Frequency of floods and land use changes in Kibra and Mathare informal settlements, Nairobi, Kenya

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ABSTRACT

Rapid urbanization and inadequate infrastructure exacerbate the risk of flooding in informal settlements, where 1.6 billion people live globally. This study, based on the theories of Political Ecology and Social Capital, explored the frequency of flood occurrence in Kibra and Mathare informal settlements in Nairobi City County, Kenya, where more than 60% of urban residents reside in informal settlements. The study adopted descriptive cross sectional research design with the target population being household heads, community leaders, non-state actors and state government agencies. Data was collected from 455 respondents (398 household heads, 42 focus group discussion participants, 10 non-state actors and 5 state actors) using multistage sampling techniques (stratified, purposive and simple random sampling). The primary data collection instruments were structured questionnaires, semi-structured interview guides, and focus group discussion guides, with secondary data and photographic evidence. Descriptive and inferential statistics were used to analyse quantitative data. The results indicated that 93.1% of the surveyed households experienced floods, with 47.9% experiencing 4-5 floods between 2020 and 2024. The spatial analysis showed that the flood prone areas have significantly increased from 2005 to 2024, with Kibra increasing from 0.8 km² to 2.0 km² and Mathare from 1.2 km² to 2.5 km². Household size (β=0.506, p=0.001) and average monthly income (β=-0.775, p<0.001) were significant predictors of flood frequency, explaining 47.5% of the variance. Land use analysis showed that built-up areas increased by 36% (Kibra) and 19.5% (Mathare) and riparian vegetation decreased by 56-57%, which reduced natural flood buffers. The study concludes that the flood risk in these settlements is chronic and structurally embedded, due to unplanned urbanization, ecological degradation and socio-economic inequalities. The results recommend the need for hyper-localised, ward-specific Disaster Risk reduction (DRR) strategies, combining engineered solutions with participatory planning and ecosystem-based strategies such as riparian restoration for sustainable urban resilience.

Keywords: Disaster Risk Reduction, Flood Frequency, Informal Settlements, Land Use Change, Nairobi, Political Ecology, Social Capital

I. INTRODUCTION

Globally, it is estimated that about 1.6 billion people live in informal settlements, which puts them at much greater risk of frequent disasters, especially floods (Satterthwaite *et al*., 2018). Essential infrastructure, sanitation and housing are always outpaced by rapid urbanization rates and population growth in developing cities (Dodman *et al*., 2023). This swift growth directly translates to the massive and increasing growth of informal settlements which inherently increases the vulnerability of urban dwellers to a number of disaster risks such as the risk of floods which occur regularly (Williams *et al*., 2019). As a result, the number of floods occurring in these informal settlements around the world is growing as unplanned urban sprawl is built over natural drainage lines that make these settlements highly vulnerable to dangerous environmental conditions and prone to flooding.

At the regional level, the issues of disaster risk reduction, especially in Sub Saharan Africa have become very alarming, causing frequent floods. Droughts, floods, or earthquakes can often affect the lives of vulnerable communities in these informal settlements, adding significant socioeconomic pressures in their daily lives (Dlamini *et al*., 2025). The capabilities of the state and nonstate actors to reduce the impacts of these common floods are largely reliant on available resources. However, hazards reduction and improving community readiness to these hazards face several key challenges (Leck & Simon, 2018). The major problems are the lack of funding for disaster risk reduction foundations and limited access at the regional level, which means that the number of devastating floods is still constantly increasing throughout the region today, every year.

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Informal settlements in Kenya are home to more than 60% of urban residents and Nairobi County alone has two hundred informal settlements. In these areas, flood occurrence is extremely frequent. As an example, in Kenya, 50% of the time, residential areas in Nairobi experience regular flooding (Kenya Red Cross, 2023). Residents of Kibra and Mathare suffer from heavy floods all through the rainy season. This is due to lack of adequate drainage structures and infrastructure to reduce negative impacts of flooding (Kwao, 2024). In turn, these recurrent floods are causing the same high health hazards, economic losses and extensive damage to property each year in the Nairobi City County of Kenya.

1.1 Statement of the Problem

Despite the global disaster risk reduction (DRR) frameworks, informal settlements in Nairobi, especially Kibra and Mathare, are facing alarmingly frequent floods. This high frequency is due to the unplanned urbanization, ecological degradation, and systemic socio-economic marginalization (Kwao, 2024). This means that almost everyone in the community is exposed, and they experience a series of knock-on effects, such as damage to their homes and health issues, which can create a "poverty-risk trap" (Ndabezitha *et al*., 2024). DRR initiatives are implemented by state and non-state actors, but they are not very effective and are constrained by governance gaps. Moreover, there is a lack of empirical evidence and longitudinal spatial analysis at the ward level in the existing literature on socio-demographic determinants of flood frequency (Space4All, 2022; Muhatiah, 2021). This study aims to fill these gaps by examining the dynamics of flood occurrence to guide proactive, localized and ecosystem-based DRR strategies.

1.2 Objective of the Study

To analyze the frequency of floods and associated land use changes in Kibra and Mathare informal settlements, with the aim of informing targeted disaster risk reduction strategies in Nairobi.

II. LITERATURE REVIEW

2.1 Theoretical Review

The theoretical grounding of this study is in two parallel bodies of theory: Political Ecology Theory and Social Capital Theory which will give a holistic perspective on flood vulnerability and Disaster Risk Reduction (DRR) in informal settlements.

2.1.1 Political Ecology Theory

Political Ecology Theory (Robbins, 2019) suggests that environmental risks, such as flooding, are not simply "natural" but socially produced as a result of power dynamics and inequalities in the use of resources, and political marginalisation over time. The political ecology theory is applicable to the informal settlements of Nairobi where it is apparent concerning structural exclusion and fragmented governance intensifying flood vulnerabilities. It critically looks at the extent to which state and non-state DRR interventions actively confront these entrenched inequalities or tacitly condone state passivity by only concentrating on short-term relief. Moreover, a Feminist Political Ecology perspective reveals that women are the most vulnerable to the effects of floods and are systematically excluded from resilience plans.

2.1.2 Social Capital Theory

In parallel, the Social Capital theory (Lamaison & Bourdieu, 1986; Putnam, 2000) highlights the importance of trust, reciprocity and social networks for collective disaster resilience. This study employs the theory to assess the use of bonding (intra-community), bridging (inter-community) and linking (community-to-institution) capital in DRR programmes to improve flood preparedness and response. The framework, however, also cautions of a "responsibility paradox": relying too heavily on community networks can be a way of hiding the problem of neglect, thus putting the responsibility for disaster management on marginalised people. In addition, there can be power differentials within communities that can prevent vulnerable groups, for example women or ethnic minorities, from participating in decision-making.

Theories highlight that community solidarity alone is not enough towards equitable flood resilience. Effective DRR must involve interventions that challenge structural inequalities, give a voice to marginalized people, and link with strong accountability of institutions and strategic infrastructure investment at the grassroots.

2.2 Empirical Review

Informal settlements are disproportionately impacted by flood disasters, which is expected to worsen as a result of climate change and rapid urbanisation (Satterthwaite *et al*., 2020). In 2024, the Global Shelter Cluster (GSC) reported that there is an urgent need for humanitarian and development actors to continue to implement gender

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sensitive and adaptive approaches to respond to the growing effects of flooding (Global Shelter Cluster, 2024). Flooding is a worldwide phenomenon and has a disproportionate impact on the Global South countries such as Somalia, China, the Philippines, Pakistan, Ethiopia, India, Brazil, Bangladesh, Sudan and Yemen have been affected by devastating floods (Global Shelter Cluster, 2024). Although the number of deaths caused by floods has decreased as a result of improvements in infrastructure and early warning systems, the occurrence of these crises has remained a constant, upsetting communities and disrupting livelihoods (Cap-Net UNDP *et al*., 2018).

In addition, the informal nature of many informal settlements, which are unplanned and often situated in high-risk areas, exacerbates the impact of flooding on people's lives, especially in conflict-ridden areas (UN-Habitat, 2019). There are cycles of intense rainfall and drought, which can be exacerbated by the recurring El Niño and La Ninas weather patterns, creating an additional vulnerability (Malteser International, 2025). Floods have become more frequent and intense and the growing number of informal settlements in flood-prone areas indicates a need to increase the interventions of states and non-state actors, which need to be proactive and scale up (Othoo et al., 2021). In addition, the gender sensitivity in the response of both state and non-state actors indicates a gradual increase in awareness of differential impacts of floods on women and men and the need to intervene accordingly. The Sustainable Development Goals (SDGs) and the Sendai Framework for Disaster Risk Reduction 2015–2030 have also contributed greatly to the research and focus of state and non-state actors on disaster risk reduction in vulnerable communities (United Nations Framework Convention on Climate Change [UNFCCC], 2017).

Floods have caused a massive impact in Africa with millions of people impacted and significant loss of life (CRED & UNDRR, 2020). Rapid urbanisation, development in vulnerable areas like riverbanks and floodplains, and low levels of infrastructure and resources, all play a major role in the vulnerability of informal settlements in sub-Saharan Africa (Jalayer *et al.*, 2015; John, 2020; Anwana & Owojori, 2023). A study in Lagos, Nigeria in 2022 suggested that slums seemed not to be included in the government's flood risk management strategies and that this gap was sometimes filled by state and non-state actors (Adegun, 2023). The lack of infrastructure, such as poorly built roads, and insecure houses lacking access to essential services further exacerbates the vulnerability of these settlements (Ndabezitha *et al.*, 2024).

In 2024, the region has also been affected by recent floods that have led to substantial loss of life and displacement affecting East African communities, revealing their continued vulnerability (Centre for Disaster Philanthropy, 2024). The literature also highlights the linkages between rapid urbanisation, rising informal settlement in disaster-prone areas, and the increasing flood disaster risk in African cities, which requires the cooperation of state and non-state actors to tackle the underlying causes of the proliferation of informal settlements and promote better urban planning (Zehra *et al*., 2019). Ecosystem-based adaptation (EbA) has emerged as a promising approach in African cities, through mangrove restoration in Nairobi, Kenya and other restoration of natural defenses in Windhoek, Namibia (The World Bank, 2017; Adegun, 2023). This means a greater move towards more sustainable and locally appropriate pathways, and opportunities for state and non-state actors to be engaged in restoration and conservation.

Over the years, Kenya has seen a number of major flood events; these have come with huge impacts on people and property, especially in informal settlements (Ngome & Yeom, 2024). In addition, informal settlements in Nairobi (Mathare, Kibera, Mukuru), Kisumu (Nyalenda and Manyatta) and Mombasa (Ziwa la Ng'ombe), among others, are often affected by floods (Tom *et al.*, 2022). Climate change and events such as El Niño have also played a major role in aggravating such floods, as in 2023 and 2024, where a lot of rainfall and flooding occurred (Nkatha, 2024). State and non-state actors such as the Kenya Red Cross Society, Earth5R, and the International Organisation for Migration (IOM) have been engaged in preparedness and response to floods in the country (International Organisation for Migration [IOM], 2024). State and non-state actors' interventions in informal settlements appear to be geographically targeted, and the repeated interventions in the same informal settlements indicate that such interventions may be based on local knowledge and networks. Many State and non-State local and international actors in Kenya point to a potentially complicated landscape of actors with coordination and collaboration essential for effective flood risk reduction.

The floods in the informal settlement areas of Nairobi are very common, primarily due to the poor drainage system, uncontrolled settlement along the riverside and increased surface run-off with the high level of urbanisation. Studies indicate that slums such as Kibera, Mathare and Mukuru are often flooded during the long rains (March-May) and short rains (October-December) and occur almost annually (sometimes even in each rainy season) (Muhatiah, 2021; Majina Ufanisi, 2023). In addition, the diagnostic tests point out that the condition of localised flooding is aggravated by the way that solid waste is concentrated in the drainage systems, causing inundation recurrently, despite the reduction of moderate rainfall (Space4All, 2022). This repetition reflects a long history of informal settlements being vulnerable to flooding and the need to integrate risk reduction measures.

The statistical tests have shown that in Nairobi, informal settlements are the ones that are exposed to frequent flooding. The Space4All Diagnostic of Urban Flooding in Nairobi (2022) reveals that almost 385,000 residents in settlement areas including Kibera, Mathare, and Mukuru are residing in regions that have been categorised as high-

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risk zones in floods. It has also been found that flood modelling estimates almost 60 per cent of households at the riparian settlements to be flooded at least once every two years, with localised flooding occurring after moderate rainfall events. Oxfam (2023), too, documents evidence of the chronic nature of the communities as thousands of households were displaced in Mathare and Kibera in March-May 2023. The figures above illustrate the need for integrated flood risk mitigation strategies which would involve infrastructural investments as well as community-based adaptation, and the urgency for such strategies.

While the studies that have been conducted offer insight into the frequency, causes and effects of flooding in informal settlements in Nairobi, there are a number of important gaps. First, the lack of temporal analysis of flood trends, longitudinally (across the years), limits the assessment of the increase in the frequency and severity of floods in the context of climate variability and the stress of urbanisation. Second, many different states and non-state actors are involved in flood risk reduction, but there is limited research systematically looking at the impact of actors on effectiveness, including how they coordinate and how governance arrangements influence outcomes. Thirdly, there is a lack of empirical evidence about the level of community response, household adaptation strategies, perceptions of risk and sustainability of grassroot initiatives. Closing these gaps would offer a more holistic picture of the dynamics of flood risks, and improve the design of integrated, context-specific disaster risk reduction solutions in Kenya's informal settlements.

III. METHODOLOGY

3.1 Research Design

A descriptive cross-sectional research design was used in this study to assess the Frequency of Floods Occurrence within informal settlements (Kibra and Mathare) in Nairobi County, Kenya. The research combined descriptive, cross sectional and exploratory case studies, allowing for the generalizable patterns of flood occurrence to be captured while at the same time providing in-depth insights into the socio-political and institutional understandings that underlie disaster interventions. This methodological complementarity was crucial to grasp the multidimensional aspects of urban flooding and the different response of the various stakeholders.

3.2 Study Site and Context

The choice of Kibra and Mathare as study sites was based on their being archetypal cases of urban vulnerability in Sub-Saharan Africa. The unplanned settlements, which are located along low-lying riparian features, are densely populated and thus extremely vulnerable to severe fluvial and pluvial flooding. The study's context was emphasised by the devastating 2024 floods which displaced thousands, destroyed property and resulted in outbreak of diseases. This underlined the need to implement effective and localised DRR interventions relevant to the following Sustainable Development Goals (SDGs 1, 3, 6, 11 and 13).

3.3 Population and Sampling Strategy

The target population included household heads, community leaders, non-state actors (NGOs/ CBOs) and State Government Agencies. The sampling strategy, used was multistage sampling with stratified, purposive and simple random sampling, with the total number of respondents 455 obtained based on Taro Yamane's formula. The sample was 398 household heads complemented by 42 focus group discussion participants, 10 non-state actors and 5 key state actors, with a view to securing both representativeness across the demographic spectrum and access to specific institutional knowledge.

3.4 Collection and analysis of data

Primary data collection instruments were structured questionnaires, semi-structured interview guides for key informants and focus group discussion guides in Kiswahili and photographic evidence. Secondary data was collected from government and NGO reports, policy documents and peer-reviewed literature. Quantitative data analysis methods were used to analyse the data comprehensively while quantitative data from household survey were analysed using descriptive and inferential statistics including Pearson's correlation and Chi-square test.

3.5 Validity, reliability and ethical considerations

A pilot test was carried out in non-study wards to assure the rigor of the study, which yielded a high Content Validity Index (CVI) of 93.8%. Additionally, reliability of the quantitative instruments was tested by Cronbach's Alpha with all constructs having acceptable alpha coefficient and qualitative instruments was tested by inter-rater reliability check. The study also addressed practical constraints such as psychological issues of flood trauma, language barriers, and local security issues. They were successfully addressed by using local languages, community elders and local administration and by following ethical guidelines. This research was carried out under Masinde Muliro University

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and NACOSTI ethical clearance, obtaining informed consent, voluntary participation, maintaining strict confidentiality and anonymising all the respondents to protect all the vulnerable populations.

IV. RESULTS & DISCUSSION

4.1. The extent of flood exposure in terms of prevalence, frequency and spatial extent

The study used completely filled questionnaires from households of 394 and dropped 4 that were incomplete hence had a response rate of 98.99%. The study finds that exposure to floods in Nairobi's informal settlements is not just episodic, but a structural reality. Only 6.9% (n = 27) of the 394 households surveyed in Kibra and Mathare said that they were not affected by flooding at all, while a whopping 93.1% (n = 367) said that they were affected at least once. This finding strongly agrees with global evidence that informal settlements are disproportionately exposed to flooding because they are located in hazard-prone areas (Satterthwaite et al., 2018; Williams et al., 2019). It reveals that almost all low-income neighbourhoods are vulnerable to flooding via these riparian corridors and informal drainage ways, and that the vulnerability of these areas is deep-rooted (UN-Habitat, 2019).

The inundation frequency is alarmingly high in addition to the exposure. One in eight households (1.3%) had a single flood event since 2020. On the other hand, almost half of the respondents (47.9%) experienced four or five flood events during this 5-year period. This is consistent with the findings of Muhatiah (2021) and Space4All (2022) who also reported that Nairobi's informal settlements experience floods annually, which affects their ability to enjoy their daily lives, leads to reconstruction of inadequate shelters, and contributes to a vicious cycle of economic insecurity as daily wage earners continue to lose their livelihood prospects (Centre for Disaster Philanthropy, 2024).

The increasing spatial coverage of floods supports this high frequency. Between 2005 and 2024, the flood-prone area in Kibra expanded from 0.8 km² to 2.0 km², while in Mathare; it grew from 1.2 km² to 2.5 km². This finding challenges the assumption that DRR interventions would result in a reduction in the severity of flooding and instead points to the shortcomings of existing urban planning strategies in safeguarding vulnerable communities (Dodman et al., 2023). The area that suffered from flooding in Mathare by 2024 completely covered the informal settlement area, displacing more than 7,000 people during the intense El Niño.

Table I

Kibra and Mathare Sub County Spatial Extent of Flooding

Kibra		
Year	**Flooded Area (km²)**	**Reasons**
2005	0.8 km²	Flooding along Ngong/Motoine River; recurrent but localized.
2015	1.5 km²	Expansion due to settlement densification; Laini Saba and Lindi most affected.
2024	2.0 km²	Severe El Niño floods; Ngong River burst banks, widespread displacement.
Mathare		
2005	1.2 km²	Seasonal Mathare River overflow.
2015	1.8 km²	Informal settlement growth increased exposure: Kosovo and Mathare North hit hardest.
2024	2.5 km²	Largest flood in two decades; water depths up to 3 m, >7,000 displaced.

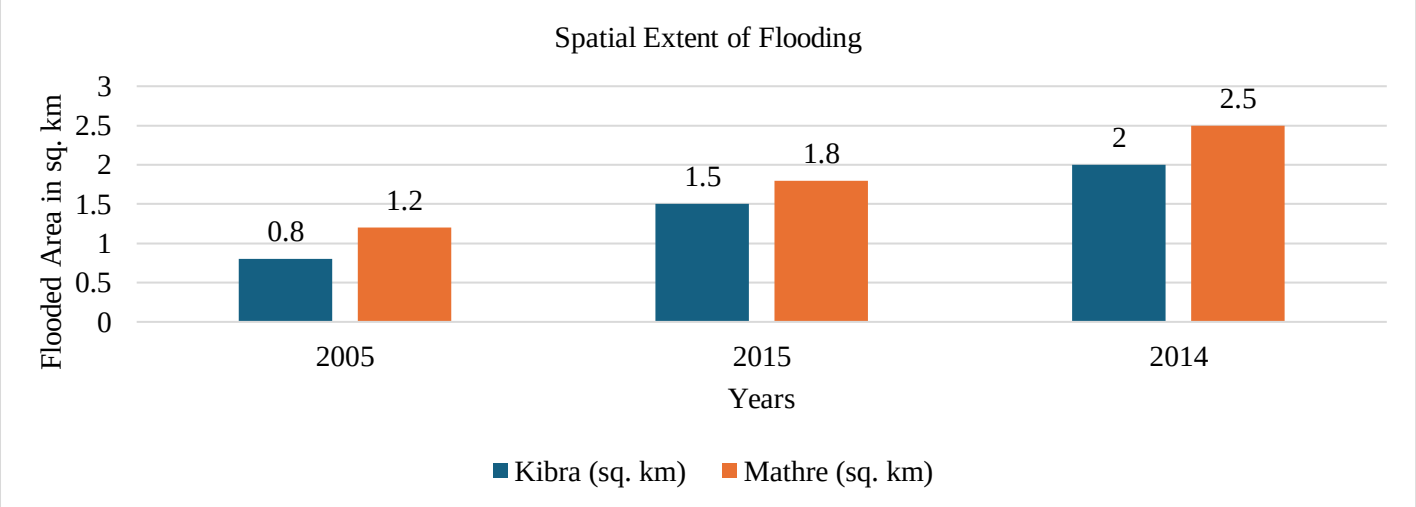

Figure I

Spatial Extent of Flooding in Kibra and Mathare informal settlements

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Events also often impacted a community-wide area: 31.7% of events flooded 1-10 households (localized ponding); a large percentage (28.9%) flooded 100 or more households at the same time. This finding builds on the work of Tom et al. (2022) by quantifying the impact of flooding, showing that flooding is not only a household issue but a community-wide crisis that requires coordinated response. This means that seasonal streams can cause mass-displacement catastrophes when they do breach their banks, or drainage systems completely fail, exceeding local humanitarian and shelter response capabilities (Tom et al., 2022).

Table II

Number of households affected by floods

Number of households affected by floods	Frequency	Percent
1-10	125	31.7
11-50	103	26.1
51-100	52	13.2
>=100	114	28.9
Total	**394**	**100**

Plate I

Status of Mathare River flood of 2024

Plate II

Status of Mathare River after flood initiative under Mto Wangu in 2025

4.2 Sociodemographic Factors and their Effect on Flood Vulnerability

A multiple linear regression was used to determine the predictive value of sociodemographic characteristics on flood frequency, to understand the drivers of this exposure. The model was statistically significant ($F(7, 386) = 49.883$, $p < 0.001$) and explained 47.5% of the variance ($R^2 = 0.475$) in reported flood occurrences. Two predictors proved to be very significant:

i. Household Size ($\beta = 0.506$, $p = 0.001$): Positive correlation which means the bigger the household size, the more often they flood. This result corroborates and builds on the study of Laji and Ayonga (2024) which found that large households are typically allocated to riskier plots. Our study offers empirical evidence that household size is not only correlated with location choice but is also a statistically significant predictor of flood frequency.

ii. Average Monthly Income ($\beta = -0.775$ and $p < 0.001$): There is a strong negative correlation which means that the higher the income, the fewer the number of flood events reported. This finding strongly supports Ngome and Yeom (2024) and confirms that economic capacity can be a protective measure: households can afford a house in a better-drained area or invest in prevention measures like raised floors and strengthening of structures. The size of this effect ($\beta = -0.775$) indicates that income is the most important determinant of flood exposure, and thus the basic importance of poverty in the production of flood vulnerability.

Interestingly, age, sex, education and length of time in residence were not statistically significant predictors. This finding is contrary to the results of the West African cities by Anwana and Owojori (2023), which indicates that there are contextual differences. This contradiction can be understood by the unique nature of land tenure insecurity in Kenya and the higher rate of unplanned urbanization in Kenya than in West Africa, which suggests that structural factors outweigh the protective effect of education in Nairobi informal settlements. Likewise, the lack of significance of residence duration suggests that the long-term residents are not necessarily moving out but rather have entrenched

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coping mechanisms and continue to be tied to high-risk areas because of their entrenched social and livelihood networks (African Cities Research Consortium, 2024).

These findings provide strong empirical evidence for Political Ecology Theory, which shows how historical marginalisation, insecure tenure and economic inequality can create a 'poverty-risk trap' (Leck & Simon, 2018). Meanwhile, Social Capital Theory is not forgotten in community mobilisation of agency within these boundaries, and unequal participation poses the question of the limits of social capital without structural change.

4.3. Spatial Distribution of Flood Hotspot and Landmark Dynamics

From the 394 households, flood prone structures were mapped, and the following landmark vulnerabilities were determined: riverbanks 66.0%, drainage lines 26.6% and dumpsites 7.4%. This spatial pattern aligns with and quantifies the informal settlement encroachment on natural waterways as the main spatial risk factor for flooding, building on the diagnostic work of Space4All (2022) and introducing ward-level specificity.

Table III

Ward, and specific hot spots in informal settlements

Specific hotspots		Landmarks most prone to flooding			Total
		Along the river	Drainage lines	Dumpsites	
Ward	Laini Saba	52	4	1	57
	Lindi	56	5	0	61
	Makina	2	14	4	20
	Sarang'ombe	48	34	0	82
	Mlango Kubwa	42	26	16	84
	Hospital	30	8	4	42
	Mabatini	30	14	4	48
Total		**260**	**105**	**29**	**394**

The disaggregation of data at the ward level showed that there was a high level of disaggregation within the municipality. The hotspots with the highest number of flood prone areas were Mlango Kubwa (21.3% of hotspots) and Sarang'ombe (20.8%) where the areas were highly congested and natural run-off had been blocked. Makina, on the other hand, had very different hotspot distribution, with 70% of hotspots occurring along drainage lines, and not riverbanks, indicative of localized failures in the piped infrastructure and pipe blockages, and not riparian encroachment. This finding builds on previous settlement-wide analyses (Muhatiah, 2021; Space4All, 2022) and shows that flood drivers are not the same in all informal settlements, and therefore interventions need to be differentiated. The Chi-square test result showed that there is a significant relationship between ward location and flood prone landmarks ($X^2 = 97.103$, $df = 12$, $p < 0.001$), which means that hyper localisation or ward-level DRR interventions are needed instead of settlement-level interventions.

Interestingly, when respondents were asked about changes in flood intensity over the last five years, 49.0% of respondents said that there was less flooding, 28.4% said that there was more and 22.6% said it remained the same. This is surprising given the known expansion of flood prone areas but could be a sign of localized benefits from interventions in specific hot spots.

The cross-tabulation revealed a very strong decrease in the number of floods in the riverbank areas (60.4% of riverine hotspots reported a decrease in the number of floods). This is a finding that is contrary to the overall trend of flood extent increase, but consistent with the reports of Space4All (2024) on successful community-led drainage clearing efforts. This is a counterintuitive finding as the known areas of high risk show a reduction in frequency, which is probably due to targeted, community-led mitigation measures, including the drainage clearing and small-scale wetland rehabilitation activities of local NGOs and CBOs (Space4All, 2024).

Table IV

Frequency of flood occurrence and landmarks prone to flooding

Frequency of floods and risk location		Frequency of occurrence of flooding in the past 5 years			Total
		Increased	Remained the same	Decreased	
Specific areas or landmarks most prone to flooding	Along the river	77	26	157	260
	Drainage lines	29	47	29	105
	Dumpsites	6	16	7	29
Total		**112**	**89**	**193**	**394**

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This disconnect between the overall flood expansion, and the local reductions, shows an important lesson: structural interventions are still the main drivers of flood risk at the settlement level, but community-based interventions can be effective in reducing flood risk at specific hotspots. This is further supported by the weak negative correlation (r = -0.150) between hotspot designation and flood frequency, which indicates that proactive, community-based interventions in identified hotspots are an effective way to interrupt the anticipated flood cycle, showing the effectiveness of the Community-Based Disaster Risk Management (CBDRM) model under proper support. This discovery, however, also points to the limitation of CBDRM: community interventions can only reduce risks locally, not systemically, unless they are complemented by structural interventions such as addressing unplanned urbanization and ecological degradation.

4.4. Household Damages

Recurrent flooding has multi-dimensional impacts which go beyond inconveniences. There is an emphasis on compound damages in the data, with the most frequently reported single impact being standalone property loss (35.8%).

Multiple harms were experienced by many households, with 16.8% reporting both property loss and health damage, 10.7% reporting all three (property loss, health damage, environmental damage) and 10.2% reporting all four (property loss, health damage, environmental damage and loss of life). This cascading effect builds on the findings of Ndabezitha et al. (2024), who quantified the compounding nature of flood damages, finding that more than 37% of households suffered from multiple flood damages.

The economic losses due to the destruction of assets and loss of livelihoods are compounded by waterborne diseases (cholera and typhoid) caused by floodwater contaminated by waste from nearby dumpsites and blocked drains (Ndabezitha et al., 2024). The low percentage of households with no damage (1.3%) suggests that there is no protection in the system. This exposure challenges the belief that individual adaptation measures effectively could protect some households in the risk places (John, 2020) and further strengthens the case for systemic solutions. This should be addressed by "whole-of-society" approaches that not only respond to the crisis in a siloed manner, but also address housing reinforcement, accessibility to health services and solid waste management.

4.5. Land Use and Land Cover (LULC) Changes; Drivers of Flood Risk

The riparian corridors between the settlements in the area have undergone significant Land Use and Land Cover (LULC) changes in 2005-2024, which is closely linked to the increase in flood extent and frequency.

In Kibra, built-up areas expanded by 36% (3.3 km² to 4.5 km²), while riparian vegetation declined by 56% (0.9 km² to 0.4 km²) and water bodies shrank by 58% (0.48 km² to 0.2 km²).

Likewise, in Mathare, the built-up areas increased from 4.6 km² to 5.5 km² while the riparian vegetation has decreased by 57% (0.7 km² to 0.3 km²).

Table V

Kibra and Mathare Informal Settlement Riparian Corridor

LULC Class	2005 (km²)	2015 (km²)	2024 (km²)
Kibra			
Built-up areas	3.3	4.0	4.5
Riparian vegetation	0.9	0.5	0.4
Agricultural land	0.6	0.4	0.3
Bare areas	0.72	0.8	0.6
Water bodies	0.48	0.3	0.2
Mathare			
Built-up areas	4.6	5.3	5.5
Riparian vegetation	0.7	0.4	0.3
Agricultural land	0.35	0.2	0.15
Bare areas	1.05	1.1	0.8
Water bodies	0.35	0.25	0.25

The above evidence demonstrates that these Land Use Land Cover changes are not a random occurrence but are a consequence of systemic exclusion from formal urban planning processes, as argued by political ecology (Robbins, 2012). These changes indicate a general reduction in ecological buffers. Over 70% of the riparian land in both settlements is now impervious, built-up areas. Historically, natural vegetation and agricultural lands have helped to provide hydrologic resiliency to the landscape, but as these areas have been lost, the hydrologic resiliency of the landscape has been significantly reduced. This finding challenges the assumption of static degradation rates, as the

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riparian vegetation loss of 56-57% observed in this study is higher than the loss reported by Muhatiah (2021) for the period 2005-2015, indicating an increase in the rate of ecological degradation. These LULC changes, coupled with the narrowing and pollution of waterways, make sure that even moderate rainfall events trigger severe and rapid onset inundation (Muhatiah, 2021; Tom et al., 2022). This finding complements the previous work by offering a direct temporal correlation between the LULC changes and the 150-208% increase in flood prone areas as reported in Section 4.1.

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Results show that flood risk within Kibra and Mathare is a result of the interplay between these structural inequalities, fast-paced and unplanned urban development and ecological degradation. The spatial dynamics of flooding is associated with riparian encroachment and the LULC changes whereas household income and size are the main predictors of individual vulnerability. The reduction in flood frequency, however, observed in specific riverbank hotspot locations provides a valuable learning point that: targeted, participatory and ecosystem-based interventions can be effective in reducing risk. Future DRR policies should consequently move away from reactive coping strategies at a household level to proactive strategies at a ward level, which include engineered infrastructure, riparian restoration and formalisation of community-led resilience strategies.

5.2 Recommendation

A ward-based, 'hyper localized' Disaster Risk Reduction (DRR) approach is needed to tackle chronic flood risks in Nairobi informal settlements, compared to a blanket approach. Ecosystem-based adaptations, such as riparian restoration and periodic desilting of drains should be prioritized with formalization of community-led early warning systems. Moreover, interventions need to account for the socio-economic vulnerabilities, by offering housing microfinance and livelihood support to those larger low-income households. In conclusion, participatory, multi-sectoral planning combined with engineered infrastructure are key components to create sustainable, long-term urban resilience.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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