Knowledge, Attitudes and Practices towards Infrastructural Developments along the Riparian Ecosystem of the Nairobi River Basin, Kenya

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ABSTRACT

Urban riparian ecosystems provide vital ecosystem services, including water quality improvement, flood mitigation, and recreation. In the recent past, infrastructural developments and encroachment by humans for agriculture and settlements have compromised their integrity and subsequently the ecosystem services they provide. This study assessed the perceptions towards these factors amongst practitioners and local residents in the Upper Nairobi River Basin comprising Motoine, Nairobi, and Mathare Rivers in Kenya. Both semi-structured and structured questionnaires were administered to a total of 305 respondents comprising 270 local residents (riparian users) within an area of five kilometers on either side and nine kilometers along the Rivers, and 35 key informants representing practitioners in environmental management, civil engineering, land appraisers, land surveyors and contractors among others. The study revealed that polycentric and uncoordinated governance by multiple government agencies are the leading cause of the complex issues and uncoordinated developments along riparian ecosystems that results to pollution by both liquid and solid waste and land degradation. About 86%n of professionals and 77% of the respondents cited corruption and population pressure due to lack of alternative land as major causes of encroachment, respectively. Other reasons cited included poor law enforcement, ignorance of existing legal and policy frameworks of Nairobi County, and poor leadership by 71%, 40% and 34 % of the respondents, respectively. There is need to formulate strong legal and policy frameworks and enhance enforcement, streamline management by involved government agencies, and sensitize citizens through a multiagency approach to ensure to protection of these vital ecosystems.

Keywords: Urban riparian, Urban developments, Built structures, Effects, Laws and Regulations, Nairobi

INRODUCTION

Riparian ecosystems are hotspots for interactions between vegetation, soil, water, microorganisms, and humans. Although it has been demonstrated that urban land use changes profoundly impact wetlands and the water cycle, there is inadequate information available on impacts of land use changes on riparian ecosystems (Groffman et al., 2003; Karisa, 2010). Riparian land is distinguished from neighboring terrestrial land by the presence of adjacent water bodies. Water is a mixture of lobed (still) and lobed (moving) water (Zaimes 1996; Erhardt, Verry & Palik, 2001). Water bodies are either natural or man-made (Zaimes, 2004). Gregory et al. (1996) defines riparian zones as resources primarily comprising vegetation along streams and Rivers. The authors stress the importance of considering scientific and policy considerations while attempting to define a riparian zone.

Leavitt (1998) observes that vegetation clearance and stream bank changes frequently occur due to human developments within riparian areas. Because of these shifts, floods may become more severe, contaminants may be introduced directly into the water, and wildlife populations may decline (Poff et al., 2011; Mwiti,

2014). Available information show that development of structures is a major cause of land degradation. Anthropogenic alterations including the deposition of plastic and metals, have adversely degraded riparian areas (Hapuarachchi et al., 2016). Alaigba et al. (2015) found that soil erosion and gullies caused by human activities, including changes in land use and land cover in riparian regions, have changed the extent of fragmentation of riparian plant life, leading to deterioration of stream ecosystems that impacted on biodiversity. According to Yirigui et al. (2019), the characteristics of riparian forests can potentially change the circumstances of stream habitats and the carrying mechanisms of materials, sediments, nutrients, and pollutants imported from the watersheds.

Alterations in the water quality of streams, lakes, and ponds linked with riparian ecosystems are linked with various hazards, the most significant of which include agriculture, grazing, mining operations, fire, timber harvesting, urbanization, and recreation (Reference). Enrichment with solid and liquid waste leads to invasion by invasive species such as water hyacinths and the accumulation of toxic substances in the vegetation (Mutisya & Yarime, 2011). This may end up in humans through direct or indirect consumption. Food crops irrigated with toxic water have been reported to cause ill health (Mureti, 2014; Santos, 2010). Bank erosion, deeper and narrow channels, reduced riparian zones, and typically larger sediments result from clearing highland vegetation and allowing excess water to flow downstream in one go (Santos, 2010).

In many regions of the Western United States, the ecosystem for woody riparian vegetation has been dramatically altered as a result of the construction of dams and the irrigation diversions channels that are frequently connected with dams (Leavitt, J. 1998). According to the findings of Stromberg et al. (2004, 2007), one of the most significant dangers to Sonoran cottonwood-willow ecosystems is the modification of water flows, mainly through the use of diversions. Dams prevent water from flowing downstream and flooding cities (Elmqvist et al., 2013). Although this helps those who reside in the lowlands further downstream, it hurts riparian areas.

Riparian zones can only thrive with periodic natural flooding (Gathira, 2016). Water, nutrients, and sediments are all brought to the area by floods (Kennedy, 2012). They also aid in forming a backwater, which is essential for maintaining fish hatcheries. Rood et al. (2005, 2007) identified River damming and the related diversions of water as one of the critical reasons for the loss in cottonwood riparian ecological systems, ranking it third after livestock farming and farming, respectively.

Generally, the intrinsic function of riparian zones is to act as a pathway for River overflow and runoff in case of flooding, among other assorted accessory functions (Mwiti, 2014). Therefore, the erection of built structures in these areas has proved a barrier to the runoff and seasonal Rivers in the Nairobi region (Alaigba et al., 2015; Zaimes, 2004).

Floods of diverse magnitude have been experienced in significant expanses of Nairobi, which have been attributed to the encroachment of the riparian areas (Mureti, 2014; Ministry of Environment, 2013). The effects of previous floods range from basic socio-economic to national disasters that caused havoc throughout Nairobi (Mureti, 2014; Mwiti, 2014). Mugambi (2014) opines that common adverse effects of floods witnessed include displacement of families, destruction of properties worth billions of shillings, the widespread flooding of the ground surface, and the subsequent submerging of houses and properties.

Studies have shown that clearing vegetation and modifying stream banks are commonplace when riparian zones are developed for housing or business. Construction of roads can hasten erosion, inject oil and other pollutants into streams, interrupt the natural flow of groundwater, and endanger local species (Poff et al., 2011). These shifts have the potential to amplify floods, boost direct pollution of water sources, and reduce animal populations. Built structures have also caused a significant threat through pollution. Solid wastes mainly comprise inorganic materials like plastic, metals, and paper bags; organic waste includes vegetable waste, food, and human waste littered in the River (Khan, M. H. 2004). Household daily waste, including excrement in some parts of the River, is observed along the riparian and in water. The debris destroys the aesthetic look of the River and poses a health hazard to the people in the area. The waste has also affected the ecological balance, including animal populations (Matunda, 2015). The air around the Rivers is polluted with a foul smell arising from rotting matter and sewage in the Rivers (Mutisya &Yarime, 2011). Currently, there is

imprecise documentation on the impacts of built structures along the urban riparian lands. To understand the patterns and impacts, the critical issues addressed in this research are guided by the following key aspects: the definition and demarcation of riparian zones along the River basin, compliance and enforcement of laws and regulations in place to protect the riparian zones; monitoring plans in place and the existing Governance gaps. This study sought to establish the various perceptions on the issue of encroachment along the Nairobi Rivers. The study's objective was to establish stakeholders' perceptions of the effects of built developments on the riparian ecosystem.

MATERIALS AND METHODS

Description of Study Area

The study was conducted in the upper basin of the Nairobi River, an important riparian ecosystem within Nairobi City in Kenya. The River's source highland areas in Kikuyu in central part of Kenya from where it runs southwards towards Nairobi. It runs through the capital city on the western flanks of Nairobi and to joins the Athi River that drains into the Indian Ocean. The River has several tributaries, but the interviews were conducted on three tributaries namely Motoine, Nairobi, and Mathare Rivers basin segments because of their diversity and falling among most encroached parts in Nairobi County. They also increase reliability concerns. The riparian users/local residents interviewed were within a zone of 2.5 kilometers on both side and 9 kilometers along the Rivers. The areas covered were Motoine River (45 KM^2), Nairobi Rivers (25 $KM^{2,}$) and Mathare River (15 KM^2). These areas represent 12.5% of the entire Nairobi River basin.

Mathare River is located within longitude 36.7791 to 36.7285 and latitude -1.24484 to -1.248318 and is characterized by low population density with single unit family homes. The upper section of the Mathare River part is marked by an increase in land ownership attributed to the area being zoned for low-density residential housing and agriculture. Due to increased land ownership in the surrounding areas, the number of tenants is substantially lower than in other areas, accounting for approximately 73%.

The Nairobi River is located within longitude 36.7790 to36.7282 and latitude -1.26372 to -1.27293 and is characterized by middle class dwellings of multistory buildings and maisonette houses. The sparsely populated area is characterized by low-density residential areas and temporary structures encroaching on the River's riparian zone. Most constructed structures are permanent residential buildings, flats, and temporary iron sheet structures comprising of the temporary structures.

Motoine River is located within longitude 36.7786 to 36.7569 and latitude -1.31496 to -1.31964 and is characterized by informal communities and unplanned structures. The River passes through informal slum areas of the Kibera distinguished by inextricably haphazard temporary structures and constructions that cover most of the accessible area. Most of the riparian area is encroached by temporary buildings, with many also erected within the Riverbank, thus interrupting the flow of the River.

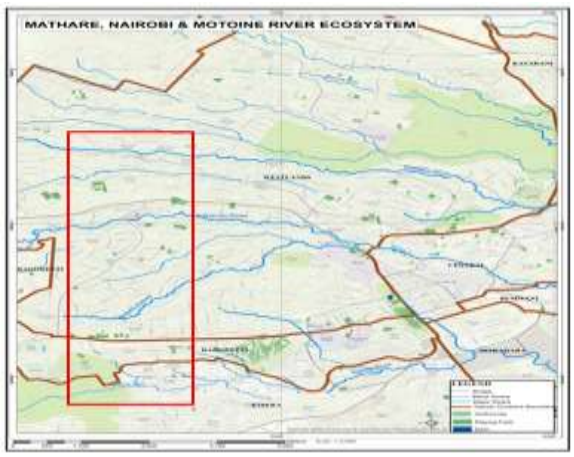

Figure 1: Study Area, Nairobi River Basin, Nairobi County, Kenya

Study Population

The key informants in this study were household participants in the study area and built environment professionals working within Nairobi County. A population of 270 household respondents was surveyed, while professionals comprised about 35 experts, including Land Valuers, GIS experts, Civil Engineers, Planners, Surveyors, Environmental Experts, Architects, Project Managers, and Contractors. The 35 key informants representing practitioners in the built environment selected for the study included (Civil Engineers 3%, Valuers 23 %, GIS Analysts (11%), Planners 14%, Surveyors, 11%, Environmental Experts 11%, Architects 9%, Project Managers 9% and Contractors 9%.

Motoine River

In Motoine River area, sample population comprise of 63 (35%) male and 117 (65%) female. Women, accounted for 54% of the 180 samples of the area. The majority of households in Kibera are headed by male (not present during survey as most are the bread winners). Families are made up of young couples aged 20 to 40 years. Most families have between four and seven family members, accounting for 55%, and 1-3 family members, accounting for 36%. 8-11 family members account for 8%, and over 12 family members account for 1%. The study found that 43% of the population is between the ages of 20 and 30, while another 36% is between the ages of 30 and 40. Less than 1% of the population was over the age of 60.

Nairobi River

There were 60 participants from upper Nairobi River comprising 37 (62%) male and 25 (32%) female. The age categories 38% between 20 and 30 years, 42% between 31 and 40 years, 10% between 42 and 50 years, and 10% between 51 and 60 years. Compared to the Motoine River, Nairobi River had a more evenly distributed population, with a higher proportion of elderly residents. 33% of households have between one and three family members, 38% contain four and seven family members, and 4% contain eight and eleven family members. Regarding education, 5% of families have at least one member with a bachelor's degree. 13% have a college education, 68% have a secondary education, and the remaining 13% have only primary education.

Mathare River

30 participants drawn from Mathare River catchment comprised of 17 male (57%), and female 13 (43%). The population age distribution is as follows: 20% are between the ages of 20 and 30, 37% are between the ages of 31-40, 20% are between the ages of 41-50, and 23% are between the ages of 50-60. The age group's general composition can be related to the type of housing ownership prevalent in this area. Families in the upper Mathare River basin constitute 23% of homes with 1-3 people, 63% of households with 4-7 members, and 7% of households with 8-11 members and over 12 members, respectively. Upper Mathare residents have a university education at a rate of 16%, a college education at a rate of 26%, a secondary school education at 36%, and a primary school education at 6%.

Land ownership

Regarding ownership, in the three catchments' land ownership, 85% do not own any land, 8.5% own land that is less than 1/8 of an acre, 3.3% own lands that range from 1/8 to ¼ of an acre, 0.7% own between ¼ to ½ acres, 1.5% own between ½ to 1 acre, and 0.4% owns between 2 and 5 acres. Motoine River's settlement is informal, and the Land on which developments occur is public land. The upper Nairobi and Mathare Rivers are marked by increased land ownership. This is primarily due to the area zoning for low-density residential housing and agriculture. Due to increased land ownership, the number of built structures is substantially less than in the Motoine River settlement.

Sample size determination

The Taro Yamane formula was applied to calculate the sample size of the number of units within 30 meters

size of the riparian for the three Rivers.

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

Whereby n is the sample size required, N = Number of people in the population, e = allowable error (5%). The total units within the Mathare River riparian was 77; the total units within the Motoine River was 625, the total units within the Nairobi River Riparian = 336, and the overall total units for the riparian of three Rivers N = 1038. The study area sample size was determined as n = 289. The sample size for each River was thus calculated based on the number of units identified within the riparian study area to come up with specific units for each River segment riparian area. Sample for the Mathare River catchment = (77/1038) *289 = 21. To increase reliability, the sample size was increased to 30. Sample for Nairobi River catchment = (336/1038)*289 = 94. Access to households was a major challenge; hence, the sample was standardized to 60. Sample for Motoine River catchment = (625/1038) *289 = 174 standardized to 180. In addition, a population of 35 key informants' professionals and a variety of institutions also participated in identifying the various impacts of built structures along the riparian zones. This was critical because the professionals play a critical role in decision-making, and thus, most of the built structures in the riparian zones reflected their actions and interpretations of riparian laws.

Data Collection

This study was conducted between March 2018 and March 2019. In July 2023 the study area was revisited and validity of earlier data confirmed. The ArcGIS software version 3.4.0 was used to analyze land use types and changes and to develop maps showing spatial distribution of these factors. Photographs were used to capture human footprints including their impacts. Topographical maps were obtained from relevant government institutions and these were used to digitize the demarcated study area, including the administrative boundaries, infrastructure, and general topography. Structured and semi structured questionnaires and interview was utilized in survey for both local residents and the professionals. The local residents' survey mainly focused on capturing the perception of the residents on perceptions of riparian encroachment and identification of built structure along the Rivers riparian zones. The survey for the professionals on the other hand focused on determining if professionals were aware of riparian encroachment, identification of allowable sizes and structures along the riparian as well as their perception of built structure along riparian lands. A reliability test was conducted separately for the professionals and other respondents from the three Rivers catchment.

Both primary and secondary data were used. Structured questionnaires were used to collect primary data, which included households, knowledge of riparian lands, size, encroachment, and protection. GIS-generated maps determined the extent of encroachments of built structures. Secondary data was obtained from statistical reports and government documents such as acts of parliament and regulations.

Ethical issues

This was a non-invasive study since no samples were collected from the participants. Authority to conduct this study had been obtained from the Wangari Maathai Institute and from the local authorities of study and Nairobi County. Government administrators and community leaders also participated in the study as key informants. Participation in the study was voluntary. Informed consent was obtained from individual respondents and community leaders. Ethical considerations were fulfilled by obtaining verbal consent and ensuring confidentiality.

Data Analysis

Responses were examined for completeness, errors and inconsistencies before being entered into MS Access database. Analyses were performed using SPSS version 22 software and MS Excel packages. The results were summarized and presented in tables and graphs.

RESULTS

The questionnaire was administered to 270 local residents/riparian users from Motoine River area (n=180), upper Nairobi River (n=60) and Mathare River catchment (n=30), and 35 professionals including civil engineers, Land Appraisers GIS analysts. The study found a Conbrac alpha of 0.798 professionals' samples and 0.446 for the other respondents from the three River catchments. The Conbrac alpha was between 0- 1, indicating the reliability of the sample data.

Perceptions among residents

Motoine River

The various responses regarding impacts whether built structures have a negative or positive impact were varied with responses of agreement or disagreement. 59% of Motoine River respondents understood what a riparian zone is, while the rest, 41%, did not understand. On the understanding of whether built structures are allowed in Riparian zones, 38% of Motoine respondents agreed, while the rest, 62%, did not agree that structures were allowed in riparian zones. Concerning the awareness of types of structures allowed within the riparian zone, 43% were not sure or gave no answer, 3% were aware of permanent buildings, 1% were of temporary buildings, 12% were aware of civil structures (bridges, sewer lines, manhole), 1% indicated awareness of boundary wall, 2% recreation buildings, 19% mentioned others not within the above. 20% of the respondents were aware of several of the above.

Regarding the causes of encroachment along the Rivers, Motoine respondents' perception was as follows: 3% perceived that there was no encroachment in riparian lands, 23% blamed encroachment on population pressure and shortage of land, and 3% perceived it as dumping sites. 5% blamed corruption and greed, and 4% viewed riparian lands as idle, which people can turn to make it productive. 4% viewed poverty and Ignorance as the cause of riparian encroachment, while 1% indicated a Lack of law enforcement by the government. 56% of the respondents gave multiple causes of encroachment.

On the knowledge of applicable sizes for riparian zone areas, 27% of the respondents did not know any defined size. 12% know 6 meters, 32% know 30 meters, 5% know both 6 and 30 meters, and 24% indicated knowledge of other sizes.

On activities that should be allowed in a riparian zone, 2% of the Motoine River respondents did not want any built structure in the riparian zone, 1% suggested high-income buildings, less than 1% informal settlement, 6% urban agriculture, 3% urban recreational parks, less than 1% garages, 3% solid and liquid disposal systems, 13 % roads and bridges, 3% service lines. 67% suggested several of the above-mentioned structures.

Regarding activities that should not be permitted in riparian areas, 82% proposed differently built structures (buildings, bridges, manholes, boundary walls), 5% no activities at all, 3% high-income development homes, 2 % quarries, 1% urban agriculture, and 2% formal business activities, 3% heavy industries, and 1% informal settlements,1% urban recreation and garages, and 1% mentioned public institutions.

Nairobi River

Among the Nairobi catchment respondents, 73% of the population understood a riparian zone, while 27% did not. 86% of the respondents cited having buildings within riparian areas had negative impacts, whereas 14% indicated positive impacts. On knowledge of types of structures allowed in a riparian area, 55% were not sure, 2% cited permanent building structures, 3% temporary building structures, 23% civil structures (bridges, sewer lines, manholes), and 2% transmission lines (power, lighting, data). 15% cited several of the above. The respondents attributed the causes of riparian encroachment to the following issues: 5% cited there were no encroachment issues in riparian lands, 22% cited population pressure/land shortage, 2% lack of dumping sites, 10% corruption and greed, 3% riparian lands are idle and people want to make it productive, 2% poverty and ignorance, and 3% cited lack of law enforcement by the government. 53% cited multiple of the above. On the

knowledge of allowable riparian sizes, 8% cited 6 meters, 44% cited 30 meters, 28% cited other sizes, and 20% did not know. For activities that should be permitted adjacent to riparian areas, the respondents cited 96% roads, sewer lines, and other utility passages, 2% roads and bridges, and 2% sewer lines. 95% of the respondents were against any activities in riparian areas, while 2% suggested public institutions.

Mathare River

In the Mathare River basin, 71% of the population understand what a riparian zone is, whereas 29% do not understand a riparian zone. On knowledge of the type of structure that should be built on the riparian zones, 55% were not sure, 2% stated permanent buildings, 3% stated temporary buildings, 23% civil structures (bridges, sewer lines, manholes), 2% transmission lines (power, lighting, data) whereas 15% stated several of the above.

A total of 87% of Upper Mathare respondents considered built structures to harm riparian, while 10% of respondents perceived they had positive effects. 3% considered the built structure to have no effects on riparian. 47% of the respondents know about built structures allowed in riparian zones, while 63% do not know the allowable riparian sizes.

The causes of encroachment in the riparian zones cited by the respondents were 13% population pressure/land shortage, 3% lack of dumping sites, 10% corruption and greed, 3% riparian lands are idle people want to make them productive; 3% cited a lack of law enforcement by the government and 67% cited multiple causes of the above. Regarding the applicable sizes of riparian zones, 13% of the residents did not know, 23% indicated 6 meters, 44% indicated 30 meters, and 10% indicated both 6 meters and 30 meters. 23% indicated other sizes. For activities that should be permitted adjacent to riparian areas, 91% of the respondents mentioned roads, sewer lines, and other utility passages, 3.3% mentioned recreational parks, and 7% had no suggestions. 97% of the respondents were against any activities in riparian areas, while 3% did not have suggestions.

In the overall, on the understanding of what a riparian zone is, Mathare and Nairobi River respondents better understood, with 71% and 73% respectively. Motoine River respondents had 59%. On acknowledging negative impacts by built structures to the riparian, Mathare River had 87%, Nairobi River 86% and Motoine River had 38%. Absence during interview in Motoine River of the male head of the home and bread weaner is a contributing factor to this low respondent understanding.

Perceptions among professionals

A population of 35 professionals from Nairobi City County was sampled to establish their perceptions of the various factors that have contributed to encroachment and to identify the solution to mitigate the causal factors. The importance of these professionals played a crucial role in identifying and bolstering the factors already identified by the River Basin population. They are also the primary decision-makers involved in the various planning processes and urban development in Nairobi County. Most of the formal development encroaching on the riparian zones were attributed to decisions made by one or several professionals whose opinions cannot be ignored.

For the factors acknowledged by the professionals as causes of encroachment, 77% of the respondents mentioned population pressure and lack of alternative lands. 86% of respondents cited Corruption and greed, 34% cited poor leadership, 71% mentioned lack of law enforcement, and 40% cited ignorance among the people and government. Population explosion, corruption, and greed among leaders were cited to have contributed significantly to the driving factors of riparian encroachment.

In mitigating encroachment in riparian zones, proposals by professionals included public education and coming up with clear riparian laws, which was cited by 57%; fighting corruption was cited by 37%, while 51% advocated for punishing corrupt individuals and lawbreakers of riparian zones. Figure 2 summarizes recommendations by the professionals to mitigate encroachment.

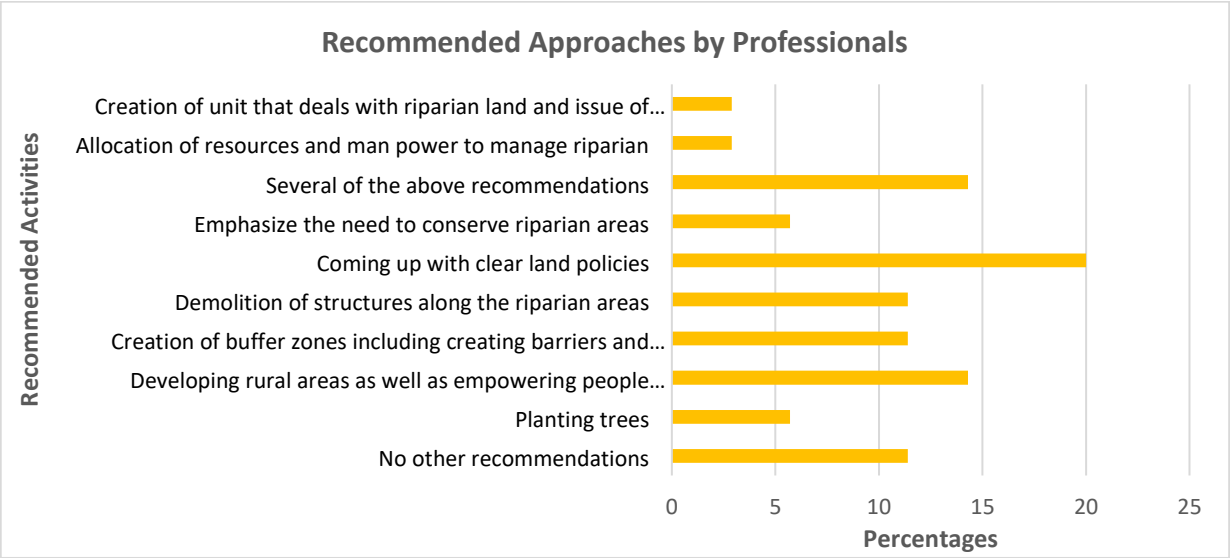

Figure 2: Recommended Approaches by Professionals to Mitigate Riparian Land Encroachment

On the impact of built structures, 26% of the professionals felt that building high-income residential buildings had no impact on the riparian zone; 31% felt they had little impact, 31% felt that high-income buildings had moderate impacts, while 11% felt they had high impacts on the riparian zone. The research notes that the professionals did not understand or agree that anything formal harms the riparian zone. Few of the professionals mentioned the high impact concerning the issue of building formal residential buildings.

On informal settlements built on the riparian zone, 6% of the professionals cited that it had little impact, 14% indicated moderate impacts, 37% mentioned high impact, and 42% stated very high impacts. Most professionals cited that informal settlement had high negative impacts on riparian zones. On placement of public institutions in riparian areas, 23% of the professionals cited that building public structures in riparian did not have effects, 57% cited low impact, 17% moderate impacts, and 3% very high impacts.

The issue of quarrying on riparian was received with relatively varied responses whereby 23% of the professionals felt it had no effect, 24% stated it had little impact, 6% reported moderate impact, 29% mentioned high impact, and 20% mentioned very high impacts. 37% of the professionals cited that agriculture had no impact on the riparian zone, 23% felt it had little impact, 26% felt it had moderate effects, and 3% stated high impacts. In comparison, the rest, 11%, stated agriculture has a very high impact on riparian zones. 6% of the professionals cited formal businesses as having no impact on riparian zones, 29% cited formal businesses as having little impact, 54% stated moderate impacts, and 11% stated high impacts. Regarding informal businesses built on riparian, 14% stated they have little impact, 37% stated moderate impacts, 20% noted high impact, while the rest, 29%, indicated very high impacts. 43% of professionals stated that built structures do not negatively impact the riparian zone. 43% stated little impact, while 6% said moderate impact. 9% of the professionals cited that urban recreation parks significantly negatively impacted riparian zones. On heavy industries' impacts, 32% of the professionals mentioned high negative impacts, 11% stated they have little impact, 32% moderate impact, 14% no impact on riparian zones, and 11% said very high impacts.

Regarding constructed garage establishments in riparian zones, 6% of the professionals felt they had no impact, 17% felt they had little impact, 48% indicated moderate impacts, 23% cited high impacts, and 6% cited very high impacts. Concerning constructed solid and liquid disposal systems in riparian zones, 17% felt they had no impact, 23% little impact, and 37% moderate impacts, while 11% and 11% high and very % high, respectively.

The impacts of constructing roads and bridges in riparian zones were noted by professionals as follows: 37% felt that construction of roads and bridges in riparian zones had no impact, 23% it had little impact, and 26% felt it had moderate impacts, while the rest 14% stated that it had high impacts on riparian zones. The various effects of service lines of riparian zones were responded to as follows: 26% of the professionals felt that they

had no impact on the riparian zone, 34% indicated that they had little impact, 34% stated they had moderate impacts, and the remaining 3% stated they had high impacts.

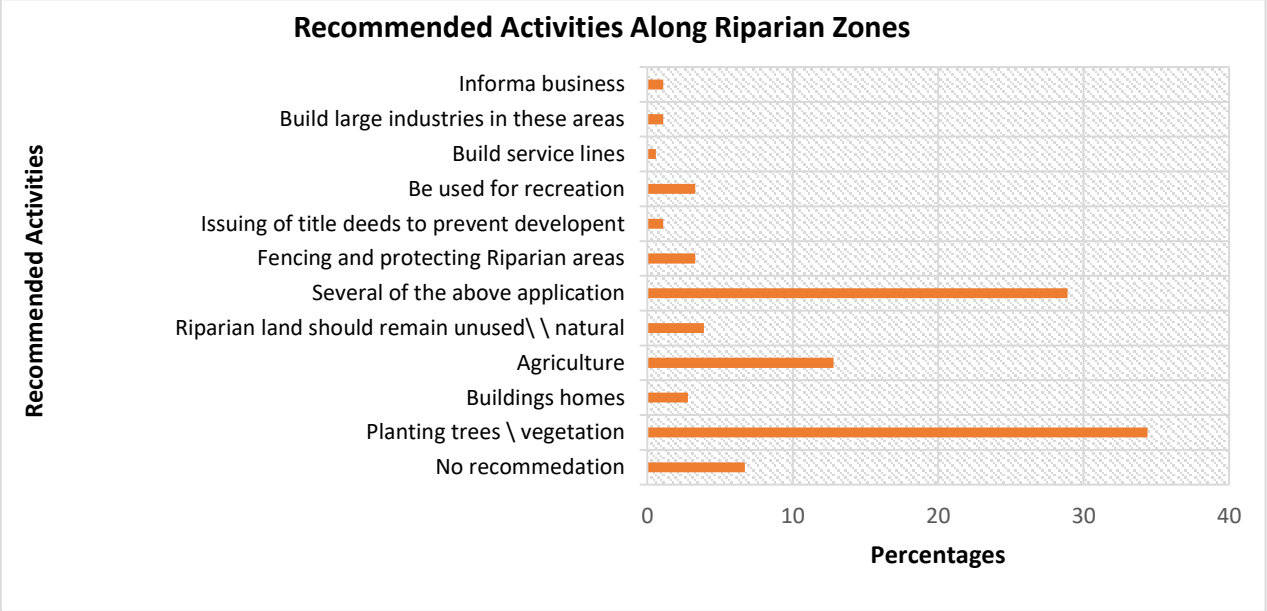

Figure 3: Recommended Activities by Professionals along the Rivers' Riparian Land

Perceptions on polycentric governance of riparian laws

The research identified that fragmented institutions with closely related mandates and therefore laws and regulations in Nairobi are the leading cause of riparian encroachment. When the professionals working in diverse sectors in Nairobi were asked about their expert knowledge of allowable riparian sizes, varied responses that lacked consistency were obtained even where some of the professionals worked in the same body. Table 1 summarizes the recommendations for allocable land uses by the interviewed professionals.

Riparian Widths	Mean	Std. Error of Mean	Std. Deviation
Industrial width	0.86	4.087	24.177
Commercial width allocation in meters from riparian	6.91	2.908	17.202
Residential (informal) width allocation in meters from riparian	9.46	2.42	14.319
Residential (formal)width allocation in meters from riparian	5.71	1.692	10.01
Urban agriculture width allocation in meters from riparian.	5.83	2.902	17.168
Open spaces width allocation in meters from riparian.	5.77	1.636	9.68
Infrastructure (sewer) width allocation in meters from riparian	9.26	3.101	18.344
Institution width allocation in meters from riparian	9.86	2.403	14.219
Service line width allocation in meters from riparian	7.94	3.098	18.33

Table 1: Various Riparian Width Sizes for Different Activities as Derived from Built Environment Professionals

Regarding high-income residential impacts, 3% of engineers felt it had moderate impacts; 9% of Land

Appraisers felt it had no impact; another 9% of Land Appraisers felt it had moderate impacts, while yet another 6% of Land Appraisers felt it had moderate impacts. In the same regard, 3% of GIS analysts felt that high-income residential had no impact; another 3% of GIS experts asserted it had a moderate impact, while another 6% of GIS experts asserted it had high adverse impacts on the riparian zone. This reflects the lack of clear rules and guidelines governing the size allowable for a riparian buffer. When subjected to the same issue, 6% of planners indicated that high-income residential buildings had little impact on riparian zones. In contrast, another 6% indicated that high-income residential significantly impacted riparian zones.

On the other hand, the same observation was noted by environmental experts, whereby 6% stated that high-income residential areas had no impact on riparian; 3% of environmental experts noted moderate impacts, while another indicated high impacts. This was the general trend in all other cases involving informal settlements, service lines, agriculture, roads, and bridges. The existing relationship between the professionals and the understanding of impacts was very weak, with a negative correlation (Pearson's R= -.101). A regression modeling was also conducted to ascertain the relationship between occupational practices and understanding of the impacts of encroachment. Table 2 below shows the regression output.

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.156[a]	.024	-.005	.460
a. Predictors: (Constant), Occupation				

Table 2: Regression Modelling

R- The correlation coefficient between the predictor and the dependent variable is 0.156. This indicates a weak positive linear relationship. R Square- This is the coefficient of determination, representing the proportion of variance in the dependent variable explained by the predictor. In this case, the occupation variable explains only 2.4% of the variance in understanding the impacts of riparian encroachment. Adjusted R Square: This is similar to R Square but adjusted for the number of predictors. It is beneficial when dealing with multiple predictors. The negative value (-0.005) suggests that the model may not be a good fit.

Std. Error of the Estimate- This estimates the standard deviation of the errors in predicting the dependent variable. In this case, it is 0.460. Table 3, ANOVA Table tests the overall significance of the regression model.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.174	1	.174	.824	.371[b]
	Residual	6.969	33	.211		
	Total	7.143	34			
a. Dependent Variable: Understanding of impacts of riparian encroachment						
b. Predictors: (Constant), Occupation						

Table 3: ANOVA[a] *Table*

The p-value for the F-statistic is 0.371, which is greater than the typical significance level of 0.05. This suggests that the overall regression model may not be statistically significant.

Coefficients

Table 4 shows the coefficient of regression modeling:

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	.854	.173		4.946	.000
Occupation	-.030	.033	-.156	-.908	.371
a. Dependent Variable: Understanding of impacts of riparian encroachment					

Table 4: Regression Coefficients

Constant- The intercept of the regression equation is 0.854. This means that when the Occupation is zero, the predicted value of the dependent variable is 0.854. The coefficient for the "Occupation" variable is -0.030. It suggests that, on average, the dependent variable decreases by 0.030 units for a one-unit increase in Occupation. However, the t-value is -0.908, and the p-value is 0.371, indicating that the coefficient is not statistically significant.

The model does not seem to be a good fit, and the "Occupation" variable does not appear to have a statistically significant impact on understanding the impacts of riparian encroachment. The low R Square and Adjusted R Square values further suggest that the model does not explain much of the variance in the dependent variable.

Flooding and Diseases

Flooding in the study areas was common during the long rains research period. As captured through GIS mapping, large tracks of the riparian areas that serve as flood plains have been built on, leaving very little room for water to infiltrate, which increases runoff. Increased runoff in these areas combined with runoff from the neighborhoods results in Rivers overflowing even after short periods of heavy rains. Floods of diverse magnitude are commonly experienced in significant expanses of Nairobi, which have been attributed to the encroachment of the riparian areas (Mureti, 2014; Otiende, 2009). Makeshift access roads are blocked or washed away, as illustrated in Figure 4. Residents have to navigate through polluted water contaminated with assorted raw sewer waste, household waste, oils, solids, and domestic fluids. All these pose physical and health risks and the prevalence of epidemics. Some of the families in these areas are street families. Human dignity in the Motoine River section has been reduced to mere survival due to poverty. This observation was similar to that by Mureti (2014), who studied the effects of riparian encroachment on the Ruaka River.

Figure 4: Navigating Through a Polluted River after Floods in the Motoine Area, Nairobi County, Kenya

Land Degradation

Through visual and photographic recording, the study observed that the riparian lands in Motoine had been

adversely degraded with anthropogenic alterations, including the deposition of plastic and metals. Soil erosion and gullies were evident in the areas, which left the land rigorously degraded and bare. The degraded lands are used to throw diverse kinds of garbage, leaving the environment vastly polluted.

Solid wastes of all types are mainly composed of inorganic materials like plastic, metals, and paper bags; organic waste includes waste vegetables, food, and human waste littered in the River. Household daily waste, including excrement in some parts of the River, was observed along the riparian and water. The debris destroyed the aesthetic look of the River and posed a severe health hazard to the people in the area. The waste has also affected the ecological balance, including animal populations. The air around the Rivers is polluted with foul smells from rotting matter and flowing sewage.

Water Pollution

The water in the Motoine River is critically polluted with diverse kinds of waste from adjacent households and nearby areas. The lack of proper solid and liquid waste disposal has resulted in the use of the Rivers as the dumping site for all types of waste including domestic and medical wastes. Motoine water has been reduced to an open sewer channel littered with garbage and severely polluted ecology, as illustrated in figure 4.

Siltation

Siltation from agricultural activities has resulted in a change in colour and turbidity of the Mathare water catchment dam. Water in the dam has turned brown due to soil and agricultural chemicals from adjacent agricultural farms.

DISCUSSION

This study sought to establish key informants' perceptions of the effects of riparian zone encroachment by built structures. More specifically the know-how and understanding of the term riparian zone, the benefits and extents, allowed structures, and suggestion of preferred uses and mitigation measures. As a result of encroachment, there are impacts not only on the physical riparian areas but also on the inhabitants of the areas. The impacts include the destruction of buildings by floods, deaths from drowning, and the issue of transportation, as also observed by Otiende (2009) in a similar study.

The research assessed perceptions on the impacts of each River section in the given area, and in assessing the impacts of encroachment, the research established that their magnitude corresponded to the level of encroachment in the area. The more the built structures in riparian land, the more severe the occurring impacts. However, the topographical characteristics of each of the areas performed a critical function in terms of the duration of flooding. More sloppy riparian zones drained faster than level areas.

Motoine River basin flood impacts created accessibility problems, destruction of houses and properties, displacement of families living near the riparian areas, and deaths reported from drowning. The extent of riparian encroachment in this River section is excessive, almost covering the accessible lands. These findings agree with a similar study by Mureti (2014) that noted flooding and accessibility problems. Studies by Ndunda et al, (2018) confirmed that there is heavy pollution primarily caused by raw sewerage from informal settlements. The pollution generally increases as the river flows through high-density urban areas.

Nairobi River water was high in observed raw sewage, which changed the water colour, was smelly, and vicious. This high River pollution level made the water unsuitable for agricultural activity. However, the pollution level decreases during the flooding, allowing for uses such as car washing in some parts of the River. Similar findings have been found in different studies by (Alaigba et al., 2015; Mureti, 2014)

Mathare River Riparian zones were the least affected by riparian encroachment. However, with the application of GIS ` various land-use changes in the areas have been detected, which are essential indicators of riparian encroachment and plant cover alterations. The research identified that the built structures along the riparian areas destroyed the vegetation and permanently altered the type of vegetation that grows. Enrichment with toxic waste has led to the growth of water hyacinths and the accumulation of toxic substances in the vegetation. This may later be transferred to the human chain either through direct or indirect consumption as

this is an agricultural area. A related study by Mureti (20140 and Santos (2010) observed that agricultural products irrigated with toxic water have been reported to lead to ill health.

The findings further illustrate that encroachment is significantly greater in areas around the urbanized city and decreases farther away. This is explained by the role of the city regarding economic provision. The pollution levels were higher in the Motoine area, located in a slum; the same was noted in the upper Nairobi River in the Gatina slum. Encroachment in the upper Mathare River was not severe, but residential and agricultural activities caused water pollution and contamination. Land, water, and environmental pollution in the study areas results from residential and commercial wastes, including other activities in the areas. The water in the study areas was critically polluted, making it unusable, unportable, and a health hazard.

The study's results also establish a general lack of interaction among professionals of the same decision centers. The existence of a polycentric form of government with varied sectors independent of each other, plus the general lack of clarity of riparian laws, can be attributed to being the key driving factors of riparian encroachment in Nairobi Rivers zones and Kenya in general. This is in agreement with McGinnis's descriptions of the various interaction problems among the decision centers (McGinnis, Polycentric Governance in Theory and Practice: Dimensions of Aspiration and Practical Limitations, 2016).

CONCLUSION

This study sought to establish the various perceptions of key informants regarding the effects of riparian zone encroachment. Built structures have had a significant impact on riparian areas. Among the main issues are poverty and overpopulation in Nairobi, which contribute to the encroachment of riparian zones due to the availability of riparian lands and the general lack of protection of public lands in Kenya. The study finds that many local, regional, and national decision centers duplicate roles that regard riparian encroachment, hence lacking clarity of the exact overseer of acknowledged illegal activity. Ignorance of the various types of structures allowable in riparian areas, including the presumed magnitude of the impact, is a major contributor to adverse decisions that facilitate riparian encroachment. The research concludes that polycentric governance in Nairobi is the main contributor to the complexity and lack of coordination in implementing riparian laws. Corruption and ignorance in public institutions mandated with laws formulation and enforcement are critically high. There is a general lack of consistency in the knowledge of permissible proportions for riparian zones. The extent of environmental pollution and land degradation is very high and has permanently changed the ecological balance of the areas under investigation.

The research recommends the formulation of clear riparian laws and regulations that apply in all Government sectors that touch on riparian buffer zones. This includes clearly stating allowable sizes, when, and where. Addressing corruption through transparency, whereby specific departmental heads are held to account, can significantly reduce law violations. Addressing housing and infrastructure provision issues in urban centers is crucial to ending significant riparian encroachment disasters. Other recommendations for taming encroachment in riparian zones include advocacy and public education, creating clear riparian laws and regulations, regular monitoring of pollution levels and pollutants, fighting corruption, and punitive penalties for corrupt individuals and lawbreakers of riparian zone conservation efforts.

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