluters in water sources. This suggests a possibility of water pollution in the Nzovwe River catchment if the commercial premises are not controlled. Additionally, a study conducted in the Kumasi metropolitan area of Ghana noted thatthe extent of pollutants from carwashes and mechanical premises was huge and mainly comprised chemical waste water which runs into water sources and causes potential harm to aquatic and terrestrial life (Abdillah *et al.*, 2020; Monney *et al*., 2020).

3.3.5. Industries

In Mbeya city, the industrial zone is located in Iyunga ward which is one of the riparian wards, although the industries are located on the other end of the ward, far from the river. Only one industry was selected in this study; thus, the distribution of this land use is null (Table 5). The industry in the study area is involved in wine fermentation activities and packaging. The main wastes from the wine industry in the study area are ginger peels, banana stems, leaves and rejected rotten fruits, plastics, waste water and broken glass bottles. These wastes increase suspended materials in the river stream which block the stream flow causing river diversion. The industrial sector is necessary for development but it can impede efforts for river catchment conservation (Ismail *et al.*, 2023; Monney *et al.*, 2020). This was also reported to be an issue of concern in a study conducted in the Ngerengere Rver in the Wami-Ruvu basin Tanzania, where industries posed a great threat to water quality (Uddin and Jeong, 2021). Marchão *et al.* (2021) and Zhang *et al.* (2021) noted that winery production is associated with the generation of large volumes of organic and inorganic waste water which when released into the environment may pose a great threat to living organisms.

3.4. Community perspective on the factors influencing undesirable land use encroachment in the riparian zone

Key informants perspectives regarding the factors influencing undesirable land uses in the Nzovwe River catchment are shown in Table 8. Their main concern about the factors influencing undesirable land use in the river catchments were lack of political will, community neglect despite their awareness of the subject matter, administrative fragmentation, poor land use planning, and limited government budget for the reallocation of people. Lack of political will in a country affects natural resource governance, distressing its government to

make wiser decisions and law enforcement (Garvey and Paavola, 2022; Stosch *et al*., 2022). It is common for community members to neglect laws provided despite their awareness; this is mainly caused by the need for cheap land (Mbele and Mubangizi, 2023; Robins *et al.*, 2024). Furthermore, law enforcement should be free from political influence thus, reducing the chance for corruption (Raile et al., 2021). Regulatory ambiguities and administrative fragmentation have also been reported to be a source of uncertainties and complexity in decision making and law enforcement (Andreasen *et al.,* 2022; Cherotich and Letema, 2021). Factors elucidated by key informants impede law enforcement efforts towards implementation of guidelines and decision making, thus accelerating undesirable land uses in the Nzovwe River catchment.

Table 8: Emerging issues on the factors influencing undesirable LU practices in the catchment

S/N	Emerging issues	Key informant	Factor deduced
1	Lack of political will	• WEO • Town planner • Environmental officer • Retired public servant	Lack of political will
2	Limited budget for reallocation compensation	• WEO • Environmental officer • Retired public servant	Limited budget for reallocation compensation
3	Administrative fragmentation (lack of coordination)	• WEO • Town planner	Poor governance
4	Community neglect	• WEO • Town planner • Environmental officer	Negligence
5	Poor Land use planning	• Town planner	Poor LUP
6	Law ambiguities	• Environmental officer	Law ambiguities
7	Policies which are not backed up scientifically	• Retired public servant	Law ambiguities
8	Poor understanding of the impacts of land uses in riparian zones	• Retired public servant	Ignorance

Responses from a household level perspective are shown in Table 9. There is no significant difference ($p > 0.05$) existing between U-M stream and D-M stream in the distribution of negligence, lack of political will, law ambiguities, lack of LUP, and an increased demand for land factors. The distribution of these factors in both streams are the same in the sense that either the factor contributes much or less to undesirable land use in the Nzovwe River catchment. Poor governance and negligence are agreed upon in both streams to contribute more to undesirable land uses in the catchment by 52.4% and 69.4% respectively. Lack of political will, law ambiguities, lack of LUP and an increased demand for land are reported to be contributing less to undesirable land use practices in the catchment by 8.3%, 2.4%, 15.1%, and 52.9% respectively. Negligence by communities and government impedes fulfilling their responsibilities, such as staying away from riparian land and law enforcement (Ahmad *et al.,* 2024; Habib *et al.,* 2022). This goes hand in hand with a lack of political will which exacerbates corruption and irresponsibility among law enforcers (Garvey and Paavola, 2022; Molleand Closas, 2019).

Furthermore, there is a significant difference ($p < 0.05$) between the U-M stream and M-D stream in terms of ignorance, poor governance and poverty factors. These factors vary in both streams with different levels of influence for an increase of undesirable land use practices in the Nzovwe River catchment. Poor governance has been reported to contribute more (74.6%) in the increase of undesirable land uses in the M-D stream than in the U-M stream. With poor understanding of the ecosystem services by local leaders, it is easy for them to be swayed by decisions which are not backed up scientifically.

Table 9: Factors influencing undesirable land use encroachment in Nzovwe river catchment

Factors	Category	Respondents' percentage proportions (%)			Chi-square	p-value
		U-M (n=126)	M-D (n=126)	Total (n=252)		
Negligence	Contributing	54.8	50	52.4	0.573	0.45
	Not contributing	45.2	50	47.6	(df=1)	
Ignorance	Contributing	27	43.7	35.3	7.66	0.01
	Not contributing	73	56.3	64.7	(df=1)	
Poor governance	Contributing	64.3	74.6	69.4	3.16	0.05
	Not contributing	35.7	25.4	30.6	(df=1)	
Poverty	Contributing	3.97	69.4	36.7	16.221	0.00
	Not contributing	96.03	30.6	63.3	(df=1)	
Lack of political will	Contributing	5.6	11.1	8.3	2.545	0.11
	Not contributing	94.4	88.9	91.7	(df=1)	
Law ambiguities	Contributing	1.6	3.2	2.4	0.68	0.41
	Not contributing	98.4	96.8	97.6	(df=1)	
Lack of LUP	Contributing	11.9	18.3	15.1	1.98	0.16
	Not contributing	88.1	81.7	84.9	(df=1)	
Increased demand for land	Contributing	52.06	53.65	52.9	0.24	0.63
	Not contributing	47.94	46.35	47.1	(df=1)	

Ignorance contributes more to the increase of undesirable land uses in riparian zones of U-M stream (43.7%) compared to U-M stream (27%). This difference can partly be caused by the difference in levels of understanding among the U-M and M-D dwellers on the importance of the catchment. Additionally, poverty also contributes more to increased undesirable land use practices in the riparian zone of the M-D stream (69.4%) of the catchment compared to upper-middle stream (3.97%). This difference is attributed to the difference in income levels between the streams. M-D stream is characterized by low income dwellers who also stayed for a long period of time in the riparian zones compared to U-M stream.

A total of 52.4% of respondents reported that community neglect influences the rate of undesirable land use in the riparian zone of the Nzovwe River catchment. This suggests that, despite community awareness of the effects of undesirable land of use practices in the riparian zone, the community is still rigid in following the available rules and regulations. This comes in place following the need for cheap land for agricultural, residential and grazing activities. These results were also documented in a study conducted in Northern Tanzania urban rivers, in which the community was aware of the restrictions of land uses associated with anthropogenic activities within riparian zones but still they encroached in the buffer zones of the catchment (Mwasenga and Mjemah, 2023).

Additionally, 35.3% of the respondents agreed that ignorance among community members on the services and values produced from the catchment ecosystem influences the influx of undesirable land use practices in the catchment. Poor understanding of the household members and local leaders increases the rate of undesirable land uses in the catchment and makes it impossible to control these land uses. A study conducted in Hebei, China, revealed the role of ignorance in undervaluing ecosystem services and irrational decision making (Chu *et al.,* 2020). Furthermore, it's documented that degradation of riparian land is mainly associated with ignorance and irrational decisions thus increasing the sustenance of undesirable land uses in catchment (Chinnasamy and Srivastava, 2021; Mugo *et al.,* 2022). The community members reported that the LGAs neglect their law enforcement responsibilities by leaving people to use the land in the riparian zones.

In addition, 69.4% of respondents stated that poor governance is one of the factors for urban land use encroachment in the riparian zones of the Nzovwe River catchment. This suggests that, the responsible government authority neglects its enforcement and implementation duties. From the key informant's perspective, poor governance was attributed to the lack of political will and administrative fragmentation. This has led to the failure of the LGAs to fulfil their duties as implementers of laws. The failure of government authorities to enforce and implement laws and policies causes changes of land uses by accelerating urban development in water sources (Andreasen *et al.,* 2022; Gupta *et al.,* 2025). Overlapping and fragmented institutional mandates lead to

uncoordinated planning, ineffective oversight, and gaps that encroachers exploit (Gupta et al., 2025; Uisso et al., 2023).

Moreover, a total of 36.7 % of respondents claim that poverty is the major issue in the study area. Household respondents complained that they cannot afford food and shelter and thus are forced to find accommodation and fertile land for agriculture along the catchment which is cheaper compared to land located far from the riparian zone. They also reported that, crop farming is the main source of income thus it is inevitable to use the fertile land in the riparian zone of the catchment. *Baidoo et al.* (2023) reported that, poverty aggravates undesirable land use in the riparian area due to food insecurities and the need for income, thus necessitating the migration of people to areas that provide them with water and food. Furthermore, poverty among the community members leads to the expansion of human activities into catchment areas for survival (Baidoo *et al.*, 2023; Mugo *et al.,* 2022; Obubu *et al*., 2022).

Only 8.3% of respondents agreed that lack of political will influence on the undesirable land uses in the Nzovwe River catchment. This is contrary to the key informants' responses who reported that lack of political will widely hinders law enforcement and policy implementation. In a study conducted by Mbele and Mubangizi (2023) in the Upper Umzimvubu catchment, it was documented that political passiveness has contributed to a strong encroachment of land uses in the catchment. Weakness in political issues intervenes with decision making processes, law enforcement and implementation of policies (Cherotich andLetema, 2021; Sibanda andAhmed, 2020).

Additionally, only 2.4% of the respondents reported that law ambiguities existing in the community contribute to undesirable land uses in the catchment. This is consistent with the key informants' responses who argued that laws and policies which are not backed up scientifically thus promote law ambiguities which in turn influence undesirable land uses in the catchment. The community members claimed that the 60 meter distance stated by regulations is unclear. The regulation does not state if it is from the highest peak the river water reaches or from the primary source of the river. Another issue was how the calculation of the particular distance elucidated was made, whether it follows land terrain or horizontal distance calculation. Catchment infringement is not essentially caused by poverty; sometimes uncertainties in the guiding regulations may provide a free chance for encroachment (Andreasen *et al*., 2022; Katusiime and Schütt, 2023). Kangalawe (2017) documented that, poor directives from regulations cause exacerbated undesirable land uses in the catchment areas, specifically in the southern highland zones of Tanzania in which the study area is found. A study conducted by Katusiime and Schütt (2020, 2023) revealed that the limitations in management regulations lead to wrong knowledge among the community members, leaving a gap for undesirable land uses in the catchment areas.

The results (Table 9) show that 15.1% of respondents agreed that lack of land use planning influences the increase of undesirable land uses in the catchment. This has also been reported by key informants that, it constrains law enforcement and drives people to use the prohibited riparian land. Land surveyors were ineffective in allocating the land, thus leaving squatter land in some places of the riparian lands without a strict warning that did not permit anyone to use the particular land. Tantoh and Simatele (2018) reported that, top-down land use planning without considering the community using the land resource causes negligence of laws since most of the local demands are not met. In a study conducted in the Hluhluwe catchment in South Africa, it was reported that ineffective land use planning exacerbated the encroachment of human activities in catchment areas (Luvuno *et al.,* 2022).

Likewise, 52.9% of respondents reported that an increased demand for cheap arable land contributes to the increase of undesirable land uses in the catchment. The community claimed that the price of fertile and arable land away from riparian buffer zones was much more costly than the riparian land, thus it was much easier for them to obtain land in the riparian zones. This can also be attributed to poverty among the community members which literally drives all other factors in increasing the undesirable land use practices in the catchment. The same phenomenon was also reported by Molaoa and Muroyiwa (2022), whereby authorities fail to control people from using arable land in the catchment which is fertile and cheap compared to the land away from the rivers.

4. Conclusion and Recommendation

Despite the presence of laws, regulations and guidelines on the prohibition of land uses in water sources, undesirable land use practices in the Nzovwe River catchment are still a problem. At household level, the factors influencing undesirable land use practices in the catchment are

negligence, ignorance, poor governance, poverty, lack of political will, lack of LUP, law ambiguities and increased demand for land. According to the key informants' perspective, the factors influencing undesirable land use practices in the catchment are lack of political will, limited budget for allocation compensation, administrative fragmentation, law ambiguities, lack of LUP and negligence. These factors contribute differently to the occurrence and prevalence of undesirable land use practices in the riparian zone of the Nzovwe River catchment.

These factors can be divided into two categories for a better understanding of how they influence undesirable land use practices in the catchment. The first group comprises the factors that constrain or hinder law enforcement and implementation, and the second group involves the driving factors. The law enforcement constraining factors are a lack of political will, limited budget for allocation compensation, administrative fragmentation, poor governance, law ambiguities and lack of LUP. These factors hinder law enforcement and implementation, thus causing a continuation of undesirable land use practices in the Nzovwe River catchment. The driving factors influencing the undesirable land use practices in the catchment are negligence, ignorance, poverty, and increased demand for land. All these factors have one major social constraining factor which is poverty. This social constraining factor drives the community members to use the riparian land so as to reduce the severity of impacts of poverty and manage to survive.

Authors recommend that policy enforcement mechanisms should be strengthened by equipping and training local government officers and environmental units to monitor and enforce riparian buffer zone regulations effectively. Another mechanism involves introducing community-based environmental patrols or catchment stewards to complement formal enforcement. Furthermore, the government should ensure that urban development plans explicitly consider the needs of low-income groups by providing access to affordable, serviced plots and prioritize land regularization schemes that protect both ecological zones and community welfare. The central government should emphasize governance through enhancement of social learning by launching targeted campaigns to educate the public on the ecological functions of riparian zones and existing legal restrictions. Additionally, the government should incorporate environmental education into development planning at the ward level and public meetings. The local government should provide alternative sustainable livelihood opportunities such as access to education on climate-smart agriculture, urban greening, or eco-enterprises that reduce reliance on riparian land. Researchers' recommend further that, future research should explore constraints of the national legal framework and its implications on law enforcement in catchment areas and integrate community-based participatory methods to further deepen understanding of local behaviours and policy effectiveness.

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Declaration of conflict of Interest

The authors declare that they do not have any known competing interest, either personally or financially that could influence the work in any way.

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