SETTLEMENT DEVELOPMENT AND ITS IMPLICATIONS ON NAIROBI RIVER RIPARIAN ZONE, NAIROBI CITY COUNTY, KENYA

Omusisi Aineah Poulman

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DECLARATION

This research project is my original work and has not been presented for a degree in any other University or for any other award.

Poulman Aineah Omusisi

Department of Environmental Planning and Management

Signature…… Date……

This research project has been submitted with my approval as the University supervisor.

Dr. Sammy C. Letema

Department of Environmental Planning and Management

Kenyatta University

Signature: ……. Date: …….

DEDICATION

I dedicate this work to the Department of Environmental Planning and Management, my supervisor, and my family. They have supported me financially and intellectually in this research study, and made me to become the person I am today.

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ABBREVIATIONS AND ACRONYMS

AWN	African Water Network
CBD	Central Business District
CRA	Comprehensive Risk Assessment
D.R.C.	Democratic Republic of Congo
DURR	Department of Urban Rivers Restoration
EMCA	Environmental Management and Coordination Act
IWM	Integrated Watershed Management
IWRM	Integrated Water Resource Management
KFS	Kenya Forest Service
LPDP	Local Physical Development Plans
LULC	Land Use Land Cover
LVPC	Lehigh Valley Planning Commission
NCCC	Nairobi City County Council
NEMA	National Environment Management Authority
NETWAS	Network for Water and Sanitation International
NMS	Nairobi Metropolitan Service
NRC	National Resource Council
NRRRP	Nairobi River Regeneration and Rehabilitation Program
PDPs	Physical Development Plans
PFC	Proper Functioning Condition
PPH	Physical Planning Handbook
RoK	Republic of Kenya
RS	Remote Sensing
SPSS	Statistical Program for Social Sciences
SSA	Sub Saharan Africa
TOC	Tragedy of the Commons
WRA	Water Resources Authority

ABSTRACT

A balance between the aquatic ecosystem such as a riparian zone and human settlement is vital for the socio-economic growth of urban areas. Human settlement is one of the primary element that characterizes urban development in developing countries. The rapid growth of human settlements in urban areas and cities has adverse effects on the relationship between natural and human environments. The capital city of Kenya, Nairobi, has witnessed rapid human settlements resulting in the degradation of Nairobi River riparian zone. Efforts to rehabilitate and restore the riparian zone have been futile since 1999. The purpose of this study was to determine how urban development has impacted on Nairobi River riparian zone. The objectives of this study were to assess human settlement developmental trends and its spatial distribution, determine the extent and nature of Nairobi River riparian zone, and assess efforts to reclaim Nairobi River riparian zone. The study employed descriptive research design through purposive sampling to identify and interview key informants from government agencies using prospective evaluation method. Landsat images between 2000 and 2020 were processed and analyzed using Google Earth Engine and ArcMap to detect land use changes as well as encroachments on Nairobi River riparian zones. The findings show a negative correlation between settlement development and Nairobi River riparian zone. The study concludes that Nairobi River regeneration plan for rehabilitating and restoring Nairobi River riparian zone has partially achieved its objectives. However, it faces challenges witnessed by presence of formal and informal settlements in the riparian zone. The study recommends that, future interventions, such as the delineation of Nairobi River riparian zone by marking its extent, enforcing development control rules and guidelines on new and existing settlement developments plus other policies on riparian conservation are necessary. Finally, there is need to ensure existing and new settlements along Nairobi River do not encroach the riparian zone for sustainable management.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Riparian zones link the subsurface and surface hydrology, where the water bodies connect with the dry lands (Zaimes and Schultz, 2015). Riparian lands are characterized by three major components, soil, vegetation, and water; which have significant functions that support human and environmental domains and maintain ecological balance (Zaimes and Schultz, 2015). Riparian vegetation is important in controlling eutrophication, reduction of water erosion, storage of floodwaters, and significant wildlife habitat (Dosskey *et al*., 2010).

Human-related developments tend to thrive near fresh waterbodies such as streams, rivers, and lakes (Iakovoglou *et al*., 2012). Urban growth and development have altered the composition of natural environment, contributing to degradation of urban rivers and riparian zones (Francis and Hoggart, 2008; Guneralp *et al*., 2015). This practice adversely affects the downstream by increasing water discharge during heavy rainfall, leading to flooding (Suriya and Mudgal, 2012). Degradation of riparian land is associated with the existence of settlement development, which causes reduced water quality, caused by sedimentation and pollution, arising from increased anthropogenic activities (O'Driscoll *et al.*, 2010).

The rapid increase in human settlements around a water body degrades the natural environment, such as the riparian zone. India's Dehradun, the capital city of Uttarakhand state has experienced rapid urbanization in the last ten years (Olokeogun & Kumar, 2020). Dehradun is made up of large networks of water streams, and the growth of human settlement has resulted in the encroachment of the riparian zones, which affects the aquatic ecosystem (Olokeogun & Kumar, 2020). An analysis of land cover changes between 2000 and 2019 showed that built up and agricultural land uses increased from 15.51% to 19.36% and 16.80% to 18.70%, respectively. Additionally, vegetation covers along the riparian zone during the same period decreased from 64.01% to 50.84% (Olokeogun & Kumar, 2020). Additionally, increasing human population and land-use changes put pressure on rivers and riparian zones (Ganie et al., 2022). China's fifth longest river, Songhua, experiences human activities such as build-up and agricultural activities, adversely affecting 60% of the riparian zone (Ganie et al., 2022).

Settlement development along rivers, lakes, and other water bodies has a devastating effect on the riparian zone. Lake Tanganyika, located at the border between D.R.C and Tanzania, experiences tremendous land cover changes associated with human activities that degrade the riparian zone (Xu et al., 2020). Settlements, agricultural activities, and seasonal pasture are the dominant land cover types associated with a decline in wetland vegetation and woodland by 2.51% and 0.09% between 1984 and 2001 (Xu et al., 2020). Therefore, settlement development around L. Tanganyika contributed to the degradation of the riparian zone. Additionally, human settlement growth in various regions of Ghana, such as Kumasi, is associated with decreasing coverage of the riparian zone of the Sisa stream (Darkwah et al., 2018). Unplanned human settlement in urban and rural areas negatively impacts the riparian zone. Human settlement development in Sisaakyi, Ghana, adversely affects the riparian zone because of limited habitable land that has influenced the community to encroach on the neighboring river's riparian zone (Darkwah et al., 2018).

The rapid growth of human settlement in Kenya's urban areas has resulted in the encroachment of riparian zones, adversely affecting the aquatic ecosystem. The encroachment of River Riara's riparian zone in Kiambu County shows the implications of rapid human settlements in urban and rural areas (Mugambi et al., 2022). A spatial analysis of River Riara using NDVI and NDBI shows an increase in built-up areas and a decrease in vegetation cover along the river between 1973 and 2021 (Mugambi et al., 2022). Urban development, characterized by expanding human settlements, interferes with riparian zones (Gesora et al., 2022). Additionally, human activities in Lake Victoria riparian zone have resulted in the loss of 50% of the papyrus riparian zone between 1969 and 2000 (Gesora et al., 2022). The degradation of riparian zones in Kenya's urban and rural areas is associated with increasing human settlement and related activities. Karisa (2010) states that the encroachment of the riparian zones in the three rivers in Nairobi City, which include Ngong, Mathare, and Nairobi, is associated with human settlement. The location of the Ukay Centre on the Nairobi River riparian zone shows the riparian zone encroachment by human settlement in urban areas (Departmental Committee on Environment and Natural Resources, 2019). Therefore, this study was designed to assess settlement development and its consequences on Nairobi River riparian zone in Nairobi City County.

1.2 Statement of the Problem

Rapid population and urban growth have contributed to more than 50% of the world's population residing in cities and urban areas (UN-DESA, 2014). Settlement development expansion into peri-urban and rural areas is characterized by unplanned and uncoordinated development (Van Asperen, 2014; Kago and Seitchiping, 2017). Conversion of agricultural land to peri-urban development results in urban sprawl, encroachment, illegal subdivision of private land, and destruction of fragile ecosystems (Kago and Seitchiping, 2017).

Urbanization coupled with inadequate planning has resulted in the expansion of human infrastructure, which has led to draining of swamps and encroachment of riparian zones for optimal use (Mbui *et al*., 2010). Despite the presence of various policies and institutional frameworks to manage urban development and conservation of riparian zones, little outcome has been achieved in cleaning and reclaiming areas along Nairobi River as espoused by recent Nairobi regeneration efforts, which has been criticized based on its execution (Departmental Committee on Environment and Natural Resources, 2019).

Urbanization in Nairobi City and its adjacent environs has been associated with diversion of rivers, clearance of riparian vegetation, increased water pollution, flooding, and development of informal settlements along the riparian zones. Encroachment and degradation have been identified as major challenges facing riparian zone in Nairobi River since the late 1990s (Lelo *et al*., 2005). Unplanned urban development and human settlement have remained noticeable elements in most sections adjacent to Nairobi River (Mwiti, 2014). Therefore, the purpose of this study was to assess human settlement development and its consequences on Nairobi River riparian zone in Nairobi City County.

1.3 Research Questions

1. What are the human settlement developmental trends and spatial distribution in Nairobi River riparian zone?
2. What is the extent and nature of Nairobi River riparian zone?
3. What is the role of Nairobi River regeneration in riparian land management?

1.4 Objectives of the Study

The objectives of this study were:

1. To assess human settlement developmental trends and its spatial distribution in the Nairobi River riparian zone.
2. To determine the extent and nature of the riparian zone in Nairobi River riparian zone.
3. To assess Nairobi River regeneration plan in reclaiming the riparian zone in Nairobi River.

1.5 Justification of the Study

Efforts to reclaim and restore Nairobi River riparian zone have been futile in the past and present. The 1999 Nairobi Basin Programme aimed to clean up the river, and subsequent efforts in 2001, 2003, and 2007 achieved less than expected (RoK, 2016). Nairobi River Regeneration and Rehabilitation Program (NRRRP) was conceptualized and outsourced by Nairobi City County Government to clean and conserve the riparian zone (RoK, 2016).

Expansion of Nairobi city is extending into peri-urban and rural areas of Kiambu County, which forms the upper catchment, affecting land use activities (Van Asperen, 2014). Agricultural land is being converted to peri-urban development, resulting in urban sprawl, encroachment of idle land (riparian zones), illegal subdivision of private land, flooding, and destruction of fragile ecosystem (Kago and Seitchiping, 2017). Land use changes have adversely affected the riparian zone downstream because of altered ecosystem at the river source, thus affecting water discharge in Nairobi River.

Degradation of the riparian zones along Nairobi River and other wetlands is linked to weak policies and institutional frameworks (Lelo *et al*., 2005). Stipulated land administrative guidelines and procedures do not clearly outline measures to secure the riparian reserve distance and vegetation cover. Moreover, failure of buildings adjacent to the river basins is associated with inadequate development control measures and building inspection by the relevant authorities.

Riparian zones are the most fragile ecosystem in urban regions because of their complex watershed system (Haase, 2017). However, riparian vegetation contributes to flood water retention. Riparian zones serves as an essential facet in enabling urban areas to become climate

change resilient (Krosby, *et al.,* 2018). They are considered nature-based solution in urban areas for mitigating and adaptation of climate change effects, such as floods and drought (Krosby *et al*., 2018). The National Climate Change Action Plan outlines the activities needed by counties to address climate change and achieve low carbon climate resilient sustainable development (RoK, 2016).

1.6 Significance of the Study

The study was conceptualized to assess the relationship between settlement development and environmental conservation of Nairobi River riparian zone. Various policies, laws, regulations, and guidelines protect riparian zones in Kenya. This study streamlined its objectives to achieve a balanced urban plan. Urban sprawl and encroachment of riparian zones in urban areas are inevitable. Assessing settlement patterns, land use activities, and delineating the riparian zone will foster re-evaluation of current regeneration plan. The study identified existing policy gaps in restoring the riparian ecosystem along Nairobi River.

The study is helpful in assisting the public and other stakeholders to understand and appreciate the role of the riparian zone in the management of water resources and other land-based resources. The public ought to understand the functions of riparian zone as one of the essential components in watershed management.

1.7 Conceptual Framework

Riparian zone management relies on three major factors: socio-economic, biophysical (physiographic), and policy and institutional. These factors influence the use of land and its management. Land tenure influences the riparian zone since it provides the landowner with permission to develop the land in whichever manner, but it is restricted through development control measures.

However, insecure land tenure results in establishment of temporal structures along the riparian zone. This is evident in the establishment of informal settlements within the riparian zone. Policy and institutional factors assist in the management of riparian zones. Mwiti (2014) notes that different laws in Kenya stipulate the minimum distance for any development from the riparian land. This factor provides for the formation of various institutions and their roles in the

management of riparian land. Biophysical factors assist to determine the implications of degrading riparian zones and develop a sustainable plan to address the effects (NRC, 2002).

Setting water quality standards and goals are essential in addressing environmental problems in a riparian zones. These standards are set by different government agencies to formulate regulations and serve as indicators. Solving a non-point environmental problem, such as watershed degradation requires integrated approach to assess conditions and come up with management strategies (US EPA and Office of Wetlands Oceans and Watersheds, n.d.).

A watershed framework aggregates the efforts of different actors in the management process to work together for a common goal. The end-result of a watershed framework is a watershed management plan that seeks to restore and protect developed actions in managing identified problems (US EPA and Office of Wetlands Oceans and Watersheds, n.d.).

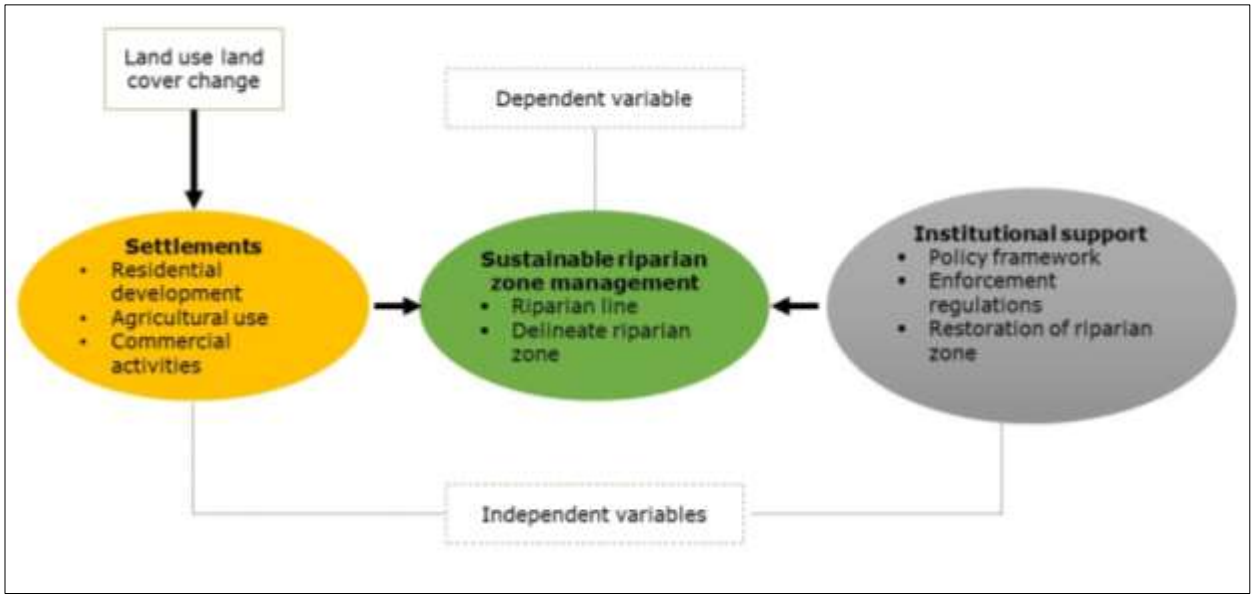

Figure 1 Multi-disciplinary approach in the development of riparian zone management plan

1.8 Definition of Terms

Comparative risk assessment is a conceptual and methodological framework that assesses the impacts different environmental threats on human health, ecological, and quality of life (Miller and Roo, 2016).

Greenbelt entails open spaces within urban areas aimed to protect land from effects of rapid urbanization, such as urban sprawl, by limiting conversion of land use (Ramesh and Nijagunappa, 2014).

Prospective or formative evaluation identifies the challenges and comes up with possible alternatives to strengthen and address weaknesses in the programme. It is continuous in nature (Jack and Breeze, 2008).

A riparian zone is an area that links the subsurface and surface hydrology, where the water bodies connect with the dry land (Zaimes and Schultz, 2015).

Urban development entails the relationship and change in the physical, social, geographical, and economic components that propel the process of urbanization (Cremer-Schulte, 2014).

Watershed is a complex connection between watershed boundaries and the hydrologic cycle that define the stream flow (Edwards, 2015).

CHAPTER TWO

LITERATURE REVIEW

2.1 Riparian Zones

A riparian zone is a land adjoining terrestrial and aquatic habitats (Karisa, 2010). In watershed conservation, greater reduction in river flow is associated with increased extent of encroachment of riparian land (Miller *et al*., 2013). Encroachment of riparian land leads to alteration of river flow, which affects riparian ecosystem functions and biodiversity (Poff & Zimmerman, 2010). The expansion of urban areas and need to establish urban activities and structures lead to clearance of fragile ecosystem in some sections of the city (UN-Habitat, 2016). Inadequate planning and increased human settlements results in encroachment of riparian zones and wetland by both formal and informal sectors (O'Driscoll *et al*., 2010).

Riparian land is a significant resource that sustains water quality, terrestrial and aquatic ecosystems by providing essential riparian functions (Swanson *et al*., 2017). These functions assist in maintenance of water temperature, provision of ecosystem services such as fisheries and recreation activities, and impacts on nutrient loads and dissolved oxygen. A Proper Functioning Condition (PFC) of a riparian zone is based on the availability of adequate vegetation and landform (Dickard *et al*., 2015). A riparian zone with these conditions has the following significance; dispel river energy linked to high water discharge thus reducing water erosion, improve groundwater discharge, and assist in development of floodplain by capturing sediment (NRC, 2002).

2.1.1 Delineation of Riparian Zones

Riparian zones delineation is determined by the landscape and the geology of the area (Ilhardt, Verry, and Palik, 2000). Geomorphology forms the basis of riparian zone delineation. Riparian zones are delineated in various methods; fixed width, variable-width methods, and multi-zone models (Ilhardt *et al*., 2000). The width of riparian zone is dependent on its function and natural factors such as soil type and topography (Lehigh Valley Planning Commission (LVPC), 2011). Single generic riparian zone width cannot support the function of the river, as the case of Kenya's regulations that stipulate a 30-metre riparian width for most water bodies (Mbui *et al*., 2010). An effective riparian zone is influenced by its width and vegetation within the zone

(LVPC, 2011). Riparian zone width for streams and wetland habitats can be established using fixed-width and variable-width methods (Johnson & Ryba, 1992).

The fixed-width method aims to protect specific functions, while variable-width focuses on site-specific conditions (Ilhardt *et al*., 2000). A fixed width buffer has a specific distance that applies to the whole catchment area. This method is easy to enforce and may not require personnel with any specialty to implement, but may result in uninformed riparian distances at various stages of the river course, which might not be appropriate since it may neglect essential components of the riparian zone or the watershed (Ilhardt *et al*., 2000). The variable-width method is flexible in nature, thus encouraging sustainable land management practices for land users (Salo, Theobald, and Brown, 2016). This method focuses on site-specific conditions and ecological functions of a particular section along the river course (Johnson & Ryba, 1992). However, this method is time-consuming in decision-making and implementation (Salo *et al*., 2016).

2.1.2 Land-Use and Land-Cover Mapping

Remotely sensed data provide detailed information for changes caused by human activities. Rapid urban development is characterized by encroachments, haphazard urban growth, and unplanned land-use change (Netzband *et al.*, 2007). Remote sensing is an essential tool in assessing the impacts of changes in urban LULC on the environment. Satellite data can be used to detect and assess information about geomorphology, hydrological features, land use, and geological features (Netzband *et al*., 2007). The dynamic nature of urban areas requires a spatial tool that is effective and reliable. Remote sensing assists in monitoring LULC changes and helps urban planners and decision makers. Remote sensing technology has been applied in detecting encroachment and land conversion (LULC) (Netzband *et al*., 2007).

2.1.3 Environmental Control in Riparian Zones

Comparative Risk Assessment

CRA uses both conceptual and methodological framework to assess the impacts of different environmental threats on human health, ecological, and quality of life (Miller and Roo, 2016). CRA analyses the environmental risks through comparison and prioritization. In risk-based environmental planning, CRA is an essential component is setting priorities, developing strategies, allocating resources, and monitoring the environment (Roo and Miller, 2004). The analysis of different factors affecting the natural environment is essential in deciding the ideal

option to adopt in conservation efforts. Schafer *et al*., (2019) states that CRA allows stakeholders in weighing options and selecting an option with the least environmental side effects.

Risk-based planning (RBP) is characterized by its ability to be information-driven and inclusivity (Miller and Roo, 2016). RBP uses available data to make informed decisions than relying on speculations towards environmental threats. RBP processes are holistic in nature because it reaches out to different stakeholders in the community (Chiueh *et al.*, 2012).

Risk-Based Environmental Planning

Initiated by Seattle Mayor, Norm Rice, risk-based environmental planning aimed to transform the way the local government managed its environmental issues without creating new office or committee (Miller and Roo, 2016). The holistic and integrated nature of RBEP would help the city government identify the environmental problem, prioritize, choose the best solution to address the problem, and outline the role of the city's government (Chiueh *et al*., 2012).

Integrated Environmental Zoning

IEZ is a comprehensive and innovative approach that uses spatial data to map out environmental problems and seeks to on how address them (Miller & Roo, 2016). IEZ seeks to protect environmentally sensitive areas from adverse effects of environmental degradation. Environmental management and land-use planning are aggregated for a comprehensive decision-making process to address arising issues (Miller & Roo, 2016).

Proposed by the Dutch government in its National Environmental Policy Plan of 1989, IEZ is spatially oriented and holistic in nature (Roo & Miller, 2004). IEZ combines various sources and types of environmental impacts in a given geographic region. IEZ focuses on mapping adverse anthropogenic activities, as in suitability analysis to make land-use maps for decision-making (Chiueh *et al*., 2012). Similar to suitability analysis, IEZ is an innovative and ambitious method in safeguarding fragile urban areas, such as residential and wetland areas (Roo & Miller, 2004).

2.2 Settlement Development

Human settlement is a location in the environment where humans reside, and it is characterized by urbanization, a process that converts a region or area to an urban state (World Bank, 2016). This process alters natural habitat and might have irreversible implications on biodiversity, agriculture, and ecosystem services (Thorne *et al*., 2013). Urban development entails four

dimensions that propel the process of urbanization: physical, geographical, economic, and social (Cremer-Schulte, 2014). The physical dimension includes land-use changes, whereas geographical domain includes demographic characteristics; whereas the social and economic dimension includes cultural changes and agglomeration economies respectively (Cremer-Schulte, 2014).

The relationship between urbanization and biodiversity conservation is a complex process (Guneralp *et al.*, 2015). Unplanned urban development and associated land-use changes result in destruction of natural habitat (Thorne *et al*., 2013). Development of urban infrastructure may lead to development of peri-urban areas beyond the city boundary, which affects the watershed, ecologically sensitive areas, and thus threatening the existence of natural habitat (Guneralp *et al.*, 2015). Interaction among land use, conservation, and urbanization policies; determine the extent to which urban development impacts on biodiversity (Reed *et al*., 2014).

Rapid urban development without appropriate legal and institutional framework poses social, economic, and environmental challenges. Xia *et al*., (2017) states that China experienced rapid urban development from 10.64 percent to 56.10% between 1949 and 2015. The rapid increase in China's urban development is a positive sign, but raises several issues, such as environmental deterioration, resource shortage, and urban waterlogging (Xia *et al*., 2017). Rapid urban development results in urban water logging witnessed in cities such as Wuhan. The change in natural hydrological processes and rapid expansion of urban areas results in these disaster. However, urban conservation in China aims to promote balance between urban development and environmental conservation. Xia *et al*., (2017) claims that the construction of Sponge City in China aims to combat the adverse impacts of urbanization on hydrological cycle.

Rapid urban development in Africa continues to adversely affect the social and environmental domains. Major cities experiencing rapid urban development are Nairobi, Kinshasa, Khartoum, Lagos, Cairo, and Johannesburg-Pretoria (Guneralp *et al*., 2017). The prevalence of urban primacy, overreliance on one city as the social, economic, and political center, poses a threat to urban conservation efforts. Gunerapl *et al*., (2017) claims that rapid urbanization with inadequate land-use planning results in loss and depredation of habitats around urban areas. Human activities, such as peri-urban agriculture and human settlements degrade the environment from the center moving outwards. Regions like southern Cameroon experience high population growth

rate, which puts pressure on existing natural habitat. Therefore, rapid urban development with inadequate land use planning degrades the environment and related conservation efforts.

Urbanization in Sub-Saharan Africa (SSA) is transforming various regions rapidly. The population of major urban areas in SSA has 472 million people, and it is forecasted to double over the next twenty-five years (Saghir & Santoro, 2018). The increase in urban population across SSA countries poses a threat to other sectors of the economy because many urban areas are not well-equipped to mitigate the risks associated with urbanization (Saghir & Santoro, 2018). Toure et al., (2018) states that Ghana's population growth has tremendously increased from 6 million in 1957 to 29 million in 2017, which is attributed to urbanization. The transformation of urban areas is associated to adversely affect the state of LULC.

Kenya is one of the countries based in SSA, and it experiences rapid urban development that negatively affects other sectors such as water resources (Ochola, 2018). Urbanization encourages industrial development, which attracts rural-urban migration, and adversely affects the environment through pollution. Karuku and Kathula (2021) found that the population of people residing in urban areas and cities grew from 23.18% in 2009 to 27.51% in 2019. Urbanization in most Kenya's towns has resulted in degradation of the environment. Nairobi River faces pollution because of the population residing adjacent to it, and River Migori that passes in Migori town experiences extreme pollution (Ochola, 2018).

2.3 Implications of Settlement Development in Riparian Zones

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

that results in loss of riparian vegetation along Sabinal River in Chiapas state in Southern Mexico (Diaz-Pascacio et al., 2018). Therefore, human settlement development adversely affects the riparian zone.

Riparian zones in Kenya experience human settlement interference that results in loss of biodiversity and other disturbance. Human settlement related activities such as agricultural activities, water abstraction for domestic use results in loss of canopy cover in Njoro River and Kamweti River (Koskey et al., 2021). Built up areas development within and around the riparian zone of Njoro and Kamweti Rivers are linked to various human activities that result in the loss of biological integrity that affects riparian vegetation (Koskey et al., 2021). Riparian zones of urban rivers in Kenya such as Sosiani River in Eldoret town, Uasin Gishu County experience the loss of riparian zone vegetation that assists in the filtering mechanism (Nyakora, 2016). Additionally, Nyakora (2016) links human settlement development along urban rivers with land use changes that alter the natural aquatic ecosystem, which explains the effect of grazing at the edge of Sosiani River. Informal settlement is one of the leading land uses that adversely affect riparian zones in Nairobi's three main rivers, Ngong, Mathare, and Nairobi river (Muketha, 2020).

2.4 Kenya Legislations on Conservation of Riparian Zone

2.4.1 The Agriculture Cap 318

This Act guides relevant government agencies and stakeholders in agricultural-related activities to promote and maintain sustainable agriculture. It encourages sustainable agricultural activities, which are characterized by soil conservation to enhance good land management. Additionally, the Agriculture (Farm Forestry) Rules, 2009 aim to protect and conserve riparian and wetland areas (RoK, 2012). The stipulated activities include inhibiting landowners or occupiers from practicing unsustainable agriculture activities such as planting Eucalyptus species in wetlands and riparian zone. Thus, the Agriculture (Farm Forestry) Rules, 2009 is a relevant Act in protecting and restoring Nairobi River riparian land.

The Agriculture (Basic Land Usage) Rules, 1965 conserves riparian land along rivers because it discourages cultivation on land with slope exceeding 12, 20, and 35 percent, as outlined in section 3 and 5 (RoK, 2012). Additionally, the Agriculture Rules, 1965 is relevant in the protection of watercourse under section 6. It prohibits any person from undertaking incompatible land use activities within 2 metres of the water course or "…in the case of a watercourse more

than 2 metres wide, within a distance equal to the width of that watercourse to a maximum of 30 metres" (Rok, 2012).

2.4.2 Survey Act Cap 299

This is a Parliament's Act used to make survey-related provisions. This Act is relevant to the conservation and protection of riparian zone because it stipulates a not less than 30-meter reservation in Part XII under section 111 on tidal river reservation (Rok, 2012). This river reservation is measured from the highest watermark, and it shall be used for Government purposes. Additionally, only the Minister has powers to direct the reservation of less than 30 meters. Therefore, the Survey Act is relevant in protecting and restoring Nairobi River riparian land from human interference and encroachment. No incompatible human activities are permitted within the 30-meter reservation.

2.4.3 Land Act 6 of 2012

This Act is guided by values and principles on the conservation and protection of ecologically sensitive areas, as stated in Section 4. Additionally, Section 11 stipulates the maintenance of public land categorized as endangered or containing critical habitat or protected areas (RoK, 2012). The riparian zone is outlined as one of the vital sensitive areas. Section 12 (2) prohibits land allocation within the riparian zone, river and stream catchment, lakes, and public water reservoirs. Therefore, this Act is relevant to the conservation of Nairobi River riparian land because it prohibits land allocation in the riparian ecosystem.

2.4.4 Physical and Land Use Planning Act, No 13 of 2019

This Act aims to prepare and implement the physical and land use development plans at the national, county, urban, rural, and cities levels. Section 16 stipulates that a regional physical development plan shall be developed to improve land and provide proper physical development, such as recreational areas (RoK, 2019). A local physical development plan shall be developed as stipulated under Section 24 in guiding and coordinating infrastructural facilities and services in sub-section. Section 30 bans anyone from carrying out development within the area of a local authority without a development permit issued by the local authority. Section 36 states that an

EIA shall be prepared and submitted to NEMA for approval on projects likely to impact the environment. Therefore, this Act is relevant in protecting and restoring riparian land along the Nairobi River because it prohibits harmful activities and calls for NEMA to approve or disapprove activities along the river.

2.4.5 Environmental Management and Coordination Act 1999 Act No.18 of 2018

Part II of EMCA 1999 asserts that every person in Kenya is entitled to a clean and healthy environment. It also gives every person a responsibility to safeguard and enhance the environment. Part VI, section 58 recommends that project's proponent must undertake an environmental impact assessment (EIA) study to determine its effects on the environment (RoK, 2018). The EIA report should be submitted to NEMA for review and approval before issuance of a license. Part VIII, section 72, 87, 88, 89, and 90 stipulates that any person undertaking activities that endanger the aquatic environment through harmful activities such as discharge of pollutants in the aquatic environment are guilty of an offense. However, that person should seek a waste management license from NEMA before commencing any activity that might pollute the environment. Therefore, EMCA 1999 is important legislation in protecting and conserving the Nairobi River riparian zone because of different land-use practices that require an EIA license from NEMA.

Part II, section 4 stipulates that a person shall not engage in harmful activities leading to the degradation of the environment, such as unsustainable use of natural resources. An EIA license must be issued before the start of such activities. Section 5 encourages conservation, recovery, and rehabilitation of threatened species (RoK, 2006). Section 8 provides the protection of sensitive areas such as the aquatic ecosystem such as rivers, and adjacent land for biological diversity preservation.

2.4.6 The Water Act of 2016

This Act provides for water resources management, conservation, use, and control. It also guides the acquisition and regulation of rights to use water. Part III, section 11 establishes the WRA to regulate, manage, and monitor water resources. Part II, section 10 outlines the procedure and content in preparing a National Water Resource Strategy to manage, protect, develop, and

conserve water resources and riparian zones (RoK, 2016). Additionally, the Act stipulates the provision of a permit for the discharge of a pollutant in any water resource. Section 38 prohibits a person from obstructing or interfering with any watercourse.

2.4.7 NEMA Integrated National Land Use Guidelines, 2011

The guidelines identify encroachment as one of the challenges in riparian zones and stipulates buffer zone width ranging between 2m and 30m from the highest watermark for the river or stream or the river's width (NEMA, 2011). The title deed for properties within the riparian land should be revoked in accordance with EMCA. Additionally, NEMA claims that river diversion, encroachment of riparian land, and siltation of rivers are some of the challenges facing the protection of waterways and wetlands. Management practices such as the establishment of compatible activities in riparian land will assist in riparian land conservation and restoration. For instance, NEMA suggests the planting of indigenous vegetation to conserve sensitive areas. Additionally, this guideline identifies inter-agency coordination and public-private partnership in the conservation and restoration effort of riparian zones. Therefore, NEMA's policy is relevant in determining challenges affecting wetlands and riparian zones along the Nairobi River.

2.4.8 Physical Planning Handbook, 2008

The PPH guides physical planners, local authorities, and other relevant personnel and institutions in preparing and implementing physical development plans. Section 3.3 on guidelines and standards stipulates the conservation of water courses through the provision of buffer zones. Additionally, section 9.3 on recreation in the urban areas defines parks and buffer zones as the major open spaces. Buffer zones are green spaces or "belts created to prevent pollution between conflicting and non-compatible land uses." This implies that riparian zone is a buffer zone protecting aquatic environment from incompatible land uses. The riparian reserve should range between 2m and 30m for seasonal and perennial rivers, or equals the full width of the river measured from the edge of the river bank.

Table 1. Regulatory requirements of riparian zone in Kenya

Act	**Specifications**
EMCA 1999 Act, No.18 of 2018	Part V, section 42 aims to protect lakes, rivers, and other water resources. A riparian reserve is protected against human activities. Lakeshore, wetland, and coastal zone or riverbank can be declared as protected area.
Land Act 6 of 2012	Section 12 (2) prohibits allocation of land within the riparian zone, river and stream catchment, lakes and public water reservoir
NEMA Integrated National Land Use Guidelines, 2011	Identifies encroachment as one of the challenges in riparian zones. Stipulates provision of buffer zone width ranging between 2m and 30m from the highest watermark for the river or stream or the width of the river. The title deed for properties within the riparian land should be revoked in accordance with EMCA.
Physical and Land Use Planning No 13 of 2019	Riparian reserves along any watercourse shall not be less than 10m wide on each riverbank
Physical Planning Handbook (PPH) 2002	A minimum distance of 2m and a maximum of 30m for seasonal and perennial rivers respectively
Survey Act (Cap 299)	Restricted to rivers lying on public land and stipulates a minimum width distance of 30m above high watermark for tidal rivers only
Agriculture (Basic Land Usage) Rules, 1965	Prohibits human activities within the riparian zone, 2-30m of the watercourse

2.5 Riparian Zone Management

Riparian zone dominated by vegetation, such as forest and grass sod are very important in reducing soil erosion caused by surface runoff (Iakovoglou *et al*., 2013). Vegetated riparian zone increase water quality by reducing surface runoff, which slows down nutrient loss and increases water quality (Dickard *et al*., 2015). Agricultural practices and urban development are non-point areas that result in nutrient pollution and sedimentation (Iakovoglou *et al*., 2013). Land-use

change in Kiambu County, which falls in the upper catchment of Nairobi River Basin has experienced tremendous land-use and land-cover changes (Mbui *et al*., 2010).

Riparian zones along a stream or riverbank form an interdependent and interconnected corridor in the landscape that links the upstream and the downstream (Iakovoglou *et al*., 2013). The watershed approach is essential strategy for sustainable riparian zones, which can be achieved through "Integrated Watershed Management" plans (IWM). IWM aims to safeguard important resources within the watershed such as water and riparian zones (Iakovoglou *et al*., 2013). IWM approach addresses issues associated with rapid population growth and climate change. IWM plans are adaptive in nature by employing holistic approach in the management of riparian zones (Klemas, 2014).

The watershed management plans demand stakeholders from different scientific fields to address the various functions of riparian zones. Riparian width is a vital element that affects sustainable management (Iakovoglou *et al*., 2013). Wider riparian zone along the river or stream and limiting human settlement developments contributes to a healthy and functional riparian zone (NRC, 2002).

2.6 Theoretical Framework

The concept 'Tragedy of the Commons' was theorized by Garret Hardin in 1968 to describe the implications of the rapid population growth on natural resource use (Ogello *et al.,* 2013). The depletion of limited resources represents 'tragedy' while communal ownership without private control means 'common' (Hardin, 1968). Hardin's concept is associated with one of the four principles of IWRM theory, which postulates that water is a scarce resource and it should be treated as a finite good and not a freehold resource. Riparian land is a significant natural resource that assists in natural treatment of water in wetlands and control flooding along river and lake basins (Ogello *et al*., 2013). The tragedy of the commons has resulted in the degradation of riparian land, deterioration of water quality, and flooding because of increased water discharge at the upstream (Penning-Rowsell, 1994; Ogello *et al*., 2013). Open access to natural resources results in depletion of resources to all (Hardin, 1968). Failure to recognize water resources and riparian land as a finite resource has led to depletion of these resources through encroachment.

The ideology of open access contributes to the development of dense settlement, lacking the supportive infrastructure that ultimately degrades the environment (Karisa, 2010). The majority

of the informal settlements and industries are located adjacent to Nairobi River Basin (Karisa, 2010). Human settlement growth along a river corridor, coupled with inadequate planning and enforcement of regulations result in encroachment and degradation of the riparian zone. The ideology of free access among the public caused by inadequate enforcement of riparian conservation rules and confusion among various governments' laws and policies has adverse implications on management and conservation of riparian zone (Lelo *et al*., 2005).

The 'Tragedy of the Commons' is a metaphor that shows a relationship between an individual and collective interest (Rowley, 1999). This concept applies to depict consequences on overexploitation of natural resources. The concept, 'Tragedy of the Commons' acknowledges the effort of external agencies in ensuring sustainable use and management of natural resources. External agencies can be institutional framework that imposes regulations to ensure sustainable use and management of resources.

Open access and common property are two significant aspects of resource use outlined in this concept (Rowley, 1999). Open access resources lack ownership, while common property resources have ownership such as the community. Riparian land along Nairobi River has been subjected as an open-access resource. This has contributed to issues of encroachment, pollution, change of river course, and land-use change in the upstream. Rivers and riparian zone are perceived as open access resources, which results in degradation stream ecosystem. To address issues of open access related to riparian zone and water resources, an Integrated Water Resource Management strategy (IWRM) was formulated (ICWE, 1992).

2.7 Research Gaps

From the reviewed literature, earlier studies on riparian zone have not yet assessed the effects of urban development on riparian zone in Nairobi River basin. In his study, "A negotiated framework for rehabilitation of riparian zones in Nairobi city: the case of Mathare river valley," Karisa (2010) recommended that there is a need to integrate planning in riparian zone management by assessing human settlements in river basins.

Therefore, this study focused on assessing the implications of human settlement development on the riparian zone in Nairobi River basin in Nairobi City County. Based on the findings, the study recommends practical and sustainable measures to protect and conserve Nairobi River riparian zone in an ever-expanding capital city.

CHAPTER THREE

METHODOLOGY

3.1 Study Area

Nairobi River riparian zone is made up of Nairobi River, which originates from Kiambu County, in the west, and flows across Nairobi City County to the east (figure 2). One of the main sources of Nairobi River water is the Ondiri swamp. Nairobi River meets River Athi that drains to Tana River and eventually Indian Ocean. Nairobi River watershed is characterized by various land use activities along its riparian zone. The study area has a coverage of 92.46 km^2, and extends from Kikuyu area as the upstream to Korogocho area as the downstream. Both formal and informal settlements are evident. It passes within a section of Nairobi Central Business District, where the river undergoes tremendous change influenced by urban development and human settlement.

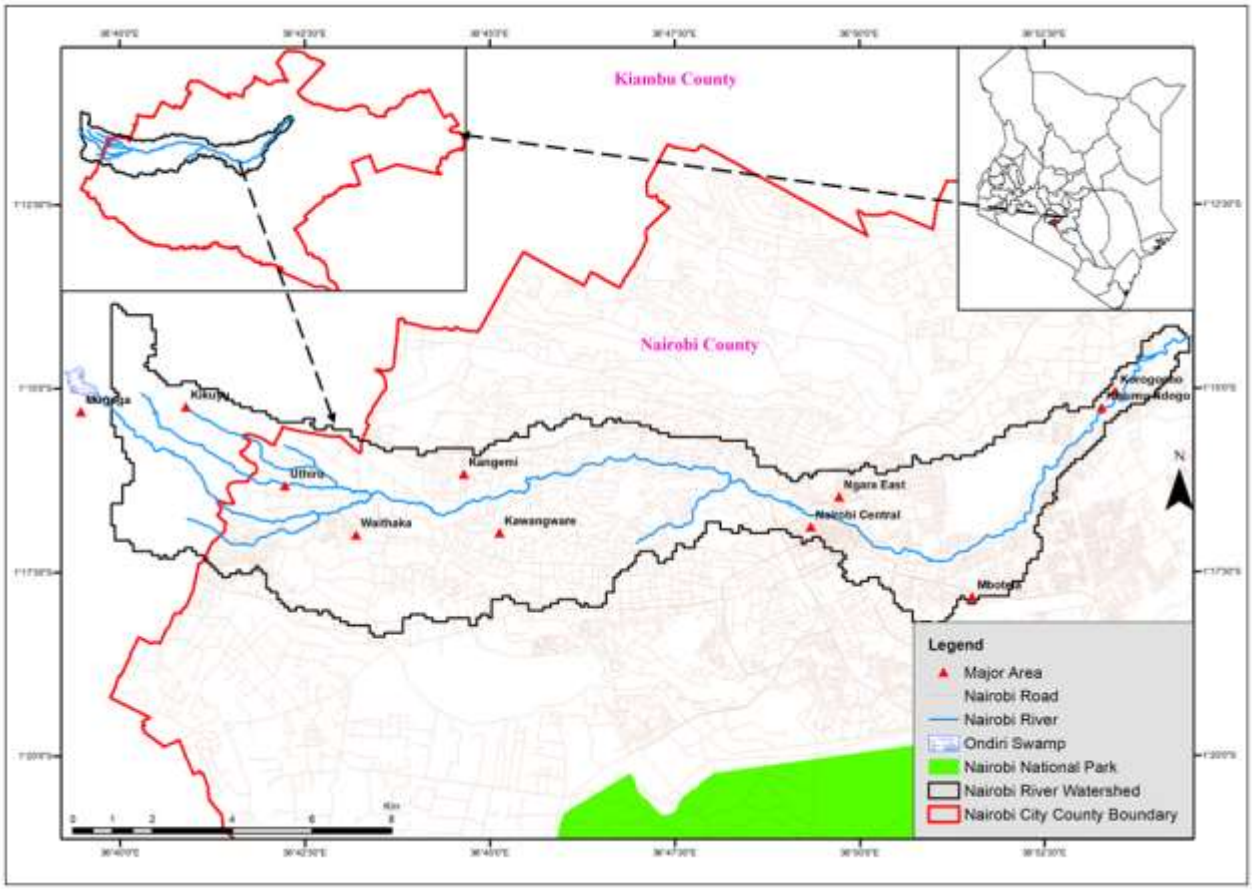

Figure 2. Extent of Nairobi River riparian zone

3.2 Research Design

The study adopted a descriptive research design to identify anthropogenic activities and their implications on Nairobi River riparian zone. Google Earth Engine and ArcMap assisted in assessing spatial and temporal changes in extent of Nairobi River riparian zone. Land use changes was performed to assessing satellite images between 2000 and 2020, with a 5-year interval to understand the relationship between riparian zone and human settlement (Gay, 1987). Additionally, the study sought to determine the relationship between the built-up environment and riparian zone using Pearson correlation coefficient (r). Pearson correlation coefficient measures the degree of linear correlation between two variables, and it determines the strength of the linear relationship (Profillidis & Botzoris, 2019). Additionally, Profillidis and Botzoris (2019) assert that if the r-value ranges between -0.8 and -1, there is "a strong negative correlation of the dependent variable Y with the independent variable X" (p 188). Finally, the study employed a mixed-method approach (Johnson *et al*., 2007), which entailed the use of quantitative and qualitative approaches to answer different research questions.

3.3 Sample Size and Sampling Procedure

Purposive sampling method was employed in selecting the relevant actors and government agencies tasked with the mandate of restoring and rehabilitating the Nairobi River riparian zone. This study targeted various officers that form key informants, such as officers from the Ministry of Environment and Forestry, the Department of Urban Rivers Restoration (DURR), NEMA, WRA, the Department of Urban Planning (under Nairobi City Council) among others from public and private sectors to provide information on restoration and reclamation of riparian zone as envisaged in Nairobi River Basin regeneration plan.

3.4 Data Collection Techniques

Interview schedules were prepared and administered to relevant key informants pertaining to the riparian zone regeneration plan for the Nairobi River. Satellite images such as Landsat, from 2020 to 2000 at an interval of 5 years were downloaded from USGS to assess land use changes in Nairobi River. The satellite images provided information on land-use and land-cover changes to correlate the relationship between settlement development and riparian zone.

Review of existing documents and records, such as reports and laws, regulations, and guidelines, from government departments was performed. Observation checklist was developed and used to

assess the extent and nature of riparian land, encroachment, ecological conditions of the riparian zone and compliance to guidelines. Site visits was conducted to ascertain the extent and nature of the riparian zone. The use of pictorials was used to capture the ecological conditions of the riparian zone.

Examination of riparian zone regeneration plan for Nairobi River Basin involved the description of the programme by gathering its background information. Determination of the optimal level of the regeneration plan involved the identification of the plan's indicators and possible outcomes. This process included the collection and organization of quantitative and qualitative data about the plan and analysing its results.

3.5 Data Analysis

Image differencing detection technique is best suited for urban and rural land cover changes. It detects changes in the forest ecosystem and urban fringe from SPOT HRV (Mishra, Shrivastava, and Dhurvey (2017). Image differencing method uses two spatial imageries acquired at different times by subtracting their pixels and bands as shown in the formula below.

$$Dx_{ij}^{k} = X_{ij}^{k}(T2) - X_{ij}^{k}(T1) \qquad \text{Equation 1}$$

X^{k}_{ij}(T1) and (T2) are the DN value of pixel X in column j and k and row i at time T1 and T2.

Desktop quantitative and qualitative methods were employed to analyze various data. Satellite images of the study area were processed using Remote Sensing programs, such as ArcMap, Google Earth Engine, Google Earth Pro, and MS-Excel, to detect and calculate LULC changes over the years. The extent and nature of the riparian zones was assessed and determined using satellite images and field photography.

Qualitative data from scheduled interviews with relevant key informants were analyzed and organized into themes related to the study objectives. This method was used to analyze information pertaining to the regeneration plan for Nairobi River basin. Analyzed data; satellite images were presented in form of maps, graphs, and tables, while qualitative data was presented in narrative form after content analysis.

CHAPTER FOUR

RESEARCH FINDINGS AND DISCUSSIONS

4.1 Introduction

This chapter presents the findings and discussion of the findings based on satellite imagery data and information from interview with relevant public and private agencies. The study findings are presented and discussed based on the objectives. The first section presents an overview of human settlement developmental trends and its spatial distribution in the Nairobi River riparian zone between 2000 and 2020. The second section provides an analysis of the extent and nature of the riparian zone along Nairobi River in specific areas. The third section presents an evaluation of the riparian zone regeneration plan for Nairobi River.

4.2 Human Settlement Developmental Trends and Spatial Distribution in Nairobi River Basin

This section presents the analysis of human settlement developmental trends and its spatial distribution in Nairobi River riparian zone between 2000 and 2020.

4.2.1 Human Settlement Developmental Trends between 2000 and 2020

It was observed that the development of human settlements in Nairobi River riparian zone increased from 28.07 km^2 to 54.58 km^2 in 2000 and 2020, respectively. Human settlement development in 2000 was detected downstream, which is characterized by the CBD, and part of the downtown such as Grogan and Kamukunji. Additionally, parts of the upstream area in Nairobi River riparian zone with human settlement included Kawangware, Kileleshwa, Westland, and parts of Kangemi.

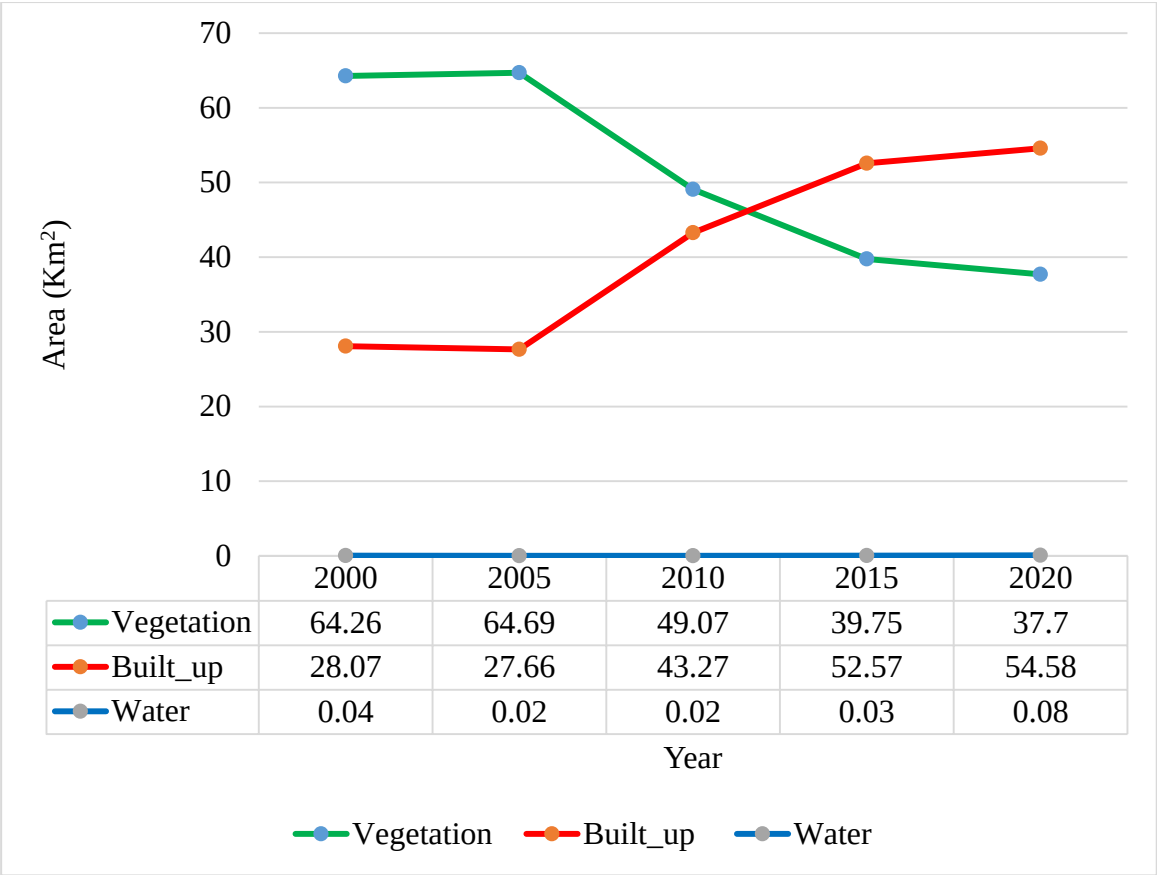

Figure 3. Land use/land cover change in Nairobi River riparian zone between 2000 and 2020

Human settlement in 2020 increased and was characterized by development of residential, commercial, and recreational land uses. Land previously occupied by vegetation cover in 2000 had been replaced by human settlements. A study done by Muketha (2020) revealed that formal and informal settlements, such as informal housing and commercial land uses result in decreased riparian width and its destruction. This study finding coincide with Muketha's (2020) claim because the downstream side of Nairobi River riparian zone has been adversely affected by increasing human settlement because of the loss of vegetation cover in 2020. Additionally, the upstream experienced change because of the increasing human settlements in terms of formal and informal settlements. The increasing human settlement development in Nairobi River between 2000 and 2020 results a decrease in vegetation cover. Tang *et al*. (2017) claims that this rapid urban change causes environmental degradation. Therefore, Nairobi River basin riparian zone has experienced increasing human settlement that characterize settlement development, and decreasing riparian zone.

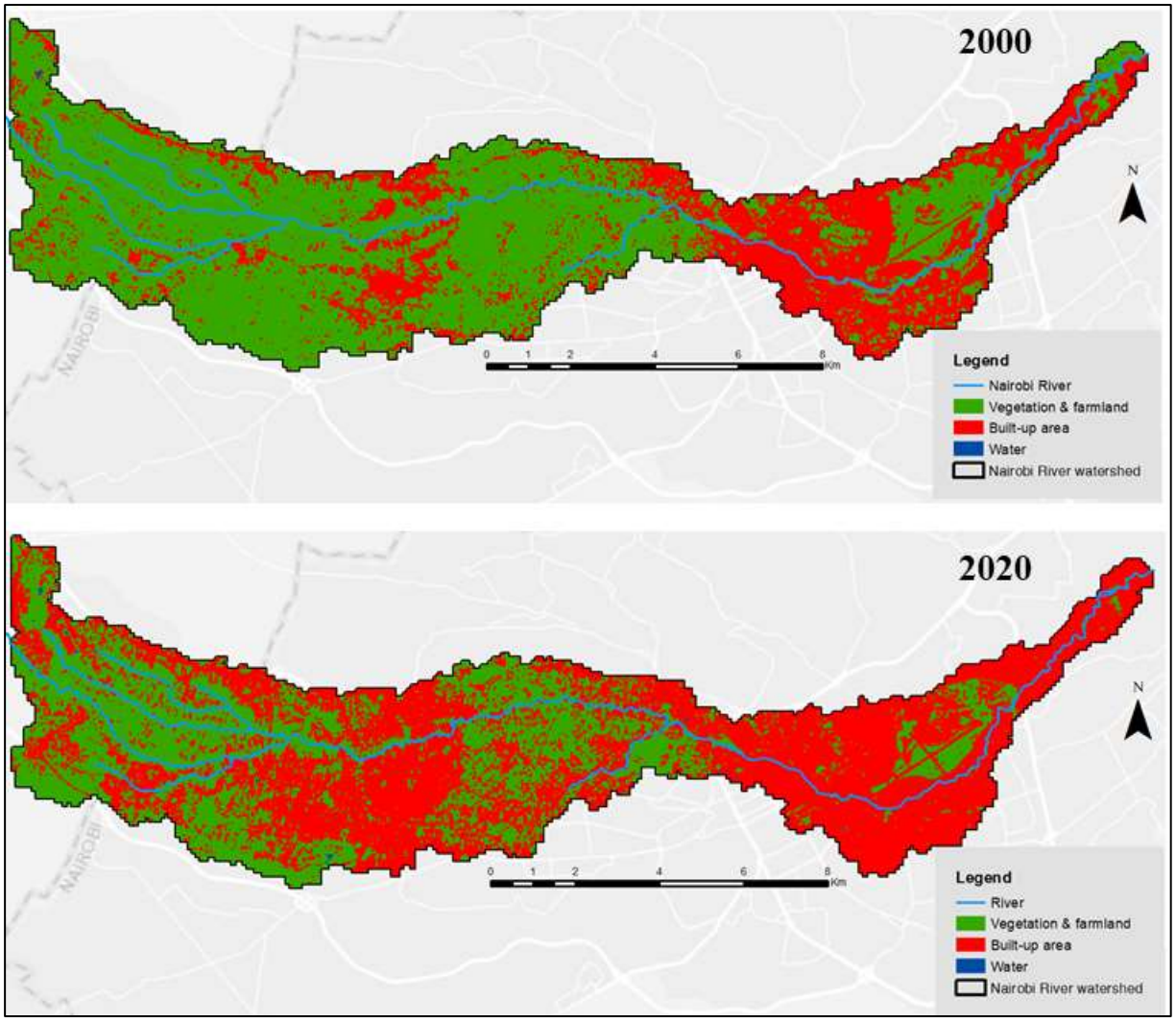

Figure 4. Changing human settlement development in Nairobi River between 2000 and 2020

4.2.2 Spatial Distribution of Human Settlement in 2000

The study sought to find out the spatial distribution of human settlement in the Nairobi River in 2000. It was detected that human settlement or the built-up environment occupied approximately 30.39 percent of the total area of Nairobi River riparian zone (92.47 km^2). Additionally, 69.57 percent of the total area of Nairobi River riparian zone was occupied by vegetation cover, which is approximately 64.26 km^2.

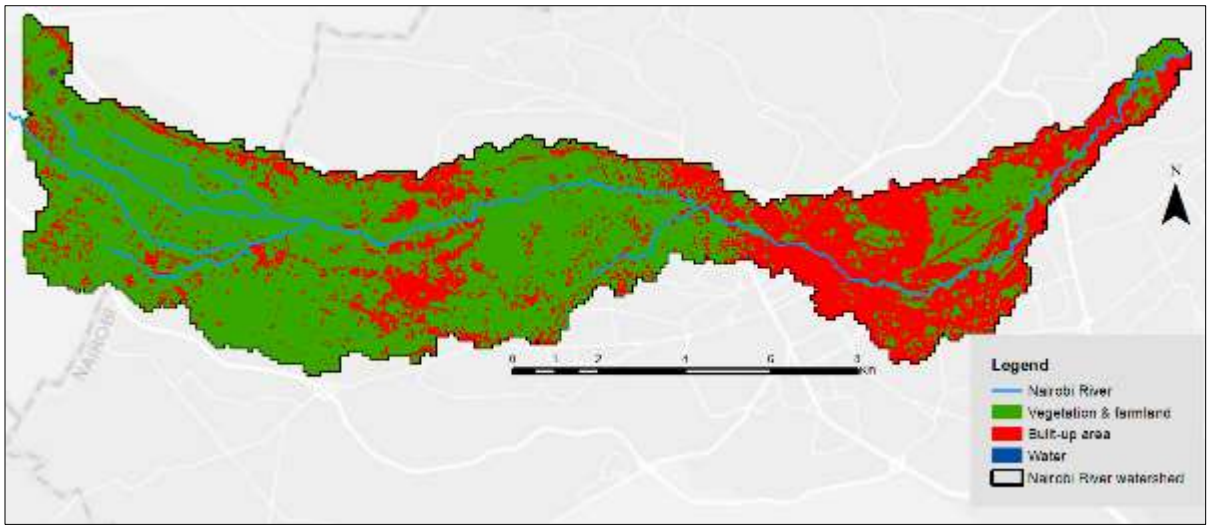

Figure 5: Human settlement and vegetation distribution in Nairobi River riparian zone in 2000

4.2.3 Spatial Distribution of Human Settlement in 2005

It was detected that vegetation cover slightly increased to 70.03 percent compared to vegetation cover in 2000. Human settlement decreased from 28.07 to 27.66 km^2 in 2005. However, human settlement was dominant in the eastern side of Nairobi River, which is made up of a section of the Central Business District, Eastleigh Estate, Makongeni, Mbotela, Shauri Moyo, Ngara, Kisumu Ndogo, Dandora, and Mathare, among others. Meanwhile, the western side of the study area experienced gradual changes as vegetation cover was a dominant land cover along Nairobi River. However, areas such as Kangemi, Kawangware, and Waithaka were characterized by anthropogenic activities.

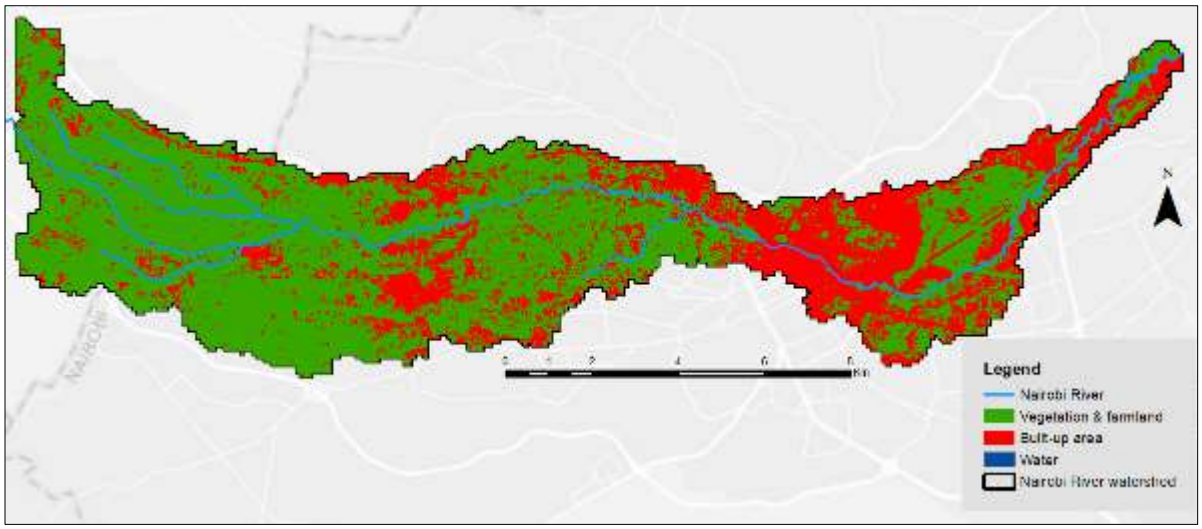

Figure 6. Human settlement and vegetation distribution in Nairobi River riparian zone in 2005

4.2.4 Spatial Distribution of Human Settlement in 2010

It was observed that human settlement drastically increased by 16.90 percent in 2010. Human settlement increased from 27.66 to 43.27 km^2 between 2005 and 2010. Vegetation cover in Nairobi River basin decreased from 64.69 to 49.07 km^2 between 2005 and 2010. This decrease in vegetation cover represent a 16.91 percent loss. Vegetation cover loss within Nairobi River was observed in the eastern and western parts of the area. For example, Korogocho in the eastern side, and Kikuyu town in the western side witnessed conversion of vegetation land cover into human settlement. It was found that the western and central side of Nairobi River riparian zone in areas, such as Kangemi, Kawangware, Thogoto, Lavington, and Westland experienced rapid expansion of human settlement.

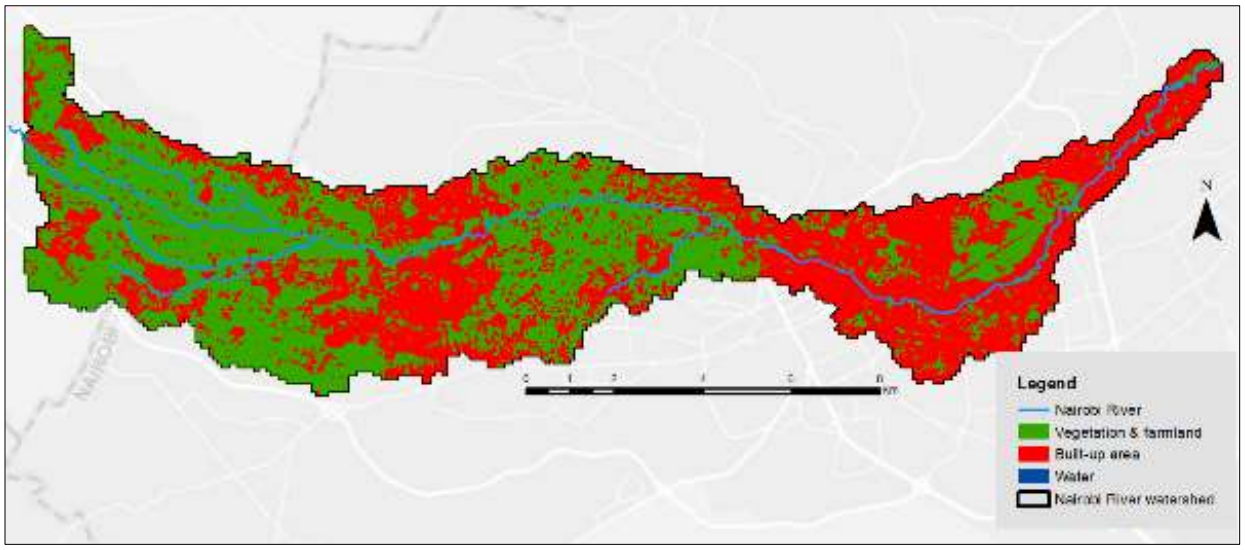

Figure 7. Human settlement and vegetation distribution in Nairobi River riparian zone in 2010

4.2.5 Spatial Distribution of Human Settlement in 2015

It was observed that the human settlement continued to become the dominant land use activity in Nairobi River watershed. Human settlement increased to 52.57 km^2 in 2015, compared to 43.27 km^2 in 2010. This drastic increase in human settlement represents a 10.07 percent increase in anthropogenic activities between 2010 and 2015. Consequently, vegetation cover in the Nairobi River riparian zone decreased from 49.07 to 39.75 km^2 between 2010 and 2015, respectively. The eastern, central and western side of the watershed experienced massive loss of vegetation cover, which was replaced by the built environment. For example, Uthiru, Kawangware, Kikuyu, and Kangemi continued to experience human settlement growth. The eastern side of Nairobi River, which is the downstream experienced massive loss of vegetation cover, which was replaced by human settlement and related activities.

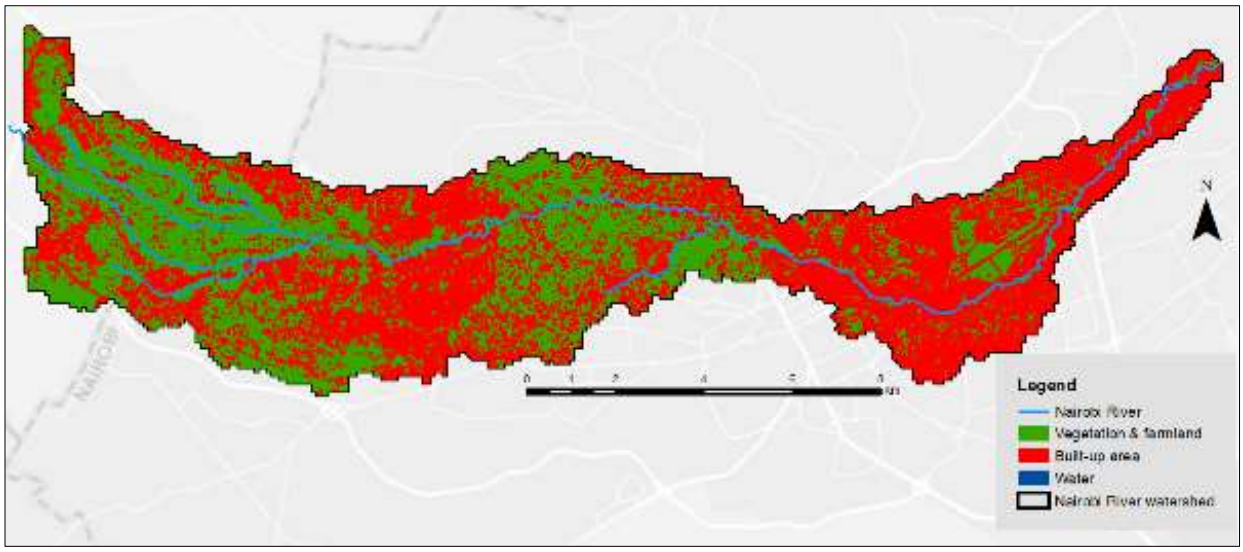

Figure 8. Human settlement and vegetation distribution in Nairobi River riparian zone in 2015

4.2.6 Spatial Distribution of Human Settlement in 2020

Human settlement steadily increased in coverage from 52.57 to 54.58 km^2 in 2020. This increase in coverage of human settlement covered 59.09 percent of the total area of Nairobi River riparian zone. Comparatively, vegetation covers progressively decreased from 39.75 to 37.7 km^2 in 2020, which represents 40.81 percent of the total areas. The eastern side of Nairobi River watershed made up of areas estates, such as Eastleigh, Makongeni, Korogocho, and section of the CBD continued to be characterized by anthropogenic activities. Residential development in a riparian zone adversely affect the services rendered by riparian zone such as protecting the river (Karisa, 2010). Vegetation cover loss was detected in the western and central parts of Nairobi River. Human settlement continued to replace vegetation cover in most parts of Nairobi River riparian zone, which coincides with Karisa's (2010) finding.

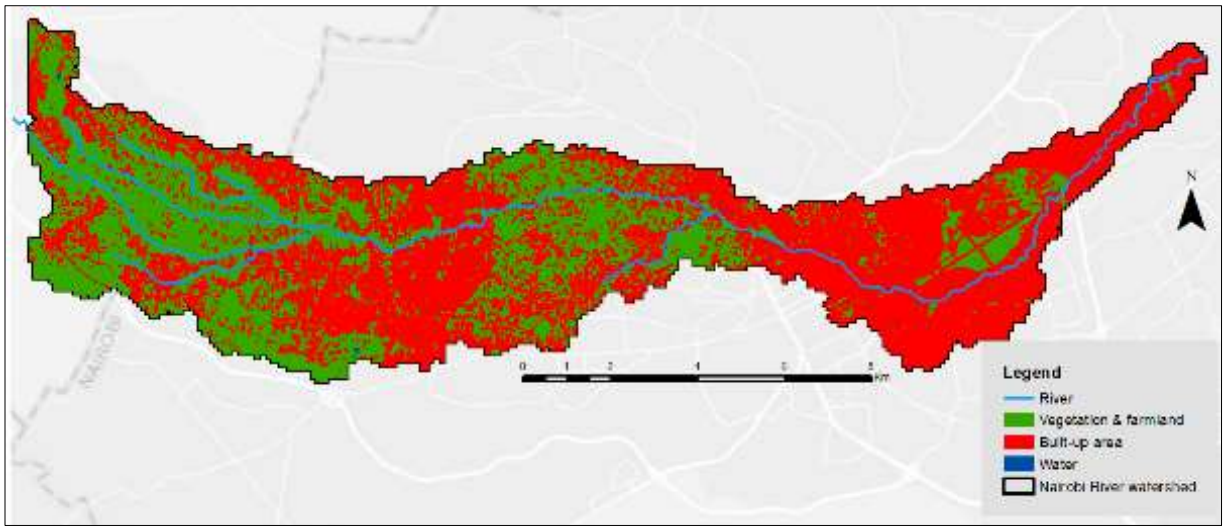

Figure 9. Human settlement and vegetation distribution in Nairobi River riparian zone in 2020

4.2.7 Relationship between Riparian Land and Built-up Environment

The results of this study concur with findings of a study done Olokeogun and Kumar (2020), which found that an increase in human settlement in a riparian zone, degrades the aquatic ecosystem. This study finding shows that an increase in settlement development adversely affect Nairobi River riparian zone. It was found that the relationship between Nairobi River riparian zone and human settlement forms a strong negative correlation with a co-efficiency of r = -.975. The r value ranging between -0.8 and -1, indicates "a strong negative correlation of the dependent variable Y with the independent variable X" (Profillidis & Botzoris, 2019). Therefore, the r value, -0.975, indicates a strong negative correlation between riparian land and human settlement in Nairobi River.

Table 2. Correlation between riparian and the built-up environment

	Riparian	Built up environment
Riparian land	1	**-0.9750**
Built up environment	**-0.9750**	1

This test implies that an increase in human settlement in Nairobi River riparian zone results in a decrease in riparian land.

4.3 The Extent and Nature of Riparian Zone along Nairobi River Riparian Zone

This section presents the analysis of the extent and nature of Nairobi River riparian zone in 2020. Additionally, to understand the nature of the current riparian zone, the study sought to assess changes in the extent and nature of the riparian zone between 2000 and 2020. Two major land uses, riparian vegetation and built-up environment are assessed to determine their relationship in understanding the extent and nature of the riparian zone.

4.3.1 Riparian Zone along Nairobi River between 2000 and 2020

It was observed that anthropogenic activities were prevalent in the eastern side of Nairobi River in areas such as Korogocho, Ngara, and parts of the CBD. Riparian land in the western side of Nairobi River faced minimal encroachment by human activities (figure 9). It was observed that built-up environment occupied a small fraction of Nairobi River riparian zone between 2000 and 2005. However, human settlement along Nairobi River riparian zone drastically increased from 2010 and 2020, which corresponds to Muketha's (2020) findings that structures within 6m to 30m are perceived to encroach the riparian zone. The central and eastern side of Nairobi River in places such as Kawangware, Eastleigh South, Pioneer Estate, Nyayo Village, Korogocho, Ngomongo Village, and Kiambiu informal settlement experienced a drastic increase in human settlement. It is evident that riparian zone in the eastern and central area of the maps in 2015 and 2020 were affected by human settlements. Moreover, the western side also experiences gradual encroachment of riparian zone, characterized by development of human settlement and conversion of agricultural land into residential and commercial land use.

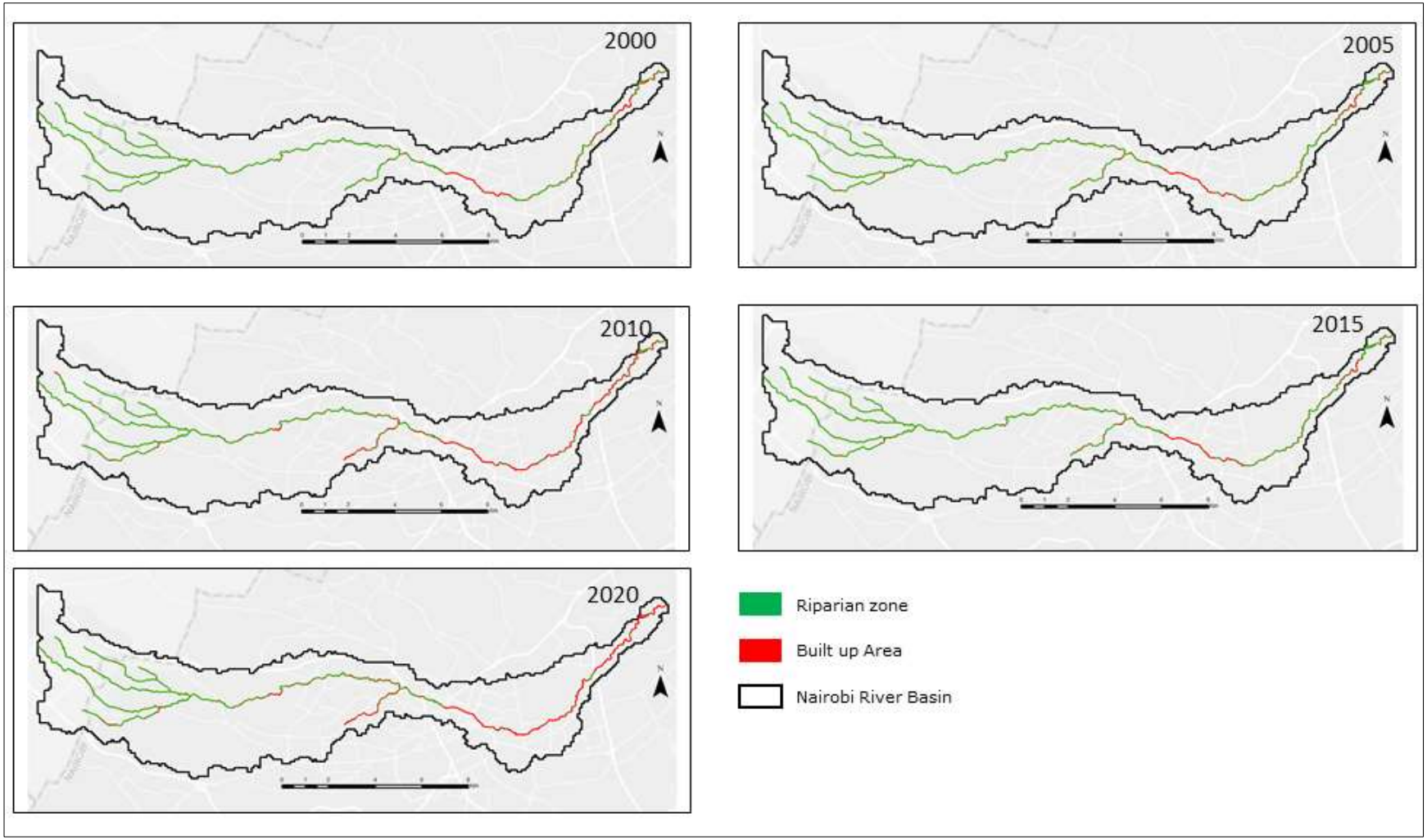

Figure 10. Human settlement and vegetation distribution within a 30-meter buffer along Nairobi River between 2000 and 2020

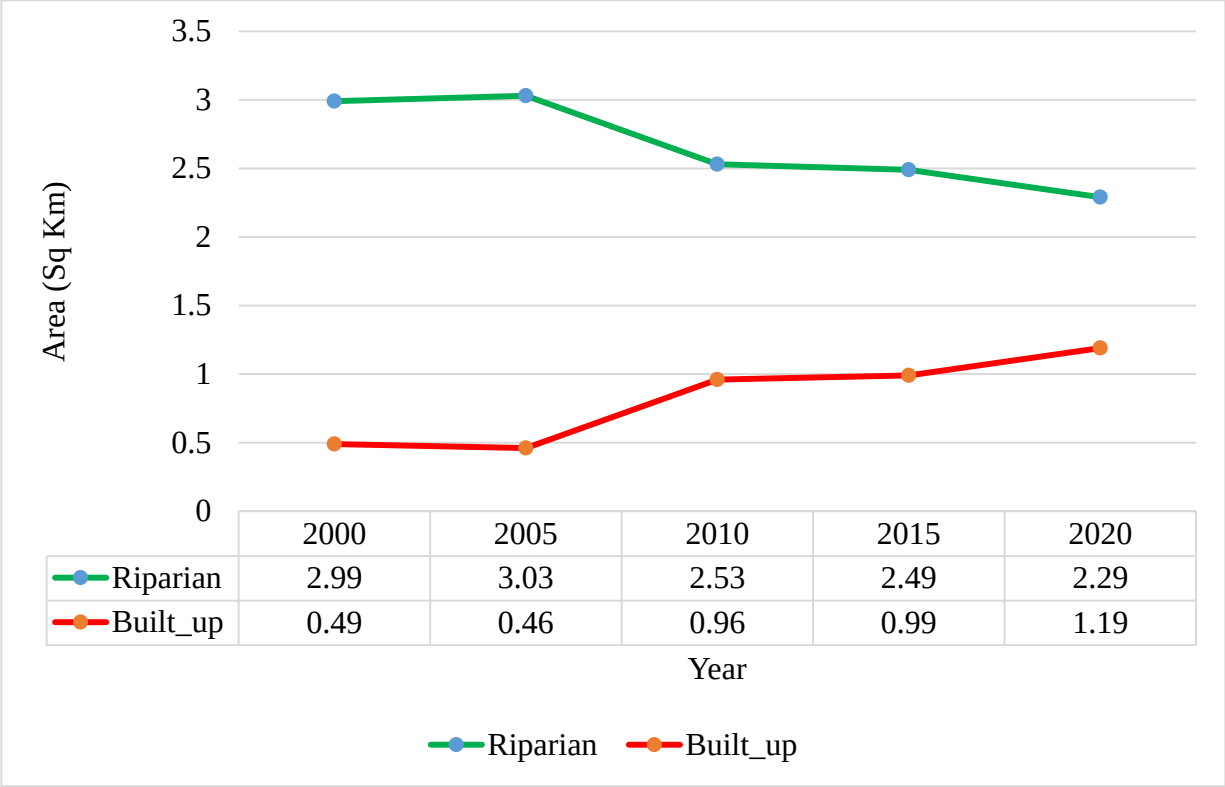

Figure 11. Riparian and built-up environment in Nairobi River at a 30-meter buffer between 2000 and 2020

Built-up environment along the riparian zone occupied 0.49 km^2, while riparian vegetation coverage was 2.99 km^2 in 2000. Riparian vegetation covers in riparian zone increased in 2005 to occupy 3.03 km^2. The same year, built-up environment along Nairobi River riparian zone decreased to occupy 0.46 km^2. However, riparian zone experienced a drastic decrease in 2015 as it occupied 2.53 km^2. Riparian zone continued to experience a decline on coverage in 2015 and 2020 by occupying 2.49 and 2.29 km^2, respectively. Comparatively, the built-up environment along Nairobi River increased from 0.46 to 0.96 km^2 in 2010. It was observed that human settlement continued to increase in 2015 and 2020 along Nairobi River, occupying 0.99 and 1.19 km^2, respectively.

4.3.2 The Nature of Riparian Zone along Nairobi River

The nature of Nairobi River riparian zone is characterized by various land uses, which includes agriculture, informal settlements, formal and informal businesses, garages, urban park, and

formal settlements. These land uses define the nature of Nairobi River riparian zone, and have an impact on it. Some of the land uses are permissible such as the Michuki Memorial Park at Globe Roundabout, while others are impermissible such as garages at Grogan, and have encroached the riparian zone.

Informal Settlements

During the desktop review and site survey in the study area, informal settlements were observed along Nairobi River riparian zone (figure 12). Some of the informal settlements detected along Nairobi River riparian zone includes Kiambiu, Blue Estate, Nyayo Village, Kisumu Ndogo, and a section of Korogocho Village, which supports Mwiti's (2014) findings that human settlement remains noticeable in most sections adjacent to Nairobi River riparian zone. Sections of these informal settlements were located in the riparian zone of Nairobi River.

Formal Settlements

The study found that formal residential settlements along Nairobi Rivers riparian zone in various sections have been established. Using satellite images from Google Earth and site visits along Nairobi River, formal residential settlements were detected within the riparian zone of Nairobi River in estates such as Groganville, Precious Gardens Estate Riruta, Kawangware, and Eastleigh South Section 3 (figure 12). These estates are characterized by high-income residential apartments and medium-income apartments.

Informal Markets

Establishment of informal markets adjacent and within the riparian zone was observed along Nairobi River. Informal markets, such as Gikomba and Korogocho were detected using satellite images and site visits (figure 12). A section of these markets has encroached the riparian zone, and human activities were observed at the edge of the river, which affected the quality of Nairobi River riparian zone.

Formal Businesses

The study found that formal businesses were established within Nairobi River riparian zone. A similar assessment conducted by NEMA and its findings presented by the Departmental Committee on Environment and Natural Resources (2019) found that the Ukay Centre encroached part of Nairobi River riparian zone. Satellite images and site visit photos detected the establishment of formal businesses such as commercial warehouses in Kamukunji area in the CBD (figure 12).

Urban Agriculture

Urban agriculture was detected in Nairobi River riparian zone, especially in the upstream regions of Nairobi River basin. It was detected that agricultural activities in the riparian zone was prevalent, characterized by replacement of indigenous vegetation cover (Figure 12).

Figure 12. Human activities at different sections along Nairobi Rive riparian zone

Urban Park and Open Spaces

It was detected that Nairobi River riparian zone is characterized by open spaces and urban park. Field survey and satellite images detected Michuki Memorial Park, Arboretum, and Kamukunji Grounds as some of the major recreational spaces along Nairobi River riparian zone (Figure 13).

Figure 13. Michuki Memorial Park along Nairobi River riparian zone
Source: Google Earth, 2021

Michuki Memorial Park covers the area between the National Museum of Kenya, Boulevard Hotel, and Globe roundabout. The riparian zone within the park has been restored and rehabilitated by fencing off the park, planting of vegetation, and management of the park by Kenya Forest Service (KFS).

Garages

Nairobi River riparian zone is characterized by the establishment of garages. Satellite images detected the presence of garages next to the river, hence, encroachment of riparian land (Muketha, 2020). For example, the stretch between Globe and Kariokor Roundabout is characterized by garages in the riparian land (Figure 14).

Figure 14. A section of Nairobi River at Grogan stretch characterized by garages at the riparian zone

Source: Google Earth, 2021

During the field survey, it was observed that the establishment of garages in the riparian zone contribute to alteration of vegetation cover and pollution of the river. Solid waste disposal and discharge of oil was common in this area such as Grogan stretch.

4.4 Riparian Zone Regeneration Plan for Nairobi River

Nairobi River Basin Rehabilitation Program (NRPB) is a joint initiative between the UN-Habitat and Kenya Government to rehabilitate, restore, and sustainably manage rivers in Nairobi Basin. NRBP's strategies included delineation of riparian zones along Nairobi Rivers, completion of a 2.5 demo work from Museum Hill to Globe Roundabout, development of a master plan for economic utilization of riparian zone, relocation of economic activities, and informal settlements.

This section examines the Nairobi Regeneration Program, which is a joint initiative by the UN-Habitat, the National Government and Nairobi City County Government. Part of the program is the Urban River Regeneration Plan (URRP), which is a five-year program, aimed at rehabilitating and restoring the riparian land along Nairobi River basin. The URRP is a multi-agency program aimed at restoring the quality of Nairobi Rivers through the development of plans in restoring riparian zone along the river to improve water quality and quantity.

Table 3. Programs in Kenya with the aim of rehabilitating the Nairobi Rivers

Program	Year	Objective	Activities	Actors
Nairobi River Basin Programme, (NRPB), Phase I	1999-2000	To assess water quality, public awareness, community outreach, and capacity building. To address pollution problems of the Nairobi Rivers	Survey and analysis of physio-chemical and biological characteristics	UNEP AWN National Government Nairobi City Council KWS UoN
NRPB, Phase II	2001-2003	To assess the conditions of tributaries of the Nairobi River system (the Motoine or Ngong River). To identify the major point sources of pollution	Survey and analysis of physio-chemical and biological characteristics Monitor water pollution levels in the upstream on a 22 km stretch, the dam, and 25km downstream on Ngong River. To enhance community outreach and capacity building	UNEP NETWAS National Government Nairobi City Council UoN
NRBP, Phase III	2004-2008	To rehabilitate, restore and manage the Nairobi river ecosystem in order to provide improved	Survey and analysis of physio-chemical and biological characteristics	UNEP UNDP UN-HABITAT National Government Nairobi City

		livelihoods, especially for the poor, enhanced biodiversity, and a sustainable supply of water for domestic and industrial, recreational and emergency uses.		Council
Nairobi River Basin Program (NRBP)	2007	To rehabilitate, restore and manage the Nairobi River ecosystem in order	Delineation of riparian zones along Nairobi Rivers, completion of a 2.5 demo work from Museum Hill to Globe Roundabout. The development of a master plan for economic utilization of riparian zone. The relocation of economic activities, and informal settlements.	UN-Habitat UNEP Belgian Government Trust Fund Ministry of Environment Nairobi City Council
Nairobi Rivers Rehabilitation and Restoration Program	2010	To improve the provision of sewerage services. To create a clean environment along the river basin	Development of waste water infrastructure Provision of sanitation, hygiene and social environmental support. Tree planting along the riparian zone to prevent encroachment and	African Development Bank Group National Government Nairobi City County Government

			enhance conservation.	NWSC, AWSB
Nairobi rivers basin rehabilitation and restoration Program: Sewerage improvement project phase II	2018	To improve the access, quality, availability and sustainability of wastewater services in Nairobi City with a view to contribute to the restoration of Nairobi Rivers Basin.	A tree planting program including rainwater harvesting systems in selected schools and along the riparian zone of the Nairobi rivers basin, which will serve the purpose of carbon sequestration and contributes to the bigger picture of making Nairobi the Green City in the Sun	African Development Bank Group National Government Nairobi City County Government NWSC, AWSB
Urban Rivers Regeneration Programme	2019-2024	To achieve Sustainable Solid waste management in the city in line with the National Solid Waste Management Strategy To combat riparian zone encroachment of the informal settlements To prevent water pollution of the rivers by effluent discharges from	Delineation of riparian land by marking and pegging. Demolition of structures on riparian reserve. Re-location of informal settlement along the river. Enhanced enforcement by inter-agency teams. Ban urban agriculture. Relocation of “Jua Kali” and garages from riparian land. Revocation of illegally allocated land parcels n	National Government NEMA NCC Community Based Organizations

		industries and sewer lines To ensure adherence to Physical Development plans and Zoning policy To promote Nairobi river rehabilitation and beautification	riparian zone. Revegetate riparian land. Creation of public parks and utilities Right of way. Upgrade existing environmental infrastructure, canalization (where appropriate).	

4.4.1 Achievements of the Nairobi Riparian Zone Regeneration Plan

a) Rehabilitation of John Michuki Memorial Park

The rehabilitation and restoration of Nairobi River riparian zone is evident within the 1.2 km stretch between Boulevard Hotel and Globe Roundabout at Ngara. According to NEMA and the Ministry of Environment and Forestry, through the Department of Urban Rivers Restoration (DURR), John Michuki Memorial Park was transformed from a dumpsite into a public recreation site. The rehabilitation and restoration of the park was part of the Nairobi River riparian zone regeneration plan to conserve the riparian land along the river. According to Kenya Forest Service (KFS) warden at the site, the park had been invaded before the initiation of the regeneration plan by illegal activities, such as illegal dumpsite and a haven for city muggers. The regeneration plan resulted in delineation of the riparian land along the river, which resulted in clean-up activities and demarcation of the riparian land to improve riparian biodiversity, water quality, and quantity.

Currently, the riparian land in Michuki Memorial Park is one of the success milestones in Nairobi River regeneration plan. The park offers a unique example of a rehabilitated and restored riparian zone along Nairobi River.

Plate 1. Rehabilitated and restored riparian zone at Michuki Memorial Park

Source: Field Survey, 2021

b) Grogan Nairobi River Stretch

The riparian land along Nairobi River at Grogan stretch is a successful milestone in the rehabilitation of Nairobi River riparian zone. Interviews with key institutions such as WRA revealed that the Grogan stretch has been rehabilitated through canalization of the river and planting of trees on the riparian zone.

Plate 2. A section of rehabilitated riparian zone at Grogan stretch near Globe Roundabout

Source: Field Survey, 2021

4.4.2 Challenges in the Implementation of the Program

Encroachment

Human settlement along Nairobi River riparian zone has increased over the years, especially in the downstream. Population increase in Nairobi River riparian zone might be attributed to rural-urban migration, development of residential and commercial areas, and development of public infrastructure. For example, the development of informal settlements and residential apartments along Nairobi River, such as Kiambiu slum and Groganville Estate in Westlands indicate human settlement in the riparian zone.

Table 4. Building within different distance in the riparian zone

Distance from Riparian Reserve	Number of Building/Structures in Riparian Zone
6 meters	217
15 meters	1,181
30 meters	4,058

Plate 3. Residential apartments and garages at the edge of Nairobi River at Korogocho area
Source: Field Survey, 2021

Interviews with key government institutions, such as NEMA, WRA, DURR, and the Department of Urban Planning in NCC revealed that encroachment is a major issue in Nairobi River riparian zone. Increase in human settlement in the riparian zone propelled by urban development degrades the riparian zone (Olokeogun *et al*., 2020). Evacuation of human settlements in the riparian zone remains as one of the major issues in the implementation of Nairobi River regeneration plan.

Urban Agriculture

It was evident that Nairobi River riparian zone is characterized by agricultural activities, especially in the upstream. Urban agriculture in the riparian zone results in alteration of riparian vegetation, which affects water quality. Agricultural activities in the urban river's riparian zone reduces indigenous vegetation richness and diversity that leads to bank erosion (Diaz-Pascacio *et al*., 2018). Interview with WRA revealed that practicing agriculture in riparian land is prohibited because it encourages clearance of indigenous vegetation cover, as outline in the Agriculture (Basic Land Usage) Rules, 1965 (Rok, 2012).

Plate 4. Presence of farming activities at Riruta area in the upstream
Source: Field Survey, 2021

Practicing agricultural activities in the upstream poses environmental threat in the riparian zone and affects the entire Nairobi River basin.

Pollution

The study found that water pollution is one of the issues affecting water quality in Nairobi River basin. During the field survey, it was noted that there are multiple discharge points of raw sewage into Nairobi River. Additionally, disposal of solid waste into the river is a major problem caused by human settlement in the riparian zone. During the interview with NEMA and NMS officials, it was evident that the location of the sewerage system along the river contributes to water pollution. For example, wastewater from informal settlements in the riparian zone is discharge into Nairobi River, which affects water quality downstream.

Plate 5. Solid waste disposal in Nairobi River from an informal settlement in Eastleigh Estate
Source: Field Survey, 2021

Weak Enforcement

NEMA and NCC play a significant role in the rehabilitation and restoration of Nairobi River basin. They are tasked with the role of enforcing laws by ensuring that developers and land owners adhere to them. However, during an interview with officials from NEMA and DURR, it was evident that NCC and NEMA have inadequate personnel in enforcing riparian zone related rules and regulations. NEMA, WRA, and NCC are some of the key agencies tasked with the mandate of approving or revoking development plans. The presence of human activities, such as informal settlement, formal businesses, garages, and residential apartments in the riparian zone indicated that the agencies have put little effort in enforcing riparian zone rules and regulations.

Plate 6. An occupied structure earmarked for demolition by WRA in Kiambiu
Source: Field Survey, 2021

The demolition of near-completed and completed structures in the riparian zone implies that the relevant agencies failed to ensure that property owners and developers do not undertake any developments without approval. Therefore, enforcement mechanism is still a problem among various government institutions in restoration and rehabilitation of Nairobi River regeneration plan.

Financial Constraint

Interviews with officials from the Ministry of Environment and Forestry, DURR, and NEMA revealed that inadequate financial resources derail the effort in implementing Nairobi River regeneration plan. The activities in rehabilitating and restoring Nairobi River basin and its riparian land require adequate finances. Some of the activities include relocation of people in the informal settlements, clean-up activities in the river, planting of trees and vegetation cover, and other related activities. For instance, Environment CS, Keriako Tobiko, argued before the parliamentary committee in 2019 that KES 110 million had been allocated for Nairobi River

regeneration initiative, which was inadequate (Kamau, 2019). Financial constraint remains as a challenge in the implementation and success of Nairobi River regeneration plan.

Political Interference

Political interference remains a hindrance in the implementation of Nairobi regeneration plan. The rehabilitation and restoration of Nairobi River and its riparian land will involve demolition of structures on riparian land. For example, Gikomba market and Grogan garages are situated in the riparian land. However, plans to demolish and relocate traders from these areas have always been futile because of political interference. During an interview with NEMA personnel, it was evident that political interference remains a hindrance in implementing conservation and management plans for riparian land.

CHAPTER FIVE

SUMMARY OF THE FINDINGS, CONCLUSION AND RECOMMENDATION

5.1 Summary of Findings

The findings of the study revealed that human activities had increased tremendously in the Nairobi River riparian zone. It was found that human settlements have expanded in the watershed from 28.07 km^2 to 54.58 km^2 between 2000 and 2020. However, vegetation covers in the watershed decreased from 64.26 km^2 to 37.7 km^2 between 2000 and 2020. Pearson's correlation statistical test was used to determine the relationship between human settlement and vegetation cover in the Nairobi River riparian zone. There is a strong negative correlation, -.975, between riparian land and the built-up environment. This finding implies that an increase in human settlement and activities in the Nairobi River riparian zone result in a decrease in coverage of riparian land and vegetation.

The study's findings revealed that there were notable changes characterized by increasing human settlements and activities in the Nairobi River riparian zone. Between 2000 and 2020, riparian vegetation decreased from 2.99 to 2.29 km^2. This decrease was influenced by increased human settlement in the watershed from 0.49 to 1.19 km^2 in the same period. It was found that the development of formal and informal residential settlements adversely affects Nairobi River's riparian zone. Additionally, formal and informal businesses, garages, urban parks, and agricultural activities were detected in the riparian zone. The reclamation and restoration of Michuki Memorial Park, situated between Museum Hill and Globe Roundabout in Ngara aims to restore and conserve riparian zone. Additionally, a section of Nairobi River at the Grogan stretch between Globe Roundabout and Kariokor Roundabout has been canalized, and trees planted to restore it.

Evaluation of the Nairobi River riparian zone regeneration plan forms the basis of the third objective. Analysis of different programs since 1999 to 2024 reveal efforts to rehabilitate, restore, and sustainably manage rivers in the Nairobi Basin. Efforts to rehabilitate and restore Nairobi River riparian zone were characterized by delineation of the riparian zone, identification of buildings or structures in the riparian zone to be demolished, and development of the Nairobi River Redevelopment plan.

5.2 Conclusion

Rapid human settlement development adversely affects vegetation cover in urban areas, especially riparian zone vegetation cover. The increasing coverage of human settlements in Nairobi River riparian zone results in a decrease in riparian zone vegetation quantity. The development of human settlements between 2000 and 2020 have transformed Nairobi River riparian zone. Increasing human settlements in urban areas degrades environmental resources, such as the riparian zones.

Human activities in Nairobi River riparian zone have increased between 2000 and 2020. The upstream region of Nairobi River riparian zone faced gradual change, whereas the downstream region faced rapid change. Human activities were detected in the 30m riparian zone, which decreased coverage of the riparian zone between 2000 and 2020. Nairobi River riparian zone was characterized by agriculture, informal settlements, formal and informal businesses, garages, and formal settlements. Human encroachment is a notable problem that degrades the riparian zone.

Efforts to reclaim the riparian zone in Nairobi River riparian zone have comprised of various regeneration plans and programs. The 2007 Nairobi River Basin Program, the 2010 Nairobi Rivers Rehabilitation and Restoration Program, the 2018 Nairobi Rivers Basin Rehabilitation and Restoration Program: Sewerage improvement project phase II, and the 2019-2024 Urban Rivers Regeneration Programme have achieved some of its objectives in reclaiming part of the riparian zone. Canalization of Nairobi River between Globe and Kariokor Roundabout and the rehabilitation of John Michuki Memorial Park depicts a partial success in reclaiming part of Nairobi River basin riparian zone. Weak enforcement, financial constraints, and political interference are challenges facing the implementation of the plan.

5.3 Recommendations

Based on the study findings on the implications of settlement development on Nairobi River riparian zone, the following recommendations are made to enhance the status of the riparian zone:

Delineation of the riparian zone along the river should be done as a joint activity after consultation between different government lead agencies. Key players such as the National Environment Management Authority and Water Resources Authority should mark the extent of the riparian zone to prevent developers from setting up development in riparian land.

Enforcement of development control rules and guidelines on new and existing projects near the river to prevent gradual encroachment of riparian zone. Nairobi City County Government should enforce and follow up on development control provisions on the approved building plans to mitigate encroachment of riparian land.

Revegetation of riparian zone with appropriate vegetation cover such as a bamboo tree to protect adjacent land from degradation. KFS should work with community groups involved in protecting the aquatic environment to plant and maintain riparian vegetation.

5.5 Area for Further Studies

Further research should be done to identify the significance of riparian zone on water quality and recreational activities along riparian zones.

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5.0 APPENDICES

Appendix 5.1: Institutional Questionnaire

KENYATTA UNIVERSITY

DEPARTMENT OF ENVIRONMENTAL PLANNING & MANAGEMENT

MASTERS RESEARCH PROJECT ON URBAN DEVELOPMENT AND ITS IMPLICATIONS ON NAIROBI RIVER RIPARIAN ZONE, NAIROBI CITY COUNTY, KENYA

***Declaration**: The data and information collected will be confidential and is intended purely for this research purposes.*

1. Are there any land use activities allowable within the riparian reserve? If yes, specify their uses and their basic minimum standards according to regulations.
2. What management tools/ strategies does the Sub county use in regards to the management and conservation of the riparian zone?

   How have these tools been effective?

   What additional tools or approaches can the sub County use to effectively manage the
3. Also, are there any activities known to the Ministry that are irregularly located within the reserve? What actions have the Ministry taken to address this phenomenon? riparian reserve?
4. What are the forces driving activities to locate in the riparian reserve?
5. How has the Ministry dealt with the issue of encroachment in the riparian reserve?
6. Are there past, present and/or future plans for the Nairobi River riparian zone?
7. What are the threats and dangers of locating within the riparian reserve in the study area?
8. What could be the other possible solutions to effectively manage and conserve the riparian? zone in the study area?
9. What factors have contributed to encroachment and degradation of Nairobi River riparian zones?
10. What do you attribute this current trend to?
11. What possible management measures or strategies would restore the biophysical functions of Nairobi River riparian zones?
12. What is your role (as a department or ministry) towards Nairobi Regeneration Plan?

Appendix 5.2: GEE Code for Land Use Land Cover

LULC Nairobi WS_2020 — Get Link | Save | Run | Rese

```
//Land Cover Change Analysis between 2000 and 2020 in GEE (Study Area: Nairobi River Watershed)//

//Determine Land Cover in 2020//

//load Landsat 7 Tier 1 TOA image collection
var landsat_1 = ee.ImageCollection("LANDSAT/LC08/C01/T1_TOA")
    .filterBounds(NairobiWS)
    .filterDate('2020-01-01', '2020-12-31')
    .sort('CLOUD_COVER')
    .first();
//print(landsat_1)
//clip by asset/roi
var landsat_2020 = landsat_1.clip(NairobiWS);

//Display the cliped image collection with visual parameters
Map.addLayer(landsat_2020, {bands: ['B4', 'B3', 'B2'], min: 0, max: 0.3, gamma: 1.4}, 'NairobiWS_2020');

//Zoom to roi
Map.centerObject(NairobiWS, 13);

//Merge sample points together into one FeatureCollection
var landcover_2020 = vegetation_and_farmland.merge(water).merge(built_up);
print(landcover_2020)

//Select Bands from mosaic Image for training
var bands = ['B2', 'B3', "B4", 'B5', 'B6', 'B7'];

//The name of the property on the points storing the class lebel
var classProperty = 'landcover';

//Sample the input imagery to get a FeatureCollection of training data
var training = landsat_2020.select(bands).sampleRegions({
  collection: landcover_2020,
  properties: [classProperty],
  scale: 30
});

//Train the classifier
var classifier = ee.Classifier.smileCart().train({
  features: training,
  classProperty: classProperty,
 });

//Classify the input imagery
var classified_2020 = landsat_2020.classify(classifier);

//Define color palette
var palette = [
  '1fd623', // vegetation (0) // green {htmlcolorcodes.com}
  'd70101', //built_up (1) // red
  '1f45f6' //water (3) // blue
];

//Display the classified result
Map.addLayer(classified_2020, {
  min:0, max: 2, palette: palette}, 'LULC_2020');

//Exporting image
Export.image.toDrive({
  image: classified_2020,
  description: 'nairobi_LULC2020',
  folder: 'GEE Data',
  scale:30,
  region: NairobiWS
});

```

Appendix 5.3: GEE Code for Processing OSM Buildings in the Study Area

WorkSpace — Get Link

```
Imports (1 entry)
  var NairobiWS: Table users/aineahpoulman/NrbRiver_WS
// Visualization of GOOGLE/Research/open-buildings/v1/polygons.

var t = ee.FeatureCollection('GOOGLE/Research/open-buildings/v1/polygons');

var structure1 = t.filter('confidence >= 0.60 && confidence < 0.65');
var structure2 = t.filter('confidence >= 0.65 && confidence < 0.70');
var structure3 = t.filter('confidence >= 0.70');

Map.addLayer(structure1, {color: 'FF0000'}, 'Buildings confidence [0.60; 0.65)');
Map.addLayer(structure2, {color: 'FFFF00'}, 'Buildings confidence [0.65; 0.70)');
Map.addLayer(structure3, {color: '00FF00'}, 'Buildings confidence >= 0.70');
//Merge sample points together into one FeatureCollection
var structure4 = structure1.merge(structure2).merge(structure3);

Map.addLayer(structure4, {color: 'd70101'}, 'Merged Structures');
Map.addLayer(NairobiWS);

//Zoom to roi
Map.centerObject(NairobiWS, 13);
Map.setOptions('SATELLITE');
//Map.centerObject(NairobiWS, 13);

var ROI = structure4.filterBounds(NairobiWS)
Map.addLayer(ROI, {color: 'd70101'}, 'Nrb WS Structures');

//Exporting as shapefile
Export.table.toDrive({
  collection: ROI,
  description: 'Buildings_v1',
  fileFormat: 'KML'})
```