

ASSESSMENT OF URBAN RIPARIAN ENCROACHMENT AND LEGAL PROTECTION MEASURES: A SPATIAL-TEMPORAL STUDY OF NAIROBI RIVER, KENYA

¹ Harrison Kirimi Nyaga, ² Kariuki Muigua & ³ Jane M. Mutune

¹ B.A (Land Economics); University of Nairobi, Kenya

MSc., Environmental Governance, Department of Earth and Climate Sciences

² Professor, Department of Earth & Climate Sciences, University of Nairobi, Kenya

³ Department of Earth & Climate Sciences, University of Nairobi, Kenya

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ABSTRACT

This study examined the extent of urban encroachment along the Nairobi River riparian zone and assessed the effectiveness of existing legal protection measures. Using remote sensing and Geographic Information Systems (GIS), the study analyzes land use changes over a 30-year period (1992–2022), highlighting significant transformations in the riparian zone. Results reveal a dramatic increase in built-up areas, from 4.6% in 1992 to 21.7% in 2022, with a corresponding decline in vegetation (from 8.4% to 1.9%) and water coverage (from 56.3% to 51.7%). The study identifies rapid urbanization, lack of affordable housing, rural-urban migration, and inadequate enforcement of riparian protection laws as factors contributing to encroachment along Nairobi River Riparian Reserves. Furthermore, the study critiques the overlapping mandates of various institutions and the lack of clear legal guidance on riparian widths. The findings suggest that enhanced coordination among state agencies, improved enforcement, and the incorporation of remote sensing technologies in riparian monitoring are essential for effective management. Recommendations also include promoting affordable housing, decentralizing economic opportunities, and fostering community engagement to mitigate encroachment. This research contributes to the understanding of riparian zone management and offers actionable strategies for improving legal and institutional frameworks to protect urban riparian zones from further degradation.

Key Words: Environment Management, Riparian Reserves, Water Resources, Nairobi River, Kenya

INTRODUCTION

The world's population living in urban centers reached 8 billion people in November 2022, surpassing the 1975 world's total population of 4.1 billion (United Nations Population Fund, 2023). The proportion of people living in urban areas currently has reached 56% compared to 34% in 1960 and 15% in 1900 (Ritchie & Roser, 2018). The urban population is projected to be 68% by 2050 with approximately 90% of that growth happening in Asia and Africa (United Nations, 2021). The world's population residing in urban areas had surpassed the rural population by 2009 (United Nations, 2018).

The rapid population increase, exacerbated by inadequate development regulation in developing nations, has generated and will persist in generating numerous environmental difficulties, particularly with the preservation of riparian reserves (Omollo & Ogendi, 2023). Consequently, riparian reserves are thus a planning requirement implemented by nations to enhance environmental conservation.

In 2021, Kenya's urban population was estimated to be at 28%, notably below the averages for other lower-middle-income nations (40%) and sub-Saharan Africa (41%) (UN-Habitat, 2023). If current urbanization trends persist, nearly half of the country's citizens are expected to reside in towns and cities by 2030 (UN-Habitat, 2023). Over the past decade, this surge in urban growth has expanded the number of urban poor, both in absolute terms and as a proportion of those living in informal settlements nationwide. Due to the high cost of housing, the effect has been that the urban poor have invaded riparian areas where they have put up informal housing units.

Humans have interacted with riparian areas since the beginning of civilization. The word riparian comes from the Latin term *ripa*, meaning the bank of a river. A riparian zone refers to the strip of land between a river or stream and the adjacent land, which often faces flooding (Republic of Kenya, 2019). It can also be described as land that borders any natural water channel or depression where water flows regularly or irregularly, such as river and stream banks (Wanjama, 2018; KIPPRA, 2017).

Riparian zones have very complex histories which connect social activities with varied effects on river ecosystem structure and functions (Groffman et al., 2003). Most of the major civilizations in history started from river banks. The Mesopotamia civilization started along River Euphrates and Tigris in what is modern day Iraq. The rise of Egyptian civilization is traced to the River Nile (Kaplan, 2004). Similarly, the Indus River and the Yellow River are recognized as the birthplaces of Indian and Chinese civilizations, respectively (Catanese & Snyder, 1979).

Human use of river ecosystems shifted over time, beginning with transport before 1700, then moving to heavy industrial use from around 1730, and more recently serving as parks and recreational green areas. (Groffman et al., 2003). However, the encroachment and destruction of riparian reserves by human activities show a different way of conceptualizing riparian zones where they are viewed as idle wastelands that can be used as dumping sites for sewerage, solid wastes industrial waste and housing especially for the urban poor. Although riparian buffers cover only limited space, they deliver vital ecosystem functions in urban settings, such as groundwater recharge, water storage, flood regulation, and biodiversity protection.

Rapid urbanization and the aftermath of past neglect in management of increased urban growth has resulted in the continued destruction of wetlands and encroachment of the already fragile riparian zones resulting in challenges such as pollution, depletion of sources of ground water, loss of bio-diversity and increased occurrences of urban flooding (NEMA, 2011; Republic of Kenya, 2008). Furthermore, this study has critically dissected governance of urban riparian zones by exploring the use of remote sensing and GIS to give historical and real time spatial data which will be used by riparian zone managers and other decision makers to improve on management of urban riparian buffers and assesses the legal protection measures thereon and gives recommendations. This study has helped understand urban riparian zones encroachment dynamics

which include investigating whether there has been encroachment over time by use spatial data collection techniques.

Extreme weather patterns which have resulted in severe flooding is becoming more frequent while the number of people living within riparian zones is increasing (Tellman et al.,2021). This necessitates the need for restoration, protection and sustainable management of the still functioning riparian areas otherwise more people will be at imminent risk of floods. Despite their scientifically proven benefits for human well-being, degradation of riparian zones is a common occurrence and, in some areas, even increasing (Janssen et al.,2020). Closer attention is urgently needed towards protection of riparian zones since they are among the worlds most degraded ecosystems (Tockner and Stanford,2002).

Management of wetlands gained heightened importance worldwide after coming into force during the Ramsar Convention in 1975. Ramsar Convention deals with conservation and protection of wetlands and their resources. Riparian zones act as natural filters for pollutants between upland environments and streams. They act to reduce nitrate concentrations in the subsurface in agricultural areas. (Lowrance et al., 1997a; Dosskey, 2001).

Although wetlands face pressure from farming and human settlement, they still support Sustainable Development Goal 11, which promotes creating safe, resilient, inclusive, and sustainable urban environments. The SDG 11 emphasis on the need to strike a balance between the green agenda (environmental protection) and the brown agenda (ecological footprint on human environment) and towards sustainably meeting economic, social and environmental needs of emerging cities (UN Habitat, 2009). However, the extent of spatial analysis on riparian and wetland encroachment remains minimally documented.

Problem Statement

Despite the multiplicity of laws on management of riparian zones, they still face encroachment, pollution, and degradation from urban land uses; hence the need to employ remote sensing in analyzing spatial and temporal extents of encroachment so as to appraise policy makers, riparian zone managers, and the academic community on the best course of action. Healthy riparian zones are expected to maintain continuous vegetation along the river profile, with suitable plant composition, structure, and adequate width to support social, economic, and ecological functions. However, while research increasingly highlights that these zones are rarely well conserved, there is still limited understanding of how best to evaluate their condition, particularly through combined spatial and temporal methods.

Traditional approaches used to protect riparian zones have proved ineffective due to several factors. For example, though there is a legislative framework that defines the extent of these zones, their boundaries have not been defined and gazetted. This has left the task of defining these boundaries to people who own land adjacent to these rivers or wetlands (Lelo Chiuri & Jenkins, 2005). This has further been compounded by the ad hoc and disjointed planning and development control activities between different counties where planning by-laws are not homogenous, which has further increased the vulnerability of these environmentally sensitive zones. Consequently, the encroachment of urban riparian zones is a persistent challenge bedeviling many developing countries. This study has shown how encroachment of urban riparian zones may be analysed through geospatial analysis and the extent of compliance to the laws of Kenya in conservation of these zones.

Kenya was experiencing an urbanization rate of 29% of total population (2022) and a rate of about 4.3% annual rate of change (STATISTA.COM), which came with its fair share of challenges. High population density has been witnessed in urban centers because of rural-urban migration. This has led to encroachment of riparian areas where people have put up dwelling units, industries where they discharge waste to these rivers, temporary and permanent shops & kiosks, grazing, dumping of wastes, transport corridors e.g., roads, communication infrastructure among others. The encroachment of urban riparian zones in Kenya is unsustainable, as was manifested by demolitions of structures and buildings built on riparian areas e.g.,

demolition of Ukay Centre, Westlands, Southend Mall on the Lang'ata-Mbagathi road junction, and parts of Visa Oshwal Centre, Westlands in August 2018.

The problems facing the Nairobi River have been addressed from different angles in studies such as Omondi (2014), who focused on the challenge of cleaning and maintaining Mathare River in the face of growth of Mathare slums settlement in Nairobi, and Matunda (2015), who explored sustainable management of riparian areas in Kenya. Despite these studies, there is scanty documentation on the application of GIS and remote sensing for mapping and spatial analysis of urban riparian landscape structural change and encroachment in Kenya using either historical or real-time data. Further, despite Kenya having many regulations and policies whose primary focus has been riparian reserve conservation pursued without involvement of the local community, there has been a resulting lack of synergy between state and communities bordering riparian reserves (Matunda 2015, Karangi 2017). This criminalization of riparian zone–community interactions has not been beneficial to the management of riparian zones (National Land Commission, 2018; Zainudin et al., 2013).

Protection of riparian zone has received a lot of attention in Kenya, particularly in Nairobi, due to the continued destruction of life and property whenever rains are experienced. This is crucial because the status quo is not sustainable and inaction will result in destruction of these areas and the ecologically sensitive flora and fauna that inhabit them. Therefore, managing these areas requires effective strategies such as restoration, rehabilitation, conservation, or preservation programs (Schiemer et al., 1999; Cals et al., 1998; Harper et al., 1999; Piegay and Landon, 1997). It is from this perspective that this study assessed urban riparian encroachment by use of remote sensing and legal protection measures in the Nairobi River in Nairobi County. The study also analyzed the legal protection measures in place to protect the Nairobi River riparian reserve and assessed the factors that contribute to urban riparian zone encroachment in the Nairobi River.

LITERATURE REVIEW

This literature review weaves together the spatial evidence, legal context, and institutional dynamics surrounding riparian zones to set the stage for the study's focus and approach. To begin, modern remote sensing technologies, including both aerial and satellite systems, make it possible to gather large amounts of physical data quickly, efficiently, and repeatedly. Geographic Information Systems (GIS) then enable spatial analysis of this information, supporting the generation of different scenarios and improving the overall planning process. These tools also integrate spatial data with socio-economic information, creating a crucial link that strengthens planning by making it more comprehensive, effective, and meaningful. Using remote sensing, Pu et al. (2021) reported a 17% decline in riparian vegetation along the Genesee River in New York between 2006 and 2015. A related Landsat 7 analysis by Olokeogun et al. (2020) covering 1999–2019 revealed that, despite the ecological role of riparian zones in flood control, 19% of built-up areas in the Eleyele region of Ibadan, Nigeria, were located within them. Likewise, Olatidoye et al. (2021) documented a 31% reduction of forest cover within the 150 m Omo Biosphere Reserve between 1986 and 2016. Nsor et al. (2021) identified grazing, bushfires, farming, and logging as drivers of a 54% decline in plant species in riparian areas of Ghana's Kamawu district. Similar patterns were observed by Xu et al. (2020), who found rapid conversion of riparian forests into cropland around Lake Tanganyika between 2001 and 2011, with conversion rates varying according to settlement proximity. From the above studies it is clear that internationally a lot of studies have been done regarding spatial mapping of riparian areas and wetlands. While there is nothing particularly new about using GIS and remote sensing for mapping and spatial analysis, its application for assessing riparian landscape structural change and encroachment has not been fully exploited in Kenya. Most studies or data available explains reasons for invasion/recommendations for protection of riparian zones but there are very few studies that have been done on use of remote sensing for spatial mapping and analysis of encroachment of urban riparian zones in Kenya over time hence the need for more research in this area.

Turning to the legal context, riparian reserves are legally protected public lands along water bodies governed by laws such as Environment Management and Coordination Act (EMCA 1999) and Water Act 2016. Naiman et al (1992) states that simple prescriptive management, such as riparian zones of fixed width, is less effective than management techniques adapted to local topography and natural disturbance regimes. This is a very important consideration for Kenya bearing in mind that the law prescribes a riparian buffer of 30 Meters on either side of the river from the highest water mark. Various studies have been done in Kenya regarding the subject of riparian areas. These include Sustainable management of riparian areas (Jeremiah Matunda., 2015). The author critiques the inadequacy of the legislative framework in Kenya governing the sustainable management of riparian zones in Kenya. This study looks at the existing laws and regulations on riparian areas in Kenya and whether these laws have been able to achieve sustainable management and protection of riparian areas. The study further gives recommendations on the need to harmonize these laws for them to be effective. There is still a need to check if there are any attempts by various stakeholders to harmonize these laws and how that would impact enforcement. Clearly legal clarity is fundamental for the effective management and preservation of riparian areas in Kenya. It is possible that there was insufficient inter-sectoral collaboration during the enactment of laws on wetlands and riparian zones.

Further, regarding ownership, management, and institutional mandates, The Land Act 2012 states that riparian land is owned by the government. Article 62 of the constitution of Kenya 2010 states that public land shall be held by the National Government in trust for the people of Kenya and shall be administered and managed on their behalf by the National land commission. Riparian reserves are classified as ecologically sensitive areas hence are not available for allocation to private entities. The National Land Commission has the power to allocate public land to private entities through a very elaborate process of alienation of public land. However, it is important to note that the commission cannot allocate land demarcated as ecologically sensitive that is along rivers, watersheds and stream catchments (Republic of Kenya; 2012b). Many institutions are involved in management of riparian zones and effective governance of these zones requires collaboration due to different legal frameworks and overlapping mandates. They include National Environment Management Authority (NEMA), National Lands Commission, and Water Resources Authority, Water Resource User Associations, Nairobi River Commission, County department responsible for riparian protection among others.

Management of riparian zones can be explained by the shortcomings of the free access mentality or challenges of managing common pool resources/tragedy of the commons (Hardin., 1968). People do not feel obliged to manage resource they perceive as free or not belonging to a particular person. his study applies the Common Pool Resource (CPR) theory to explain the management challenges facing wetland riparian reserves. Hardin's concept of the "commons," rooted in Mancur Olson's theory of collective action, suggests that individuals or resource users often fail to cooperate voluntarily in pursuing common goals. Left unchecked, this tendency can lead to the collective destruction of shared resources (Schlager, 2004). To prevent such outcomes, Hardin proposed coercive measures through centralized, top-down control by government agencies or external authorities. Such regulation can be implemented using different management strategies, including Command and Control (CAC) measures or incentive-based economic tools. CAC approaches involve direct government legislation and standards that specify what activities are permitted or prohibited, requiring strict compliance. The "control" aspect refers to enforcement mechanisms, such as penalties or sanctions, which are applied in cases of non-compliance. These strategies, while authoritative, aim to ensure sustainable use of common resources by balancing access rights with the need to protect human life and ecological systems.

Incentive-based economic approaches to environmental protection are regulatory tools led by governments that promote conservation by using incentives and price mechanisms, motivating firms and resource users to adopt practices that align with their financial interests (Anderson, 2002). These strategies are guided by the "principle of full cost accounting," which emphasizes state intervention when market activities

fail to reflect the environmental costs of actions, such as wetland degradation. In practice, this involves taxing environmentally harmful activities, raising their costs, lowering demand, and making sustainable alternatives more appealing (Sandborn, 1997). Specific policies may include stricter penalties and civil liabilities for riparian damage, property tax incentives for ecologically valuable lands, transferable tax credits, rewards for environmentally sensitive designs, development rights transfers, and performance bonds for developers. Command and Control policies and economic incentives are sets of instruments that are embedded in complex regulatory systems influenced by politics, and are primarily top-down in approach. Command-and-control measures and economic incentives function as regulatory tools within politically influenced systems that generally apply top-down control. Critics argue that centralized strategies relying heavily on coercion overlook natural human resistance to enforced compliance, often encouraging users to resist such demands (Ostrom, 1990; Ostrom et al., 1994). While state-driven, authoritarian interventions have succeeded in slowing or even reversing environmental degradation, this model alone is inadequate to address the broader and more complex nature of environmental challenges (Schlager, 2004).

Theoretical Framework

This study has employed the landscape governance theory and the stakeholder theory to show how the wetland riparian management dilemma can be solved. Landscape governance theory in riparian management emphasizes a holistic approach that takes cognizance of the interconnectedness of social, economic and ecological factors within the riparian landscape. It promotes integrated management practices as opposed to traditional approaches where management was fragmented and different actors were acting independently. This theory acknowledges that riparian ecosystems are complex hence the need for collaboration, stakeholder participation and addressing power imbalances. It will also ensure that riparian zones are healthy while still meeting the expectations of those who depend on them.

Furthermore, the use of remote sensing techniques to observe riparian landscape will improve on landscape governance since riparian zone managers would be able to observe encroachment patterns and make decisions faster thus preventing further destruction and encroachment of these critical reserves. Inclusivity will ensure that the social and economic aspects of communities living within or near riparian zones is taken into account when making policies and decisions on management of these zones.

In addition, stakeholder theory which is also a key component of this study assumes that shareholders are not the only group with a stake in a company or a corporation. Stakeholder theories argue that clients or customers, suppliers, and the surrounding communities also have a stake in a corporation. Therefore, managers have special obligations to ensure that all stakeholders (not just the shareholders) receive a fair return from their stake in the company (Donaldson & Preston, 1995). Organizations and environmental laws should be formulated with the interest of all stakeholders in mind. It is imperative to note that destruction of riparian zones and wetlands affects everybody hence the need for inclusivity of everybody on environmental issues and decision making.

Accordingly, this implies that NEMA, WRA, WRUAs, County Governments, Ministry of Environment and other institutions act as our managers on matters of protection of riparian areas/environment and there is need for supervision or measurement of performance.

Conceptual Framework

Figure 1 shows how this study links laws, institutions, and evidence to protect riparian reserves. It brings together spatial tools with stakeholder actions to explain what leads to protection or encroachment.

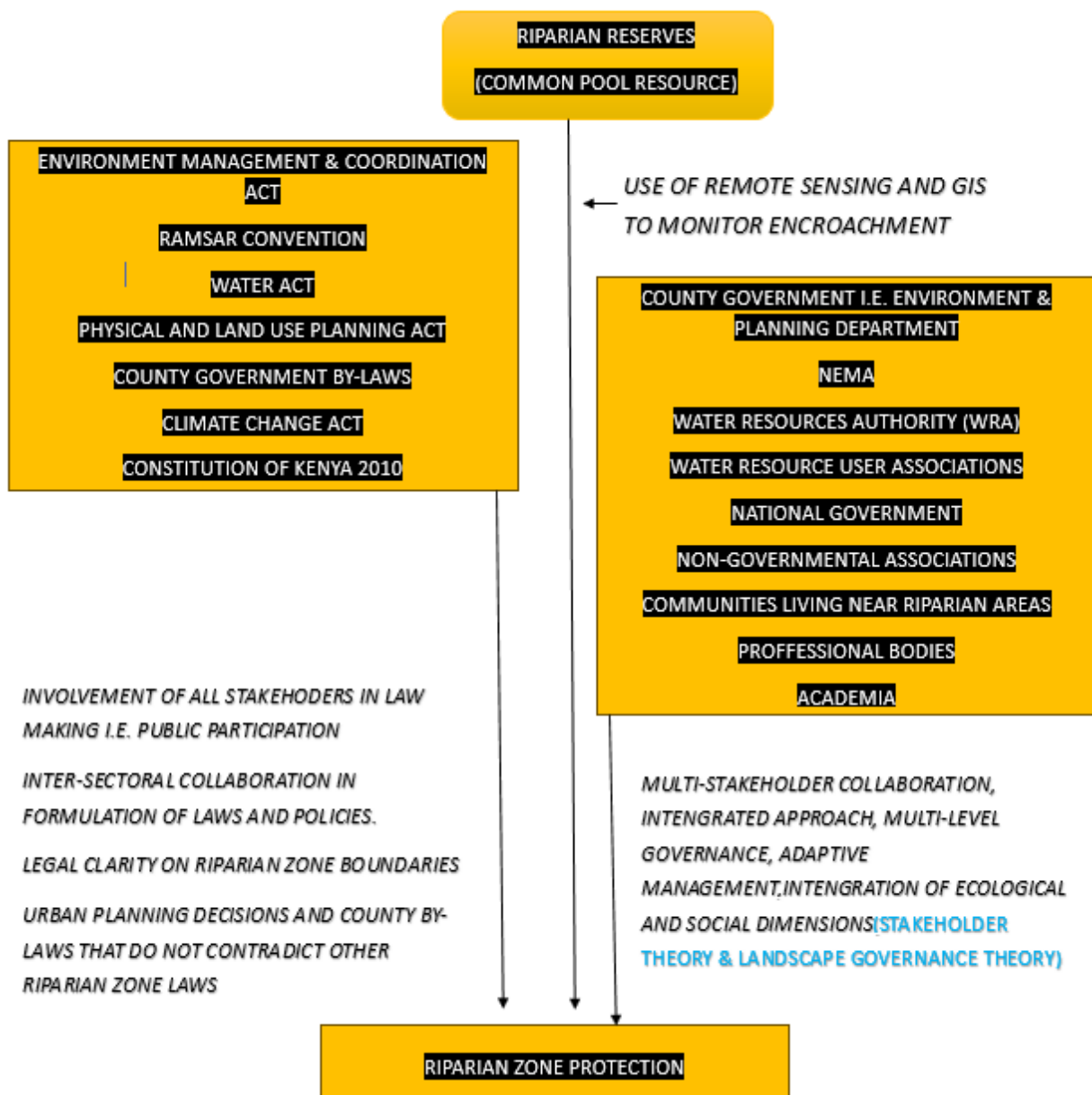


Figure 1: Conceptual Framework for Riparian Encroachment

Source: Researcher (2024)

The framework lists the institutions that should enforce compliance with environmental laws. These include County Government environment and planning departments, NEMA, WRA, WRUAs, the Ministry of Environment, the National Government, non-governmental organizations, communities near riparian areas, professional bodies, and academia.

MATERIALS AND METHODS

The study focused on a 10-kilometer section of the Nairobi River riparian reserve, from Chiromo within the University of Nairobi to Nairobi River Primary School in Kariobangi (coordinates: -1.272497, 36.808331 to -1.268304, 36.876835), as shown in Figure 2. This corridor lies within Nairobi County. It was chosen to examine how governance and socio-economic factors affect riparian protection. The study contrasts areas around government institutions, such as Chiromo and Moi Air Base, where controls are stronger, with places like Globe Roundabout and Gikomba, where enforcement is minimal. The wider span helps show how governance influences buffer protection and what drives encroachment.



Figure 2. Showing study area from Chiromo to Kariobangi (Nairobi River Primary School). (Source Google map images).

The research used both longitudinal and cross-sectional designs. The longitudinal part tracked trends in riparian encroachment over time, while the cross-sectional part provided a snapshot of land use changes and reasons for encroachment. Satellite imagery from Google Earth was used for 1992, 1997, 2002, 2007, 2012, 2017, and 2022. Images were processed in Google Earth Engine at five-year steps, producing six classified images across 30 years. This made it possible to visualize and assess change in the riparian zone. Where helpful, imagery and mapping support from IMAP International and Google Maps were also used.

A combination of purposive and systematic sampling ensured a broad and focused sample. Purposive sampling targeted people living in or near the riparian buffer. Systematic sampling divided the 10-kilometer stretch into ten 1-kilometer segments and selected eight respondents from each. In total, 76 respondents took part, 79% male and 21% female, from varied age groups, education levels, and work experiences. Most were residents or business owners operating within the riparian zone. Using both methods improved coverage and representation.

Data collection included key informant interviews, focus group discussions, and a review of legal and environmental policy documents. Interviews were held with officials from agencies responsible for riparian protection, such as NEMA, the Nairobi County Government, the Ministry of Environment, and the Nairobi River Commission. Focus groups captured views from people living near or within the riparian reserves, including those involved in encroachment. GIS and remote sensing data from IMAP International, Google Maps, and Google Earth supported tracking land use and cover changes from 1992 to 2022.

RESULTS AND DISCUSSIONS

Extent of Encroachment along the Nairobi River Riparian Zone

The study employed Land Use Land Cover (LULC) analysis using satellite imagery from Google Earth Engine (GEE) to assess changes along the Nairobi River riparian zone over the years. Satellite data from Landsat (1992–2022) was used to categorize land cover into four main classes: Water, Built-up Area, Vegetation, and Bare Land. The analysis was conducted at five-year intervals to track the spatial dynamics over time. The results of this analysis, showing the distribution of the land cover classes over the years, are summarized in Figure 2.

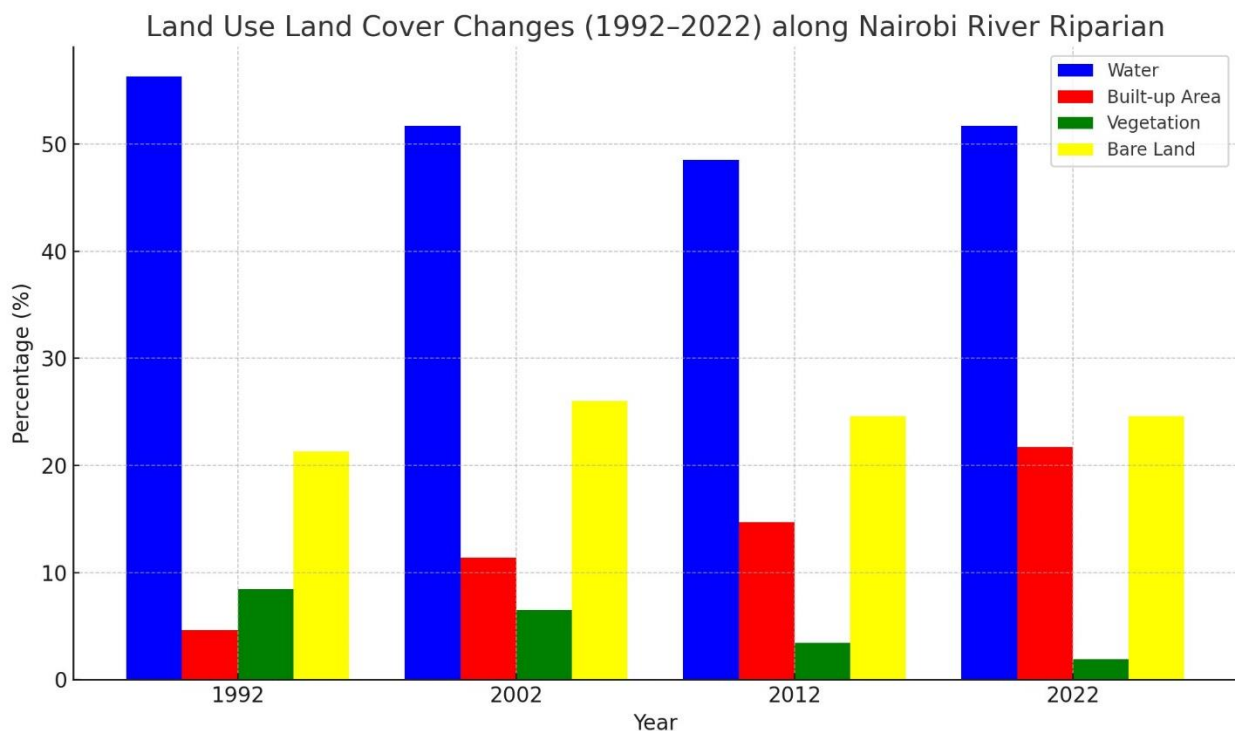


Figure 2 Encroachment trends between 1992 and 2022

Figure 2 shows encroachment trends along the Nairobi River riparian zone between 1992 and 2022, highlighting significant land use changes. Built-up areas grew dramatically, increasing from 4.6% in 1992 to 21.7% in 2022, reflecting rapid urbanization. This expansion, particularly in areas like Gikomba, Globe Roundabout, and Shauri Moyo, has resulted in the encroachment of previously protected riparian zones. In contrast, vegetation coverage sharply declined from 8.4% in 1992 to 1.9% in 2022. Water coverage slightly decreased from 56.3% in 1992 to 51.7% in 2022, driven by factors such as water abstraction and reduced rainfall. Bare land fluctuated over the years, peaking at 26.04% in 2012, with areas like Shauri Moyo showing high levels of exposed land as urban sprawl continued.

In Gikomba, the 2004 satellite image shows an area with more open land along the river, while the 2022 image highlights the spread of informal settlements and businesses into the riparian zone. Similarly, Globe Roundabout saw a shift from minimal development in 2004 to significant construction by 2022, with residential and commercial structures encroaching on the river's natural buffer. In Shauri Moyo, illegal settlements and business activities have progressively taken over the riparian area, further diminishing the natural environment. These changes are evident in both the 2004 and 2022 images, which show a stark transformation from a more open space to one dominated by informal structures.

These encroachment trends are directly linked to the LULC analysis, which tracks the rise of built-up areas and the decline in vegetation and water coverage, highlighting the growing pressure on the Nairobi River's riparian zone.



Figure 3. Globe round about area year 2022 (Google Earth image) showing encroachment.



Figure 4. Globe round about area 2014 (Google Earth image) before encroachment.



Figure 5. Gikomba market area/Majengo, year 2022 (Google Earth image) showing encroachment.



Figure 6. Gikomba market area/Majengo 2004 (Google Earth image) before encroachment, as shown by the arrows.

The following stacked area chart illustrates the land use changes along the Nairobi River riparian zone from 1992 to 2022. By showcasing the area (in square kilometers) occupied by Water, Bareland, Built-up areas, and Vegetation, it provides a clear visual representation of the environmental changes that have occurred over the past three decades.

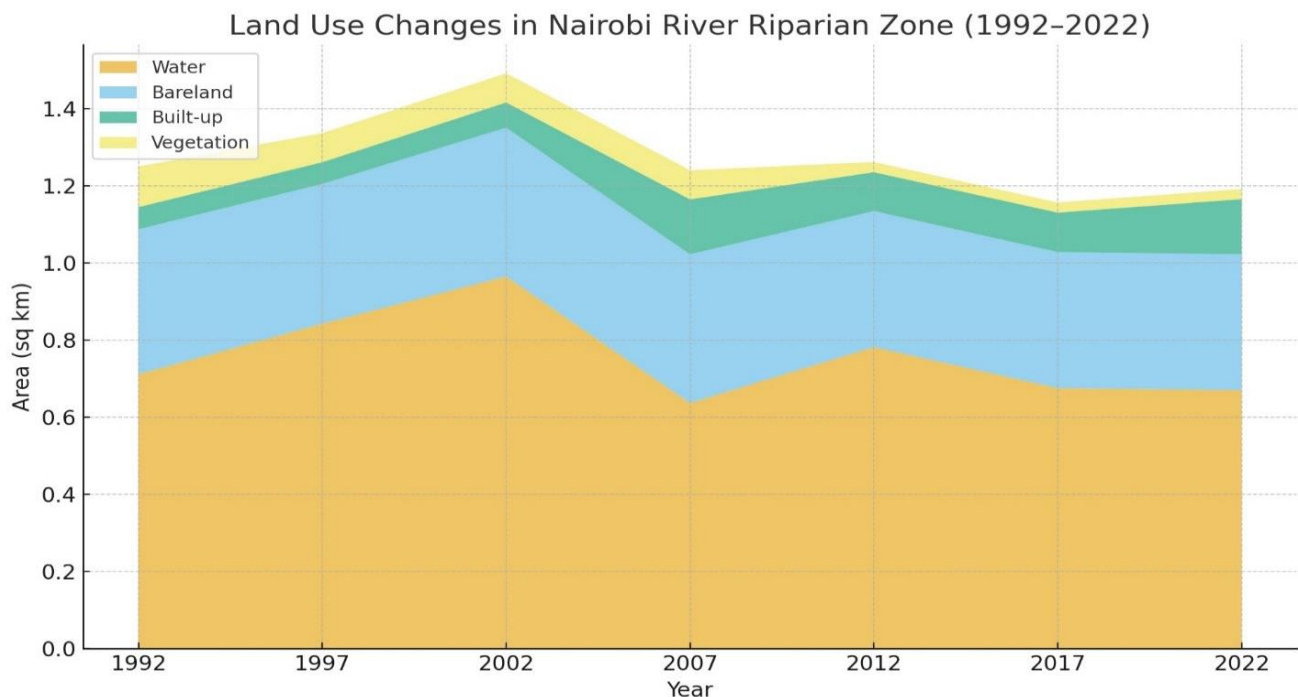


Figure 7. Land Use Land Cover Change Detection

Figure 7 highlights the steady increase in built-up areas, particularly in the last few decades. From a modest 4.61% of the riparian zone in 1992, built-up areas have surged to 11.38% by 2022. This trend reflects rapid urbanization and encroachment into the previously protected riparian zones, with significant developments observed in areas like Gikomba, Globe Roundabout, and Shauri Moyo.

Simultaneously, vegetation coverage has significantly decreased, dropping from 8.44% in 1992 to a mere 2.10% in 2022, illustrating the loss of natural habitats and green spaces. Water coverage has seen a slight decrease, from 56.87% in 1992 to 51.74% in 2022, likely due to urban expansion and changes in water flow. These shifts reflect the broader impact of urban sprawl on the riparian environment, leading to a growing need for sustainable management practices to preserve the ecological balance of the river's banks.

Factors Contributing to Encroachment Along Nairobi River Riparian Zones

The study also identified three key factors contributing to encroachment along the Nairobi River riparian zones. These factors were a combination of socio-economic, environmental, climatic, and infrastructure-related drivers. It emerged that socio-economic factors are key contributors to encroachment along the Nairobi River riparian zones, particularly driven by urbanization, poverty, and the lack of affordable housing. These factors push people to settle in environmentally sensitive areas, further exacerbating the degradation of the riparian buffer. As urbanization continues at a rapid pace, there is growing pressure on land within and around Nairobi, especially in low-income areas. The lack of affordable housing in the city centre has led many individuals and families to settle in riparian zones, where land is perceived to be cheaper or even unregulated. This trend has been exacerbated by the influx of people seeking housing and employment opportunities, further pushing development into environmentally sensitive areas.

The key informants revealed that urbanization, coupled with population growth, has made it increasingly difficult for low-income individuals to find affordable shelter in the city. One urban planner noted:

“As Nairobi grows, we see more people coming into these informal settlements, which are often built in riparian zones. They have no other option because housing in the city centre is simply too expensive.”

This indicates that many people are forced to live in riparian zones due to the lack of viable alternatives for affordable housing.

Similarly, the study found that poverty plays a significant role in driving encroachment. As one participant in a focus group discussion shared:

“The rent in the city is too high. I live here because I can’t afford anywhere else. The government is not doing enough to build houses for people like us. We are forced to settle wherever we can find land, even if it’s near the river.”

This underscores how the lack of affordable housing options in urban areas pushes individuals to settle in informal settlements, often in environmentally protected areas like riparian zones.

In addition, unemployment and the need for economic survival were also significant factors in encroachment. Many people in these areas depend on informal businesses for their livelihoods. As a key informant explained:

“Most of the people you see around here selling goods and services have no other choice. The land is free, and they can easily establish businesses along the river, where customers are always passing by. It’s a way of surviving.”

This suggests that the riparian zone is seen not only as a place to live but also as an economic resource for informal businesses, further contributing to the degradation of the area.

These findings highlight the socio-economic pressures that drive encroachment in riparian zones. The lack of affordable housing, rapid urbanization, and the economic necessity of informal businesses are all intertwined, pushing vulnerable populations to settle and conduct activities in environmentally sensitive areas. Addressing these socio-economic factors through policy changes that promote affordable housing and sustainable livelihoods will be crucial in mitigating the ongoing encroachment on riparian zones.

Having explored the socio-economic drivers of encroachment, the study also identified significant environmental and climatic factors contributing to the degradation of riparian zones along the Nairobi River. These factors, including climate change and water use practices, have further exposed riparian areas to encroachment, as environmental shifts reduce water availability and soil stability in the region. The following section discusses how these environmental changes have led to the increased vulnerability of the riparian zones.

The study found that climate change is a significant driver of encroachment in the riparian zones. Changes in rainfall patterns, along with rising temperatures, have led to reduced water levels in the river, making riparian land more exposed and accessible for settlement and agriculture. An environmental expert who was a key informant highlighted how these climate-induced changes have altered the river's flow and contributed to the degradation of the riparian areas:

“The riparian zones are shrinking because of the changing climate. During the dry seasons, the water levels drop, and the land gets exposed. This has created an opportunity for people to settle there, as the land is no longer covered by water.”

Furthermore, over-abstraction of water from the river for various uses, including car washing, farming, and industrial purposes, has contributed to the decline in water volume within the riparian zones. As one Focus Group Discussion participant shared:

“We see a lot of people coming to use the river water for washing and farming. Over time, the water level keeps dropping, and what was once a protected area becomes a place where people are building.”

These findings suggest that both climate change and water extraction practices have directly impacted the availability of water in riparian zones, further exposing these areas to encroachment.

In addition to climatic factors, the degradation of riparian vegetation has also played a role in the vulnerability of these zones. Unsustainable land management practices, such as deforestation, overgrazing, and poor agricultural practices, have led to the loss of vegetation along the riverbanks. This loss of vegetative cover makes the land more prone to soil erosion and exposes the riparian zones to further human activity.

The study indicates that these environmental and climatic factors are not only reducing the ecological integrity of the riparian zones but also making them more accessible for illegal settlements and unsustainable businesses. Addressing these environmental challenges will require improved management of water resources, soil conservation, and climate change mitigation strategies to ensure the long-term protection of the riparian buffer.

The study also found that poor urban planning and infrastructure development are major contributors to encroachment on riparian zones. Uncontrolled urban sprawl, the lack of zoning regulations, and inadequate planning in rapidly growing urban areas have led to increased pressure on riparian land. This lack of proper planning often results in encroachment into protected riparian zones, where developments such as residential settlements, roads, and markets are constructed.

One urban planner key informant highlighted the problem, saying:

“There are no clear boundaries for riparian zones in the city. As Nairobi expands, developers build wherever they can, even in areas that should be protected.”

Additionally, infrastructure projects like roads and commercial buildings are frequently constructed in riparian areas, further reducing the natural buffer that protects water bodies. These developments contribute to the degradation of the riparian environment, disrupting both the ecological balance and the physical landscape of the river's banks.

Other factors that emerged from the data include a lack of awareness about the importance of riparian zones and their role in environmental protection. Many individuals encroaching on riparian land do so without understanding the long-term ecological consequences. As one focus group participant pointed out, many people do not realize the importance of these zones for flood control and water purification, and they settle in riparian areas because it is cheaper, without understanding the associated environmental risks.

The findings also highlighted corruption and lack of political will as significant challenges in enforcing riparian protection laws. A key informant emphasized that the problem lies not only in the existence of laws but in their enforcement, noting that many land-grabbing cases go unpunished due to corruption within local government offices. Additionally, unclear land tenure and insecure land ownership were found to contribute to encroachment. One informant explained that many people who settle along the river do so without land titles, simply building because they have no other place to go. This lack of formal land ownership further facilitates the encroachment process.

Legal Protection Measures for Nairobi Riparian Zones

The study found that there are several existing legal frameworks aimed at protecting riparian zones, including the Environmental Management and Coordination Act (EMCA) 1999, the Water Act 2002, and the Physical and Land Use Planning Act 2019. These laws are designed to regulate land use around water bodies and establish riparian reserves to protect sensitive environmental areas. However, despite these frameworks, enforcement remains a significant challenge. The study found that overlapping mandates and conflicting provisions in the laws create confusion among institutions and stakeholders responsible for enforcement.

As one key informant explained, “There are challenges in enforcement which have been created by overlapping mandates/roles of different institutions. This necessitates the need for inclusiveness,

collaboration, and synergy among all stakeholders.” This highlights the need for clearer jurisdiction and better coordination among institutions to address the gaps in legal clarity and ensure consistent protection of riparian zones.

Further complicating the situation, the study identified weak enforcement and a lack of clear guidance on riparian width in various laws. For example, the Survey Act 1994 stipulates a 30-meter buffer for riparian reserves on government land, but it does not provide guidelines for private or community land. This lack of uniformity leaves riparian areas vulnerable to illegal development. A key informant pointed out, “The law is clear, but conflicts with other laws regarding the definition of riparian width for different wetland classes.” This inconsistency in riparian buffer definitions creates confusion about what constitutes a legally protected area, leaving room for encroachment.

The Water Quality Regulations (2006) and Physical and Land Use Planning Act (2019) set out similar riparian reserve requirements, but the study found that these regulations are poorly enforced, especially in urban areas. The Physical and Land Use Planning Act calls for a 10–30-meter buffer for rivers, but without proper coordinated action between NEMA, the National Land Commission, and County Governments, these provisions are inconsistently applied. One key informant stated, “The problem is not only about the laws, but also about who enforces them. Many land-grabbing cases go unpunished because of corruption within local government offices.” This underscores how political interference and corruption further undermine the effectiveness of legal protection for riparian zones.

While several legal protection measures exist, the study found that the current legal framework for riparian protection is not fully effective in preventing encroachment. The gaps in enforcement, coupled with overlapping mandates and institutional conflicts, have resulted in weak governance in the management of riparian zones. Corruption, political interference, and insufficient resources have further hindered the enforcement of existing laws, leaving riparian zones vulnerable to continued encroachment. One key informant noted that it is not just the existence of laws, but the effectiveness of enforcement that remains problematic, as land-grabbing cases often go unpunished due to these issues. To address these challenges, the study recommends improving coordination between NEMA, County Governments, the Water Resources Authority, and the National Land Commission. Additionally, the study suggests amending existing laws to provide a clear, standard interpretation of riparian width and to establish stronger enforcement mechanisms, ensuring the effective protection of riparian areas.

CONCLUSION AND RECOMMENDATIONS

This study highlights the significant encroachment of the Nairobi River riparian zone, driven by rapid urbanization, socio-economic pressures, and weak enforcement of existing legal frameworks. The findings underscore the critical need for more effective protection measures to safeguard these vital ecosystems. With clear and harmonized legislation, strengthened institutional coordination, and community involvement, riparian zones can be preserved for future generations. Effective land use planning, alongside improved enforcement mechanisms, would help prevent further degradation. Additionally, integrating modern tools like remote sensing for monitoring and decision-making can significantly enhance the management of these sensitive areas. Ultimately, with committed efforts from all stakeholders, the protection of Nairobi's riparian zones is achievable, ensuring ecological stability and urban resilience against flooding and other environmental challenges.

Based on the findings from the study, the following recommendations are proposed to improve the protection of riparian land reserves along the Nairobi River. The government should prioritize the Affordable Housing Program (AHP) and enhance national slum upgrading programs. By focusing on increasing the availability of affordable housing for low-income urban populations, the pressure on riparian zones for settlement purposes can be reduced. Through the Bottom-Up Economic Transformation Model, the

government can bridge the housing gap by ensuring that the urban poor have access to decent and affordable housing, thus decreasing the desire to encroach on riparian lands.

Addressing the issue of rural-urban migration is also crucial. The migration of youth in search of education and employment is a major contributor to urban encroachment. To reduce the pressure on urban areas, the government should introduce programs and projects that promote economic growth within rural areas. This includes decentralizing government projects, such as Export Processing Zones (EPZs), to offer job opportunities closer to home. By doing so, fewer people will feel the need to move to urban areas, thus reducing the number of people settling in informal settlements and encroaching on riparian reserves.

County governments should conduct proper inspections before issuing development approvals for buildings near riparian areas. It is essential that Planning Officers or relevant authorities physically inspect sites to ensure that new developments do not fall within riparian zones. Land uses that are compatible with riparian areas should be encouraged, while industrial developments that could pollute these areas should be avoided. Additionally, county governments must be adequately funded to carry out these inspections and improve enforcement to protect riparian zones effectively.

There is a pressing need for enhanced collaboration between state agencies like NEMA, the Water Resources Authority, the Ministry of Environment, and County Governments. These agencies must work together to create policies and action plans aimed at protecting riparian reserves. The government should establish clear guidelines defining the responsibilities of each institution and the permissible land uses within riparian buffers. Effective inter-agency collaboration will streamline enforcement, reduce overlaps, and ensure that riparian areas are protected from further encroachment.

The government should invest in the use of remote sensing technology to map and monitor riparian areas. Setting up a GIS and earth observation laboratory would enable NEMA and other agencies to regularly monitor riparian zones, allowing for the identification of encroachment trends in real-time. This cost-effective method of monitoring will reduce the need for physical ground surveys and provide decision-makers with timely data to take swift action to prevent further encroachment.

Public awareness campaigns and community engagement are also vital in the effort to protect riparian zones. Educating local communities, especially those living in or near riparian areas, about the ecological value of these zones and the consequences of encroachment is critical. Involving local communities in the management and decision-making processes through participatory governance can foster a sense of ownership and responsibility, ultimately leading to more sustainable riparian management.

To further support riparian protection, the government should incentivize green infrastructure development. Developers should be encouraged to incorporate sustainable practices such as rainwater harvesting, green buffers, and eco-friendly drainage systems into their projects. Offering incentives, such as tax breaks or development permits for green buildings, would encourage environmentally-conscious urban development while protecting riparian zones from further degradation.

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