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Riparian Land Control, Contestation and Its Implication to Conservation in Nairobi City:

A Case Study of Nairobi, Mathare and Ngong' Rivers

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Abstract

The riparian zone is perceived depending on how the concepts of land and land use are defined, used, and managed. When the riparian zone is seen in the context of land for development or ignored as unique land use in its own right, then it faces challenges of encroachment and degradation. The purpose of this paper is to assess riparian land control and contestation and its implication to conservation in Nairobi, Mathare, and Ngong' rivers. The specific objectives include mapping out the river, establishing the number of structures on the river channel, at 6, 10, and 30 metres from the riverbank, and proposing strategies for appropriate riparian zone measures using riparian width and condition as the surrogates. The study used both secondary and primary methods of data collection. Secondary data was sourced from published journals, past research documents, and relevant books. Observation and key informant interview methods were used to collect primary data in the nine rivers traversing Nairobi City County, with greater attention given to Nairobi, Mathare, and Ngong' rivers. The tool used for data collection was the Kobo collect tool. The study found out that land use and biophysical factors constitute a complexity of issues. A diversity of land uses heavily contests the riparian zone uses. These include; industrials and informal settlements on the Ngong' River, and high, medium, and low-density residential land uses along Nairobi and Mathare rivers. The study further established that there is limited control of the riparian zone for better conservation. This has resulted in adverse implications on the environmental health of the riparian zone as well as adverse health and social outcomes to the urban residents. The study has, therefore, proposed strategies to address identified gaps, which include: to secure and regulate the use of the riparian zone, land use planning, land surveying of the zones, land registration, and environmental impact mitigation.

Keywords: Conservation, Contestation, Land use and control, Riparian land.

INTRODUCTION

Riparian zones are defined as ecosystems located along the banks of rivers, streams, creeks, and any other water body (Frietag et al., 2008). The zones are narrow strips of land that line the borders of watercourses. This means the zone should have an uninterrupted continuum of vegetation cover that has appropriate vegetation structure and lateral width where ecological, social, and economic functions can take place. Even though they are significant urban landscape elements, riparian zones are facing pollution, encroachment, and degradation from urban land uses in the Nairobi River basin. It appears there is improper determination, use, and management.

Hawe & Smith (2005), maintain that properly conserved riparian zones have significant social, economic, and ecological functions. They include, among others, the protection of water quality and reduction of loss of properties due to flooding. According to UN-Habitat (2009), river basins worldwide are experiencing increased conflicts between different land uses, and their capacity to meet social, economic, and environmental demands is decreasing.

There are significant adverse implications of land use and land tenure systems to the conservation of riparian zones (Njogu & Dietz, 2006). Njogu & Dietz (2006), observe that there is need to develop a clear boundary between specific land use and

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land tenure on the one hand, and riparian zones as public land on the other. Otherwise, where land use and land tenure systems appear to conflict with riparian zones and other natural resources, it leads to their physical encroachment and degradation (Murphy, 2000). Consequently, it seems necessary that riparian zones secure individual tenure to enhance a sense of ownership. This is as opposed to the free, idle, or typical land mentality being observed (Lelo et al., 2005).

The Constitution of Kenya, on its part, has noted that land in most communities of Kenya is the most important form of natural resource required for wealth creation (ROK, 2010). Consequently, it makes riparian land control and contestation a significant issue. Existing laws and policies governing land tenure, land use, and methods of acquisition and disposition of land rights that were applicable during colonial times are sources of tension, strife, and litigation in land matters (ROK, 1991). It implies the need for better delineation of riparian lands to minimize misuse and contestation.

The main objective of the paper is to assess the control and contestation of riparian zones and its implication to conservation in the Nairobi River Basin. The specific objectives include mapping out the river, establishing the number of structures on the river channel, at 6, 10, and 30 metres from the riverbank, and proposing strategies for appropriate riparian zone measures using riparian width and condition as the primary surrogates.

THEORY

Contestation of space is a theoretical concept that has been used in international relations. It can be applied to show how ambiguity, omission, and contradiction in complex relations of competing land uses occur. Odell (2019) opines that the contestation of space facilitates the establishment of new equilibria in land-use regimes, but it can also act as a source of misperception and conflict during transitions (**Figure 1**).

Odell (2019) further argues that contestation of space model demonstrates that a legal agreement

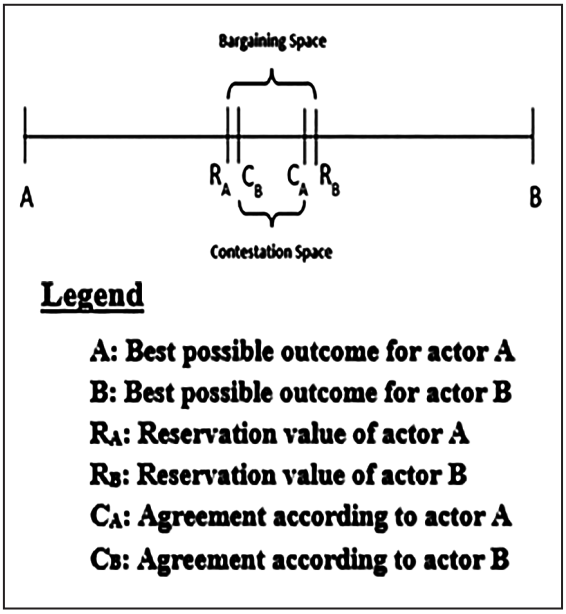

FIGURE 1
Contestation space in a Basic Bilateral Bargaining Model
Source: Odell 2019

is formally concluded or a new informal equilibrium regime is perceived by most actors to have been established. But, there is no one point within the bargaining space that both sides agree upon. Instead, both sides either genuinely, but incorrectly, perceive or disingenuously, but incorrectly, assert that the agreement that has been reached lies within their range of acceptable outcomes (Odell, 2019).

Thünen (1826) observes that location theory has become an integral part of economic geography, regional science, and spatial economics. Location theory addresses questions of what economic activities are located where and why. Location theory or micro-economic theory generally assumes that agents act in their self-interest. Firms thus choose locations that maximize their profits, and individuals choose areas that maximize their utility.

Heinrich von Thünen (1783-1850) developed a model of land use that showed how market processes could determine how land in different locations would be used. Von Thünen was a skilled farmer who was knowledgeable in economics.

Briassoulis (2001), has noted that theories of land-use change are applied to understand the "what" and the "why" of land-use change. The argument advanced is that land-use change is an outcome of processes that include consumption patterns, lifestyles, technological change, population growth, and urbanization (Briassoulis, 2001). The "why" aspect would lead to better understanding and, therefore, change what people do. Briassoulis (2001), has clarified that the "why" in human-nature relations is best understood through the social side of the equation. It is understanding the nature of individuals and societies that creates the "what" of that change and simplifies land-use change (Briassoulis, 2001).

Conservation as the Proponent Theory

Mitchell et al. (2009), conducted a study on "Conservation theory and forest management: Foundation, utility, and research needs." The study found out that conserving biodiversity is a matter that is increasingly raising concern among natural resource managers and many stakeholders. The study has advanced the view that theoretical underpinnings of biodiversity and conservation practice have not attracted much research attention (Mitchell et al., 2009). The study by Mitchell et al. (2009), provides lessons on examining different theoretical approaches in the conservation of riparian zones. Whereas land users, practitioners, and policymakers may view different riparian zones issues in contrasting ways, the factors which underlie the riparian zone should be examined holistically rather than in an isolated stand-alone manner.

Riparian Land

The riparian land forms a transition zone between the terrestrial environment, and the watercourse or aquatic environment. The riparian corridor consists of the following: first, the channel which comprises the bed and banks of the waterway, and second, the vegetated riparian zone adjoining the channel (**Figure 2**).

Riparian areas provide essential life functions such as maintaining stream flows, cycling nutrients, filtering chemicals and other pollutants, trapping and redistributing sediments, absorbing and detaining floodwaters, maintaining fish and wildlife habitats, and supporting the food web for a wide range of biota (**Figure 3**). The protection of healthy riparian areas and the restoration of degraded riparian areas relate directly to efforts by multi-national agencies, which include: protection of water quality, protection of wetlands, protection of threatened and endangered species, and reduction of flood damage.

Concept of Land

Land in Kenya, like in other parts of the world, means different things to different people. However, multiple meanings affect the control and access to land. Kenya Land Alliance (KLA) (2002), defines land as a space that provides goods and services required for the welfare and prosperity of people. Conservationists, on the other hand, consider land as a fragile, ecological entity resulting from the initial workings of living and non-living things on the surface of the earth (KLA, 2002).

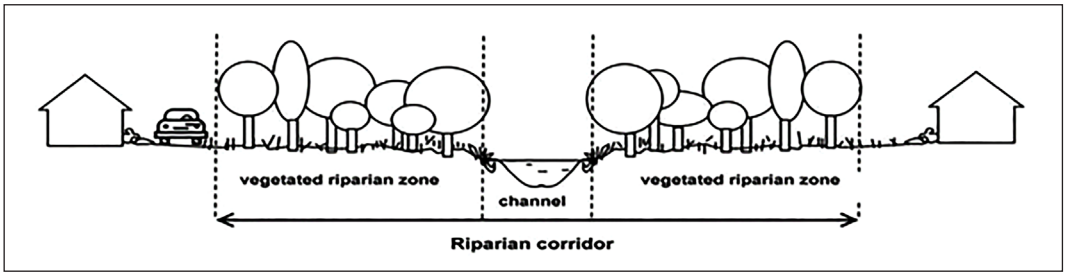

FIGURE 2
Illustration of a riparian corridor
Source: Njogu & Dietz 2006

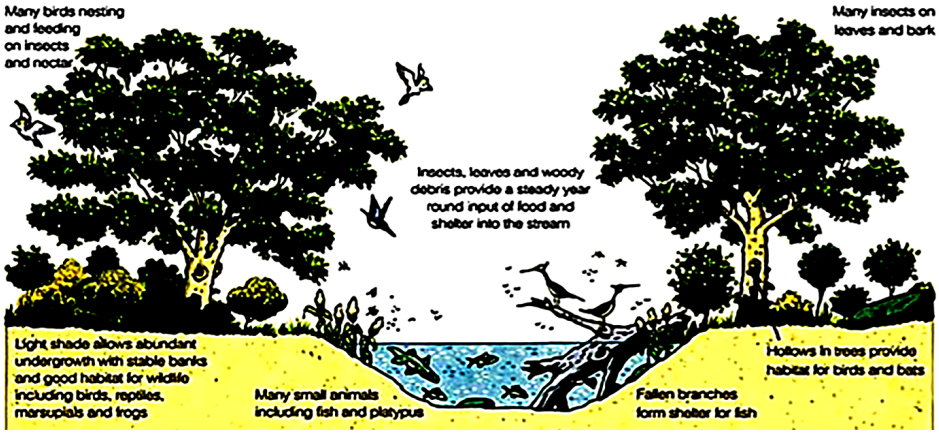

FIGURE 3
Essential life functions of riparian land
Source: Njogu & Dietz 2006

Perceptions by different people generally translate into often competing interests in land that have impacts on the land policy (Njogu & Dietz, 2006). The Kenya Land Alliance argues that no single definition can adequately explain the divergent perceptions (KLA, 2002). However, article 260 of the Constitution of Kenya, defines land as;

"The surface of the earth and the subsurface rock, any body of water on or under the surface, marine waters in the territorial sea and exclusive economic zone, natural resources completely contained on or under the surface and the air space above the surface" (ROK, 2010).

The definition attempts to define land from an economical and natural resource perspective.

Land Use

Briassoulis (2001), observes that human use of land resources gives rise to land use, which varies with the purpose it serves, whether they be food production, provision of shelter, recreation, extraction or processing of materials, and the biophysical characteristics of the land itself. Briassoulis (2001), further argues that two broad sets of forces shape land use: the human needs, as well as environmental features and processes. However, neither of them is static. Briassoulis (2001), therefore, defines land-use change as follows:

"Changes in the uses of land occurring at various spatial levels and within different periods are the material expressions, among others, of environmental and human dynamics and of their interactions, which are mediated by land." According to Briassoulis (2001), these changes are beneficial, and at times, they have detrimental impacts and effects.

The magnitude of land-use change varies with the time being examined as well as with geographical area where assessment depends on the source, definitions of land use, the spatial groupings and the data sets used (Briassoulis, 2001). To this end, there are inherent difficulties in assessing changes in land use due to definitional and data problems (Briassoulis, 2001).

Human activity has consequences on several phenomena, among others, climate change, greenhouse effects, and loss of biodiversity (Briassoulis, 2001). At stake, is the human vulnerability to say floods, food insecurity, health, and safety, which makes it necessary to study land use and environmental changes (Briassoulis, 2001).

Enger & Smith (2000), observed that most of the land surface had been changed by human activity; the change has occurred without evaluating and determining the most logical use of land. Enger & Smith (2000), conclude that most land tuse decisions are made based on economic considerations. Land values for specific uses can be increased or decreased by changing use.

Change of use is, however, constrained by the fact that each parcel of land has a unique set of characteristics that make the land suitable for limited types of service (Kihagi, 2000). Land use types are also limited by land ownership regimes and access arrangements (KLA, 2002).

Space Contestation

The concept of space, on the other hand, has taken increased importance in the appropriation of land for different activities by stakeholders in the built environment to attract and retain optimal benefits. Schneekloth & Shibley (2000), argue that space, both as a concept and a discrete place on earth, is a contested terrain. Contested spaces may be defined to include sites of conflict where people or ideals collide, resulting in a scramble for a place by each individual, owners, and some land uses within the situation. According to Schneekloth & Shibley (2000), contested spaces refer to locations where existing land uses compete for accommodation and all struggle for control of these spaces. The contested areas may include riparian lands, forest reserves, open spaces, and undeveloped lands; among others.

Despite the potential contestation, an ideal location is where there is an orderly spatial relation between urban land use activities and natural environmental resources from an urban planning context (Hall, 2002). Land uses near each other may likely show varying degrees of compatibility (Kihagi, 2000). However, UN-Habitat (2009), observes that the lack of adequate planning, weak development control, and misuse of riparian zones in developing countries has hindered their proper functioning. Based on the definitions, land use ought to embrace the sustainability of riparian zones. It should be on the wise use and management of riparian zones without impairing their physical extent and ecological character.

RESEARCH METHODS

The study employed mixed methods of data collection. The approach involved archival, observation, and key informant interviews. The key informants included Nairobi City County Government officials, local administrators, community leaders, and residents' representatives.

The study objectives called for the use of both quantitative and qualitative data collection methods.

The unit of analysis included structures located on the river channel, at a distance of 6, 10, and 30 metres, from the riverbank. The location of the study Nairobi City County. Specifically, the riparian zones of the rivers within the city. **Figure 4** shows the location of Nairobi, Ngong' and Mathare rivers in the city of Nairobi.

The Nairobi, Ngong' and Mathare rivers were characterized by a significant number of residential, commercial, industrial, informal garages, urban agriculture and quarry mining on the river or within their riparian zones. The three rivers were purposefully selected to represent the nine rivers passing through the city. From satellite imagery of 2018, the three rivers have the most significant encroachment and degradation from land use. Besides, the rivers are primarily within the core of the city. The other rivers are mainly at the periphery of the city, where their contestation, appears less significant.

The study targeted structures, and land uses at the river channel, 6, 10 and 30 metres from the river banks. The study also considered the two-metre elevation above the riverbanks to assess land uses within the wetted flood plain. These are the areas of the river ecosystem that would ordinarily be affected by floods.

The study used both secondary and primary methods of data collection. Secondary data was sourced from published journals, past research documents, and other books relevant to this study, while primary data was collected along the rivers in the Nairobi City County. Spatial data collection tools used in the field included handheld global positioning systems (GPS), cameras and Kobo-Collect application customized to collect data. The Physical Planning Act, Legal Notice No. 140 15(c) and (d) of 1998, Water Resource and Management Rules of 2007, and the Survey Act, CAP 299 were the basis on which the riparian widths of 6, 10, and 30 were determined. The criterion for

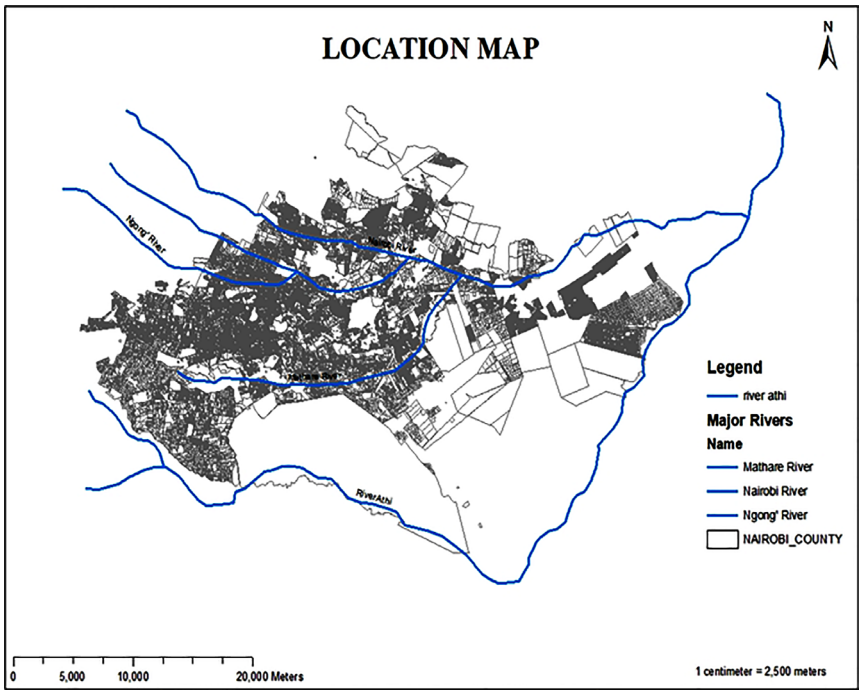

FIGURE 4
Location map
Source: Author 2020

determination of the high-water mark was guided by the Physical Planning Handbook of 2007.

The study used the geographic information system (GIS) software ARCGIS 10.3 to analyze existing data from satellite imagery, survey plans and digital elevation model (DEM), and field data. The analysis involved geo-referencing of the updated Nairobi topographical plans. They were useful in digitizing the river course where it was not evident in the satellite imagery. The imagery enabled to assess the existing ground situation as well as creating the river course profiles across the upstream, midstream and downstream as well as to map the wash area- total active flood area and the vegetation corridor thereon. The aim was to examine the structures, including developments and parcels of land within the riparian zones, using the two-step criteria of two metres above the riverbank and the distances from the riverbanks.

Based on the created floodplain, a buffer analysis was done to determine the number of structures in the flood plain. The structures contained within the flood plain or touching the boundary of the flood plain were marked as red to indicate high risk due to flooding. The buffer analysis identified whether structures were on the river channel or were contained at specific distances from the riverbank.

Visual analysis was conducted to assess the Folio Register (FR) maps on whether they had provided or not provided the recommended riparian zones. The outputs were presented in maps, graphics, and tables.

RESULTS AND DISCUSSION

The study established that there is no empirical evidence to suggest that riparian zones are appropriately determined to ensure they perform their functions. Hence, all rivers in the city are adversely affected by structures and their associated wastes. From **Table 1**, it is clear that only 40% of the length of rivers is situated in the built up area. In this area, the structures are very close to the river. As a result, it has directly affected the physical extent and ecological character of riparian zones. However, 60% of the length of the rivers are still not occupied by structures.

Informal structures cover only 11% of the length of the rivers.

The analysis of all the survey plans available revealed that there are sections where a 3m riparian reserve is indicated, while in other areas, a 30m riparian reserve is indicated. Some survey plans also indicated some areas where a riparian land of 6m was provided. Most of the survey plans had no riparian zone indicated. **Table 2** shows the number of parcels with the riparian zone indicated.

Figure 5 shows the comparison in the enumeration of the number of structures on 10m riparian reserves of various rivers. Ngong' River, which passes through major informal settlements and industrial zones, has the highest number of structures, followed by Mathare River and Nairobi River.

The study further established types of land uses that are physically encroaching and degrading riparian zones along the three rivers of Mathare, Ngong', and Nairobi. These three rivers traverse through major informal settlements where dumping of solid waste is most common, and quarries are present. Ngong' River passes through the largest slums: Mukuru Kayaba, Mukuru kwa Reuben, and Mukuru kwa Njenga; thus having the most number of structures on the river channel and the riparian reserve. These findings confirm that the type and location of land use adjoining the riparian zone is a critical factor that influences the conservation of riparian zones. Hence, the effect of each land use must be considered when developing a model for determination, use, and management of riparian zones.

The determination of the riparian extent was also based on an established flood plain as stipulated

TABLE 1: Analysis of the total length of Nairobi Rivers in various sections

	Zone	Length in kilometers	% of the length of the city
1	Built-up zone	80.79 km	39.6%
2	Informal settlement	21.71 km	10.64%
3	Open areas (unbuilt)	101.55 km	49.8%
	TOTAL	**204.05 km**	**100%**

Source: Field survey 2018

TABLE 2: Analysis of riparian attribute from survey plans

	Riparian attribute	Total number of parcels affected
1	Total parcels with riparian not indicated	423
2	Parcels where riparian is sketched without indication of the width	2
3	Parcels where a 12ft riparian is indicated	5
4	Parcels where a 3 metre riparian is indicated	11
5	Parcels where a 30 metre riparian is indicated	26
6	Parcels where a 6 metre riparian is indicated	6

Source: Adopted from survey plans (Author 2020)

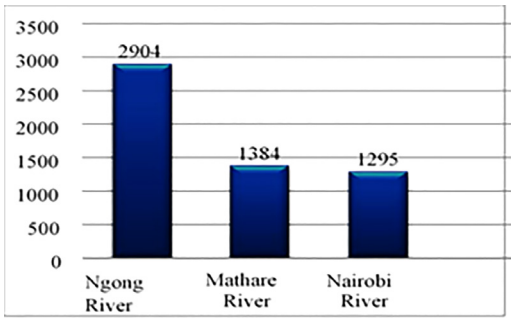

FIGURE 5
Comparison in the enumeration of the number of structures on 10m riparian reserves of various rivers
Source: Field survey 2018

in various legislations. The location of land uses within stipulated widths of 6m, 10m, and 30m are perceived as encroachment depending on the applicable laws, namely Water Act, Physical Planning and Land Use Act, and Survey Act, respectively. **Figure 6** shows a sample output of the spatial analysis done using the GIS tool to determine the state of the riparian land. Illustrated is a section of the Ngong' River.

Based on mapping analysis, the total number of structures on the river channel, 6m, and 10m riparian reserves, and 10m from the established flood level were enumerated as shown in **Table 3**.

The assessment using GIS tools revealed the following: first, the flood plain varies depending on the width and elevation of the river. In Ngong' River, for example, at the former South End Mall- which was at a confluence point of Motoine River and Ngong' River- the flood plain on the upper side of the river was relatively constant while on the lower side, the wetted area changes regularly. The former South End Mall appears to have been within the flood plain area of the river.

Second, the cadastral plans delineating parcels of land do not seem to respect the flood plains. Earlier plans from the 1990s ignored environmentally sensitive areas, such as isolated swamps, and other wetlands. As a result, there are developments at the risk of being flooded while tandem interfering with the river ecosystem. Proper site analysis is crucial before new land allocation or further development on wetlands.

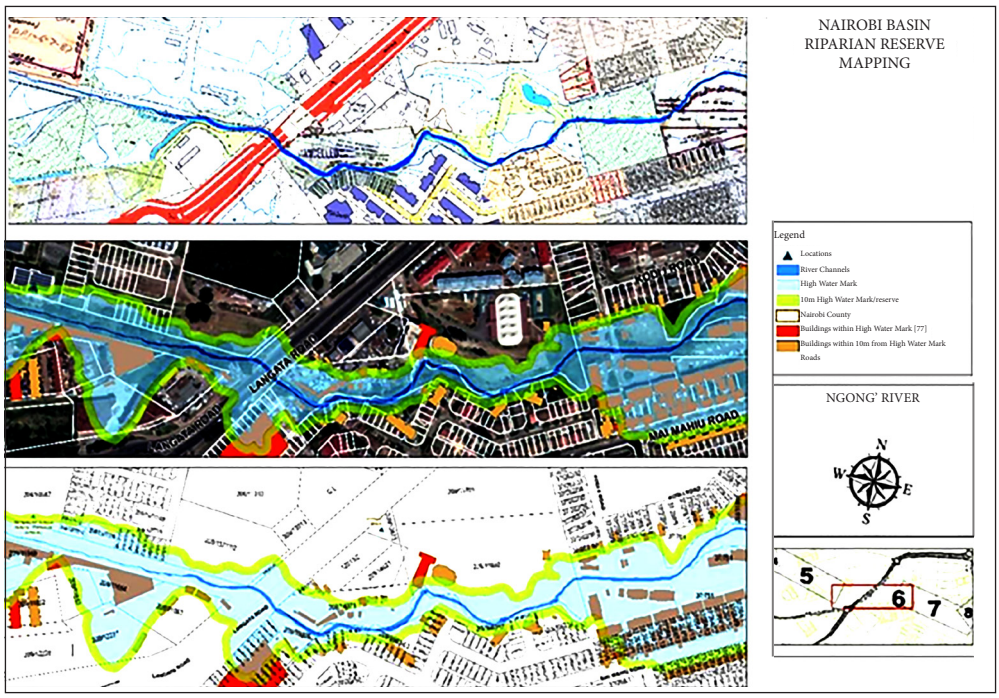

FIGURE 6
Flood plain of Ngong' River at former South End Mall, 2018
Source: Author 2020

TABLE 3: Summary of structures on River Channel, 6m, 10m, and 30m from riverbank

	River	On	6m	10m	30m
1	Ngong'	87	981	1836	5654
2	Mathare	28	476	880	2797
3	Nairobi	30	393	883	3527
	Total	**165**	**1850**	**3599**	**11980**

Source: Field survey 2018

Based on the land uses that were sampled, informal housing and businesses, informal garages, urban agriculture and quarry mining, formal industries, and commercial land use, as well as formal high-income residential housing, were situated within the stipulated riparian widths. This has led to a reduction of the riparian width and degradation of its ecological quality. Human activities that come along with such developments- including, indiscriminate cutting of vegetation, construction of structures, conducting business activities, and dumping of solid and liquid waste- manifest the problem.

These findings support views advanced by the Nairobi River Basin Programme on the significant concentration of chemicals and metals in Mathare; Ngong', and Nairobi. Pollution of rivers results from residentials, commercials, industrials, informal garages, urban agriculture, and quarry mining, close to or on riparian zones. These activities reduce the capacity of riparian zones to filter pollutants in surface run-off and to curtail riverbank erosion. **Figure 7** is an example of a building under construction on the Mathare River Channel.

FIGURE 7
A building under construction on Mathare River
Source: Field survey 2018

Land Use Contestation in Riparian Land

Riparian land is primarily reserved for hydrological and ecological purposes. However, there are many land uses situated at the channel and close to the river bank that make the river ecosystems dysfunctional. Primeness and competition for land or space is another factor that promotes contestation in riparian land. The weak enforcement and development control forces people into open spaces and riparian lands. As a result, it provides avenues for encroachment and degradation of riparian land. Besides, the lack of demarcation of the riparian zones provides users with the opportunity to encroach.

The findings of the study further reveal the degradation of riparian zones where there was no adequate and reliable solid and wastewater disposal systems, particularly in informal settlements. These findings show that the availability and condition of solid and wastewater disposal systems are essential for the effective conservation of riparian zones. This finding agrees with UN-Habitat (2005), who showed that raw sewage from informal settlements was discharged in the zone and the river channel. **Figure 8** shows raw sewerage being released into the Nairobi River. **Figures 9** and **10** show dumping of solid waste on Ngong' River Channel.

The study also found out that public and private institutions, open recreation grounds, and public parks had not encroached and degraded riparian zones. These set of land uses had also allowed access by the public. This agrees with the public

FIGURE 8
Raw sewer discharged into Nairobi River
Source: Field survey 2018

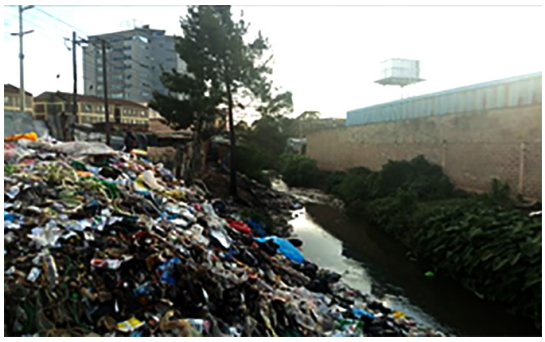

FIGURE 9
Solid waste dumping in Ngong' River- South C section
Source: Field survey 2018

FIGURE 10
Riparian land converted into dumpsite in Vumilia Estate
Source: Field survey 2018

enterprise theory that public institutions aim to promote general good/interest. Besides, private institutions, including hotels, schools, and religious institutions, had maintained adequate riparian widths and riparian vegetation in the zone. However, they had restricted the use of the area exclusively for their clients who patronize the institutions. The finding is in agreement with the private enterprise theory that private firms aim at profit maximization.

The study agrees with Hardin (1968), in the "Tragedy of the Commons", that in situations where the riparian zone is poorly defined, and the system for enforcing development control is weak, the zone is open to over-exploitation, misuse, and mismanagement with devastating environmental consequences. Also, it is crucial to identify land uses that should be situated within the riparian zone.

Land Use Density/Spatial Concentration Issues

Results of data analysis revealed high land use densities in informal settlements, informal businesses, and motor vehicle garages. It contrasts with the low land use density in the sampled formal residential settlement. These findings are in agreement with those of Kimani et al. (2009), that high levels of land use densities are quite prevalent in the 30 metre riparian zone in Nairobi River Basin. A high influx of population and failure to provide solid and wastewater disposal systems aggravates pollution and degradation of riparian zones.

A useful finding was, however, with respect to urban development at high-income residential housing, which had also encroached on the riparian zone. The settlements had an adequate solid and wastewater disposal system that curbed the dumping of waste on riparian zones.

The density of built structures is, therefore, a critical factor in the conservation of riparian zones. The density is directly derived from population resident in a unit parcel of land or structure. The spatial concentration referred to the intensity of land use per unit area in the 30 metre riparian zone. The result of a high occupancy rate in settlements that were underprovided with infrastructure services was dumping of solid and human waste on riparian zones. The findings also agree with the view of Dimas and Gabriel (2008), that the economics of ecosystems and biodiversity

are not valued in the commodity market. It has led to the loss of riparian habitat and isolation of animal and plant species populations.

Bio-Physical Effects

From the field survey, the study found out that dumping of both solid and liquid waste into the riparian reserve had led to pollution of the river contents to an extent of changing the colour of the water. The colour varied from clear to black, depending on the extent of pollution. **Figure 11** shows a change of watercolour as a result of dumping liquid and solid waste along Ngong' River channel.

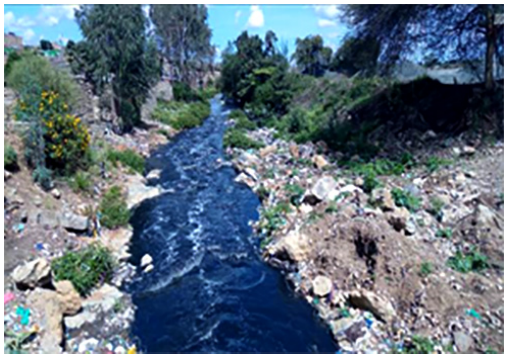

FIGURE 11
Ngong' River along with Mukuru informal settlements
Source: Field survey 2018

Also, the study established that houseflies, mosquitoes, and birds were the dominant ecosystems in the river sections in informal settlements. Others included: cows, lizards, chicken, dogs, goats, and pigs, as a result of structures being close to the river. A large number of houseflies and other flies were evidence of the massive pollution in the area. **Figure 12** illustrates the presence of goats within the riparian reserve of Ngong' River.

Implications of Land Use and Biophysical Factors

The study established that both formal and informal urban land uses and biophysical factors influence the determination, use, and management of riparian zones in the Nairobi River Basin. These include: informal residential, commercial, industrial, informal garages, urban agriculture,

FIGURE 12
Goats in the riparian reserve Ngong' River- Kayole section
Source: Field survey 2018

and mining activities. The land uses have led to the dumping of solid waste, discharge of wastewater and industrial effluents, and removal of vegetation cover. These land uses have led to a reduction in the width and degraded the ecological quality of riparian zones.

The land uses deemed to have the most effects on riparian zones in a descending order are as follows:- (i) informal settlements, (ii) garages, (iii) industries, (iv) quarries, (v) informal businesses, (vi) urban agriculture, (vii) formal businesses, (viii) sewers, (ix) high-income residential, (x) private institutions, (xi) open recreation spaces, (xii) public institutions, and (xiii) urban parks. This order could be translated into future interventions in the protection of riparian zones.

The density of built structures is a critical factor in the conservation of riparian zones. The result of high densities and spatial concentrations of settlements that are underprovided with infrastructure services is dumping of solid and human waste on riparian zones. Protection of riparian zones is, therefore, not a practical imperative that is exercised to regulate and control the consequences of changing land use in the river basin.

There are multiple land tenure and ownership of riparian zones in the study area. The size and configuration of parcels of land along riverfronts do not promote desirable/optimal riparian zones.

The records of survey plans and deed plans in the Department of Surveys show property boundaries as the centre line of rivers. It means that the riparian zone is not adequately defined in cadastral data to restrict incompatible land uses. These findings contradict government policies and laws that define riparian zones as public land.

The study also found out that different locations of the same river have different widths of the river. As a result, it does not warrant the application of a uniform width of the riparian zone. The results of statistical analysis using student t-test at 5 percent level of significance established that the observed riparian widths are less than the tested minimum widths in policies.

The statistical analysis of riparian vegetation cover using Chi-square at a 5 percent level of significance also established that there is no significant vegetation cover to secure riparian zones against adjoining land uses in the study area. These two statistical tests confirmed that the policy and institutional variables in the study area have not significantly influenced the determination of appropriate riparian zones.

Significant slope variability across the study area and in different rivers in the basin was also noted. Therefore, variable, and not uniform width of the riparian zone, appears to be a more plausible approach in riparian width determination. The result of the laboratory test of soil samples indicated that the basin has predominantly black and red clay in the 30 meter riparian zone. However, since the soils in the study area are mainly clay with near homogenous soil permeability characteristics, soil type as a variable may not be significant in the determination of riparian widths in the basin.

Every unit of the riparian zone has site characteristics that directly relate to the natural features of the landscapes. These uses of the zone were, however, constrained in that each riparian space has a unique set of biophysical characteristics that make it suitable for some and no other types of land use.

CONCLUSION

The study concludes that riparian land control and contestation has a direct impact on the conservation of such lands. Besides, there is improper determination, use, and management of riparian zones within the Nairobi River Basin. It has resulted in encroachment and degradation by urban land uses of areas that physically and ecologically ought to be riparian zones. Some urban land use and biophysical factors influence the determination, use, and management of riparian zones in the Nairobi River Basin.

There was an inherent lack of GIS applications in the determination and management of riparian reserves. Decisions were based on isolated local physical development plans presented by registered planners to Nairobi City County for approval. There were multiple applications of lower limit riparian widths without regard to the effects of adjoining or proposed land uses, biophysical characteristics, and the width of the river.

RECOMMENDATIONS

There is a need to develop a GIS system for determining the extent of interference and aid in management and enforcement on the ground. There is also a need to adopt the Nairobi City County GIS database as a base map to incorporate the appropriate riparian extent that does not endanger both the river and properties.

A negotiated riparian reserve should be enforced, in addition to a proper management framework for solid and liquid waste disposal. In addition, to mitigate the effects of flooding, engineering solutions should be used to protect properties in the built-up areas. In some instances, there may be a need to consider relocating structures where flood risks are beyond mitigation. A policy should be immediately developed to ensure maximum protection of the adjoining properties, the rivers, and the riparian reserves based on the flood level and the 10m freeboard as stipulated in the Physical Planning regulations.

There is a need to formulate a riparian zone management handbook and policy in Kenya, that incorporates scientific research and best practices. It shall harmonize the riparian zone definition from which all relevant legislation will adopt one definition of riparian reserves and identify their importance. The policy should discontinue the use of the centerline of the river as the boundary.

Erection of concrete pillars, similar to those of KeNHA, to mark the extent of riparian reserves will help improve awareness of riparian reserves. These pillars should be geo-referenced using GIS mapping techniques. **Figure 13** is an illustration of how demarcation of Riparian reserves can be done using KeNHA like pillars.

Protection of riparian resources is, therefore, a practical imperative that must be exercised to regulate and control the consequences of changing land use. Pointedly, this would have to overcome the mentality, and perception that riparian zones in Nairobi River Basin are free, idle and common public property for pervading formal and informal land uses and developments. Public education and awareness creation campaigns would be some of the most effective means of popularizing proper approaches in the determination, use, and management of the zones.

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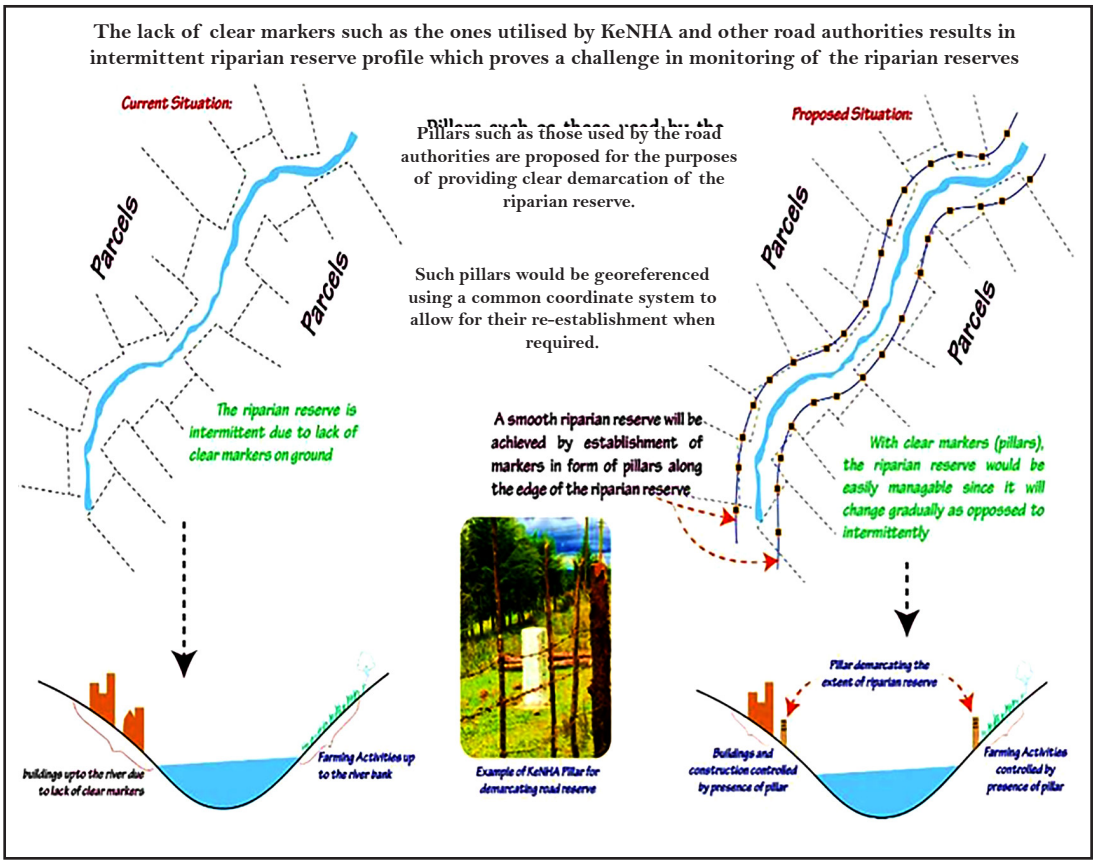

FIGURE 13
Marking boundaries of riparian reserves
Source: Field survey 2018

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