Analysis of Pressure Drivers within an Urban River Riparian Reserve: A Case of Nairobi River in Kenya

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Rapid urban development is characterized by encroachments, haphazard urban growth, and unplanned land-use change. Nairobi river is a perfect example where urban pressure emanating from the expansion of Nairobi City has undergone immense land use land cover changes for the past 20 years. Pressure drivers as a result of anthropogenic activities such as expansion of human settlements, urban agriculture and commercial activities continue to compete for the fragile ecosystem spaces of the riparian reserves which ideally should have been left for biodiversity, pollution filtration, flow moderation and slope stabilization. The aim was therefore to analyze these pressure drivers in three sampled river riparian segments. The methodology adopted involved a sampled survey of 650 respondents drawn from the segmented sections of Nairobi River of Upper, Middle and Lower segments where a mobile data questionnaire using Open Data Kit (ODK) with geolocation capability was administered to the various users of the riparian areas. The segmentation was done based on the topography and elevations as per the available Digital Terrain Model (DTM). The results showed that urban agricultural activities consisting of vegetables, maize and banana farms dominated upper segment at 69% while commercial ventures including shops, open markets, car wash and garages constituted 79% of the middle segment and residential usage comprising of re-used old iron sheets houses, makeshift shelters and some semi-permanent structures at 89% in the lower segment signifying significant degradation from crop cultivation of the river slopes, pollution infiltration and loss of biodiversity respectively. Continued encroachment by these pressure drivers have subsequently caused depletion of the riparian space to perform its functions which if left unmitigated could result to more floods as recently depicted in Nairobi City with more property and lives being lost.

Keywords: Riparian Reserve, Urban Agriculture, Land Use Land Cover, Pressure Drivers

Introduction

The root word "riparian" comes from the Latin word "ripa" which means bank (Webster, 1976). This suggests that, riparian lands are found along the edge of water bodies including rivers, streams, lakes, wetlands, springs, and ponds. Karisa (2010) outlines a classical definition of riparian lands to mean woody vegetation cover associated only with surface flowing water. This definition identifies a riparian reserve to be the interface between land and a flowing surface water body. Within many cities including Nairobi, linear strips of vegetated riparian corridors represent the last tracts of remnant bushland and are thus highly valuable ecologically, environmentally, socially, economically, and aesthetically (Gurnell *et al.*, 2007).

Urban riparian reserves are important due to their contribution for good air quality, food security and water availability as documented in SDG goal 11 on Sustainable cities and goal 6 on water and sanitation alongside goal 12 on responsible consumption and production. Nairobi as the capital city of Kenya and the Centre for both Industrial and residential habitats generate a lot of pressure to the surrounding ecosystem specifically to the river riparian.

Physical benefits of vegetated riparian corridors include the improvement of water quality through buffering the stream from nonpoint source sediments and pollutants and geomorphic stabilization of stream bed and banks (Stutter *et al.*, 2021). Ecological benefits include providing input of energy and organic matter (Mati et al., 2008), maintaining biodiversity both locally and regionally (By & Julius, 2013) enabling the movement of organisms throughout the landscape and in addition to these services, riparian corridors in urban landscapes often provide significant aesthetic, recreational and psychological benefits to city residents.

Riparian zone is sensitive to human influence because it consists of riverine vegetation and rivers that are threatened by settlement development (Koskey *et al.*, 2021). The emergence and expansion of human activities, such as the increasing demand for water resources and land-use changes in riparian zones negatively affects riverine ecosystems processes (Koskey *et al.*, 2021). Riparian zones in some rivers in Japan, such as Shonai River and Miya River experience human interference (Cao & Natuhara, 2019). The construction of recreation spaces and footpaths results in the creating of impervious surfaces, which are strongly associated with riparian degradation and alteration of hydrological and sediment regimes (Cao & Natuhara, 2019). Riparian zones in urban and rural areas experience human pressure. Diaz-Pascacio *et al*. (2018) claims that 73% of the aquatic systems in Mexico experience different types of degradation. Adjacent human centered land use influences the state of the riparian zones, such as riparian zone modification that results in loss of riparian vegetation along Sabinal River in Chiapas state in Southern Mexico (Diaz-Pascacio *et al*., 2018). Therefore, riparian zones all over the world are continuously affected by human settlement development.

Riparian zones in Kenya experience human settlement interference that results in loss of biodiversity and other disturbance. Human settlement related activities such as agricultural activities, water abstraction for domestic use results in loss of canopy cover in Njoro River and Kamweti River (Waturu *et al*., 2023). Built-up areas development within and around the riparian zone of Njoro and Kamweti Rivers are linked to various human activities that result in the loss of biological integrity that affects riparian vegetation (Lia, 2022). Riparian zones of urban rivers in Kenya such as Sosiani River in Eldoret town, Uasin Gishu County experience the loss of riparian zone vegetation that assists in the filtering mechanism (Nyakora, 2016). Additionally, Nyakora (2016) links human settlement development along urban rivers with land use changes that alter the natural aquatic ecosystem, which explains the effect of grazing at the edge of Sosiani River. Informal settlement is one of the leading land uses that adversely affect riparian zones in Nairobi's three main rivers, Ngong, Mathare, and Nairobi river (Muketha, 2014).

With all these benefits, urban riparian reserves are heavily encroached with anthropogenic activities which continue to swallow up the ecological spaces that they were meant for. These anthropogenic activities range from built up residential and commercial premises, urban agriculture, solid waste landfills, infrastructure such as sewer and roads just to mention a few. With rapid urbanization and Nairobi city expanding to the fringes of the city County, these pressure drivers continue to eat up the riparian space that would otherwise be preserved for ecological functions (Study *et al*., 2020).

Rapid urban development is characterized by encroachments, haphazard urban growth, and unplanned land-use change (Juma *et al*., 2021). Riparian spaces have for a long time being used as free land susceptible for grabbing by informal and formal land uses however the driving pressures and forces are yet to be analyzed. The informal land uses constitute uncontrolled expansion of informal settlements, illegal dumping of solid wastes, urban agricultural firms, industrial and commercial premises which are predominantly skewed along the Nairobi River riparian corridor.

Study Area

Nairobi occupies an area of about 700 km² at the south-eastern end of Kenya's agricultural heartland. At 1600 to 1850 m above sea level, it enjoys tolerable temperatures year-round (Tibaijuka, 2007). The western part of the city is the highest, with a rugged topography, while the eastern side is lower and generally flat. The Nairobi, Ngong, and Mathare rivers traverse numerous neighbourhoods and the indigenous Karura forest still spreads over parts of northern Nairobi. The Ngong hills are close by in the west, Mount Kenya rises further away in the north, and tremors occasionally shake the city since Nairobi sits next to the Rift Valley, which is still being created as tectonic plates move apart. Due to its rapid growth, urbanization processes have led to immense pressure to the Nairobi River. Nairobi river traverse the county from the upper side in the west, through the middle at the CBD all the way to the lower side at on the eastern direction. The area of the study is provided in Figure 1.

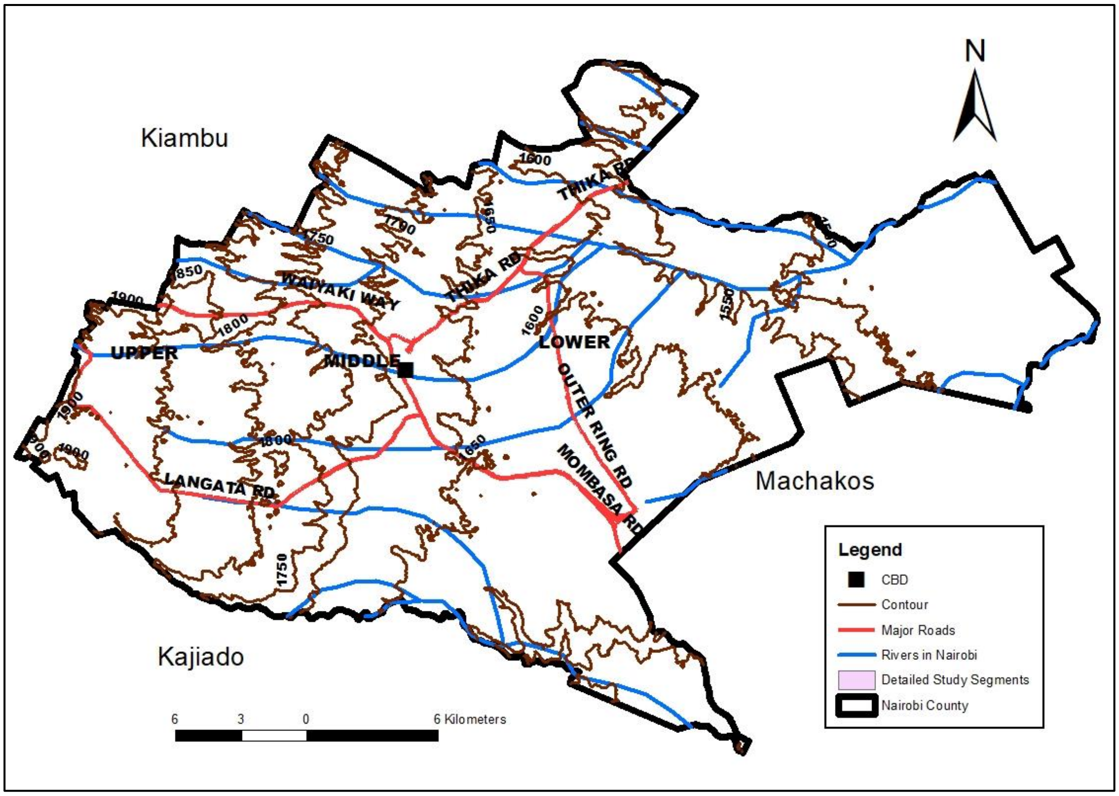

Figure 1: Nairobi City with a network of Nairobi River traversing and selected study sites (Researchers, 2024)

Drivers in the urban riparian space

Rapid urbanisation is characterised by an increased number of residential buildings, industrial, commercial and transportation routes, however there is a drastic decrease of vacant land, while in other cases land use is changed. A typical example would be a naturally vegetated land being transformed to residential; this affects ecological stability as less land is available for preservation of the natural ecosystem (Kwena, 1999). The pressure drivers are accelerated by several factors and activities taking place on the earth's surface. These factors include urban farming, restoration by planting trees and harvesting and management of urban waste (Owoeye & Ibitoye, 2016). Due to the nature of developing countries, it is expected that rapid changes will occur within the riparian spaces as a result of the growth of cities resulting from rural- urban migration and high birth rate, as compared to developed countries(Lefulebe *et al.*, 2023).

The impact of rural-to-urban migration and high birth rate on riparian space is the rapid growth of informal settlements, growth of built-up areas, and a decrease of vacant land, wetlands and the occupation of flood-prone areas (Ives, 2011).

Research Methodology

Quantitative data collection techniques were adopted where a questionnaire was designed to capture some of the demographic information such as age, gender as well as their understanding of the pressure drives emanating from various land uses such as residential, urban agriculture, commercial and industrial.

A sampling frame spanning 100m on either side of the river was used to compute the samples sizes based on Yamane's formula (Juma *et al.*, 2021) and at a linear distance of 2km each from the start of each section of upper side, middle side and the lower side segments of the river at elevations of above 1800, 1700-1800 and 1600-1700 sides respectively from the Digital Terrain Model (DTM).

n = N/(1+N(e)2)

n= sample size

N=population

e= error (0.05)

The actual sample sizes which were interviewed were slightly more than the computed sizes for more statistical data redundancy as shown in Table 1.

Table 1: Sample sizes by each riparian segment

Name of Riparian segment	Frequency	%
Upper	101	15.5
Middle	243	37.4
Lower	306	47.1
Total	650	100.0

(Source: Field data, 2024)

Plate 1: Geolocation

A digital form was developed in ODK and uploaded in a web platform which included questions on demographics, geographical coordinates and perceptions on pressure drivers. The digital form was designed in Microsoft Excel then configured in ODK with a geolocation capability so that the research assistants collecting questionnaire data could be geocoded and constricted with the sampled areas which were buffered at 100m each from the river's center line and 2km stretch along each riparian segment. The mobile form was distributed to the three research assistants who were first trained on how to use ODK for data collection and submit their completed form to the server for downloading and cleaning. The mobile data collection is shown in Plate 1 and the real time map in Figure 2.

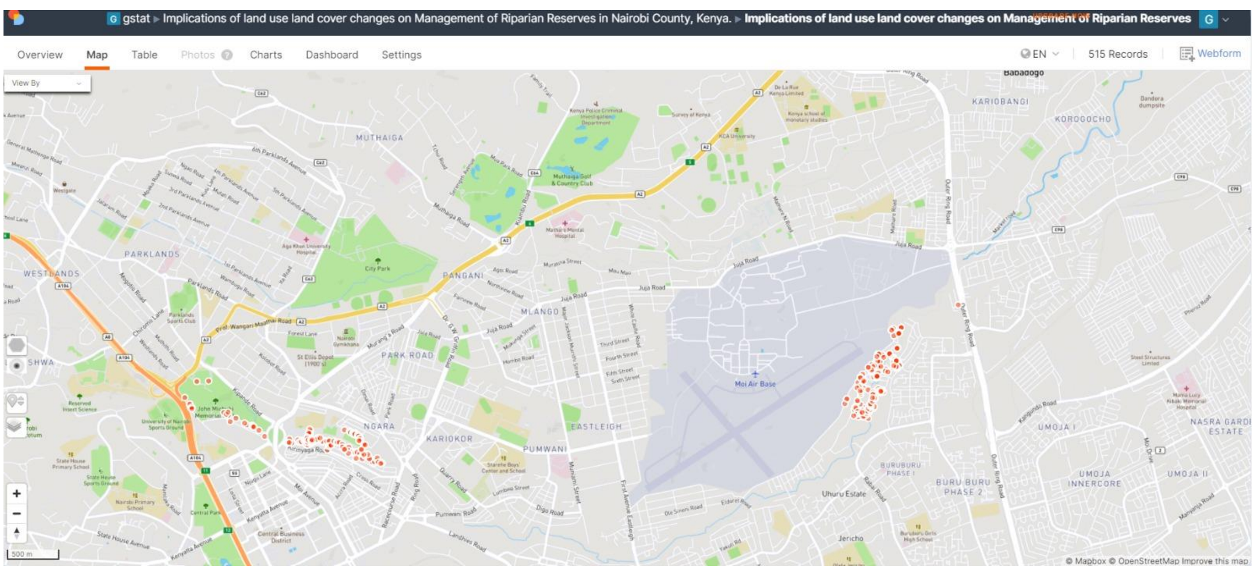

Figure 2: Geolocation of data collection at the sampled areas

Data preparation and cleaning

The data from the quantitative interviews was obtained from 670 respondents. These comprised of riparian users from the upper, middle and lower segments of the Nairobi River based on the coded Open Data Kit (ODK) tool kit used for data collection. The collected data was downloaded as Excel files, from the two ODK Collect accounts used, since the sample sizes were above 500 for use in one free account. The two datasets were later merged by the ID variable autogenerated from ODK.

The data was first checked for missing observations. In this case, all the empty entries, were deleted, entry by entry. The rule of thumb was that all responses without the Name of Riparian segment of Nairobi-River were deleted, to retain only the complete entries for the purposes of completeness of the analysis. The deleted observations were excluded from the analysis, leaving only a sample of 650 persons, used for the entire analysis.

The cleaned dataset was imported in Statistical Package for Social Sciences (SPSS) version 27, to allow for data analysis. The analysis comprised of cross-tabulations by Name of the riparian segment, graphical presentations, Kruskal Wallis H test and Chi-square test of association.

Data analysis and association test

The Kruskal-Wallis H-test, or one-way analysis of ranks, is a non-parametric statistical method used to assess significant differences between two or more independent groups, where the dependent variable is ordinal or continuous but does not follow a normal distribution. This makes it a suitable alternative to one-way ANOVA, especially for non-normally distributed data or small sample sizes. By ranking data instead of relying on raw values, the Kruskal-Wallis test is robust against outliers and skewed distributions (Sheskin, 2020). It serves as an extension of the Mann-Whitney U test, allowing for comparisons across multiple groups rather than just two. While the test identifies the presence of significant differences, it does not specify which groups differ; post-hoc pairwise comparisons are required for further analysis (Field, 2021).

The test is given by the formula;

$$H = \frac{12}{N(N+1)} \sum_{i=1}^{k} \frac{R_i^2}{n_i} - 3(N+1)$$

Where;

k is the number of groups

N is the number of observations across all groups

n_i is the number of observations in group i

R_i is the sum of ranks for group i

Chi-square tests of association

Chi-square test of association is a measure used in determining the association between two categorical variables. The variables for use are always nominal such as demographics (gender, race etc.) or ordinal such as Likert scale variables (Turhan, 2020). The test assesses the hypothesis of whether there exists an association or independence between the various variables included in a study. Theoretically, chi-square (χ^2) is calculated by computing both the observed and the expected frequencies of the two cross-tabulated variables. The formula is given by;

$$\chi^2 = (\sum \frac{(O-E)^2}{E} \ldots \ldots (15)$$

O is the observed frequencies

E is the expected frequencies.

The expected frequencies is obtained by;

$$E_{i,j} = \frac{Row\ total\ x\ Column\ total}{Grand\ total} \ldots \ldots (16)$$

The critical values of the test statistic is obtained from Chi-square tables , with the relevant degrees of freedom realized using the formula;

$$Degrees\ of\ freedom = (Row - 1)x(Column - 1) \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. (17)$$

At the specified level of significance such as 5% or 10%.

Results and Discussion

Demographic statistics

The findings revealed that females dominated the upper and lower riparian segments at 56.0% and 56.9% respectively, unlike the middle segment dominated by males at 56.8%. On education, most of these respondents had attained secondary school education at 61.4%, 66.5% and 50.4% for the upper, middle and lower segments respectively. In terms of age distribution, most of these respondents were aged 18-35 years at 42.0%, 62.1% and 55.5% for the upper, middle and lower segments respectively.

On marital status, most of these respondents were married at 72.3%, 65.8% and 66.6% for the upper, middle and lower segments respectively. On the type of employment, 83.9% in the upper segments had formal employment, similar to 72.2% in the lower segment. Nonetheless, 57.7% had formal employment in the middle segment, as 42.3% had informal employment type.

On tenancy arrangement, majority of the respondents across the upper, middle and lower segments were tenants with 40.9%, 38.5% and 13.1% respectively.

In terms of daily incomes, majority of the respondents in the upper section earned 201-500 at 41.0, unlike the middle segment with earnings of 501-1000 at 31.3% while the lower segments earnings from 201-1000 at 81.6%.

The findings informed that there existed significant associations between name of riparian segment and gender, education, age, marital status, type of employment, daily income and tenancy arrangement ($p<.05$).

Table 1: Demographic statistics

		Name of Riparian segment			
Variable	Sub-category	Upper (%)	Middle (%)	Lower (%)	Sig
Gender	Male	44.0	56.8	43.1	<.05
	Female	56.0	43.2	56.9	
Education	Primary	23.8	14.9	37.0	<.05
	Secondary	61.4	66.5	50.4	
	Tertiary	14.9	18.2	12.3	
	Others	0.0	0.4	0.3	
Age	18-35 years	42.0	62.1	55.5	<.05
	36-45 years	39.0	28.0	35.3	
	45-60 years	17.0	9.5	8.8	
	Over 60 years	2.0	0.4	0.5	
Marital status	Married	72.3	65.8	66.6	<.05
	Single	22.8	30.5	26.2	
	Divorced/separated	2.0	1.6	6.2	
	Widowed	3.0	2.1	1.0	
Employment	Formal	16.1	57.7	27.8	<.05
	Informal	83.9	42.3	72.2	
Daily income	<140	4.0	4.2	1.6	<.05
	141-200	19.0	10.8	15.1	
	201-500	41.0	22.1	43.1	
	501-1,000	25.0	31.3	38.5	
	1,001-20,000	11.0	29.6	1.6	
	20,001-50,000	0.0	0.8	0.0	
	Above 50,000	0.0	1.3	0.0	
Tenancy arrangement	Tenant	40.9	38.5	13.1	<.05
	Landlord	21.2	29.9	20.1	
	Structure owner	15.2	19.0	18.5	
	Owner occupied	12.1	4.1	8.7	
	N.C.C House	7.6	5.4	16.8	
	Lease	1.5	1.8	20.5	
	Other	1.5	0.9	2.3	

Pressure drivers

On the riparian land pressure drivers, the analysis noted that 89.0% of the individuals in the lower had the pressure emanating from residential purposes, similar to 6.3% on the upper segment and 4.6% on the middle segment. On agricultural purposes, the analysis showed that 69.0% of the upper segment dwellers used it, followed by 27.6% of the lower segment dwellers. The least on agricultural use was witnessed on the middle segments of the river at 3.4%. On mining or quarrying, it was reported that 100.0% of the individuals in the lower segment of the river engaged in such activities, as opposed to the upper and middle segment dwellers who had no mining activities. On industrial purposes, the lower segment was the most dominant at 100.0%, as opposed to the middle and the upper segments of the river. On commercial uses, it was noted that the middle segment of the river was the most dominant at 79.0% followed by the lower and the upper segments at 11.2% and 9.8% respectively. On recreational uses, the findings indicated that 54.7% of the individuals in the lower section used the land for recreational purposes, followed by the middle segment at 35.8% as the least being the upper segment at 9.4%. The results also indicated that there existed a significant difference between the pressure drivers and the segments of the river (upper, middle and lower) ($\chi^2(12)$=497.376, p<.05). This indicated that the pressure drivers were heterogenous across the different segments of the river.

From the study, contributors of the pressure drivers and pushing the extinction of the riparian reserve are majorly the quest for supplementary income though both dietary complements of the urban agriculture and available free space for residential or commercial premises, and frequent evictions that have pushed the vulnerable communities further to the fragile river ecosystems. The graphs of the pressure drivers are shown in Figure 3 and the pictorial representation in Figure 4.

Table 2: Pressure drivers by name of riparian segment

		Upper	Middle	Lower	χ^2	Df	P-value
Dominant land uses Before occupation	Riparian Vegetation	24.3%	43.4%	32.4%	10	216.205	0.000
	Bare land	12.4%	81.8%	5.8%			
	Quarry	0.0%	0.0%	100.0%			
	Built up	9.2%	21.4%	69.4%			
	Urban Agriculture	40.4%	0.0%	59.6%			
	Others	0.0%	75.0%	25.0%			
Pressure Drivers	Residential	6.3%	4.6%	89.0%	12	497.376	0.000
	Agricultural	69.0%	3.4%	27.6%			
	Mining/Quarrying	0.0%	0.0%	100.0%			
	Industrial	0.0%	0.0%	100.0%			
	Commercial	9.8%	79.0%	11.2%			
	Recreational	9.4%	35.8%	54.7%			
	Others	15.0%	0.0%	85.0%			
Future projections on the current pressure drivers	Extension of development	3.0%	25.4%	71.6%	6	165.367	0.000
	Planting of trees	7.6%	54.8%	37.6%			
	Urban agriculture	57.5%	10.6%	31.9%			
	Others	5.7%	40.0%	54.3%			

Causes of the riparian pressure drivers

The results showed that the main reason for having activities within the riparian reserve was majorly to supplement incomes as a result of high poverty levels in developing countries such as Kenya. This was noted at 21.57% in the lower segment, 21.96% in the middle segment and 13.92% in the upper segment of the river, this could be due to urbanization pressures both at the Kyambiu informal settlement and CBD dominating lower and middle segment respectively while the upper segment slightly lower because of its peri-urban nature and quite far from the city centre approximately 20km from CBD. The figures informed that income levels were the major reason for the individuals having their activities within the Riparian Reserve as an alternative to supplement their deficit. The second notable reason was the individuals having suffered displacement elsewhere as it is in the history of Kenya where evictions have been rampant since the year 1990s, reported by 18.04% in the lower segment of the river predominantly informal and cases of flooding were reported and 4.71% on the middle segment of the river over time possibly as a result of expansion of the city and more space required for formal buildings. The upper segment of the river did not report any reasons for suffering displacement elsewhere since it was predominantly ancestral occupation and urbanization invaded their ancestry. Free land availability was the third reason, at 6.08% in the lower segment of the river, followed by the middle segment at 4.51% which could probably because occupation invaded fragile lands that were not planned for any development but for river ecosystem and breathing space. Other reasons were also witnessed at 3.92% on the lower segment of the river, 3.33% in the middle segment and 0.59% on the upper segment of the river which could be attributed to informal allocations by village elders and some opinion leaders.

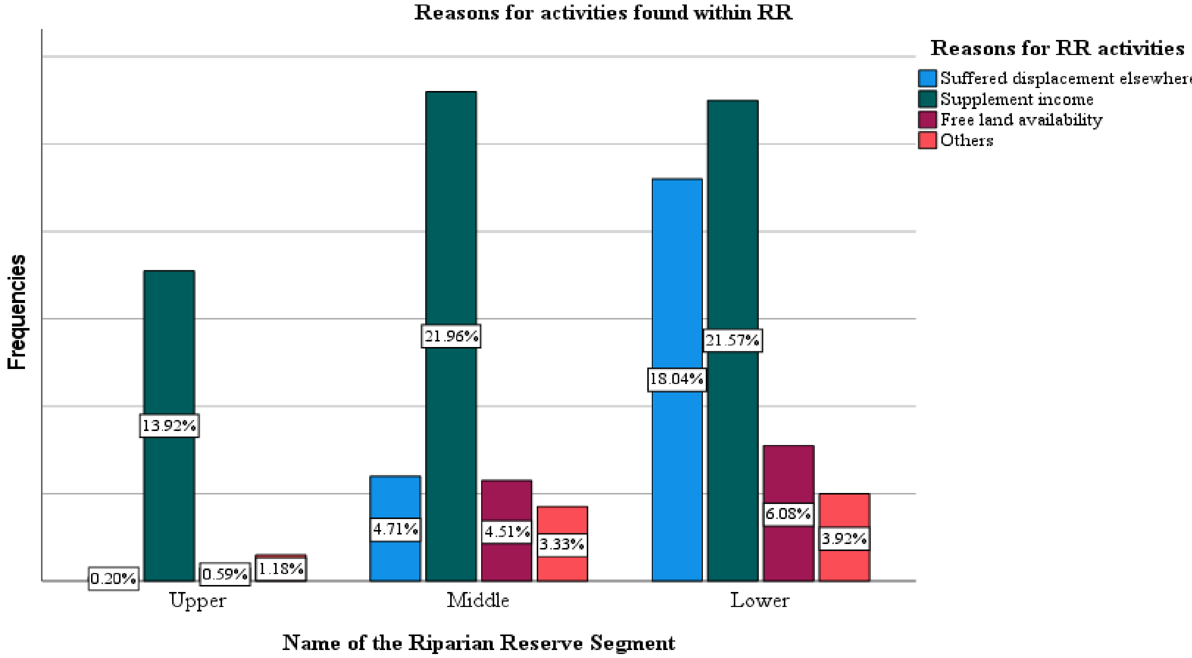

Figure 3: Reasons for the occupation of the riparian reserve

Figure 4: Competing pressure drivers

The agencies involved are represented in Figure 5 and their effectiveness in Figure 6. On the agencies involved in the protection of the riparian reserve by each of the riparian segment, the analysis showed that NEMA was the most dominant at 35.12% in the lower segment, 28.20% in the middle segment and 9.86% in the upper segment of the river since environment conservation and protection is domiciled at the Ministry of environment and NEMA is its lead agency well-structured with departments such as enforcement, ecosystem and urban rivers.

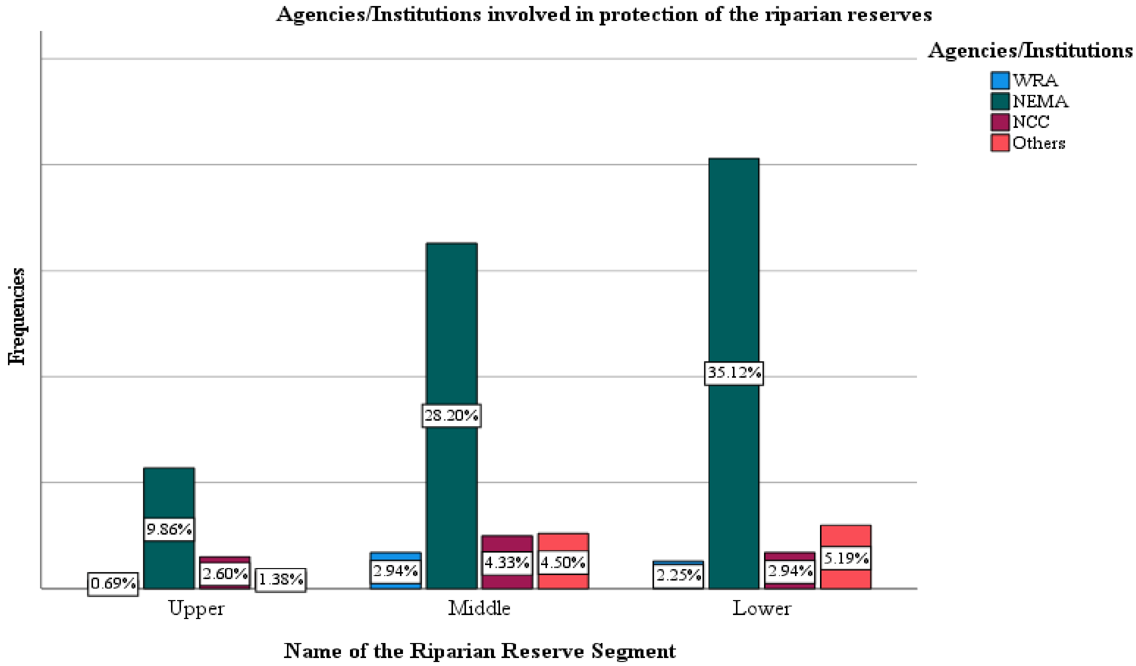

Figure 5: Agencies involved in protection of riparian reserves by riparian segment

The findings informed that in the lower segment, the institutions working on the riparian river segment were somewhat effective at 26.56% owing to the interventions of the flood victims followed by not effective in the middle segment at 17.08% probably due to little or no interventions, not effective in the lower segment at 16.61% and not effective in the upper segment at 6.52%. Those who stated very effective were only 4.50% in the middle segment and 1.95% in the upper segment. The findings clearly informed that the institutions working on the riparian river segment were not effective in terms of their policies and interventions in place over the period.

The pressure drivers were found to be heterogenous across the different segments of the Nairobi River riparian reserve with the Upper segment recording predominantly Urban Agricultural activities standing at 69% for supplementary diet, Middle segment commercial activities at 79% for income generation and lower segment dominated by residential activities at 89% as a result of lack of affordable housing. This could be attributed to peri-urban situations, closeness to CBD and informal settlements respectively at the upper, middle and lower segments. These activities have consistently eaten up the formally riparian vegetation which stood up at 24%, 43% and 32% before occupation at the upper, middle and lower segments in that order.

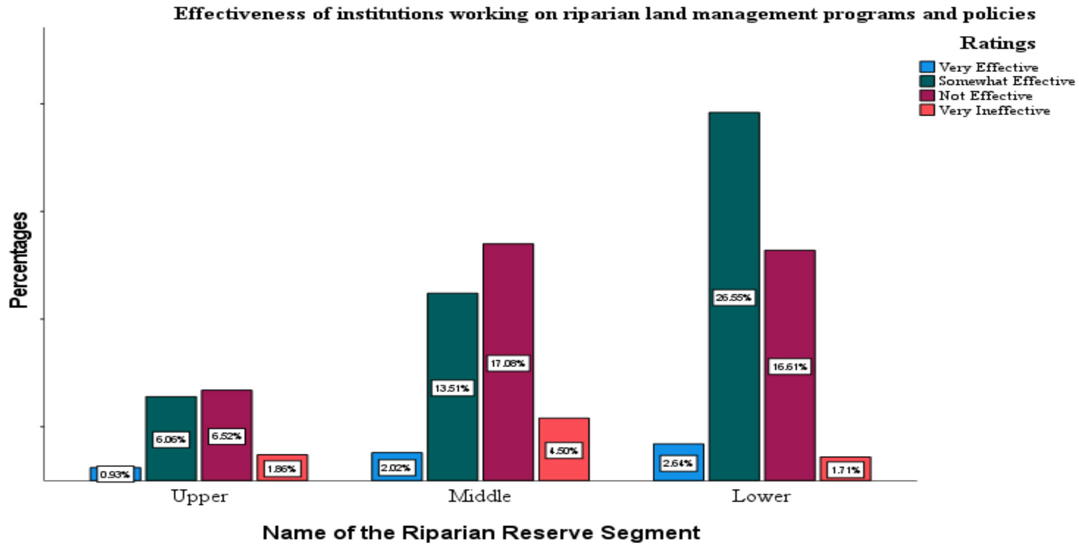

Figure 6: Effectiveness of institutions working on the riparian river segment by name of the riparian segment

The pictorial representation is illustrated in Figure 7.

Figure 7: Residential pressure drivers

Conclusion

In conclusion, riparian pressure drivers emanated from more settlement expansion occurred at the lower segment at 72% arising from poverty and lack of proper housing, while conservation measures of planting of trees were found at the middle segment at 55% witnessed under the establishment of Michuki Park through restoration initiatives and more urban agricultural farming at the upper segment at 58% for dietary supplement.

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