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The Management of Climate Change-Induced Flooding in Ziwa La Ng'ombe Informal Settlement, Mombasa County, Kenya

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Abstract

Climate change presents a significant challenge for residents of informal settlements worldwide, exacerbating vulnerabilities and threatening livelihoods. This study investigates the management of climate change-induced flooding in Ziwa la Ng'ombe informal settlement, leading to displacement and property damage during extreme weather events. Despite the growing body of literature on climate change adaptation in informal settlements, there remains a critical gap in understanding how these communities perceive and respond to flood management strategies within the context of rapid urbanization and limited resources. The study employed a mixed-methods approach, combining quantitative data from 158 household surveys with qualitative insights from key informant interviews. The study found that 78% of the respondents have noticed changes in rainfall patterns, with 59% reporting increased intensity and frequency. Poor drainage systems and inadequate waste management are identified as primary causes of flooding. Residents have undertaken individual measures such as creating small drainage channels and constructing flood barriers. However, institutional efforts appear to be lacking, with 85% of residents unaware of any formal flood management initiatives. Further investigation revealed that local NGO, KECOSCE, has established an early warning system such as SMS messages, radio broadcasts, and community meetings. Additionally, the Department of Housing also plays a vital role in regulating land use and enforcing zoning regulations. The effectiveness of these interventions appears limited, as evidenced by continued flooding and resident dissatisfaction. Based on these findings, the research proposes climate change induced flood management strategies, including upgraded infrastructure to improve drainage and waste management, community empowerment and participatory planning to ensure that flood management strategies are aligned with the needs and priorities of residents, and increased awareness of formal flood management initiatives to bridge the gap between institutional efforts and community awareness in Ziwa la Ng'ombe informal settlement.

Keywords: Climate change, adaptation strategies, informal settlements, flood management, Mombasa

INTRODUCTION

The impacts of climate change pose a profound and undeniable reality for residents in informal settlements. Informal settlements, an integral yet often overlooked component of urban landscapes globally, represent a dynamic and integral part of urban landscapes, formed by rapid urbanization and economic disparities. However, these vibrant, yet vulnerable communities face the brunt of escalating global temperatures, disrupted rainfall patterns, and a surge in extreme weather events.

In the Global North, despite the advancements made in infrastructure and disaster management, flooding remains a significant challenge (Bakkensen & Blair, 2020), particularly impacting marginalized communities in informal settlements. In the United States, coastal states such as New York and Florida face the looming threats of sea level rise and the accompanying risks such as coastal erosion and storm surges, (Schwartz, 2018). Since 2000, the severity of flooding has increased by 24% (Keech, 2020), posing undeniable risks to over 5000 informal settlers, with this number expected to increase to over 9000 vulnerable inhabitants by 2033. Despite efforts to improve resilience, informal settlements in developed countries continue to experience significant losses in terms of lives and property during flooding events.

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The challenges of flooding in informal settlements extend beyond the U.S. In Europe, coastal flooding and erosion have triggered mass migration due to land loss, with projected indications for a substantial increase in affected populations under high sea-level rise (Ciscar et al., 2009). The situation in Asia is equally concerning. In Japan, the country's extensive coastlines and low-lying areas make it susceptible to flooding and typhoons. In July 2018, Japan experienced two contrasting and consecutive extreme events; first, a devastating flood in early July followed by unprecedented heat waves a week later, accompanied by loss of life and extensive economic losses (Wang et al., 2019).

In developing countries, informal settlements bear the brunt of extreme weather events, with climate change-induced flooding being a significant concern. The expansion of urban populations is marked by informality, illegality, and unplanned settlements, significantly contributing to the vulnerability of these areas to climate change and flooding. African cities, being the most rapidly growing, yet vulnerable to climate change globally, are challenged with informal settlements and flood hazards. The urban poor, according to Amoako (2018), are the most vulnerable due to their lack of adaptive capacities in dealing with flood disasters. This vulnerability is exacerbated by the lack of housing and municipal infrastructure, water and sanitation, and community organization (Pelling, 1997).

In Accra, Ghana, The Glefe informal settlement is exposed and vulnerable to perennial flood hazards from storm surges over the past two decades. According to (Amoako, 2018) the residents of this community have adapted to living in response to the flooding events as they occur, dealing with the particular exigencies of each flood event, all the while learning useful lessons for future occurrences.

In Kenya, floods are the leading hydro-meteorological disaster, particularly in informal settlements (Otiende, 2009). These settlements are ubiquitous in virtually all urban areas, with a pronounced presence in key cities like Nairobi, Kisumu, and Nakuru. In low-lying areas, flooding has become a frequent phenomenon with devastating impacts. Exacerbated by climate change and the altered precipitation (Awuor, 2012; Kebede et al., 2012; Moser et al., 2010) and poor drainage system, there have been significant flood events in the past two decades. These areas experience a flooding event or two annually leading to loss of lives and destruction of property and infrastructure. The brunt of this damage is often in informal settlements leading to displacement and long-term community impacts.

Despite the growing body of literature on climate change adaptation in informal settlements, there remains a critical gap in understanding how these communities perceive and respond to flood management strategies within the context of rapid urbanization and limited resources. This study addresses this gap by investigating the management of climate change-induced flooding in Ziwa la Ng'ombe informal settlement, Mombasa County, Kenya **Figure 1**.

This informal settlement experiences significant vulnerability to extreme weather events, which cause displacement and property damage. By employing a mixed-methods approach, this research examines the interplay between residents' perceptions of changing rainfall patterns, existing flood management efforts, and their own adaptive capacities. This investigation aims to contribute valuable insights for developing effective and community-driven flood management strategies in similar contexts.

THEORY

Climate Change and Flooding

In recent decades, the frequency and intensity of extreme weather events have risen due to climate change. Studies have shown a correlation between rising temperatures and precipitation patterns, resulting in more intense and prolonged storm events globally (Cheng et al., 2017). This phenomenon is attributed to rising global temperatures, which enable the atmosphere to hold more moisture, resulting in heavier rainfall and subsequent flooding. In 2020, flooding in East Africa, exacerbated by unusually warm Indian Ocean temperatures, displaced millions of people and caused widespread damage across the region (UNDRR, 2020). This unprecedented increase in heavy precipitation poses significant challenges to urban areas, whose conventional stormwater management systems are proving inadequate in coping with the erratic and intensified rainfall and storm events (Chizewer & Tarlock, 2012). This is

FIGURE 1
Locational context map of Ziwa La Ng'ombe settlement
Source: Google Earth, 2024

particularly critical for informal settlements like Ziwa la Ng'ombe, where inadequate infrastructure, poor drainage, and precarious housing conditions create heightened vulnerability to flooding. The combination of inadequate infrastructure and increasingly intense rainfall patterns creates a dangerous scenario for residents of Ziwa la Ng'ombe, placing them at a significantly higher risk of experiencing flood-related damage and displacement.

The impacts of climate change and climate change induced flooding extend beyond land inundation, and encompasses loss of life, disruption of livelihoods, displacement and exacerbation of existing vulnerabilities, especially borne by low-income communities in society (Kocornik-Mina et al., 2020). In Africa, for instance, severe flooding has led to widespread displacement and a surge in waterborne diseases, further straining already limited resources and hindering effective adaptation efforts. There is a glaring disproportionality on the addressing of climate change issues in vulnerable regions across the globe and more particularly within the region.

Impacts on Informal Settlements

Rapid urbanization and climate change intersect to heighten the vulnerability of poor urban communities to natural hazards, thereby undermining urban resilience. These fast-growing urban areas already grapple with high levels of poverty, unemployment, informality, and environmental risk, alongside housing and service backlogs. The location of informal settlements on floodplains, coupled with inadequate waste and drainage networks, exacerbates the impact of flooding on vulnerable communities. Cities within these affected regions are vulnerable to natural hazards because of the high populations and clustered socio-economic developments. The increased runoff from hardened surfaces like roads and pavements further compounds the vulnerability of informal settlements to flooding (Douglas et al., 2008).

In Ziwa La Ngombe informal settlement, these vulnerabilities are starkly evident. Previous research on Ziwa la Ng'ombe has highlighted the community's awareness of changing rainfall patterns and the increasing frequency and severity of flooding events (Haji, 2021; Moser et al., 2010; Okaka & Odhiambo, 2019). However, there remains a critical gap in understanding the specific status of climate change-induced flooding in the settlement and the effectiveness of existing flood management strategies.

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This study finds that 71% of residents in Ziwa la Ng'ombe have noticed changes in rainfall patterns, with 59% reporting increased intensity and frequency. This has led to more frequent flooding events, with 50% of respondents attributing these floods to the area's poor drainage systems. The consequences of flooding on informal settlements are wide-ranging and severe, encompassing loss of housing, inundation, soil erosion, compromised water quality, injuries, fatalities, disruptions to livelihoods and city economies, damage to homes, assets, and public infrastructure, population displacement. (Moser et al., 2010) . These impacts are consistent with the experiences of residents in Ziwa la Ng'ombe, who highlighted displacement and loss of property in the aftermath of flooding events.

RESEARCH METHODS

Materials and Methods

This study employed a mixed-method sequential explanatory design to develop a framework for managing climate change-induced flooding in Ziwa La Ng'ombe informal settlement. This research design involved using an initial quantitative phase to assess the extent and nature of the flooding problem, followed by a qualitative phase to delve into the underlying reasons, community perceptions, and experiences.

The quantitative phase utilized structured questionnaires administered to a representative sample of Ziwa la Ng'ombe households . The questionnaires gathered numerical data on flood frequency, severity, types of flooding experienced, impacts on livelihoods and well-being, awareness of flood risks, coping mechanisms, and demographic information. This data was analyzed using descriptive statistics to identify patterns, relationships, and differences among various groups within the settlement. The qualitative phase employed semi-structured interviews with key informants and residents. This method explored the underlying reasons behind the quantitative findings, capturing community perceptions, experiences, and local knowledge regarding flood management. Thematic analysis was used to identify recurring themes and patterns in the qualitative data, providing a deeper understanding of the social, cultural, and institutional factors influencing flood risk and management in Ziwa la Ng'ombe.

A sample size of 158 households was determined using Yamane's (1973) formula, with a 95% confidence level and a 7.8% margin of error. This sample size was deemed appropriate to ensure proportionate representation within the overall population of 3,942 households in the study area **Table 1**. A stratified sampling approach was employed, dividing the settlement into seven strata based on housing types (formal, semi-formal, and informal) and their geographical location to ensure representation of the different socio-economic groups and varying flood risk.

Within each stratum, cluster sampling was used to select individual households. According to (Kothari, 2004)this is the most practical way of

TABLE 1
Summary of the correlation analysis

Stratum	Households in Stratum	Proportion of Area	Formal Household	Semi-formal Household	Informal Household	Sample Size /Stratum
Stratum 1	394	10%	1	5	10	16
Stratum 2	276	7%	1	4	6	11
Stratum 3	315	8%	1	4	8	13
Stratum 4	710	18%	1	8	19	28
Stratum 5	788	20%	1	11	20	32
Stratum 6	473	12%	1	6	11	18
Stratum 7	986	25%	1	15	24	40
TOTAL	**3,942**	**100%**	**7**	**53**	**98**	**158**

Source: Field survey, 2024

sampling. This involved dividing each stratum into smaller clusters and randomly selecting a few clusters for data collection, where a random sample of households was surveyed. The selected households were surveyed using questionnaires to gather quantitative data on flood experiences, impacts, perceptions, and coping mechanisms.

RESULTS AND DISCUSSION

The target sample population for this study consisted of 158 resident respondents of Ziwa La Ng'ombe informal settlement. All questionnaires were completed, resulting in a 100% response rate. This surpasses the recommended >70% respondent threshold for robust data analysis, as suggested by Mugenda, (2003).

The study sample consisted of a near-balanced gender distribution with 54.6% female and 45.4% male respondents. his closely mirrors the broader demographic makeup of Ziwa la Ng'ombe, where women constitute approximately 51.2% of the population (KPHC, 2019). The age distribution skews towards a younger demographic, with the largest group falling within the 33-39 age bracket (27%), followed by the 40-46 age group (25%). Additionally, researchers (Prina et al., 2024); Sawangnate et al., (2022), have postulated that younger individuals might exhibit greater physical resilience and adaptability, while older residents could face heightened vulnerability due to mobility constraints and health limitations.

Larger households were common, with an average household size of 7 members. Most respondents had lived in the settlement for over a decade, and 82% identified as renters. This characteristic is also contributed by the familiar structure and social norms of the community with many households consisting of extended families and multigenerational living arrangements (Diep et al., 2019). Larger households are more predisposed to vulnerabilities of climate change related flooding, as more individuals are exposed to potential risks and impacts. According to Diep et al., (2019). Patel & Mitlin, (2010), postulate that long term residency of majority of respondents highlights the need for flood management strategies that prioritize in-situ upgrading and resilience building, rather than relocation and displacement. A notable lack of tenure security exacerbates flood vulnerability. Uleme, (2021) states that the dynamic between landlords and tenants often creates barriers to implementation of adaptation strategies, as renters are hesitant to invest in improvement without tenure security.

As highlighted in **Figure 2,** a significant majority (71%) of respondents perceived changes in rainfall patterns over the past 5 years, with 59% reporting increased intensity and frequency. This suggests a trend towards heavier and more frequent downpours, potentially increasing the risk of flash floods and associated damages.

Additionally, 22% of respondents cited unpredictability of the severity and intensity of rainfall, indicating shifting rainfall patterns. Additionally, 14% of respondents cited the diverse

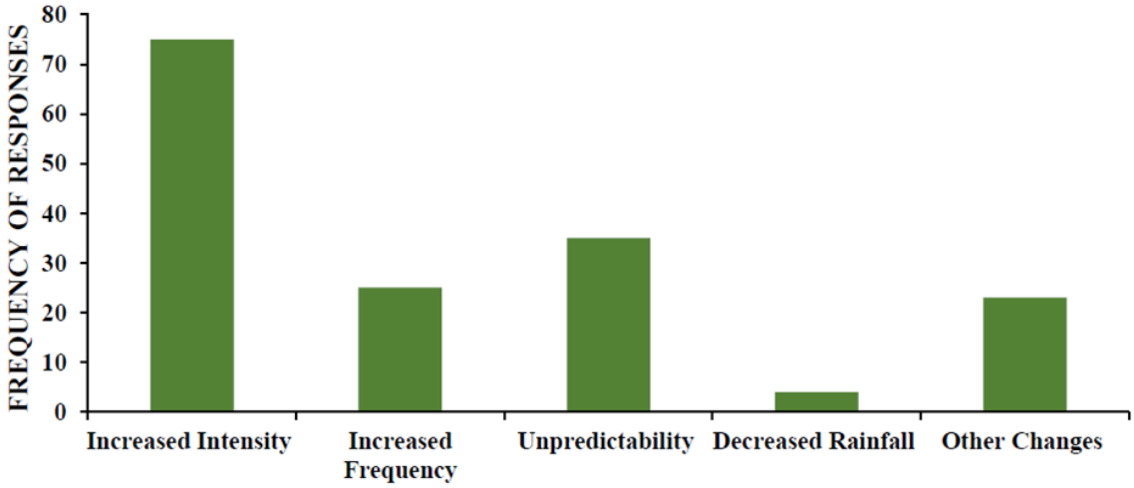

FIGURE 2
Respondent's changes in rainfall patterns
Source: Field survey, 2024

range of climatic shifts observed by the community categorized under other changes such as extreme temperature fluctuations alongside other weather disturbances.

The primary causes of flooding were identified as poor drainage systems (50%) and inadequate waste management (36%), as shown in **Figure 3**. The analysis of respondents' perception on changes in rainfall patterns reveals a community acutely aware of shifts in their local climate.

This observation is aligned to the climate change projections for the region. Which anticipate more intense rainfall events with interspersed prolonged droughts (MCIDP, 2019). This suggests a trend towards heavier and more frequent downpours, potentially increasing the risk of flash floods and associated damages.22% of respondents cited unpredictability of the severity and intensity of rainfall, indicating shifting rainfall patterns. Additionally, 14% of respondents cited the diverse range of climatic shifts observed by the community categorized under other changes such as extreme temperature fluctuations alongside other weather disturbances.

Existing Flood Management Strategies

The study reveals a significant gap in awareness and engagement regarding existing flood management efforts. 85% of respondents were unaware of any initiatives by local authorities or community organizations. This lack of awareness has hindered effective flood management and underscores the need for improved communication and collaboration between authorities and residents.

Despite the challenges posed by flooding, the community demonstrates a degree of resilience and adaptation. Findings show that 39% of respondents reported taking steps to mitigate flood impacts at the household level, such as building barriers and clearing drainage channels, however a concerning 61% have not taken any action. This highlights the need for increased awareness and capacity-building initiatives to empower residents to proactively address flood risks.

Residents of Ziwa La Ng'ombe informal settlement have taken some individual steps to mitigate the impact of flooding on their households. These include building barriers at the entrance of their houses to prevent floodwaters from entering, clearing stagnant water and blocked drainage systems, and constructing retaining walls as resilience measures. **Figure 4** shows some of these household-level flood management measures.

Institutions have also undertaken initiatives to address the flooding problem in the study area. The Department of Environment and Solid Waste Management has been actively involved in improving the city's drainage infrastructure. This includes constructing new drainage channels, regularly cleaning and maintaining existing drains, and implementing measures to prevent the clogging of drains by solid waste. Additionally,

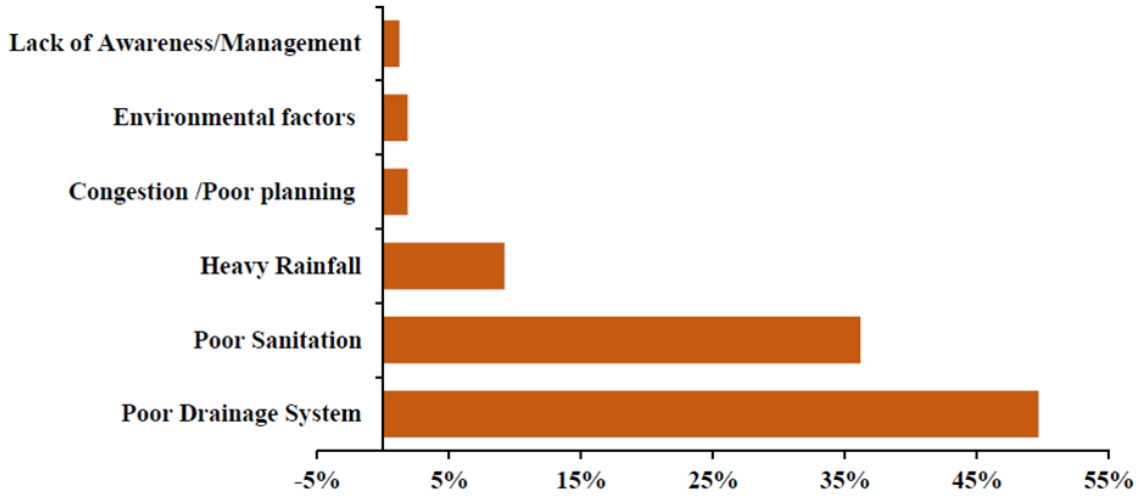

FIGURE 3
Respondent's perceived causes of flooding
Source: Field survey, 2024

FIGURE 4
Household level management including flood barriers and trenches
Source: Field survey, 2024

the Department of Housing plays a crucial role in regulating land use and enforcing zoning regulations to minimize construction in flood-prone areas.

Non-governmental organizations (NGOs) such as KECOSCE have also been actively involved in flood management efforts in Ziwa la Ng'ombe. KECOSCE has established an early warning system to alert residents of potential floods, utilizing SMS messages, radio broadcasts, and community meetings to disseminate timely information. They also engage in community sensitization, monitoring and evaluation, and reporting of high-risk areas, working with the community to increase awareness and improve risk perception among residents.

At the local level, community-based organizations (CBOs) and residents play a crucial role in organizing self-help initiatives such as drainage cleanups. Key informant interviews revealed that challenges such as inadequate infrastructure, lack of coordination and communication, insufficient data and information, inadequate funding, and rapid urbanization persist. These challenges underscore the need for a more comprehensive and integrated approach to flood management involving greater community engagement, improved communication and coordination, and increased investment in flood-resistant infrastructure and early warning systems.

Spatial Distribution

The spatial distribution of flood vulnerability within Ziwa la Ng'ombe exhibits a complex pattern influenced by both physical and socio-economic factors. As visualized through **Figure 5**, the heatmap overlay, with its concentration of red and orange zones, vividly illustrates the areas of heightened flood risk. These areas appear to cluster around the settlement's low-lying regions, particularly those adjacent to the drainage channels. The spatial distribution of flood vulnerability is not solely determined by topography. The qualitative data collected through household surveys and interviews indicate that residents in the most flood-prone areas are often those with limited resources and access to secure housing.

Furthermore, the geolocated images expose the challenges posed by the settlement's dense and unplanned layout. The congestion of houses, coupled with encroachments on drainage channels and natural waterways, creates a bottleneck effect, impeding water flow and exacerbating flood events.

In essence, the spatial distribution of flood vulnerability in Ziwa la Ng'ombe is a complex tapestry woven from both physical and socio-economic threads. The concentration of flood risk in low-lying areas and its disproportionate impact on marginalized communities highlight the critical need for targeted interventions that address both the physical and social dimensions of vulnerability.

Proposed Solutions

A dominant theme in the responses is the call for improved infrastructure, particularly enhanced drainage systems. Resonating with Birkmann et

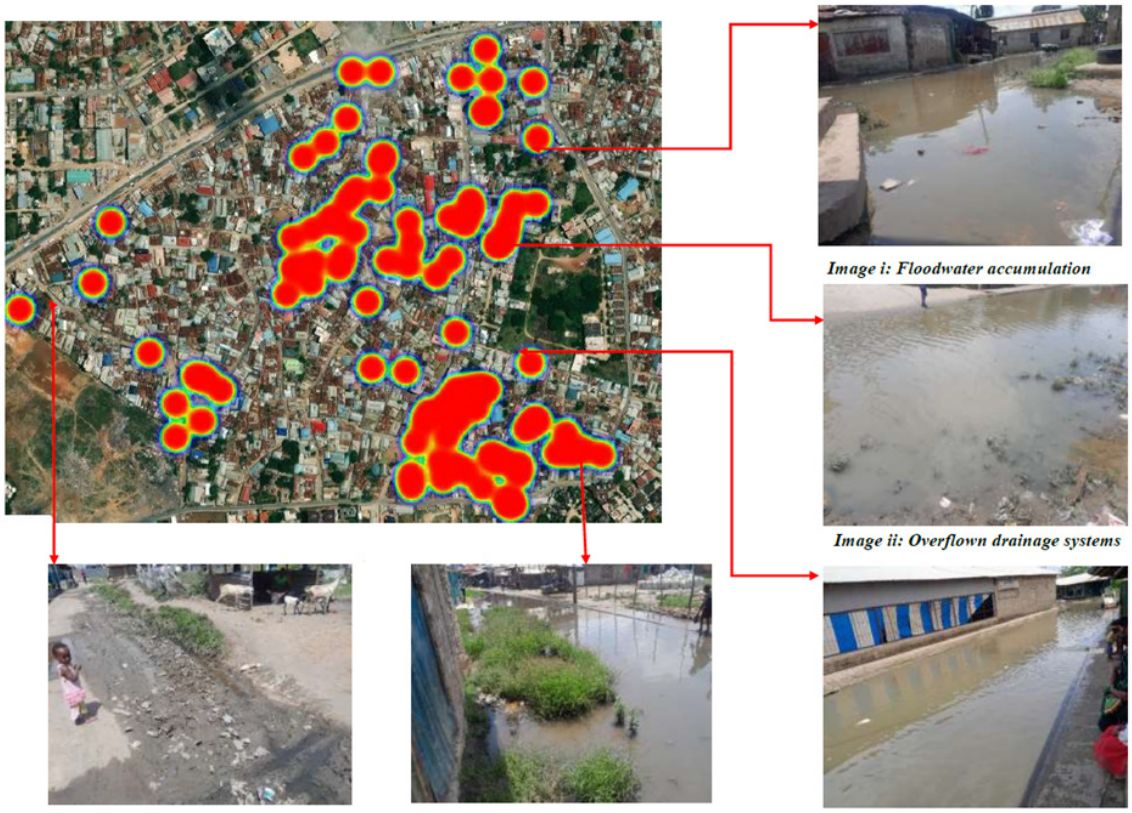

FIGURE 5
Map showing spatial distribution of flooding in Ziwa La Ng'ombe
Source: Field survey, 2024

al., (2022) these responses emphasize the role of physical factors in shaping disaster risk . The study shows that 42% of the respondents recognized that the current drainage infrastructure is inadequate to handle the increased intensity and frequency of rainfall, leading to waterlogging and flooding. Respondent suggestions ranged from the construction of new drainage systems and culverts to regular maintenance and clearing of existing infrastructure. A study by Jha et al. , (2012) in Mumbai, India, found that investments in large-scale infrastructure projects, such as improved drainage systems and flood barriers, significantly reduced flood risks in informal settlements. This study highlights the limitations of such an approach in Ziwa la Ng'ombe informal settlement, where inadequate drainage systems and lack of proper waste management continue to pose significant challenges.

Furthermore, 24% of the respondents emphasized the need for community awareness and education programs with knowledge and skills to adapt to and mitigate flood risks. This highlights the role of attitudes and perceived behavioral control in shaping resilience actions ((Ajzen, 1991). Through education and awareness campaigns, the community can be actively engaged in flood preparedness and response.

Key informants form a localized NGO, emphasized the need for further capacity building and training programs, stating,
"We have done our best to provide early warning systems, however, we need to equip residents with the knowledge and skills to protect themselves and their homes."

Figure 6 highlights proposed flood management solutions, where 22% of the respondents suggested nature-based solutions such as reforestation and sustainable land use practices. The respondents recognize the implications of deforestation and unsustainable land use can exacerbate flood risk and advocate for nature-based solutions that promote ecological balance and resilience. 12% of the respondents called for stricter enforcement of building codes and zoning regulations, improved waste management practices and climate change adaptation policies. This highlights the

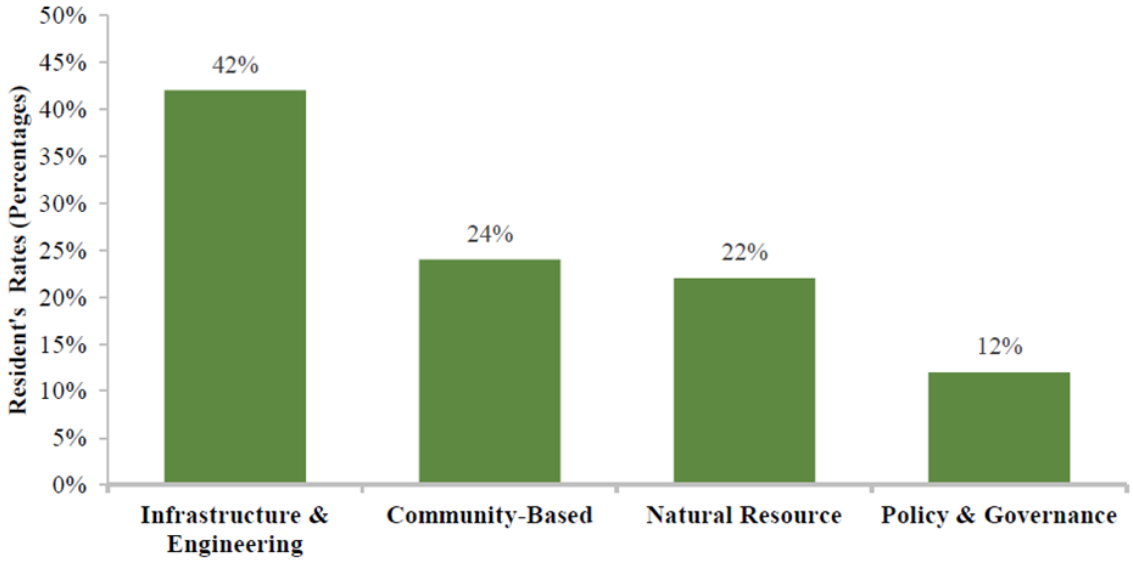

FIGURE 6
Proposed solutions for flood management
Source: Field survey, 2024

community's desire for stronger governance and institutional frameworks.

The local government official acknowledged these challenges, stating,

"Enforcement has been a challenge, but we are working towards community engagement and better waste management practices."

This indicates a recognition of the need for improved governance and policy implementation. The proposed solutions reflect a strong sense of community ownership and agency. Participatory approach is crucial for ensuring that solutions are contextually relevant, culturally appropriate, and sustainable in the long run. The community demonstrates a proactive approach to flood management, organizing self-help initiatives to clear drainage systems. As one community leader noted,

'Sometimes we organize ourselves as a neighborhood and clear the drainage systems when we expect heavy rainfall. If we don't, we have to deal with water in our houses and streets."

This highlights the community's awareness of the flood risks they face and their willingness to take action to protect their homes and livelihoods.

CONCLUSION

This study highlights the pressing reality of climate change-induced flooding in Ziwa la Ng'ombe informal settlement. The findings underscore a community grappling with the tangible impacts of a changing climate, manifested in increased rainfall intensity and frequency, and the devastating consequences of flooding. The study findings, additionally, underscore a complex interplay of factors that contribute to Ziwa la Ng'ombe's heightened vulnerability particularly, inadequate infrastructure similarly to Satterthwaite et al., (2012). Furthermore, limited resources and socio-economic disparities, reflected in the high percentage of residents engaged in informal employment and earning below the poverty line, further exacerbate the community's susceptibility to flood impacts.

This study recommends conducting a comprehensive flood risk assessment that integrates both physical and socio-economic vulnerabilities, going beyond mere identification of flood-prone areas. This recommendation is firmly grounded in the research findings, which paint a stark picture of the settlement's susceptibility to flooding. A significant number of respondents perceived changes in rainfall patterns, noting increased intensity and frequency. Leveraging advanced technologies like GIS and remote

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sensing to develop detailed flood risk maps is paramount. These maps should not only delineate areas prone to inundation but also incorporate socio-economic data, such as income levels, housing quality, and access to services, to create a multi-dimensional vulnerability index(Blaikie et al., 2014; Cutter et al., 2012). By understanding the multifaceted nature of vulnerability, interventions can be targeted to address the root causes of flood risk and enhance community resilience.

This approach enables targeted interventions and prioritizes resource allocation for maximum impact, and understanding the multifaceted nature of vulnerability to develop effective adaptation strategies.

RECOMMENDATIONS

This study proposes the following recommendation to manage climate-change induced flooding in Ziwa La Ng'ombe informal settlement;

a) Improved Drainage Infrastructure

This study recommends investment in upgrading and expanding the drainage system to accommodate increased rainfall intensity and frequency. This includes constructing new drainage channels, culverts, and retention ponds, as well as implementing regular maintenance programs to ensure the system's functionality, through the local county council and environmental offices. Aligning with the findings of this study, 50% of respondents identified inadequate drainage as a major cause of flooding and 33% cited it as a major barrier to flood management. It also echoes the successful interventions in Wat Kao, Thailand, where the community and government collaborated to construct a barrier wall along the riverbank and implement drainage upgrades, demonstrating the effectiveness of combining structural measures with community-based adaptation.

b) Community-Based Early Warning Systems

Establishment of a robust early warning system that incorporates both technology and local knowledge, is crucial in disaster risk reduction. In Tandale, Tanzania, community engagement in disaster risk reduction proved effective through the use of localized rainfall forecasts and historical precipitation data, this recommendation emphasizes the importance of involving residents in the design and implementation of the early warning system. This is crucial given the study's finding that 21% of respondents cited limited access to early warning systems as a barrier to effective flood management.

Community based warning systems include utilizing SMS messages, radio broadcasts, and community networks to disseminate flood warnings, empowering residents to take timely action. This also requires collaboration with local government departments, community leaders and non-governmental organizations in the area.

c) Strengthened Institutional Framework

This study finding show a disconnect between the community and the authorities, with 98% of respondents being unaware of any flood management initiatives by their local government. Strengthening the institutional framework for flood management by establishing a dedicated task force or committee that prioritizes inter-agency collaboration and community representation. Strengthening coordination within stakeholder agencies and the community will ensure flood management efforts, the development of comprehensive flood management plans and ensuring effective implementation of management strategies.

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