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Land Use Policy Change and ITS Contribution to Urban Flooding in Downstream Zones: A Case of Nairobi City County

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Abstract

Urban flooding has become a significant problem in urban areas driven by land use policies. Inadequate flood mitigation measures in downstream zones have exacerbated the research problem. This study investigates the effects of changes in land use policies over time on urban flooding of downstream urban areas. Specifically, the study set out to assess the nature and trends of land use change and its implication, to determine the effects of land use policy change, and to examine the drivers of land use policy change and flooding on downstream zones in Nairobi City County. Finally, to propose strategies for sustainable land use policy change and protection of downstream zones from floods.

The study employed quantitative and qualitative approaches that integrated secondary and primary data collection methods. Secondary data was gathered through archival methods. Land use policy, peer-reviewed journals and government records were reviewed using content analysis. Geographic information systems (GIS) mapping of remotely sensed data from Google Earth and Satellite Imagery completed the secondary data collection. Kobo Collect tools collected primary data through a survey and observation. The results indicate contradictions in land use policy changes from pre-independent to post-independent, particularly in the 2004, 2006, and 2022 policies. The policies have reduced the minimum plot sizes, increased the ground coverages and plot ratios, and increased the number of floors to more than 20 from the original two without concomitant changes in the support infrastructure. The study concludes that land use policy changes in Nairobi City County have increased surface runoff and flooding downstream zones. The study recommends comprehensively mapping the city's drainage system utilizing remote sensing, GIS, and other methods. Furthermore, the study suggests that policy measures should critically consider the downstream by creating clear guidelines on land use policies that will help reduce surface runoff from the upstream.

Keywords: land use policy change, GIS, remote sensing, flood hazard

1. Introduction

1.1 Background

The challenge of reconciling socio-economic development with adequate environmental protections has become increasingly complex due to ongoing urbanization and rapid industrial growth (S. Suriya, 2012). According to (Liu, 2022), inadequate infrastructure combined with land use policies that provide limited guidance on protecting downstream zones has made urban flooding a significant issue; therefore, it is essential to revise land use policies to mitigate these effects (Liu, 2022). (Villanueva, 2018) highlights that many urban land use policies primarily focus on land use while often neglecting the impact of land use densification on increasing surface runoff in the city's lower reaches. Villanueva further argues that rather than adopting a region-wide approach, these policies frequently target localized areas, overlooking the more vulnerable downstream zones. Recognizing the susceptibility of lower urban areas to flood events is vital for developing comprehensive land use policies that prioritize resilience and sustainability in urban planning (Villanueva, 2018).

According to (Tollan, 2002) Flood risks and hazards can result in loss of life and property and long-term economic disruptions that impede community recovery and development. The author also points out that it is crucial to establish clear policies in urban areas that outline solutions for protecting riparian zones and other environmentally sensitive areas to prevent this natural disaster (Appollonio, et al, 2016). He also observes that as time passes, different urban areas undergo land use changes, and the impacts of these changes are not uniform across various urban contexts. In his study, Apollonio argues that the effects of land use on hydrological responses vary with the watershed scale, suggesting that smaller watersheds may experience more abrupt changes in flooding patterns due to land use alterations.

(Andreasen, M. H. et al, 2022) explains that the escalating population in urban areas intensifies the demand for land and open spaces, often threatening the health of riparian zones and other critical environmental areas. The situation is particularly concerning when changes in land use have significant consequences for downstream areas near water channels, resulting in an alarming increase in flood risks. Unfortunately, as cities develop policies and land use plans, there is frequent oversight in protecting downstream land uses by failing to establish adequate infrastructure to handle escalating flood events.

(Tollan, 2002) observes that consequences are severe: loss of biodiversity, increased pollution, and pervasive urban flooding, which are primarily driven by rising flood occurrences linked to upstream densification and the lack of proactive policies considering the relationship between land use and flood risk. To foster sustainable urban development, robust land-use policies that prioritize the protection of vital ecosystems must be formulated (Githinji (n.d.)., 2014). Githinji observes that it can mitigate flood risks and preserve natural heritage for future generations.
In Kenya, healthy river systems support informal economies, including urban agriculture and small-scale trade, according to (Luo et al., 2020). Nairobi's unchecked urban expansion has led

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to the degradation of its rivers. Koskey et al. (2021) link upstream densification to increased paved surfaces, leading to a higher surface runoff that inundates downstream informal settlements. On the other hand, Machado et al. (2022) criticize land use policies for encouraging development in upper areas while neglecting increased drainage due to poor drainage systems in low-income areas like Kibera. Luo et al. (2020) stress that informal settlements in flood-prone zones lack relocation options, forcing residents to deal with recurrent losses. As Suriya (2012) warns, Nairobi’s rivers, once lifelines, now symbolize urban inequality, where policy neglect transforms seasonal rains into humanitarian crises.

1.2 Problem Statement.

Global studies, including Tollan (2002), highlight that rivers serve as natural infrastructure for flood regulation, biodiversity support, and water resource provision in urban areas. However, despite their critical role, high urbanization rates and trends prioritize high-potential development in elevated zones, disregarding the consequences of increased urban floods in lower zones, as observed by (Liu, 2022).

Land use policies often increase densities through increased ground coverages and plot ratios, leading to increased floors. As a result, it increases impervious surfaces and reduces infiltration in those zones. The effect increases the surface runoff and reduces flood travel time to lower zones. Studies, including Villanueva (2018), on the other hand, add that fragmented governance frameworks fail to address downstream flooding issues, where concentrated stormwater overwhelms drainage systems and that this scenario, in most cases, leads to ecological degradation and recurrent flooding in lower watersheds of the urban areas.

Upstream land cover change through deforestation and unregulated construction destabilizes hydrological cycles, affecting the lower areas and increasing surface water runoff velocity. As Konrad (2016) pointed out, downstream informal settlements that lack storm water infrastructure suffer the most from flooding because natural barriers have been damaged.

The role of African rivers as they underpin livelihoods, agriculture, and urban water security is documented in studies, including (Andreasen et al., 2022). However, rapid urbanization often disregards riparian ecosystems. As a result, land use plans for managing flood water have remained hypothetical, as supported by Githinji (2014), who argues that weak enforcement of environmental policies allows encroachment into riparian zones.

1.2.1 Significance of the Study

This study assesses land use policy changes in urban areas, focusing on upstream and their impact on flooding in downstream zones. It provides clear, evidence-based insights into the consequences of these changes. It identifies specific areas for improvement, empowering policymakers to implement sustainable land use strategies that effectively address flood risks. The findings will align with local and global frameworks for developing climate-resilient cities.

This will drive the necessary advancements toward a sustainable future by effectively balancing land use planning, flood risk management, and social needs.

1.2.2 Study Objectives

The study examines how land use policy change in upstream zones of a city affects flooding in downstream areas. The specific objectives are to:

1. To examine the nature and trends of land use policy change over time in Nairobi City.
2. To determine the effect of land use policy change on upstream and flooding of downstream zones in Nairobi City County.
3. To examine the drivers of land use policy change and flooding of downstream zones in Nairobi City
4. To propose strategies for sustainable land use policy change and mitigation of flooding of downstream zones in urban areas.

1.2.3 Research Questions

1. What are the nature and trends of land use policy change in Nairobi City County over time?
2. How does land use policy change affect upstream areas and flooding of downstream zones in Nairobi City County?
3. What are the drivers of land use policy change and flooding on downstream zones in Nairobi City
4. What strategies can be employed for sustainable land use policy change and mitigation of flooding in downstream zones in urban areas?

1.2.4 Study Assumptions.

1. Land use policy changes in upstream zones significantly contribute to flooding of downstream zones in urban areas
2. Integrated land use policy change that addresses flood management in downstream zones is the panacea to sustainable urban areas

1.3 Relevant Scholarship

1.3.1 Theoretical Background

The Land Use Transition Theory by Meyfroidt (2010) explains how land use changes occur over time due to socioeconomic and policy-driven factors. It theorizes that the growth rate and unplanned land use change natural ecosystems to built-up states, but it denies the consideration of long-term environmental impacts. The conversion of waterways into informal settlements and commercial development, as identified in Nairobi, is such a transition that creates flood vulnerability when coupled with the generally low levels of stormwater management reported by (Mwangi, 2021)

Urban political theory, as discussed by Swyngedouw (2014), adds a crucial socio-political perspective, emphasizing how policies shape environmental risks. It highlights that inequitable power dynamics in urban planning led to policies favouring economic development over sustainability, disproportionately affecting marginalized populations in flood-prone areas. In Nairobi, policies prioritizing high-density development in affluent neighbourhoods overlooking the needs of those downstream, and worsen spatial inequalities in flood exposure (Nguah, 2024). This highlights the urgent need for equitable and sustainable urban policies that serve all urban communities.

1.3.2 Theoretical framework: Hydrological Response Theory

The Hydrological Response Theory explains how changes in land cover and urbanization influence runoff characteristics and flood regimes in urban areas (Leopold, 1968). This theory states that urbanization disrupts the natural hydrological cycle by increasing impervious surfaces, decreasing the infiltration rates, and increasing the rate of surface runoff. Leopold also established the foundational relationship between urbanization (e.g., impervious surfaces) and increased surface runoff. According to (Appollonio, et al, 2016), higher rate of urbanization of upstream zones significantly impacts the hydrological response of the downstream area with increased flood susceptibility.

1.3.3. Determination of Surface Runoff

The hydrological response theory guided the determination of surface runoff. The theory postulates that urbanization increases impervious surfaces, increasing the rate of surface runoff flow. According to Dottori (2021), the effects of runoffs and infiltration over impervious surfaces significantly alter the circle of hydrology, particularly in urban environments. Dottori further observes that in medium-density environments, about 30% of rain transforms into runoff, and 35% infiltrates the ground. Dotto further argues that in high-density urban environments, runoffs escalate to 55%, and infiltration drops to 15% with a high cover of impervious coverings such as buildings and highways.

With such a transformation, increased build-up during rain exacerbates urban flood peril (Dottori, 2021) The author further indicates that urban development often narrows river channels and hastens siltation, reducing river depth and drainage capacity. Deforestation hastens this issue through increased topsoil loss and sedimentation in river channels, effectively lowering floodwater capacities (Dottori, 2021). Figure 1 represents the effects of impervious surfaces on the surface runoff volume.

Figure 1 Impervious surface and its effect
Source: (Dottori, 2021). https://www.riversmarthomes.org/isr

(Dottori, 2021) Seem to differ with (Chow, (1988)) who emphasizes using a uniform coefficient value for urban paved surfaces (C= 0.75) with minor infiltration, evapotranspiration, and surface retention included in the allowance. Chow using Applied Hydrology believes that in intensively paved urban areas, values for coefficients of runoff range between 0.70 and 0.95, which is equal to 70% to 90% of the runoff, with lesser values, including minor infiltration through cracks, evaporation, and transient surface storage in the allowance.

Calculations

According to the literature, there are various methods of surface runoff computations, including The SCS Curve Number Method (USDA, 1954), which predicts runoff depth using soil type, land use, and rainfall, suited for agricultural areas but data-intensive for cities. Horton's Infiltration Equation (Robert E. Horton, 1933) models time-dependent infiltration, valid for natural catchments but complex for urban zones. The Unit Hydrograph Method (Leroy K. Sherman, 1932) relates rainfall excess to runoff over time, which is practical for large basins but impractical for flash floods. The Kinematic Wave Equation (Pierre Julien, 1998) models unsteady flow dynamics, which are computationally heavy and rarely used in basic urban design. For this study, the Rational Method, developed by Thomas J. Mulvaney (1851) and refined by Emil Kuichling (1889), is preferred since it calculates peak runoff. It is ideal for small and medium urban catchments because it is simple and relies on rainfall intensity, land-use-based runoff coefficients, and area.

Using the rational method of calculating the Surface runoff as prescribed by (Venture, 2013), the surface runoff $Q=CIA$ *where*: Q: Maximum runoff (Volume of water per unit time), C: Runoff coefficient (dimensionless), I: Rainfall intensity (rainfall depth per unit time), and A: tributary Area of watershed to the runoff

According to Dingman (2015), the Rational Method assumes that rainfall distribution is uniform over an entire region for a year. In practice, rainfall intensity varies in location and time, most notably in urban locations with localized storms. (Venture, 2013) also assumes that uniform rainfall over time and space produces a steady peak runoff after water from all parts of the watershed has reached the runoff location considered.

1.4 Land Use policy change and its implication on downstream zones in Nairobi city county

Nairobi's history has been shaped by a series of town plans, each with its priorities and land use policy. From the colonial era to the present, these town plans have shaped the city's development, infrastructure, and environmental management, including flood control. The course of Nairobi's planning policy is informative regarding how land use policies have shifted unintentionally, aggravated urban flooding problems (Kingoriah, 1980).

1.4.1 A Chronology of the Planning Framework of Nairobi City County

a) The Plan for a Railway Town, 1906

Nairobi's history can be traced back to 1898, when it was developed as a railway depot during the construction of the Kenya Uganda Railway. Nairobi was preferred as a suitable site because of several comparative advantages, such as geography and its strategic location. In post-World War 1, Nairobi's first plan was established (Mbatia, 2008).

Dubbed 'the plan for a railway town' of 1906, this initial plan was designed by Arthur Frederick Church. A few years later, in 1900, the Nairobi Municipal Community (NMC), which was provided for under an order-in-council of 1897, published its first regulations, which defined the first official boundary of the city as approximately 1.5 miles from the existing administrative centre. (Halliman & Morgan, 1967). Nevertheless, this original scheme did not incorporate measured flood control and management mechanisms. Perhaps this created a legacy of future land use pressures in Nairobi.

b) The Plan for a Settler Capital, 1927

The 1920s was a period of accelerated economic and spatial growth for Nairobi as a primary administrative and commercial node. This era ushered in the development of the 1927 plan (Banyikwa, 1990). The plan proposed expansion of the city's growth limit to accommodate a growing population covering 32.4 square miles. Additionally, the plan made provision for improving drainage and draining swamps. Even though the plan enhanced drainage was included, the policy shift was directed towards new residential zone development and not towards enhancing the existing natural drainage systems (White, Silberman , & Anderson, 1948). The focus on land use expansion without adequate environmental study is to blame for the degradation of the floodplain and increased runoff. It increased the risks of flood hazards in subsequent years.

c) The Master Plan for a Colonial Capital, 1948

The 1948 master plan was a significant shift towards contemporary urban planning principles by incorporating zoning plans that distinguished space for official buildings, business, industry, residential, and open spaces. Urban development of Nairobi's industrial zones, mainly south of the railway station, altered the city's hydrology by introducing impervious surfaces and diminishing natural areas of water infiltration. Furthermore, the segregationist planning policy resulted in the concentration of the poor groups in the flood-risk zones, further increasing flood vulnerabilities. (White, Silberman , & Anderson, 1948). Re-designing the railway line to allow for the expansion of Uhuru Highway resulted in encroachment into riparian areas and, hence, increasingly frequent flooding incidences. The Ngong River was channelized to improve the flow of the river, but created more challenges as residential and industrial land use were located at river banks (White et al., 1948)

d) Nairobi Metropolitan Growth Strategy and Its Implications on Urban Flooding, 1973.

The 1973 growth strategy aimed to provide solutions and a growth strategy to the urban challenges faced in Nairobi and provide long-term development planning policies and proposals (the Nairobi Urban Study Group) (NUS, 1973). It produced several components, including urban and regional strategies, transport policies, and phased development plans. Despite being an informative growth strategy, the plan failed to give an impactful strategy on the climate resilience sector, leaving out clear guidelines on developments close to the rivers. The absence of a localized physical development plan led to the unregulated urban expansion into the riparian reserves and inadequate infrastructure to handle stormwater runoff, leading to health and safety concerns. (NUS, 1973)

While formulating the strategy, the Nairobi urban study group (1973) Focusing on addressing the rapid growth would increase the population in the suburbs and metropolitan areas. It did not focus much on environmental conservation since it was based on population and economic expansion, particularly in the Northern and Southern parts of the city. The plan did not adequately give out flood mitigation measures with the rise of population leading to an increase in impermeable surfaces, reduced green spaces, and disruption of natural water flow patterns. This led to the rise of informal settlements in the city, encroaching on the riparian zones (NUS, 1973).

e) 2014 Nairobi Integrated Urban Development Plan NIU PLAN (County, 2014)

The Nairobi City County Government formulated the Nairobi Integrated Urban Development Plan (NIUPLAN) in 2014 (County, 2014); this plan was focused on the increase of densities, especially in zones 3,4 and 5. The plan only describes stormwater drainage and sewage drainage projects in the city. It also describes the Nairobi Rivers Basin Rehabilitation and Restoration Program, which provides a comprehensive framework for water and environment management in Nairobi City. The former Nairobi River Basin Program (NRBP, 1999-2008) elaborated the framework. This program did not anticipate high-rise buildings with concrete surfaces in the upper reaches that would increase surface runoff in downstream zones of the city. (County, 2014). Although the plan discussed creating transparent sewer systems, it did not address how to deal with urban floods caused by high-rise buildings, which led to a lack of natural water penetration mechanisms. The policy ignored that urbanization reduces water absorption ability by soil, resulting in an increase in surface runoff and river siltation.

1.4.2 The Zoning Guidelines in Nairobi City County

a) A Guide to Nairobi City Development Ordinances and Zones, 2004

According to the Guide of Nairobi City Development Ordinances and Zones (2004), the city council of Nairobi outlined regulations and zoning guidelines for land use and building developments across Nairobi. It zoned the city into different categories, each with its requirements on building heights, plot coverage, land use, and environmental concerns. These regulations ensure orderly urban growth and balance economic development and environmental sustainability. However, rapid urbanization and high-rise developments, especially from zones 3,4 and 5, have continuously raised concerns over their impact on drainage systems and flood risks in the lower zones, especially those near rivers and riparian lands. Table 1 represents the ground coverage, plot ratios, type of development and the minimum permitted area in zones 3, 4 and 5 of Nairobi.

Table 1 Zone 3,4, and 5 specifications as per the policy (Council, 2004)

Zone	Areas Covered	G.C. %	P.R. %	Type of Development Allowed	Min Area (Ha)	Remarks / Policy Issues
3	Parklands • Residential • Commercial	 50 35	 100 75	Commercial / Residential (High-rise Flats)	0.05	Policy under review
	City Park Estate / Upper Parklands	35	75			
	Westlands - Westlands CBD - Westlands / Museum Hill - Block 1 Commercial - Block 2 & 3 offices and High-rise - Block four offices - Block 5 Commercial / Residential - Hotels	80	200	Commercial / Offices / Residential (High-rise Flats) Four storey max.	0.05	Policy under review
4	Spring Valley, Riverside Drive, Kileleshwa, Kilimani, Thompson, Woodley	35 (s) 25 (u)	75(s) 25(u)	Residential (Apartments allowed on sewer only) - 4 storey max.	0.05	Policy under review
5	Upper Spring Valley, Kyuna, Loresho, Lavington / Bernard	25 (s)	25 (s)	Low-density Residential (One Family House)	0.2	Maisonettes are allowed in the sewered

	Estate • On Sewer (s) • Unsewered (u)	35 25	75 25			areas of Lavington.

G.C. %: Ground Coverage Percentage, P.R. %: Plot Ratio Percentage, (s): On Sewer, (u): Unsewered
Source: (Council, 2004)

b) Policy Review for Zones 3, 4 and 5, Nairobi, Kenya 2006. (NCC, 2006)

This was the policy review in Zones 3, 4, and 5 within Nairobi City County, dealing with rapid urbanization and the stress that this places on infrastructure, the environment, and land use. These areas include, among others, Westlands, Kileleshwa, Lavington, and Spring Valley; these zones are traditionally low-density, high-income residential but have recently witnessed a shift with high demand for housing, offices, and commercial space. The policy advocates for sustainable development through infrastructure improvements, the protection of riparian reserves, and environmental conservation by proposing infrastructure levies and stringently controlling developments to retain livability and ecological balance. The total area of the three zones is approximately 40,000 hectares (NCC, 2006). The policy further proposed that the three zones proposed by the city ordinance. (Council, 2004) Be subdivided into sub-zones, each with specific land-use plans, sub-zonal guidelines, and requirements.

c) Nairobi City County Development Control Policy,2022

This policy was enacted in 2022 to put guidelines on development control. It gave out standards for the newly proposed higher plot ratio, ground coverage, and minimum plot sizes for planning and construction purposes in Nairobi City County. The policy gave out guidelines that increased the densities of the buildings on the existing land. The policy did not consider riparian zones and the downstream effects. It also did not consider the impacts of high-building skylines on small parcels of land, which, in a typical scenario, would need a lot of ground coverage to sustain the building height.

1.4.3 The Legal Context of Land Use Planning and Flood Management in Nairobi City County

The constitution of Kenya under Article 60(c) mandates sustainable land use that can cater for all. County governments prioritize revenue and economic gains that promote upstream densification, which violates the act due to downstream impacts. Article 42 also states that everyone has the right to a clean and healthy environment, but solid and liquid waste management is still an issue in the river system. Despite Article 69(1)(d) obligating the state to protect water catchment areas, many upstream projects have disrupted natural drainage, worsening downstream flooding.

The County Governments Act of Kenya dictates the county government's land use and zoning administration. The non-stringent use of the zoning rules has helped create unplanned settlements and development within the riparian zones that interfere with natural drainage and augment downstream floods. The Act's inability to promote compulsory public participation

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(115) in formulating land decisions has allowed illegal rezoning of the wetlands into commercial development that increases flood risk.

The Urban Areas and Cities Act 2011 requires counties to adopt integrated urban development plans for drainage and disaster management. Nairobi's non-compliance with these plans has permitted dense, impervious developments (e.g., highways, malls) without compensating green spaces or stormwater systems. The Act's vague penalties for violating environmental safeguards have allowed developers to bypass flood-resilient designs, exacerbating runoff into downstream slums like Mukuru.

The Physical and Land Use Planning Act of 2019 (PLUPA) mandates EIAs for development. Approval of developing high-rise buildings within the wetlands (for instance, Southlands and Ondiri Swamp) with minimal EIAs has disrupted natural drainage and contributed to flood bulkiness. The nonretroactive use of the Act against preexisting illegal buildings (Section 30) has placed floodplain settlements at constant catastrophe.

The Survey Act (1989-Section 18) enforces accurate land demarcation to prevent encroachment into riparian zones. However, uncontrolled development permissions in Nairobi have legalized titles on flood-prone land (e.g., Ngong River banks), shrinking buffer zones. The Act's outdated and weak technical standards only implement decisions arrived at by planners. The decisions are not made after proper topographical surveys to establish the highest water marks.

Section 42 of the Environmental Management and Coordination Act (EMCA) (2012) aims to protect the environment. It prohibits specific activities within protected areas, and no individual shall undertake cultivation, construction, or any form of development within this zone without permission from NEMA.

The Water Resources Regulations, (2007) (Legal Notice No. 171), Regulation 116 defines "riparian land" and sets management controls on land use to protect water resource quality. It provides that the riparian land on either side of a watercourse shall be at least six meters or equal to the entire width, up to a maximum of thirty meters on either side of the bank. (GoK, 2007).
The significance of these regulations is that they should protect water resources by regulating land use in riparian zones. However, the regulations contradict the Survey Act, which establishes the riparian zone as 30 m above the high-water mark, and the physical planning rules of 1998, which indicate that the riparian zone should be determined 10 m from the highest flood level. In addition, there is a lacuna at the point of determination of the riparian zone. Survey plans show the centre line of the river, other legislation uses the river bank while others use the established flood plains or the high-water marks. No proper mapping has been done to geo-reference the actual measurement points in all these scenarios.

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1.4.4 Conceptual Framework

The study assesses the effect of urban land use policy change on flooding by linking separate variables within a system model. This research operationalizes the independent variable as policy-driven changes in urban land use that result in upstream densification and sprawl of impervious surfaces; mediating factors are erosion of riparian protection, deficiencies in drainage infrastructure, and the attendant acceleration of surface runoff; and the dependent variable is downstream urban flooding with its attendant community and economic consequences. This research combines GIS modelling, remote sensing, and policy analysis to graphically represent the causal chain from policy choice to environmental effect and intervention policy.

The variables in this study are formulated through an extensive review of literature and policy documents so that each variable selected represents key aspects of the theoretical framework. This study is significant because it determines the relevance of upstream densification and its hydrologic implications, the intermediary role of riparian areas, and the ensuing flood hazard, thus formulating an integrative model that guides specific, sustainable interventions.

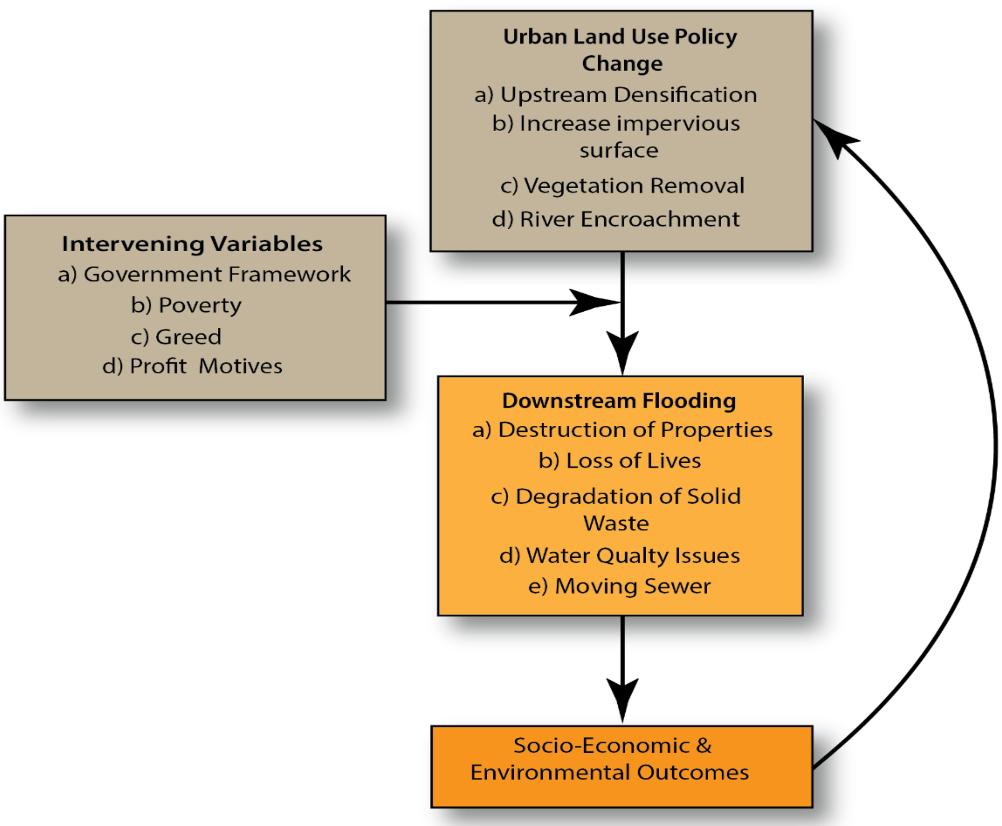

Figure 2Conceptual Framework
Source: Author, 2025

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a) Operational definition of terms

Upstream refers to areas located higher in the watershed or river system, including areas where water originates, such as in high rainfall regions or near the source of rivers. *(Nordblom, 2021)*

Downstream: Refers to areas located lower in the watershed or river system. (Nordblom, 2021)

Surface runoff: That part of the rainfall that enters the stream immediately after the rainfall (Venture, 2013)

Riparian Zone: These are the transitional ecosystems along riverbanks that regulate water flow, filter pollutants, and mitigate flooding by acting as natural buffers (Tollan, 2002)

Drainage: It refers to the natural or artificial systems designed to remove excess water from an area, including rivers, streams, and engineered infrastructure like sewers and stormwater channels, with inadequate systems (Villanueva, 2018)

Encroachment: The unauthorized or illegal occupation and use of land that is designated as a buffer zone around rivers and other water bodies, Muketha (2014)

Degradation: The disruption of ecological balance, where loss of vegetation, pollution, and habitat destruction result in declining water quality and loss of aquatic biodiversity. Petts & Amoros (1996)

2. Research Methodology

2.1 Research Design

Various studies reviewed, including Dash (2021) applied hydrological modelling. Others, including Ridzuan and Rahman (2022) used a qualitative methodological approach. On the other hand, a study by (Birkland, 2003) marries environmental examination and policy historical analysis to criticize historical flood prevention through dams and levees. (Salami, 2017) argues that a participatory, mixed-methods research approach integrates community participation with quantitative and qualitative data to create a tailored vulnerability assessment tool.

The reviewed study reveals several approaches, including qualitative and quantitative. The study mainly focuses on a quantitative approach based on GIS mapping supported by a descriptive survey. It used a descriptive cross-sectional study to compute floods before and after land use policy change. It sought to establish and describe the effects of land use policy change.

2.2 Location of the study

Digital Elevation Map of Nairobi City County

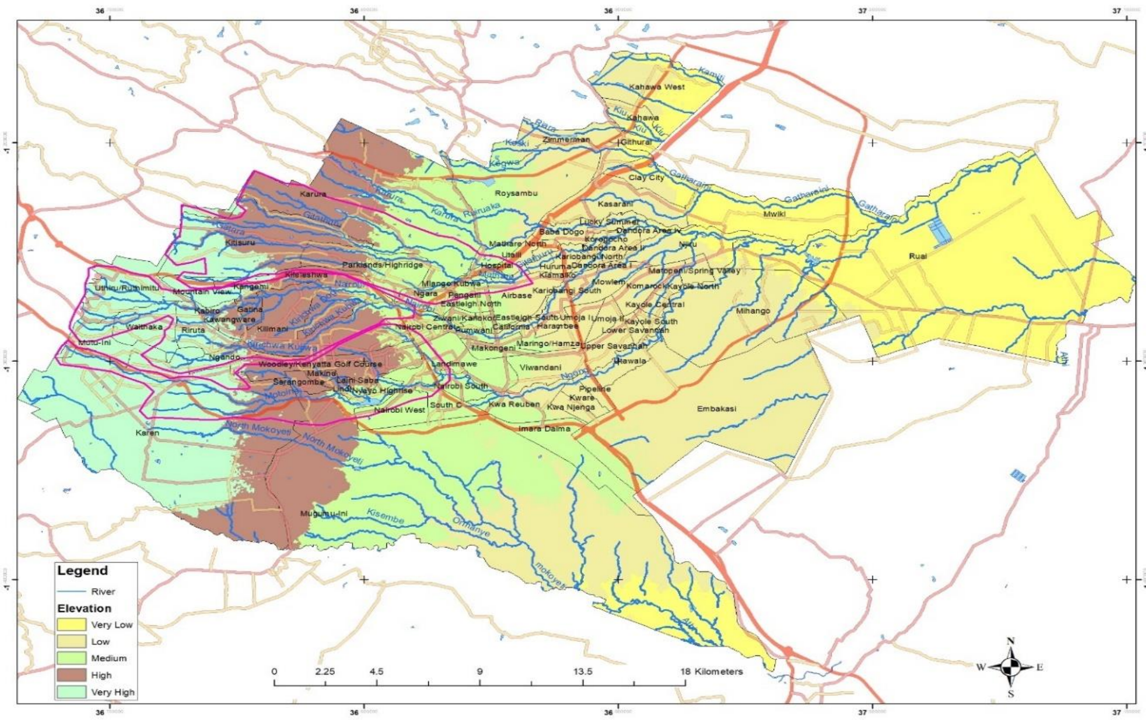

Figure 3The digital elevation map of Nairobi
Source: GIS Mapping, 2025

The map shows that the elevations of Nairobi City County slopes from the west to the east.

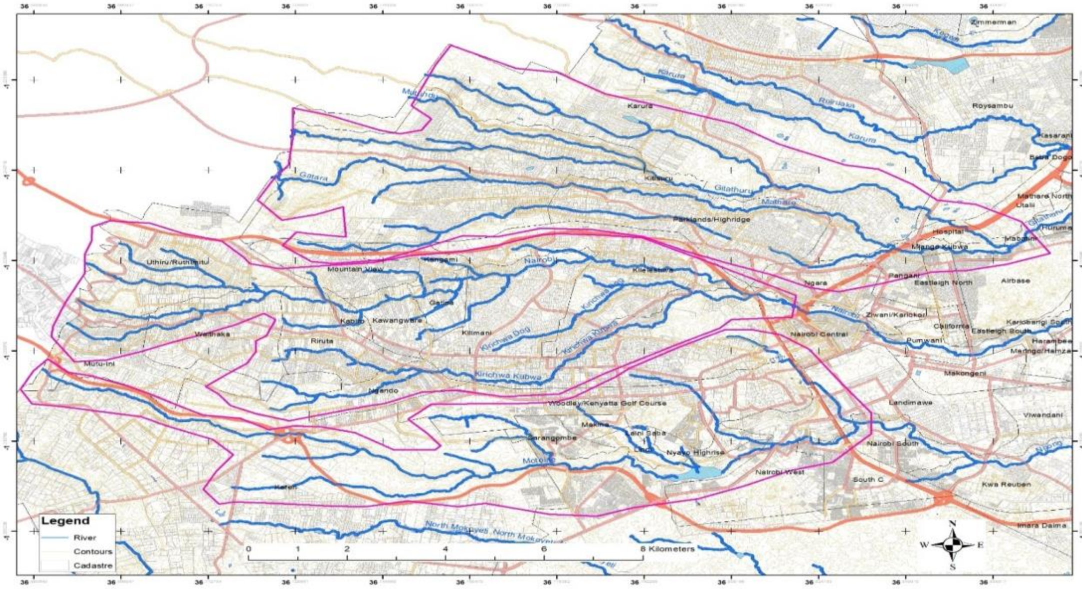

Figure 4 Catchment area Map
Source: GIS Mapping 2025

The catchment area of Nairobi River, Ngong River and Mathare River originates from zones 3,4 and 5, to the downstream. The study area Zones of Nairobi covers the following neighbourhoods:

Table 2 Zones Covered

	Zone	**Neighborhood Selected**	**Rivers passing through**	**The area covered in Ha**
Upstream Zones	Zone 3	Parklands, City Park Estate, Westlands, areas near Museum Hill	Nairobi river and Mathare river	14,367
	Zone 4	Lower Spring Valley, Riverside Drive, Kileleshwa, Kilimani, Thompson, Woodley/Ngong Road	Nairobi river and Ngong river	
	Zone 5	Upper Spring Valley, Kyuna, Loresho, Lavington/Bernard Estate	Mathare River and Nairobi River	
Downstream zones	Zone 7	Mathare informal settlements	Mathare river	5237
	Zone 8	Carton Village informal settlements	Nairobi river	
	Zone 9	Mukuru Village informal settlements	Ngong river	

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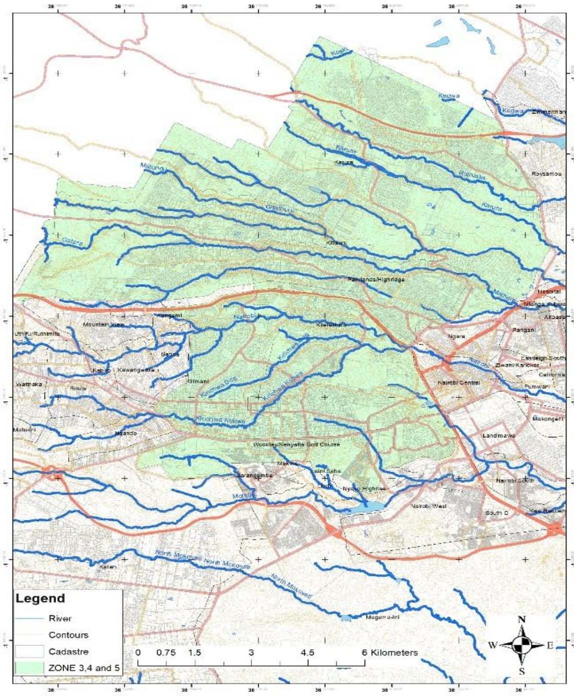

Figure 6 Upstream Zone

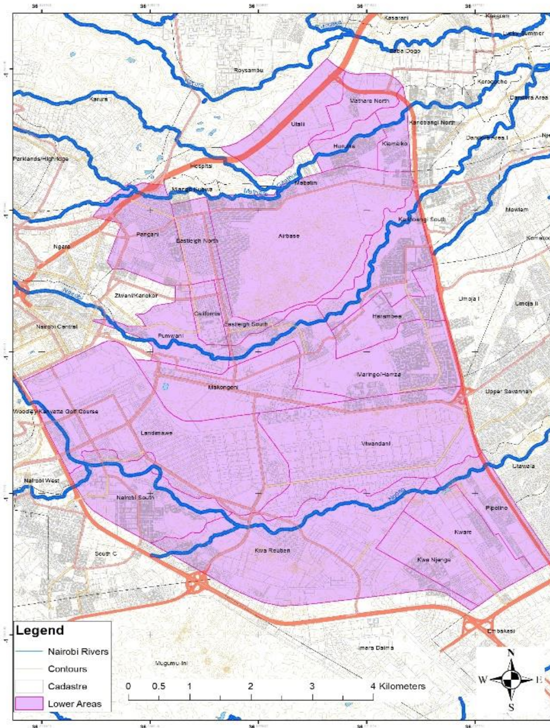

Figure 5 Downstream Zones

Source: GIS mapping 2025

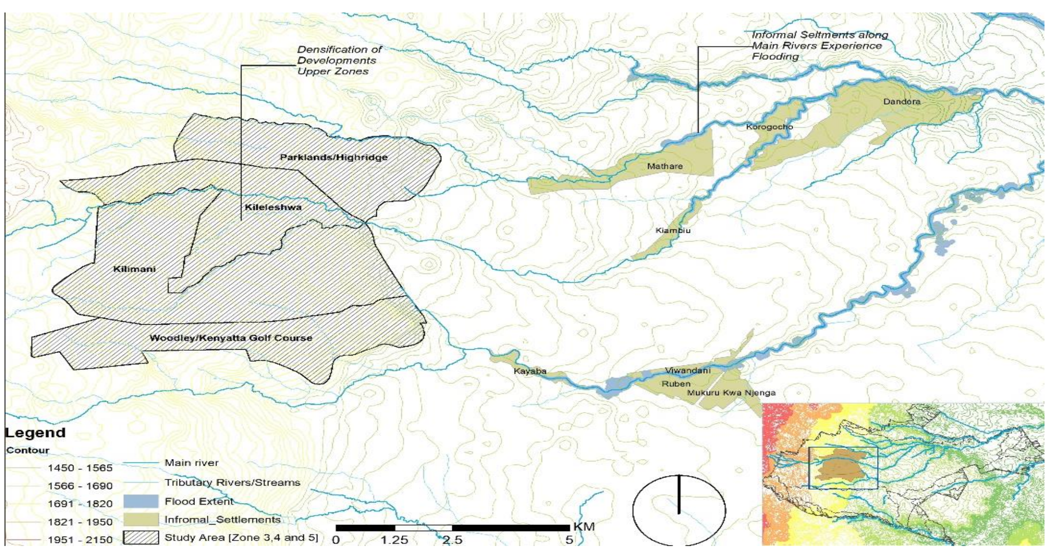

Figure 7 Upstream area in relation to downstream with contours
Source GIS 2025

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Population

Nairobi city is one of the most densely populated and rapidly growing cities in Africa (World Population Review, 2024). Speedy urban growth, combined with weak enforcement and inadequate policy frameworks of river protection, poses a significant threat to the city's rivers. The primary cause of this degradation is the presence of informal settlements along the waterways brought by the high population, leading to social conflicts over their use. This situation underscores the urgent need for updated urban policies to address the environmental crisis and promote sustainable development (Population Matters, 2024).

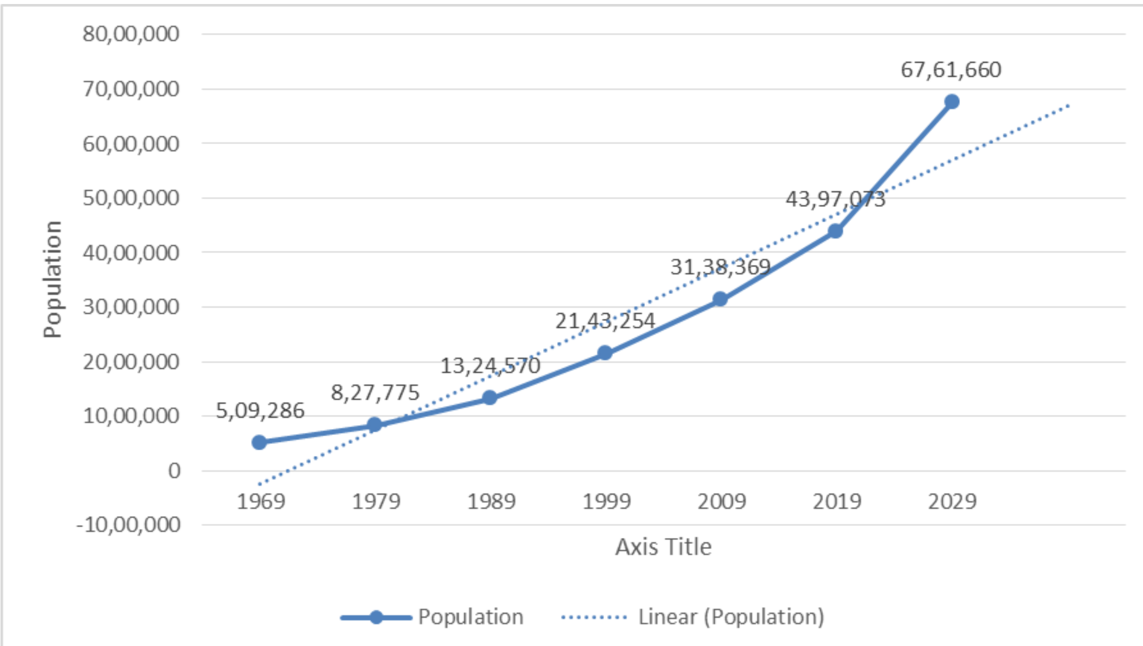

Figure 8 Nairobi population growth
Source: KPHC (Center, 2021)

The study found that over the years, the management of Nairobi City County has made efforts to develop guidelines for urban development control. However, implementation and enforcement of these policies mainly focus on the upper zone of the city—specifically Blocks 3, 4, and 5, which include high-end residential and commercial areas. This policy focus has overlooked the critical role of Nairobi's major rivers, including the Nairobi, Ngong, and Mathare rivers, which flow through these urban areas and into downstream regions. As a result, poor management of these rivers has increased flood risks, especially for informal settlements built on river banks. The lack of clear flood management policies and the failure to include river areas in urban planning have left vulnerable communities at risk of recurrent flooding and environmental degradation (Omoto, 2024).

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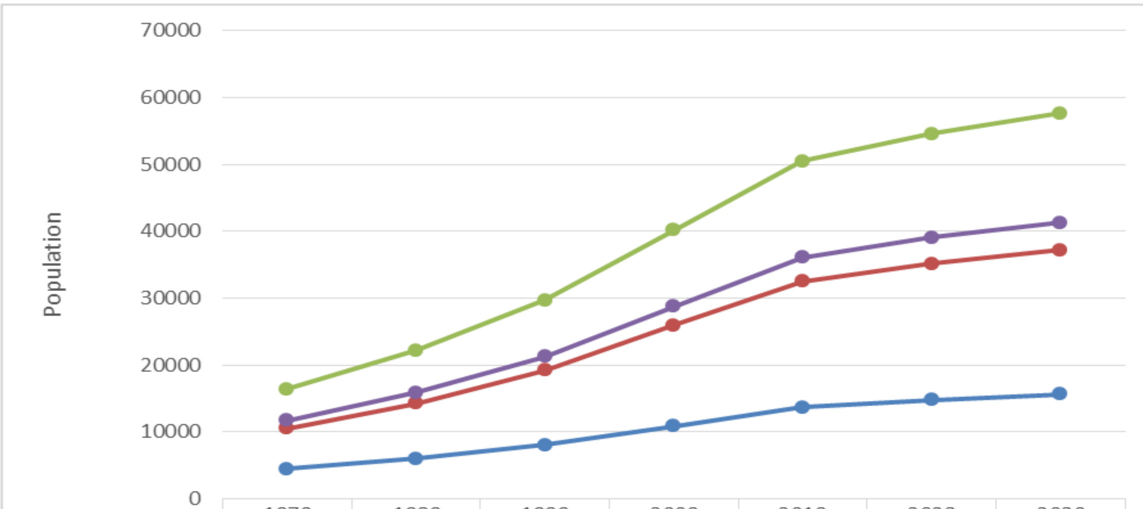
2.2.1 Population of Zones 3, 4 and 5

Drawing from the Kenya Census data of 2009, the population of the Westlands ward in Zone 3 was 247,102 (KNBS, 2009). The follow-up cycle of the 2019 census established that the population grew to 308,854, recording a growth rate of 2.3 (KNBS, Kenya Population and Housing Census, 2019). This growth rate has been used in this study to estimate the population of the neighbouring wards since the preceding national census did not provide the disaggregated population at the ward level. Figure 9 illustrates the projected population and growth for the four wards within the study area.

Population of the study Area (Zones 3,4 and 5)



	1979	1989	1999	2009	2019	2023	2030
Parklands	4419	5995	8036	10867	13641	14759	15592
Kileleshwa	10532	14289	19155	25900	32513	35177	37163
Kilimani	16344	22175	29726	40194	50457	54591	57674
Woodley	11698	15872	21277	28769	36115	39074	41281

Figure 9 Population projection of four wards within the study area

The study found that Zones 3, 4, and part of Zone 5, which flow their surface water to the Ngong River, Nairobi River, and Mathare River, have developed the highest number of informal settlements in the city. (Muketha, 2019).

2.2.2 Inclusion and Exclusion Criteria

Inclusion was based on the geographic proximity of the 3 rivers selected in the upstream and downstream zones, and the people affected by floods in the downstream areas. It excluded anyone not along the floodplain and was unaffected by any flooding incident in the Nairobi, Mathare, and Ngong rivers. Due to the large geographic scope of the downstream areas, only the area from the upper zone to the Outer Ring Road was included in the study. This area is deemed to have the highest flood impacts in the county.

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2.3 Sampling

A purposive sampling strategy was employed to get data along the Nairobi City County River corridors where urban flooding is worst. Nine rivers were initially selected based on their relevance to urban development in the county, but three rivers, the Nairobi, Ngong, and Mathare Rivers, were selected for in-depth analysis. These rivers were chosen because they pass near the CBD, where the city has the highest development intensity. Second, they are the longest and biggest rivers that traverse the different land uses, presenting a unique critical case for the study; third, they originate from the upstream zones 3,4 and 5 and pass through the informal downstream settlements.

Table 3 Inclusion and Exclusion Criteria

River Name	Areas they pass through	Reason for Inclusion/Exclusion in Study
Nairobi River	Upstream (Westlands, Parklands), Midstream (CBD, Industrial Area), Downstream (Kiambui, Carton Village)	**Selected**: Primary river basin; directly impacted by upstream policy changes (Zones 3–5) and critical for downstream flooding.
Ngong River	Upstream (Karen, Ngong Hills, Langata) Downstream (Mukuru Villages)	**Selected**: Represents upstream-downstream hydrological connectivity; Has a tributary in the Nairobi CBD
Mathare River	Upstream Parklands, Spring Valley, Muthaiga Downstream (Mathare Valley informal settlements)	**Selected**: Epitomizes downstream flooding due to upstream urbanization; 80% of structures violate riparian reserves downstream.
Rui Ruaka River	Githurai, Kasarani	**Excluded**: Smaller tributary; less directly impacted by upstream Zones 3–5 policy changes.
Gitathuru River	Eastleigh, Huruma	**Excluded**: Localized flooding but minimal linkage to upstream policy-driven densification.
Karura River	Karura Forest, Runda	**Excluded**: Protected forest area; limited informal settlements or policy-driven land use changes.
Kamiti River	Kiamaiko, Kamiti	**Excluded**: Peripheral to Zones 3–5; fewer policy conflicts.
Kirichwa River	Kileleshwa, Kilimani	**Excluded**: Short length; primarily affects affluent areas with better drainage infrastructure.
Gatharaini River	Embakasi, pipeline	**Excluded**: Minor tributary; insignificant role in city-wide flooding dynamics.

2.4 Methods of Data Collection

Through a multi-agency approach, the government commissioned a task force in which the researcher was the lead consultant in the GIS mapping of Nairobi rivers and riparian reserves. The study employed 43 National Construction Authority field assistants (NCA), 3 GIS experts and a team of 8 other research assistants to gather information relevant to the study. Photography and observations were taken with the Kobo toolbox mobile application. It was used as a research instrument to collect and analyze the data in the field due to its modern real-time data collection capabilities.

2.4.1. Secondary data collection

Secondary data was obtained after a review of related literature, past research, journals, magazines, articles, and government archives. The research also referenced secondary data from policies and Acts of Parliament, from the National Government and the Nairobi City County. The review focused on previous Nairobi land use policies and guidelines to determine the trends in the policies and how they affected the flood regime in the city.

2.4.2 Primary Data Collection

Focus Group Discussions (FGDs) and interviews with key informants were conducted with downstream and upstream residents. Key informants like the village elders, youth leaders and other community leaders were used as important informers to understand how flooding affected them. Each FGD group consisted of a different number of participants to obtain diverse opinions on urban flooding and land use change in the downstream zones. The study did not use questionnaires since the chosen approach efficiently got detailed and specific insights that standardized questionnaires might miss.

Kobo Collect was a very important and advantageous data collection tool used during the study. KoBo Toolbox is an open-source mobile data collection tool available to all. It allows data collection using mobile devices such as mobile phones, tablets, or laptops. The data-driven application enables real-time data collection, ensures efficiency and speed in data collection, and completes integration. It works on smartphones, mobile applications (app), and has GPS to show the location of data collected, a digital compass, a camera/voice recorder, and a barcode reader. Its offline use was also a key consideration due to the network issues experienced in the field.

2.4.3 Research instruments.

The study employed Geographic Information Systems (GIS) as a primary analytical tool to assess land use changes and floodplains in the study area over time. GIS was the key tool used to map spatial patterns of urbanization, including upstream densification, riparian zone encroachment, and impervious surface expansion, using satellite imagery (e.g., Landsat, Sentinel-2) and Google Earth Pro. These models helped to quantify policy-driven land use changes, e.g., the 2006 amendment. altered runoff coefficients and downstream flood susceptibility. To contextualize spatial findings, policy analysis tools—such as document reviews of, for example, the NIUPLAN (2014) and stakeholder interviews—were paired with Kobo-Collect outputs to evaluate enforcement failures and zoning issues. Finally, GIS-generated flood risk maps and 3D visualizations show the spatial nature of the different areas of Nairobi City County related to flooding.

Threats to internal Validity

The study could have faced several issues that could affect the accuracy of its findings. Firstly, the focus group discussion with the key informants may not have represented the whole community's views on who was affected by the floods. This could have interfered with the data since some key informants would have their settlements in areas unaffected by floods. risk of errors in recording observations or interpreting responses differently was another challenge. The use of many researchers could have unintentionally influenced the discussions, leading to biased results, which may have interfered with the data. To reduce these risks and biases, the study used structured data collection tools to compare information from different sources and ensured consistency in how data was recorded and analyzed. These steps helped improve the validity and reliability of the findings.

2.5 Data Analysis Techniques

The collected data was analyzed using Kobo Collect, a powerful mobile application tool for data collection and analysis. Further descriptive data analysis was done through Microsoft Excel, while the GIS data analysis and modeling tools were used in spatial visualization.

To quantify the impact of land use policy changes on surface runoff, the study applied the rational method (Q = CiA). In this formula: **Q** represents the peak surface runoff rate (cubic meters per second), **C** is the runoff coefficient that varies with land use and surface permeability the co efficient of 0.75 was used as highlighted (Chow, (1988)) who emphasizes using a uniform coefficient value for urban paved surfaces (C= 0.75) with minor infiltration, evapotranspiration, and surface retention included in the allowance. I is the rainfall intensity (millimeters per hour), a uniform rainfall intensity was used for the three years (2004,2006, and 2022). The uniform rainfall intensity was to show the increased runoff of the years when all parameters are the same except for the coefficient value, which changed due to an increase in the impervious surface. **A** is the catchment area (in square kilometers).

Using the rational method, the study calculated and compared surface runoff before and after key policy changes (2004, 2006, and 2022), demonstrating how increased impervious surfaces in upstream zones influenced downstream flood risks. The results of the rational method were integrated with GIS flood mapping to visualize the hydrological impact of urban densification in Nairobi.

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2.6 Data Presentation Methods

The analyzed data were presented in different forms. The qualitative data were presented in descriptive themes, patterns, and photographs. Quantitative data was presented using GIS mapping, bar graphs, pie charts, figures, and tables.

3. Results and Discussions

3.1 Nature and trends of land use policy change over time in Nairobi City.

3.1.1 Historical Policies

The study found that pre-2004 historical policies set the foundation for Nairobi's urban expansion without adequately considering flood hazards in downstream zones. The initial plans of the 1906 Railway Town, the 1927 Settler Capital, the 1948 Colonial Master Plan, and the 1973 Metropolitan Growth Strategy were mainly responsive to rapid population and economic expansion. These plans focused on urban boundary extension and the convenience of infrastructural development without strictly incorporating robust flood control or riparian zone protection. These policies unintentionally increased impervious surfaces and promoted development in surface runoff-prone areas, exposing downstream areas to recurring flooding.

3.1.2 Guidelines after 2004

After 2004, the situation worsened with newer policies such as the 2004 City Development Ordinances, the 2006 policy review for Zones 3, 4, and 5, and the 2022 Nairobi City development policy encouraging high-density and high-rise development in formerly low-density areas. These policies reduced minimum plot sizes, increased ground coverage ratios, and allowed higher building heights, significantly contributing to increased surface runoff. Despite efforts to upgrade infrastructure, the emphasis on upstream densification without complementary flood resilience measures has enhanced flood risks downstream, with the worst effects on informal settlements and environmentally sensitive riparian areas.

Table 4 Zoning guidelines and laws

Zone	Parkland	Westlands	Kilimani	Woodley
Year: 2004				
a) Ground Coverage (GC)	50	80	35	35
b) Plot Ratio PR	0.75	2.00	0.75	0.75
c) Number of Floors	-	4	4	4
d) Minimum Area	0.05	0.05	0.05	0.05
Year: 2006				
a) Ground Coverage (GC)	50	35	53	35
b) Plot Ratio PR	2	1.5	1	1.5
c) Number of Floors	-	-	-	-
d) Minimum Area	0.2	0.1	0.2	0.2
Year: 2022				

a) Ground Coverage (GC)	80	80	75	75
b) Plot Ratio PR	16.0	24.0	15.0	7.5
c) Number of Floors	20	30	15	10
d) Minimum Area	0,05	0.05	0.05	0.05

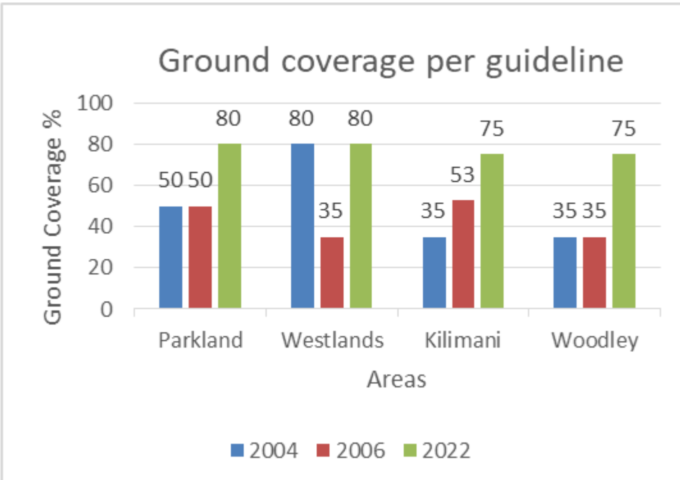

Figure 11 Ground Coverage per guideline

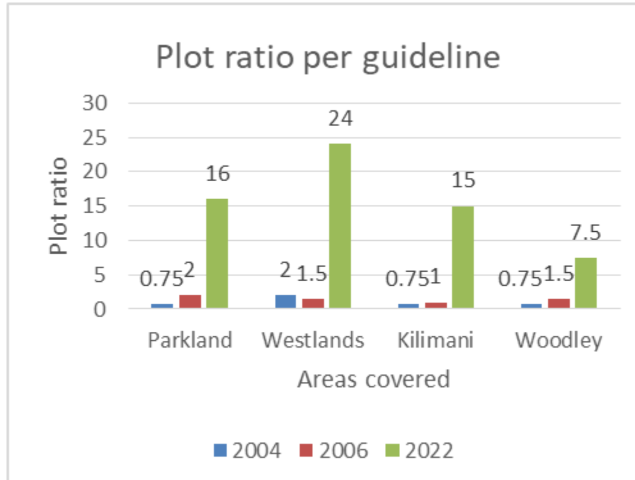

Figure 10Plot ratio per Guideline

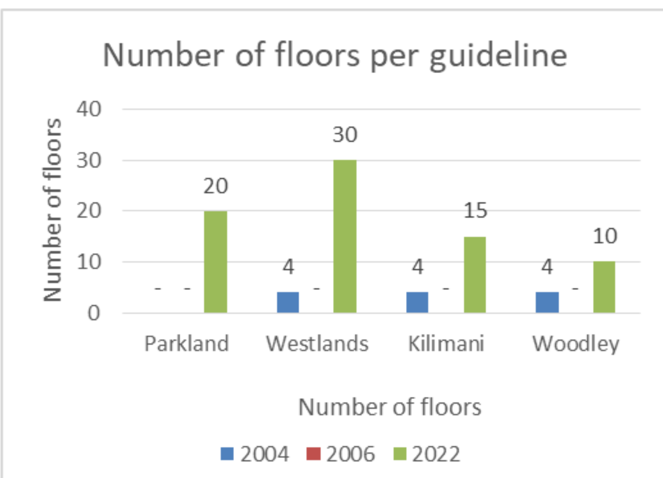

Figure 13 Maximum Number of floors per guideline

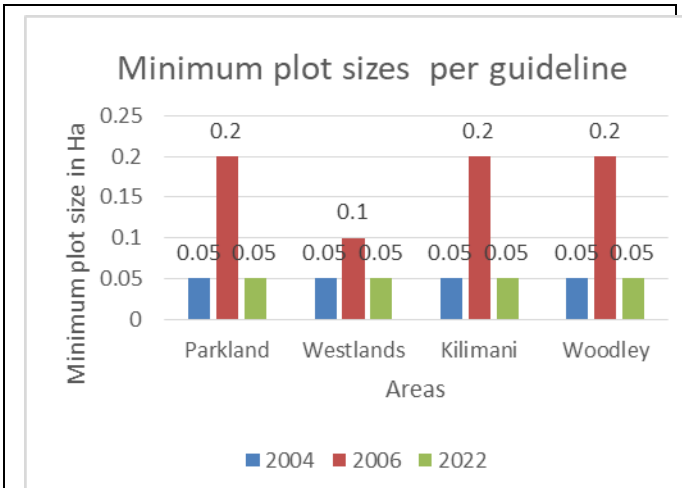

Figure 12Minimum plot size per guideline

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The findings reveal that there were significant changes in the policy. The 2004 policy had already increased the densification of those zones from single dwelling units to a maximum of 4 stories, as described by (NCC, 2006). This created more impervious surfaces on the already existing infrastructure. 2022 went further on to increase the plot ratios and number of floors. It drastically reduced the minimum plot area from 0.2 in 2006 to 0.05 hectares in all zones. The 2006 land-use policies, on the other hand, had some limitations; they did not provide for the maximum number of floors in the different zones.

3.1.3 Discussion

The Land use policies of Nairobi City County, from the early stages of planning to the more recent ones with the planning standards from 2004,2006, 2014 and 2022, have always been focused on the best economic use of land over environmental sustainability, which makes them the genesis of the increased runoff problem. Initially, they focused on urban expansion and how to manage it through densification without prioritizing the protection of riparian zones. 2004 and 2006 emphasized increased ground coverage and densifications through higher plot ratios and high-rise development. While the 2014 guidelines did not provide explicit standards with figures, they also talked about the increase in densification and creating more multi-storey developments to cater to the rising population. 2022 guidelines further increased the plot ratios and building heights, reducing plot sizes.

One major mistake in Nairobi's planning was draining the swamp along the Nairobi River at Grogan. These moves maximized land use but ignored the swamp's primary role in soaking up and slowing down floodwater. These actions led to Nairobi's increasing flood problems, highlighting a continuous failure to include flood prevention and environmental protection in urban planning.

Figure 14 Kilimani Neighborhood landscape illustrating different building densities over time
Source: Author, 2025

Figure 14 shows how the different guidelines affected the building heights, from single-dwelling homes to higher floors in areas to accommodate the population increase.

3.2 Effect of land use policy change on upstream and flooding of downstream zones in Nairobi City County.

3.2.1 Upstream

a) River encroachment

The study found that upstream areas of Nairobi have been ancestrally known for being single dwellings before 2004 (NCC, 2006). They experienced rapid densification, replacing the low-density residential with high-density residential and commercial zones, supported by the Land use zoning guidelines. It has led to encroachment in those zones, narrowing the river channels and increasing impervious surfaces, which increases surface runoff downstream.

Figure 15Encroached development near the Bernard estate in Kilimani
Source: Google Earth, 2024

Figure 15 shows how new development has encroached on the Nairobi River near Benard Estate. In 2001, the area did not have many developments along the river, but as time passed, the river encroached with modern upstream buildings, reducing the riparian zones obstructing floods.

b) Densification

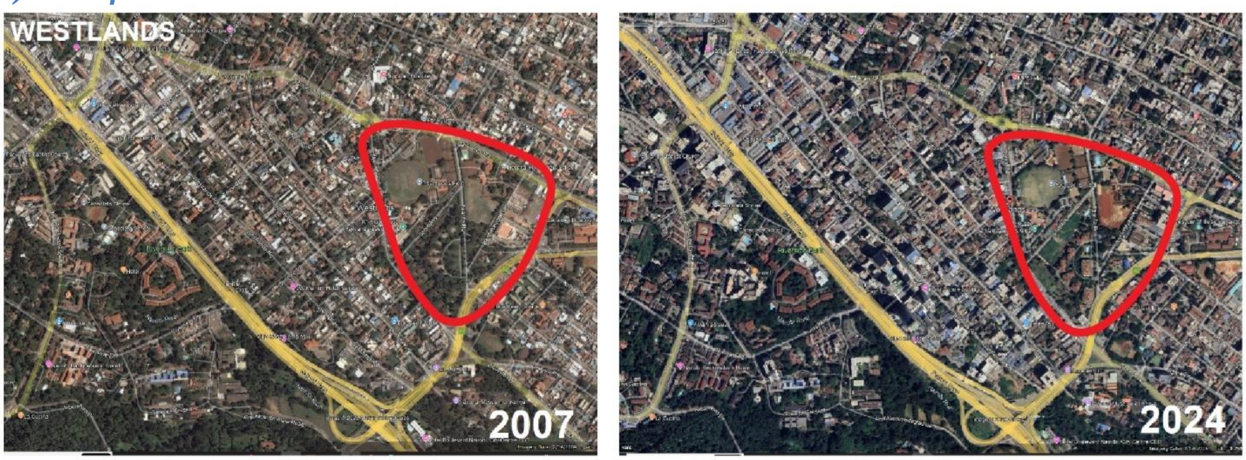

Figure 16Increase in densification in Westlands after the policies

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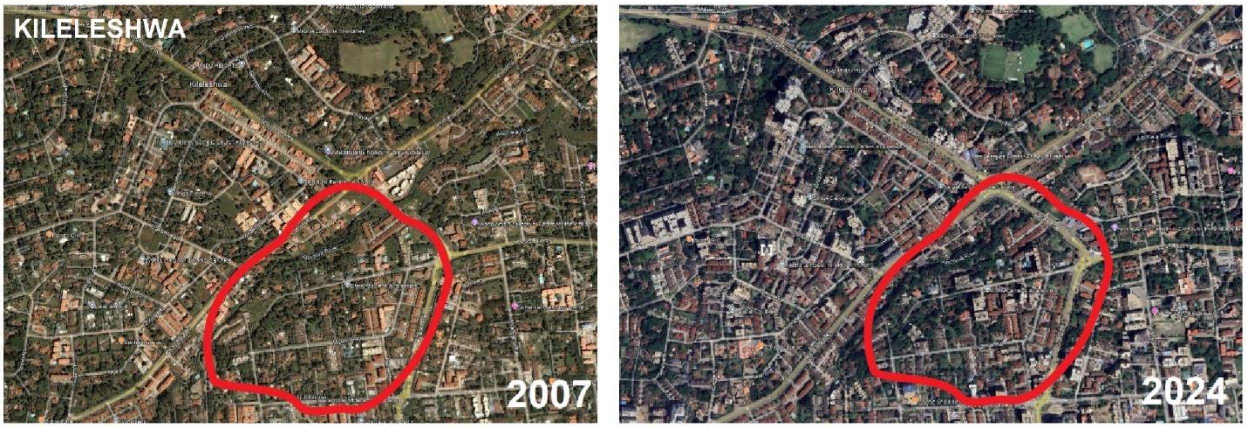

Figure 17Increase in densification in Kileleshwa after the policies

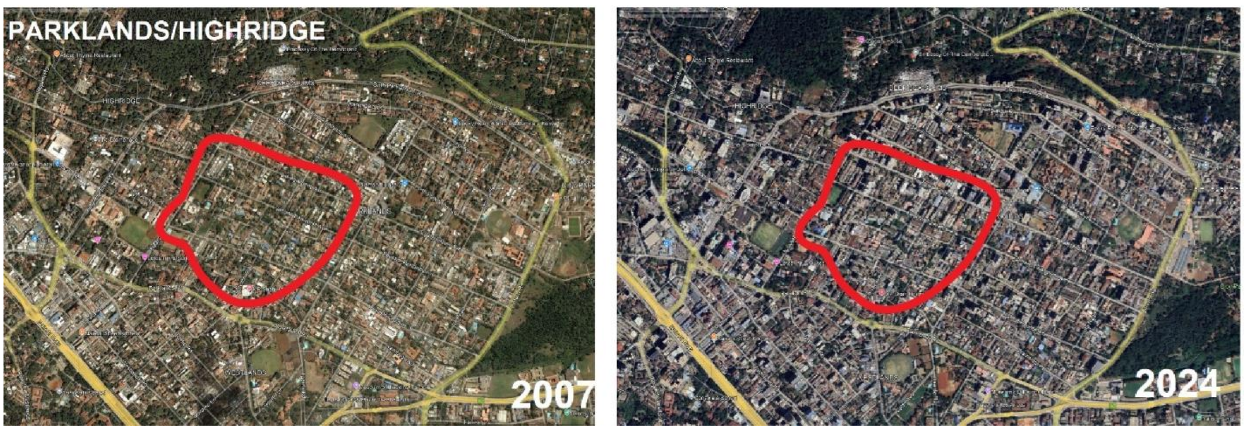

Figure 18 Impacts of densification in Parklands
Source: Google Earth 2024

Figures 16, 17, and 18 show the difference between the areas and how land use has changed over time due to the land use policy change.

c) Increased Surface Runoff

Highrise buildings from the upper areas of the city, which are developed and paved, have increased impervious surfaces due to the redevelopment from low-density to high-density zones. It has reduced water infiltration, accelerated runoff, and heightened flood risk. This agrees with (Feng, Zhang, & Bourke, 2021).

These areas are seen in zones 3, 4, and 5 of Nairobi, where water flows from Westlands, Parklands, Kilimani, Lavington, and other high-elevation areas draining to the lower zones of the city, creating flood risk challenges. The study used the Rational method (Q=CiA) to calculate the total surface runoff of the areas. It assumes that rain distribution and intensity and the coefficient values were the same due to the uniform nature of the upstream in both years (2004, and 2024) to give a valid answer that explains the increase of the surface runoff in a constant rainfall intensity.

Table 5 The surface runoff of the area's rational method

Area	Area (km²)	Surface Runoff (m³/s) to the river				
		(Q)Year 2004	(Q) Year 2024	I (2004 mm/hr.)	C (2004)	C (2024)
Woodley/Kenyatta Golf Course	9.249541	0.612	1.312	0.189	0.35	0.75
Kileleshwa	8.704287	0.576	1.220	0.189	0.35	0.75
Kilimani	16.657532	1.102	2.304	0.189	0.35	0.75
Parklands/Highridge	8.33504	0.552	1.152	0.189	0.35	0.75

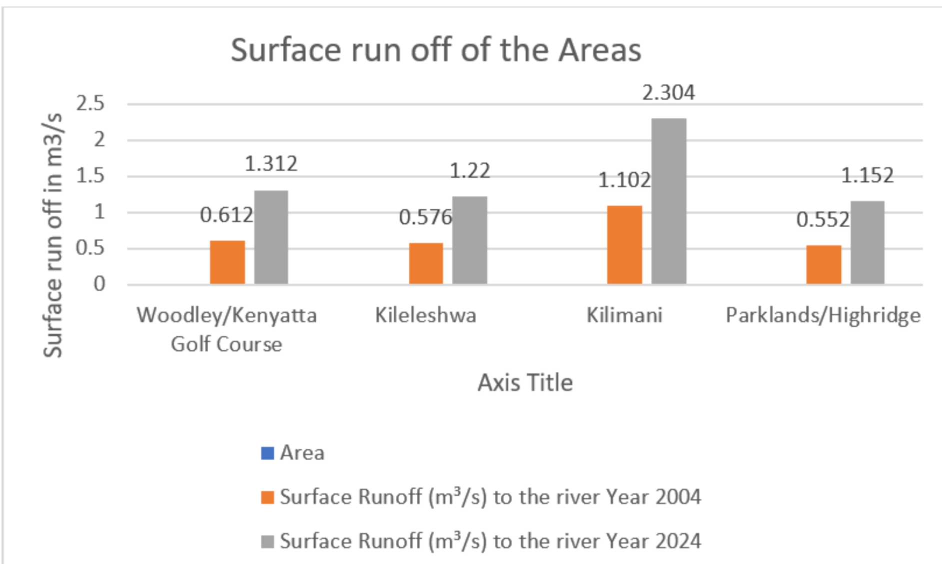

Figure 19 Surface runoff of the areas in 2004 and 2024

In 2004, the areas still had single-dwelling residents. The surface runoff was lower compared to 2024, where more impervious structures were built, thus bringing a difference in the runoff. Kilimani has the highest surface runoff (2.304 m³/s) due to its larger area and more redevelopment. Parklands/Highridge has the lowest surface runoff (1.152 m³/s) due to its smaller catchment and less redevelopment. Woodley and Kileleshwa have intermediate runoff values of 1.312 m³/s and 1.220 m³/s, respectively.

3.2.2 Downstream

Nairobi City County recorded 75% of the urban population growth consisting of informal settlements, which will double in the next 15 years (UN-Habitat). These informal settlements, which are primarily located downstream, are included in this study. The areas are served by rivers from upstream, as indicated in Figure 20.

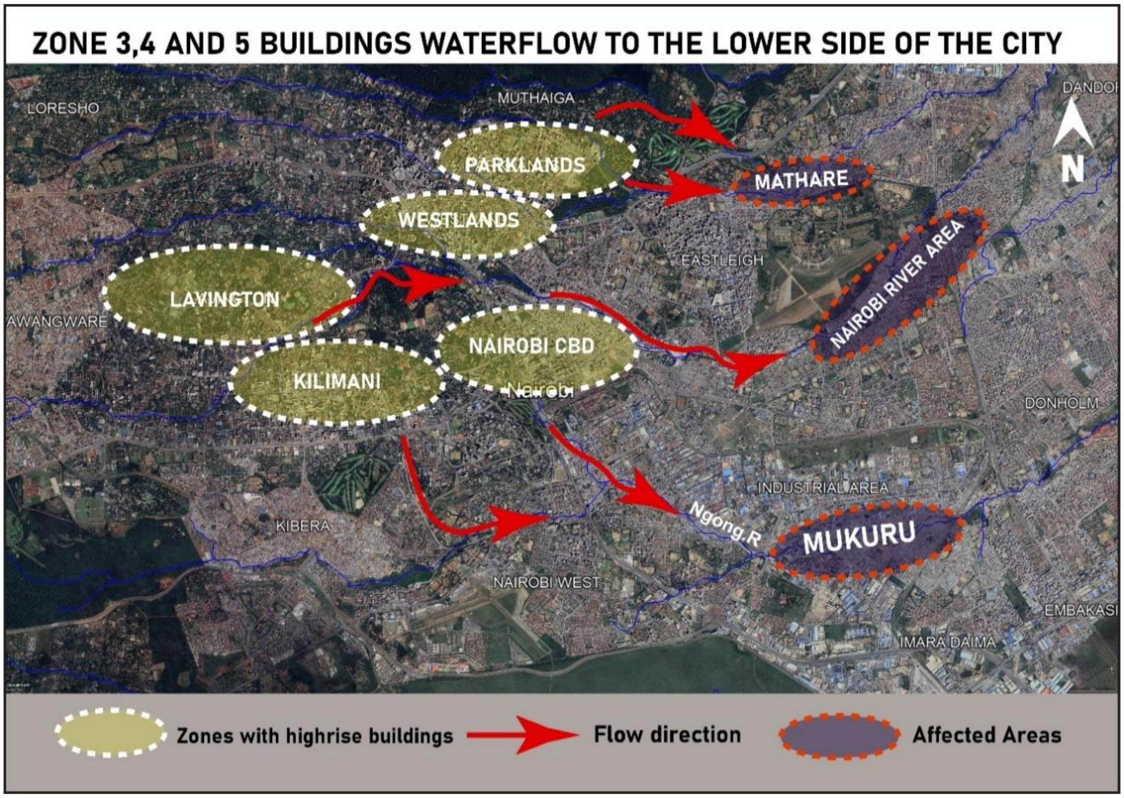

Figure 20 Surface Runoff from Upstream

The study found that Ngong, Mathare and Nairobi Rivers have the highest informal settlements near the riparian zones as shown in figure 21

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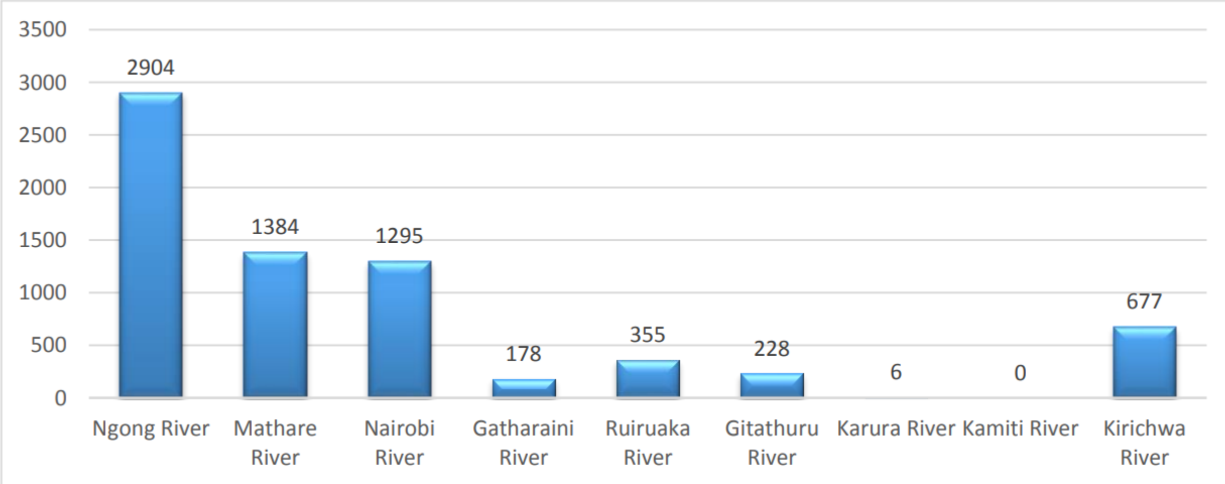

Figure 21 Number of Informal settlements near the rivers

Areas like Westlands, with high-rise buildings upstream, have been draining water into the Nairobi River, which flows to the Kiambui informal settlements and poses flood hazards.

Figure 22 Comparison of the type of housing densities between the upstream and downstream
Source: GIS, 3D Open Street map, 2025

3.2.3 Effects on both upstream and downstream

The policy changes affected both zones where buildings encroaching near rivers were seen. The number of buildings was calculated using GIS mapping and presented in Figure 23.

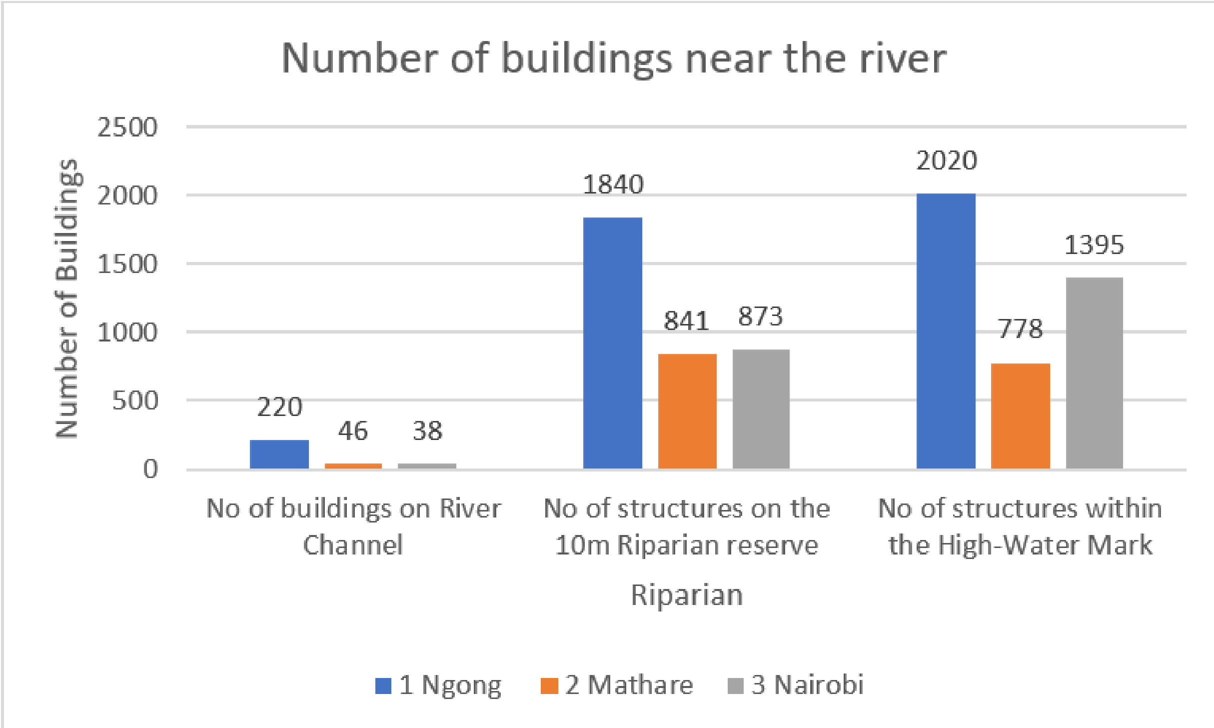

Figure 23 Number of buildings near the river
Source: Fieldwork 2019

Figure 24 shows the number of buildings encroaching on the rivers; the number of buildings on the river channels indicates the severe risk of flooding, erosion, and water pollution. The structures on the 10m riparian reserve indicate that they are violating policies and regulations and pose a threat to themselves. The number of structures within the 30m High-Water mark poses a danger to seasonal flooding, which impacts human settlements.

a) Solid Waste Management

The situation downstream, where more informal structures have been built near the riparian zones, with deposits of solid waste near the river banks making the river narrower, has led to the overflow of the river banks. Excess water is forced to overflow into the residential areas in the informal settlements since the narrow river cannot convey the large water volume, causing flooding of the adjoining areas.

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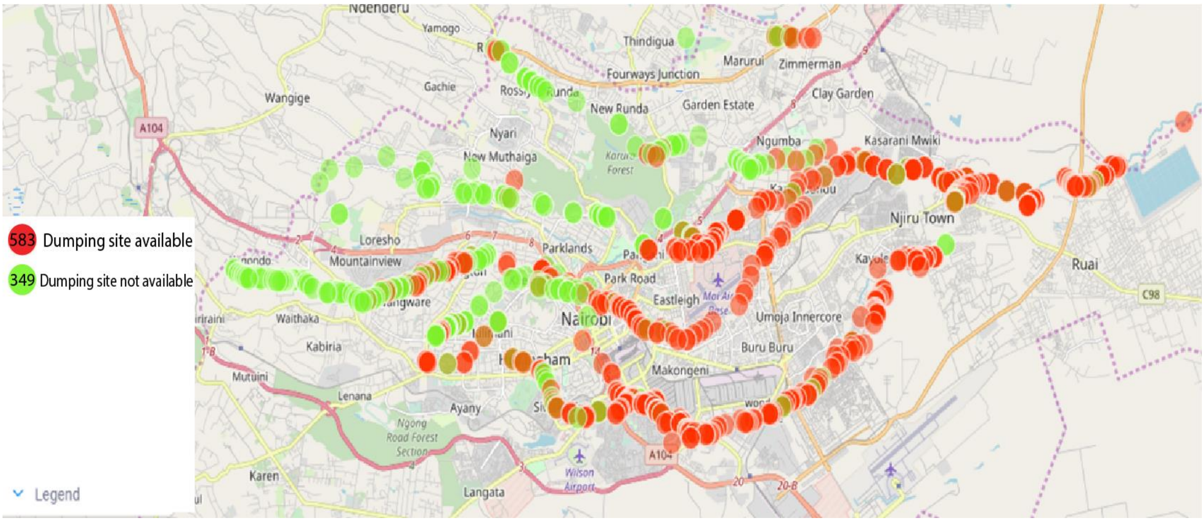

Figure 24 Distribution of Solid waste in Nairobi River
Source: Fieldwork, 2019

b) Flood Incidence

The study found that one of the effects of the increase in surface runoff led to flood hazards in the downstream areas. Take the case of the Mukuru Viwandani settlement in 2024, where flooding occurred on 20th April in Mukuru; it caused the demolition of structures and loss of homes to vulnerable communities. (Christian Sonntag, 2024). The Ngong River went out of control and found its way to the informal residential buildings near the river, causing damages as described by (Christian Sonntag, 2024) This situation was caused by the busting of the narrow Ngong River channel and increased runoff from the upstream zones.

Figure 25 Flooding incidence in Mukuru Viwandani
Source: ©Shakur Njeru, Viwandani Comprehensive Community Organization (VICCO), 2024

c) Efforts done by the government

The main question is whether or not the land use policy changes affected Nairobi's downstream flooding. Land use policies impact development control tools, including ground coverages, plot ratios, and minimum plot sizes. The upstream zones increased the impervious surfaces, causing uncontrolled surface runoff in the downstream zones. On the other hand, the continued encroachment and degradation by developments to the river ecosystem reduced the channel widths and blocked the riparian zones. It highlights the shortcomings of the policies intended to safeguard these areas.

Despite the government's effort to demolish the buildings near the riparian zones in 2024, it did not consider that the upstream was the primary source of the flooding problem. The demolitions only reduced the population nearer the 10m mark from the river but did not solve the overflow of the floods into the neighborhood.

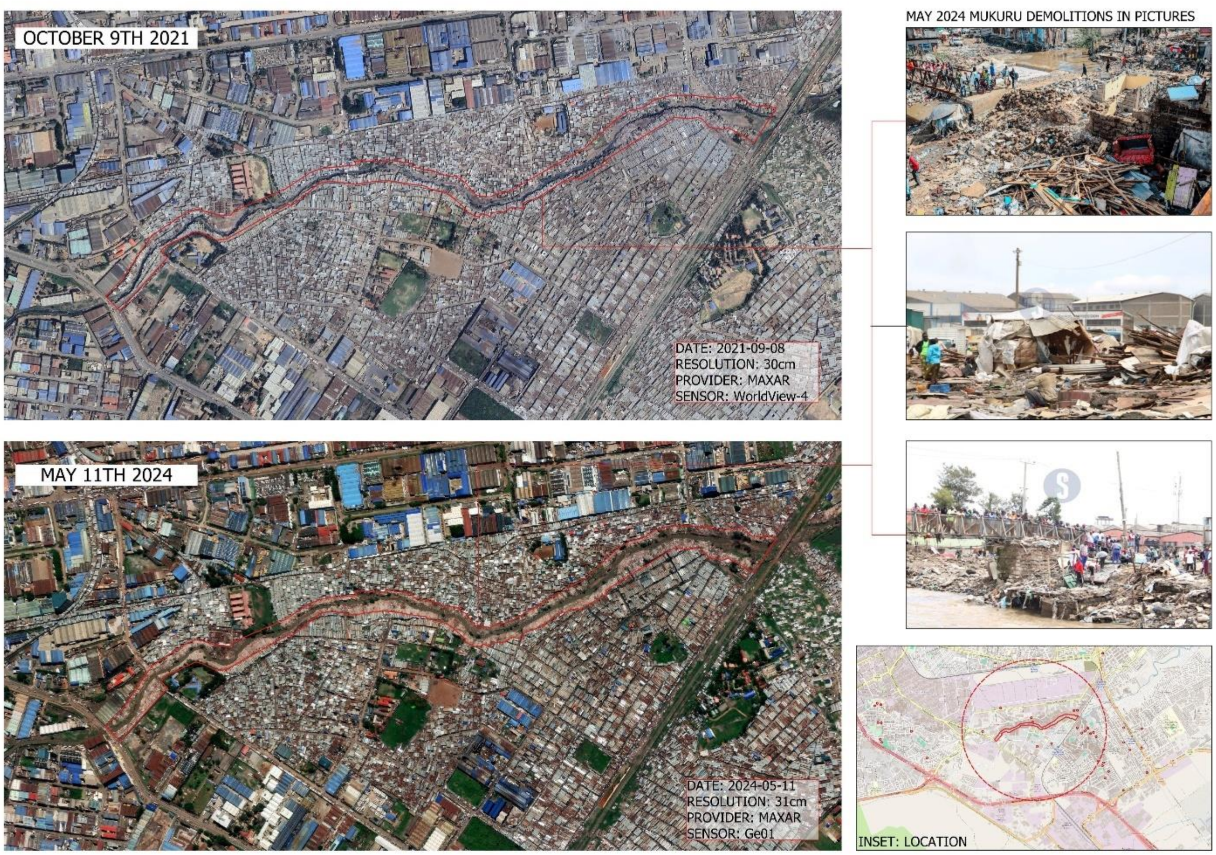

Figure 26 Governments trial to demolish buildings in areas near the riparian
Source: Mark at X platform, 2024

3.3 drivers of land use policy change and flooding on downstream zones in Nairobi City

a) Population increases

The study found that the population increase of Nairobi by 4.1%, as prescribed by KIPPRA, is one of the main drivers of the emergence of informal settlements downstream, causing higher densification. Nairobi City County has a growth rate of 2.3 (KNBS, Kenya Population and Housing Census, 2019). The hardcore poverty level in Nairobi County is 58.2 %. This could be the primary driver of the informal settlements near rivers due to the invasion of what is considered free public land. This agrees with Muketha (2014), who reported the invaders' conception of the riparian zone as free land.

Table 6 Densification increased change in informal settlements over time in Nairobi

Number	Name	Area/ha	Inhabitants/ha 2000	Inhabitants/ha 2010	Inhabitants/ha 2020	Net Increased Inhabitant/ha 2000-2020
1	Dandora	182.15	248.61	403.18	585.31	336.7
2	Huruma	78.14	614.44	911.93	1381.42	766.98
3	Estate	249.08	146.32	281.17	318.26	171.94
4	Kawangware	329.14	186.25	272.76	399.94	213.69
5	Kiambiu	50.02	284.62	289.78	526.9	242.9
6	Kibera	287.13	439.43	671.88	985.57	546.27
7	Korogocho	99.74	281.84	451.86	589.36	307.49
8	Kwa Njenga	133.21	155.27	267.06	315.85	160.58
9	Majengo	60.45	253.27	380.81	577.98	324.71
10	Mathare	100.7	329.72	491.78	523.65	193.92
11	Mukuru	49.02	92.56	122.64	181.65	89.09
12	Soweto	192.23	139.83	224.86	335.43	195.6
13	Tsaia	40.51	125.09	188.38	257.73	132.64
14	Viwandani	167.11	140.22	211.09	306.58	166.36

Source: (Hang Ren, 2020)

b) Urbanization

Rapid Urban expansion has driven economic opportunities in the area, prioritizing affluent high-density developments in upstream zones, with an average annual growth rate of about 3.44%, as the World Cities Report 2022 reported. Both upstream and downstream zones have faced an increase in population. Even though the rate of urbanization has gone higher, the minimum plot areas of the zones have remained the same. However, vertical densification has occurred in these zones. There is a lack of commensurate development of infrastructure, such as stormwater drains, to mitigate against flood hazards brought about by this densification

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The fact that the policies recommended the increase in Highrise buildings while maintaining the minimum plot area of 0.05 hectares raises concerns since that is a small area for skylines with many floors, i.e. a high-density building of 24 floors in Westlands requires a large base area to sustain the height of so as not to interfere with the stability of the building, This disagrees with World bank(2018) who emphasizes mixed-use developments and allocating 20–30% of plot area for amenities and open spaces. Therefore, for a 24-floor building: require 0.6–1.2 hectares (including amenities) and not 0.05 Hectares.

Table 7Minimum plot area

	Area	**2004**	**2006**	**2021**
Zone 3	Westlands Parklands Ngara West	0.05	0.05	0.05
Zone 4	Spring Valley Kileleshwa Kilimani Woodley	0.05	0.05	0.05

SOURCE: (ISoCaRP, 2006), (City Council of Nairobi, 2004), (NCC, 2006)

3.4 strategies for sustainable land use policy change and conservation of riparian zones.

EMCA stipulates that development should begin at 6-30m from the riverbank to avoid hazardous river stream narrowing and to create buffer zones to prevent river encroachment. Using GIS tools to map and monitor the hydro sheds, the data can be used and analyzed in different ways to help reduce flood risk downstream. The tool can also be used to identify places that are hazardous and pose a threat to settlements. Policies should also consider the downstream areas while planning for land use and zonal ordinances to ensure that the upstream areas do not affect the downstream through floods.

3.5. Interpretation of Findings

The study found that the upstream areas have high surface runoff that goes into the narrow river channels, increasing pressure and affecting the downstream areas covered by informal settlements. The river overflow into the residential areas, leading to flood hazards and loss of properties, as illustrated in Figure 27. This situation could not have happened had the previous policies catered to the strict zoning and development guidelines in the upstream areas to reduce impervious surfaces. Even after the Nairobi Integrated Urban Development Plan (NIUPLAN) was enacted in 2014, weak enforcement and a lack of flood resilience measures for downstream areas have exacerbated the problem.

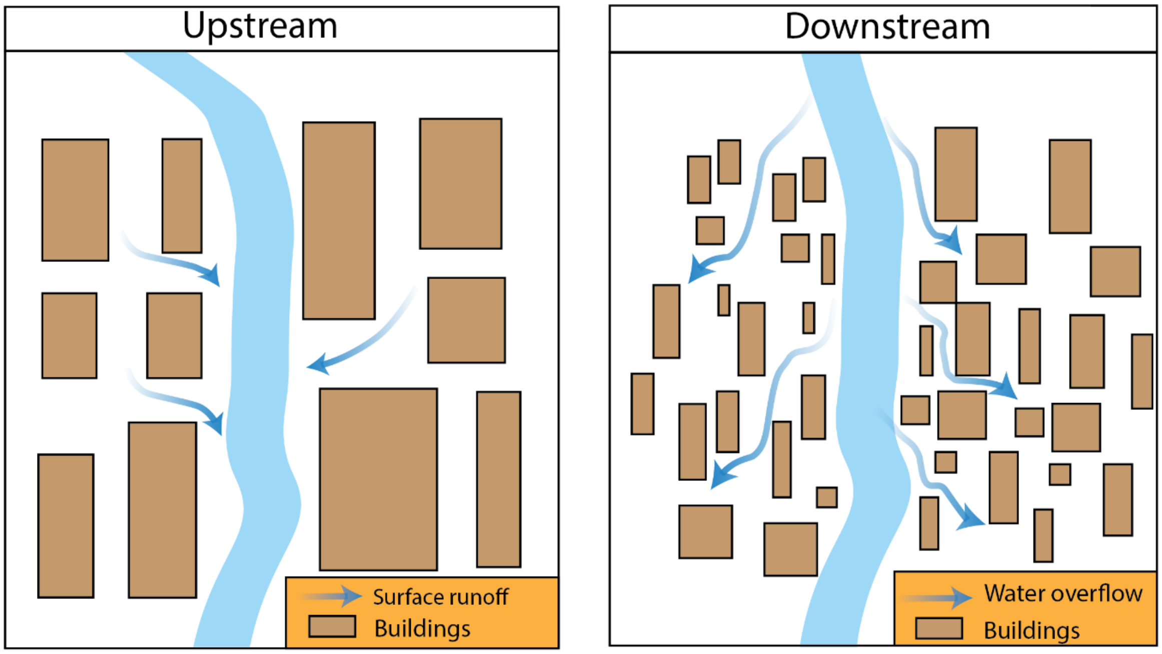

Figure 27 Illustration of the effects of surface runoff in Upstream and Downstream Zones
Source: Author, 2025

3.6 Discussion

The findings agree with global and regional literature, including (Dash, et.al., 2021) who established the need for sustainable governance and proactive flood management, echoing what Nairobi City County has suggested regarding integrated urban land use planning with flood management. Similarly, the study agrees with (Ridzuan & Rahman, 2022) who stress the inclusion of local communities in the disaster risk reduction gap observed in Nairobi's policies. Conversely, the study further agrees with (Birkland, 2003) who suggested approaches that include wetland preservation, which relates to Nairobi's encroached and degraded riparian zones. Regionally, the study agrees with Salami (2017) who identifies that African cities have vulnerabilities because of a lack of adequate policies, which shares similarities with findings in Nairobi. Besides, this study agrees with Arinabo (2023), who emphasized the need for adaptive and inclusive flood management strategies lacking in Nairobi's policies. Locally, the results agree with (Mukuna, 2015) and (Oyugi, 2017), who blamed Kenya's fragmented policies and their contribution to exacerbating urban flooding, as identified in this study.

4. Conclusion

This study has successfully achieved its objectives, providing critical insights into the interplay between land use policy changes and urban flooding in Nairobi City County. The sub-conclusion based on the objectives included the nature and trends of land use policy change over time which was analyzed through the examination of the evolution of land use policies in Nairobi, revealing a clear trend toward densification driven by rapid population growth and economic prioritization.

The previous policies, including the 2004 zoning guidelines, 2006 policy amendments, and the 2022 guidelines, progressively prioritized high plot ratios, expanded ground coverage, and promoted taller buildings—particularly in upstream zones like Westlands and Kilimani. Satellite imagery and policy analysis demonstrated how these changes replaced low-density developments with impervious surfaces, systematically neglecting environmental safeguards. For instance, the draining of swamps (e.g., Grogan swamp along the Nairobi River) to accommodate urban expansion exemplifies this trend, eroding natural flood buffers over decades.

The study also analyzed the effects of land use policy change on upstream and downstream flooding, determining that upstream densification policies directly accelerate downstream flooding, by encouraging high-rise developments and impervious surfaces in upstream zones, policies such as 2022 zoning guidelines amplified surface runoff, overwhelming drainage systems. The study also shows the encroachment of buildings near the riparian which narrows the river channels was also a root problem. Hydrological models and field surveys confirmed that increased runoff from upstream areas like Parklands and Lavington inundates downstream informal settlements (e.g., Mathare, Mukuru), where inadequate infrastructure and narrowed river channels worsen flood impacts. The findings show a spatial imbalance indicating that economic gains in affluent upstream zones lead to flood risks to marginalized downstream communities.

The study also assessed the drivers of Land Use Policy Change and Downstream Flooding The findings show that the prioritization of economic growth over environmental resilience is evident in the policies that maximize land utility at the expense of riparian zones and wetlands. The study also finds out that apart from the zoning guidelines there is a weak enforcement of environmental regulations in Nairobi City County, such as the Environmental Management and Coordination Act (EMCA, 2012), which has led to unchecked encroachment into critical buffer zones especially in the informal settlements. Furthermore, rapid urbanization and population growth in a limited land area have increased pressure to develop flood-prone areas like the riparian zones. Political and institutional fragmentation has also exacerbated these challenges, as agencies often prioritize short-term development over long-term flood resilience.

Finally, the study highlights the need of the enforcement of sustainable land use and riparian zone protection through the same zoning policies to minimize flood risk, it highlights that there is a need of the integration of economic and environmental factors. The Environmental Management and Coordination Act (EMCA) stipulates buffer strips of 6–30 meters in riparian reserves, yet non-enforcement has promoted river encroachment and increased surface runoff from the upstream. Hydrological mapping via the GIS can enhance flood risk assessment by outlining hazardous areas and guiding policy interventions. Good zoning guidelines is to be complemented with downstream flood resilience, to avoid cumulative flooding in informal settlements as a result of upstream urbanization. There should be enhanced implementation of policy and flood mitigation incorporated into urban planning for the protection of communities and the preservation of riparian ecosystems.

5. Recommendations

The study recommends that policymakers be considerate when planning for upstream and downstream zones to prevent flood risk in the downstream zones. The GIS and other tools are essential in mapping out the areas faced with flooding issues and the places where the impact can be felt.

5.1 Implication of Theory

According to this study's findings, the hydrological response theory is considered the proponent theory due to its link with urban densification to increased flood risk. The theory argues that the increase in impervious surfaces from the upstream leads to reduced water infiltration, thus accelerating the surface runoff. From the study, it becomes clear that from 2004 to the current 2022 zoning guidelines, which encouraged higher ground coverage, elevated plot ratios, and taller buildings, have drastically interfered with the city’s natural drainage patterns. The changes have increased surface runoff, leading to high flood risk downstream. The rational method calculations, which show rapidly increasing surface runoff evince this.

By explaining the relationship between urban land use transformation and the environmental consequences of policy decisions, the theory provides an understanding of the environmental consequences of policy decisions, especially in urban areas with more impervious surfaces. It explains how prioritizing economic development through increased urban densification without flood-resilient measures leads to the disruption of natural hydrological circles, causing flood risks. This theory highlights the need to integrate urban land use practices that balance growth with essential environmental protection.

Nairobi City County is a good example of an urban area that has faced policy changes that affect the hydrological cycles. The study suggests that planning theory must incorporate an integrated approach that balances economic development with environmental resilience to protect people downstream from flood risk. Most historical urban planning models, which often prioritize densification and urban growth, are insufficient when they fail to address the critical interplay between increased impervious surfaces and urban flood risks. This creates the need to include the downstream zones to protect people's lives through flood mitigation strategies.

5.2 Policy Recommendations

The study recommends strengthening the protection of the downstream areas by enacting strict policies and regulations to avoid encroachment and degradation of riparian reserves through GIS tools. The government and its people should focus on actions more than written laws to ensure that the existing ones, like the EMCA and the water management laws, are strictly observed. The policies should also consider downstream flooding scenarios caused by the upstream impervious surfaces by enacting laws that protect the environment from increased impervious surfaces from the upstream.

5.3 Recommendation for Planning Practice

The study uses Nairobi City County as a case to suggest practical ways for urban planners to reduce flood risks downstream and promote sustainable development. Cities should protect and restore downstream zones along rivers, as these areas act as natural buffers and sponges against floods and support local ecosystems. Planners should also consider the upstream to be one of the significant causes of flooding in cities. Using GIS and remote sensing to monitor these zones effectively will work well.

Urban planning must include disaster management practices in every zone. Plans should encourage compatible land uses to avoid conflicts and regulations to prevent unauthorized construction in flood-prone areas. Sustainable growth should balance environmental protection, especially regarding high-rise buildings and storm water management. Real-time data from geospatial technology can enhance flood risk management.

Urban development should align with global frameworks such as the United Nations Sustainable Development Goals-Goal 11, which talks of Sustainable Cities and Communities, and Goal 13, Climate, which provides momentum for sustainable and climate-resilient urban development. Following these recommendations, cities can lower flood risks, protect vulnerable populations, and support fair growth. Nairobi offers valuable lessons for planners working to create resilient cities amid rapid growth and climate challenges.

5.4 Implication to academia/ suggestions for future research

This study recognizes a research gap concerning the impact of land use policy changes and how they cause flood hazards in urban areas. Future studies should develop GIS- and remote-sensing-based predictive models to assess the long-term impact of land use change on floods. Researchers must also investigate how informal settlements can be integrated into sustainable urban planning to reduce vulnerability. Comparative studies in other cities facing the same issues would also be valuable information for policymakers, city planners, and managers.

5.5 Contribution to existing knowledge

This research contributes immensely to the body of knowledge by identifying the intrinsic conflict between urban planning policy and environmental sustainability. The study stands out from other studies by identifying policies as the main drivers of flooding. Urban planning policies have historically focused on optimizing land use and promoting economic development, sometimes without considering the environmental impacts of densification. The study emphasizes that planning policies operate in isolation, dealing with urban expansion as an independent variable without adequately considering its downstream hydrological implications. This research bridges the gap between urban planning decisions and environmental impacts, demanding a concerted effort balancing the two realms by demonstrating the extent to which policy-induced changes upstream result in increased surface runoff and downstream inundation.

The study argues against planning policies that prioritize urban development over environmental concerns. It challenges the idea that policies should only focus on economic benefits and argues for balancing urban growth and ecological sustainability. Based on a case study in Nairobi City County, it offers evidence-based explanations of how policy changes, such as increased ground coverage and plot ratios, increase urban flood hazards. Building on knowledge of urban planning's unintentional environmental effects, this discussion calls for scholars and policymakers to review zoning policies using a more integrated approach.

Furthermore, this study adds to understanding the problems of urban land use change and its effect on flood hazard. Whereas other studies have quoted urbanization as one of the causes of flooding, this study adds to the literature by demonstrating how specific policy changes throughout the years have fueled the problem. The application of GIS and remote sensing devices in analyzing such changes is a methodological innovation, indicating the promise of technology in assessing and reducing urban flood vulnerability. In highlighting the imperatives of interdisciplinarity—integrating urban planning and environmental science this research paves the way for subsequent investigations to examine more adaptive, resilient, and sustainable approaches to urbanization.

This research observes that urban planning requires a new approach, prioritizing environmental resilience over economic efficiency. It emphasizes the necessity of policy agendas recognising the interconnection of urban land use, hydrological processes, and disaster management. By considering downstream areas within rapidly urbanizing cities, this research contributes to understanding current flood challenges and developing actionable recommendations for creating more resilient urban areas.

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