Catalytic Tech-Based Participatory Methods To Build Climate Resilience Locally:

A Case Study Of Mathare Informal Settlement, Nairobi, Kenya

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2025

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Abstract

Urban informal settlements are disproportionately vulnerable to the impacts of climate change, with extreme weather events exacerbating socio-economic inequalities, displacement, and environmental degradation. This study investigates the catalytic role of low-tech participatory methods in enhancing climate resilience at the local level, using Mathare Informal Settlement in Nairobi, Kenya, as a case study. It critically examines how participatory planning tools both non-scientific community engagement methods and technology-based can empower marginalized communities to co-produce climate adaptation strategies, particularly in response to climate-induced disasters such as flooding and forced evictions. Drawing on a mixed-methods approach and case study research design, the study integrates qualitative and quantitative data through community workshops, key informant interviews, and spatial analysis. A collaborative digital co-design platform has been developed with community members and urban practitioners to facilitate inclusive planning and real-time engagement. The study also critically analyses governance structures and institutional responses shaping urban climate resilience, exploring the intersection between disaster risk reduction, human rights, and socio-ecological justice. It highlights the role of political actors and humanitarian aid organizations in addressing the vulnerabilities of informal settlement residents, while also interrogating the limitations of conventional public participation mechanisms. This study therefore aims to bridge the gap between top-down climate adaptation policies and grassroots-driven solutions by contributing to the discourse on urban climate governance, participatory planning, and technological innovations for resilience. The findings of this study offer policy recommendations and practical insights for integrating low-tech and digital participatory tools into climate resilience planning in informal settlements, fostering more inclusive, equitable, and sustainable urban development.

Keywords: Participatory Methods, Climate Resilience, Co-design, Urban Governance, Socio-ecological justice

1. Introduction

1.1 Background and Rationale of the Study

In recent years the world has seen the rate of urbanization skyrocket, coupled with technological advancement, has seen the acceleration of transformative ways of dealing with the pressing challenges of climate change, an issue that most countries, if not all, in the world grapple with. The World Cities Report (2024) by the United Nations puts cities at the forefront of this escalating crisis, with riverine flooding and heatwaves being the biggest hazards cities are exposed to, and this trend is showing no decline. The exposure of populations and infrastructure, particularly to flooding events around the world, has been increasing (UNISDR, 2015). Extreme urban floods can have devastating effects on urban citizens' lives, properties, and potentially limit future development. (Wang et al., 2022). In urban Africa, Oluchiri (2025) notes this threat worsens due to both fast and unplanned urbanization. Kenya is not spared from these effects. In 2024, the March to May Kenyan rainy season came with heavy downpour that led to flooding in most parts of the country. In Nairobi County, which was hit the hardest, informal settlements including Kibera, Mukuru and Mathare bore the brunt of the flooding and its aftermath. In Mathare alone more than 7,000 people had been displaced (Mutura 2025). The rise of urban flooding events brought about by the adverse effects of climate change necessitates the need for urgent climate action and mitigation strategies to deal with the corresponding disastrous effects which heighten the risks to lives, economies and ecosystems as a whole.

Within cities, informal settlements bear disproportionate climate risks due to precarious locations, inadequate infrastructure, and limited access to essential services (Islam & Winkel, 2017; Satterthwaite et al., 2020; UN-Habitat, 2024b). These communities, often situated in environmentally sensitive areas, face compounded vulnerabilities during disasters and receive minimal post-disaster support (UN-Habitat, 2024b). The urban poor, as highlighted in the World Cities Report 2024, endure exacerbated inequalities, lacking resources to mitigate climate impacts (UN-Habitat, 2024b).

1.2 The Problem

Community-based resilience planning is increasingly critical in the wake of the climate crisis, where residents must not only identify their priorities but also effectively communicate them within governance frameworks. While participation is often initiated by grassroots communities using diverse tools and techniques (Rzeszewski & Kotus, 2019), current discourses on climate-resilient cities tend to privilege top-down decision-making. Such approaches shape projects and design interventions in ways that reproduce socio-

spatial inequalities and exclude the "urban invisibles", the most vulnerable and marginalized groups (Visconti, 2023).

The institutionalization of public participation, though widespread, often remains formalistic and procedural rather than genuinely inclusive. Mitlin (2021) critiques these processes as counterproductive, arguing that they inadequately create spaces for entrepreneurial citizenship and innovation. Instead, they can be co-opted by powerful actors to serve narrow interests, perpetuating exclusion. Visconti (2023) therefore emphasizes the need to move beyond consultation mechanisms toward innovative tools that enable genuine co-production. This aligns with Ouma's (2023) call for participation to define the production of urban space itself, and Wamuchiru's (2017) framing of community-driven planning and governance as a vehicle for structural change.

Traditional participation methods, such as community meetings and workshops, have too often reduced engagement to tokenistic consultation, characterized by one-way flows of information from experts to residents. These methods not only limit authentic knowledge exchange but are also time-consuming and inefficient. Consequently, they fail to capture differentiated vulnerabilities across urban populations, particularly in informal settlements (Islam & Winkel, 2017). As Cities Today (2024) highlights, participatory urban planning must prioritize context-specific, localized strategies, rather than uniform, technocratic approaches that overlook socio-cultural and economic realities.

Against this backdrop, there is an urgent need for new participatory approaches that strengthen community agencies in climate resilience planning. This project proposes "catalytic" technology-based participatory methods to enhance community-led resilience in Mathare. The concept of "catalytic" emphasizes triggering and amplifying locally defined solutions rather than imposing external interventions (Oasis Mathare, n.d.). Technology, through participatory mapping, data collection, early warning systems, and information dissemination, offers promising pathways for deeper engagement (Fransen et al., 2024; Mastercard Foundation, 2024; Nuvoni Research, n.d.). Through involving residents in the co-design of resilience measures, particularly around flooding, these tools foster ownership and sustainability (Omoto et al., 2024). This approach aligns with growing global evidence that sustainable climate resilience is possible only when affected communities assume active leadership in shaping interventions (Cities Today, 2024; Sudhakar, 2024).

Figure 1.1: Climatic and eviction related stressors in Mathare informal settlement

Source: Adapted from K24 TV on X and Mathare Social Justice Centre, 2025

1.3 Relevance and Significance

This research addresses critical climate resilience gaps within Mathare—an informal settlement that exemplifies the socioecological injustices experienced by marginalized urban communities disproportionately affected by climate change yet excluded from mainstream adaptation planning (Islam & Winkel, 2017; Resilience Pathways, 2023; UN-Habitat, 2024a). While grounded in the lived realities of Mathare, the study is purposefully designed to develop and test a co-created low-tech participatory tool that serves as a rapid neighborhood planning toolkit, providing live community polling and quick participatory surveys to inform preferred planning interventions and resilience priorities. Although piloted within the context of an informal settlement due to its heightened exposure to socioecological injustices, the methodology and toolkit are intended to be adaptable and replicable across other urban contexts, particularly those characterized by riverine ecosystems and communities vulnerable to climate-induced flooding, pollution, and ecological degradation. The focus on informal settlements thus provides both a testing ground and a model for rethinking inclusive, scalable, and context-sensitive climate adaptation strategies. This study therefore aims to advance climate justice principles, ensuring equitable resource allocation and prioritizing populations most vulnerable to climate risks by centering community-led solutions (Fransen et al., 2024). The deployment of low-tech digital solutions could significantly strengthen community engagement and co-

production of knowledge for building climate resilience. This participatory tech-based approach aligns with global evidence demonstrating that sustainable resilience requires active leadership from affected communities (Cities Today, 2024; Sudhakar, 2024).

1.4 Alignment with Global and Local Agenda

This research directly supports several key frameworks and policy instruments. It contributes to the Sustainable Development Goals by promoting sustainable urban planning through SDG 11, which focuses on creating inclusive, resilient cities, and by advancing SDG 13 through measures that enhance adaptive capacity to climate change (UN-Habitat, 2024b; Sudhakar, 2024). Furthermore, the research aligns with the Paris Agreement by strengthening local adaptive capacity and protecting vulnerable populations, thereby reinforcing the Agreement's objectives (UN-Habitat, 2024b). Additionally, it informs Kenyan policy by supporting the implementation of the National Disaster Risk Management Bill (2021) and the Disaster Management Fund Regulations (2022), serving as a model for community-led disaster preparedness.

1.5 Operationalizing Participatory Resilience through the MWAMKO Digital Infrastructure

A digital platform was developed for this research called *Mathare Warning and Mitigation Knowledge Outreach (MWAMKO) – Resilience Mtaani*. The naming convention *MWAMKO–Resilience Mtaani* strategically reconciles local specificity with broader applicability. "MWAMKO" (Mathare Warning and Mitigation Knowledge Outreach) grounds the platform in its place of origin, while "Resilience Mtaani" (Sheng for "Resilience in the neighborhood") serves as a transferable identity enabling replication across urban settlements in Kenya and beyond. Built using open-source, web-based tools, the platform is suited to low-resource environments while fostering local ownership of data and reducing reliance on external experts.

The *MWAMKO* platform integrates participatory research, spatial data infrastructure, and digital knowledge sharing to document, interpret and act upon climate-related risks, especially those linked to flood-prone riparian ecosystems.

MWAMKO functions not only as a repository of local experiences but as a scalable and replicable digital toolkit that can inform the design of catalytic tech-based participatory methods in other urban vulnerable communities. Its architecture is structured around three interoperable modules:

1. Data Collection,
2. Data Visualization and Analysis

3. Community Engagement and Co-Production of Knowledge

The first module facilitates ground-level data generation through a combination of customizable digital forms, geospatial tools, and multimedia documentation. This allows researchers and trained community volunteers to collect both quantitative and qualitative data on flooding incidents, blocked drains, and displacement trends. The geospatial component ensures each record is referenced to a specific coordinate, thereby enabling ward-level mapping of vulnerabilities and hazard hotspots. The platform also supports multimedia functionalities which further enhance the legitimacy of collected data such as photographs, videos and audio recordings which serve to document lived experiences that are often absent from formal planning datasets. This approach transforms local residents from passive beneficiaries of aid into active producers of spatial knowledge and evidence.

The second module of the *MWAMKO* platform transforms citizen-generated data into actionable insights. It hosts dashboards that visualize climate risks, demographic vulnerability profiles, and community adaptation preferences in the form of static charts and spatial dashboards as shown in the figure below. It has layered maps which allow users to view geolocated reports of flooding, informal structures within riparian buffers, pollution zones, and proposed land use scenarios. This is complemented by an automated reporting system that synthesizes collected data into periodic climate insights, which is envisioned to support rapid dissemination of such information to municipal authorities, NGOs, and researchers. The visualization and analysis module thus acts as a bridge between raw citizen-generated data and policy-relevant interpretation, making climate risk information understandable to both experts and non-experts.

Figure 1.2: MWAMKO User Interface
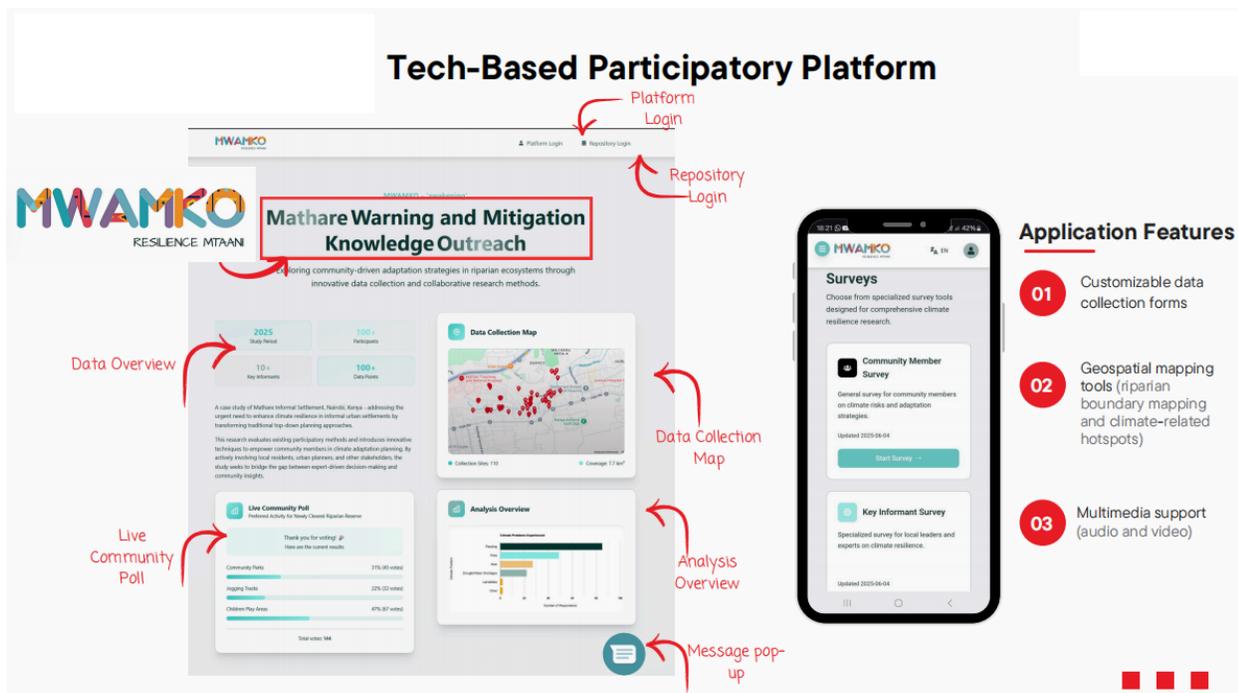
Source: Author, 2025

The third module supports participatory decision-making and shared learning. It includes digital polling tools that allow residents to verify their location and vote on preferred adaptation interventions and priorities in cleared riparian areas ranging from community parks and walking paths to urban agriculture plots and outdoor recreational spaces. The platform also provides a space for storytelling, where residents can submit narratives about recurring floods, eviction threats, coping mechanisms, and communal strategies for survival. In addition, *MWAMKO* hosts an open-access repository where community groups, academic institutions, and civil society organizations can upload toolkits, policy briefs, case studies, and design proposals. This ensures that the platform functions not only as a data system but also as a living archive for resilience knowledge co-produced between communities and technical actors.

A key strength of *MWAMKO* lies in its potential for scalability and replication. The modular nature of the platform means it can be adopted in phases or adapted to other informal settlements with minimal technological barriers. Furthermore, because the system decentralizes knowledge production and enables local ownership of data, it embeds resilience planning within community institutions.

1.6 The Study Area: Mathare Informal Settlement

Situated within Nairobi's Eastlands and known as Kenya's oldest and second largest informal settlement, Mathare houses approximately 500,000 residents, with Mathare Valley alone accommodating more than 206,564 residents according to the 2019 Census report by the Kenya National Bureau of Statistics. The settlement comprises of 13 villages: Mabatini, Mashimoni, Mathare 4A, 4B, 3A (Bondeni), 3B, 3C, Village 2, Kiamutisya, Kosovo, Gitathuru, No.10 and Kwa Kariuki with varying socio-economic conditions, infrastructure quality, and exposure to urban flooding and its effects. The study focused on all the wards that Mathare river and its tributary Gitathuru, flow except Utalii Ward due to security concerns.

The villages particularly their formation and origins trace to pre-1950s stone extraction activities and evolved significantly post-independence through the informal occupation of government land by migrants lacking affordable housing options, a process which occurred outside formal urban planning frameworks. (Mathare.org, n.d.). This historical neglect entrenched systemic marginalization, leaving Mathare with inadequate infrastructure and heightened exposure to urban flooding. According to *Mathare Flooding Relief and Resilience Initiative, 2025*, in April 2024, Mathare witnessed severe flooding leaving thousands displaced, specifically 7,800 households across all the four wards in Mathare. However, preliminary assessments during the reconnaissance field visit indicated that approximately 50% of these households (3,900) remain accessible due to post-flood relocation. This number formed the target population for this research.

Furthermore, homes were destroyed, with education for more than 4,500 students disrupted due to damaged school infrastructure. It is worth noting that the reporting of the flooding aftermath in Mathare varies from source to source due to lack of a unified disaster reporting and recording system, hence the variation in numbers of affected households.

These flooding effects highlighted the unpreparedness of Mathare in the face of extreme weather-related hazards. Additionally, the area faces extreme population density, unemployment, poverty, and pervasive land tenure insecurity (Kinuthia-Njenga, 2015; Resilience Pathways, 2023). These conditions hinder climate resilience, as residents lack financial and material resources to adapt to or recover from shocks.

Figure 1.3: Map of Mathare Villages

Source: Adapted from Un-Habitat, The Case of Mathare,2020

1.7 Research Objectives, Questions, And Expected Outcomes
1.7.1 Research Questions

The research study was guided by the following research questions:

1. What roles do formal, informal, and humanitarian actors play in addressing socio-economic urban climate governance vulnerabilities within informal settlements?
2. To what extent do participatory low-tech and digital co-design methods strengthen absorptive, adaptive, and transformative resilience among marginalized urban communities?
3. How can low-tech participatory tools be adapted to support community-led, climate-resilient planning in flood-prone areas such as Mathare's riparian corridor?
4. How can co-designed, low-tech participatory approaches be scaled and replicated to advance community-driven climate adaptation in other informal settlements?

1.7.2 Research Objectives

In answering the above questions, this research intends:

1. To examine the roles and interactions of formal, informal, and humanitarian actors in addressing socio-economic vulnerabilities within urban climate governance frameworks in informal settlements.
2. To investigate how participatory low-tech and digital co-design methods enhance absorptive, adaptive, and transformative resilience capacities among marginalized urban communities.
3. To co-design, pilot-test, and validate a context-sensitive digital and low-tech participatory platform that integrates community-led practices and innovations for climate-resilient planning of Mathare's riparian reserve, and to develop a replicable toolkit to strengthen participatory climate resilience in informal urban settlements.

Guided by these research objectives, the study aims to comprehensively understand the current research landscape on low-tech-based participatory methods and its evolving dynamics. Particularly, the research concerns itself with the following illustrated five thematic clusters each addressing a key dimension of the research as illustrated in figure 1 below.

Figure 1.4: Thematic Clusters of the Participatory Climate-Resilient Research Questions
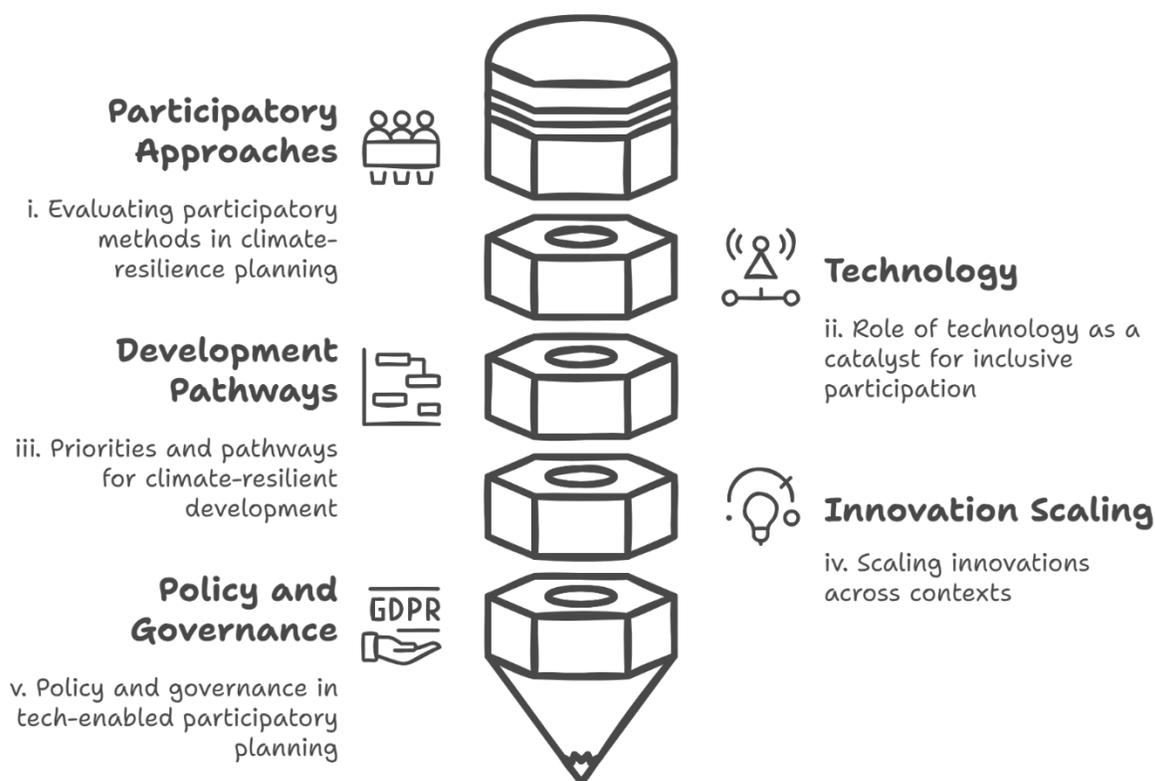
Source: Author, 2025

2. Literature Review

2.1 Climate Resilience in Informal Settlements
2.1.1. Vulnerabilities and Risks Faced by Informal Settlements

Informal settlements are globally recognized as critical hotspots of climate vulnerability due to interconnected physical, socio-economic, and governance factors that increase their susceptibility to escalating climate impacts (Atkinson, 2024; Kemarau & Nor, 2025). Physically, these settlements are often situated in environmentally fragile and hazard-prone areas, such as low-lying floodplains, unstable hillsides, or coastal zones with high population density and poorly constructed and non-resilient housing materials such as corrugated iron, mud, sticks, resulting in widespread damage and loss of life during extreme weather events (UN-Habitat, 2018; Wanjohi, 2018).

Socio-economically, residents face insecure land tenure, which disincentives investment in more resilient housing or infrastructure improvements, Limited or non-existent access to basic services like piped water, sanitation, and waste management creates unsanitary conditions, increasing susceptibility to waterborne diseases such as cholera, typhoid and other climate-sensitive health issues. Poverty restricts access to financial resources for recovery or adaptation, while low literacy levels can hinder understanding of climate risks and effective adaptive measures The informal nature of livelihoods also means residents often lack social safety nets, making them highly susceptible to economic shocks from climate disasters. (Ouma et al., 2024; Zerbo et al., 2020; Hussain et al., 2021).

From a governance perspective, informal settlements are frequently marginalized and excluded from formal urban planning and development strategies (IIED Briefing, 2025). This neglect often translates into an absence of risk-reducing measures, inadequate public service provision, and limited political voice, perpetuating a cycle of vulnerability (African Cities Research Consortium, 2025). The lack of disaggregated data on informal settlements further complicates effective planning and resource allocation, making residents "invisible" in official records (William, 2016; World, 2025b).

2.1.2 Existing Approaches to Building Climate Resilience in Informal Settlements

Climate resilience, particularly within the dynamic and challenging context of urban informal settlements, refers to the capacity of individuals, communities, and systems to anticipate, prepare for, absorb, accommodate, transform, and recover from the effects of

climate-related hazards in a timely and efficient manner (Intergovernmental Panel on Climate Change (IPCC), 2023).

Efforts to build climate resilience in informal settlements have historically varied, encompassing a spectrum from conventional top-down interventions to more empowering community-led initiatives. Traditional top-down approaches involve large-scale infrastructure projects like drainage systems and flood barriers but often fail due to limited community participation and inability to address underlying vulnerabilities, potentially leading to maladaptation (Cotton & Franceys, 1994; Pelling, 2010).

Conversely, community-led initiatives, often supported by non-governmental organizations (NGOs) and grassroots federations, emphasize local knowledge, self-help groups, and community-based adaptation (CBA) strategies (Cocina, Camila; Philanda, 2025; Venkatachalam et al., 2022). CBA recognizes that local communities possess unique insights into their environment and are often the first responders to climate impacts (Venkatachalam et al., 2022). Examples include community-managed waste collection systems that prevent drainage blockages, small-scale infrastructure improvements (e.g., raising house foundations), and local awareness campaigns on climate risks (ARISE Consortium, 2024). Community city-based adaptation emphasizes local knowledge and participation, with successful examples such as the Mukuru Special Planning Area in Nairobi and the Jaga Mission in Odisha, where residents co-developed integrated solutions incorporating land rights, services, and climate-resilient housing (Venkatachalam et al., 2022; SDI Kenya, 2023; Cocina, Camila; Philanda, 2025).

However, persistent challenges include fragmented short-term investments, poor coordination among stakeholders, insufficient climate finance mechanisms, and participatory processes that fail to redistribute power, often reinforcing tokenism (African Cities Research Consortium, 2025; Hati, 2020; UN-Habitat, 2024; UN-Habitat, 2018). These barriers open possibilities   for innovative, tech-based participatory methods that can facilitate coordination, bridge information gaps, and enable truly inclusive, locally led approaches to address systemic vulnerabilities.

2.1.3 Best Practices

Effective participatory approaches require genuine power redistribution beyond consultation, moving control to marginalized populations through critical reflection on Eurocentric frameworks and understanding diverse local contexts (Koch, 2013; Parsons et al., 2025). Implementation must include inclusive engagement strategies for women, youth, elderly, and those in poverty, sustained capacity building including digital literacy,

flexible adaptive processes responsive to community priorities, and long-term trust-building relationships (Lee, 2025; South et al., 2020; Baztan et al., 2020). Crucially, approaches must address structural barriers like insecure land tenure and political marginalization to create enabling environments for sustained action (IIED, 2024).

The Integrated & Inclusive Infrastructure Framework (3iF) developed by the Kounkuey Design Initiative (KDI) in collaboration with the Architectural Association of Kenya(AAK), academia and the civil societies provides a context-specific guide to improve informal settlements in Kenya. Its principles of inclusive infrastructure (involving excluded residents as partners), integrated infrastructure (combining multiple systems for multifunctional solutions), and collaboration through co-design (treating residents as equal partners) directly support genuine participation and knowledge co-production. The 3iF's Participatory Flood Modelling tactic exemplifies the integration of GIS and citizen science, allowing communities to co-create flood risk maps using lived experience, while its community-led Neighborhoods principle validates tech-based participatory mapping to address systemic urban planning vulnerabilities within the Kenyan context.

2.2. Integration of Technology into Climate Resilience
2.2.1 Role of Technology in Climate Action

Technology plays an increasingly indispensable and multifaceted role in addressing the global climate crisis through both mitigation and adaptation, serving as a powerful enabler that enhances capacities across climate risk management stages from preparation and early warning to evaluation (UNFCCC, 2016; UNU-EHS, 2025). Beyond physical infrastructure, "soft" climate technologies including digital platforms and energy efficient practices for knowledge sharing and training are equally crucial for building resilience (UNFCCC, 2016). Technological applications that enhance climate resilience include *mobile technology and SMS platforms.* Mobile phones have become ubiquitous, serving as critical channels for early warning alerts and enabling localized data collection through crowdsourcing where residents report conditions like blocked drains and water levels. These platforms enhance communication among community members and external organizations, fostering rapid emergency response and coordination (Hossain et al., 2020; Slum Dwellers International, n.d.). *Geographic Information Systems (GIS) and Remote Sensing* also play   a key role. Satellite imagery and drone mapping provide high resolution spatial data on land use and infrastructure, which GIS integrates with community collected data to create detailed vulnerability maps for identifying hazard prone areas and planning targeted interventions (MDPI, 2024a; Public Knowledge Project, 2024). *Social media and online platforms* also play a part in that they enable community mobilization, information

dissemination, and knowledge sharing while providing spaces for residents to voice needs and priorities, directly influencing adaptation planning through bottom-up approaches (World, 2021; World Bank, 2025a; World Bank, 2025b). *Crowdsourcing and citizen science*, which transform   residents into data collectors and co-researchers, empowering communities to co-define research objectives and collect environmental data, as demonstrated by successful flood monitoring projects in Fiji and Indonesia (UNEP, 2025; Cogitatio Press, 2021).

2.2.2 Challenges and Ethical Considerations in Tech Integration

Despite its immense potential, the integration of technology into climate resilience efforts, particularly in informal settlements, presents several significant challenges and ethical considerations that must be carefully navigated. *The digital divide*, which refers to disparities in internet connectivity, electricity, affordable devices, and digital literacy in informal settlements, limited access to these resources can exclude significant portions of the population, particularly the elderly, women, and those with lower literacy levels, exacerbating existing inequalities (Haider et al., 2021; UNU-EHS, 2025). *Data privacy and security* are also another key ethical consideration. The collection of sensitive personal data through digital tools raises profound questions about who owns the data, how it is stored, accessed, and used, and for what purposes (Karapetyan, 2024; Trust Community, 2025).

Algorithmic bias, where AI systems can reflect the biases embedded in their training data or design, can lead to discriminatory outcomes, such as under-prioritizing marginalized groups for aid or misclassifying their needs, thereby undermining principles of impartiality and equity in humanitarian interventions should also be checked out for. (Kubanek & Szymoniak, 2024). *Misinformation and Disinformation* including the use of digital platforms, while powerful for communication, can also be conduits for the rapid spread of inaccurate or misleading information, which can undermine climate action efforts, create panic, or lead to maladaptive behaviors (GCoM, 2024). Addressing these complex challenges requires a paradigm shift from viewing technology as a purely technical solution to recognizing it as a social technology embedded in human values, power structures, and lived realities (*Centre for BOLD Cities*, 2024; *Trialog, 2024*). This necessitates embedding humanitarian and ethical principles (dignity, impartiality, humanity) into technology design, mandating inclusive participation from affected communities, implementing robust accountability mechanisms and ethical audits, and investing in local capacity-building and South-led innovation (Chandola, 2023).

2.3 Theoretical Framework

The theoretical framework for this study is built upon three complementary theories: Adaptive Governance Theory, *Climate Resilience Theory, and the concepts of Community-Based Resilience, and Citizen Science and Participatory Action Research.* Each theory and concept offers a distinct yet interconnected lens through which to analyze the complex dynamics of building climate resilience in informal settlements using catalytic tech-based participatory methods.

2.3.1 Adaptive Governance Theory

Adaptive governance theory provides a framework for understanding institutional and collaborative arrangements necessary for building climate resilience in complex socio-ecological systems like informal settlements (Folke et al., 2005). Adaptive governance provides analytical framework for examining institutional arrangements and collaborative dynamics necessary for sustained implementation and scaling of tech-based participatory methods. It facilitates understanding of how effective climate resilience requires responsive, collaborative governance environments that integrate diverse knowledge forms (local and scientific) and enable collective action across scales and actors. The theory helps examine power relation navigation, decision-making processes, and social learning within multi-stakeholder climate action environments in informal settlements. It emphasizes shifting from rigid, hierarchical control to flexible, learning-oriented, collaborative approaches that respond to uncertainty and change, particularly relevant for multi-stakeholder climate action involving community groups, government, NGOs, and tech developers (Dietz et al., 2003). Some of the key principles of this theory include:

Polycentricism: The principle recognizes multiple decision-making centers rather than top-down control from single entities, allowing diverse responses, experimentation, and redundancy that enhances resilience (Ostrom, 2009). In Mathare, this involves *Informal leaders and CBOs* including community-based organizations, youth and women's groups acting as key decision-making centers with significant local influence. *Formal authorities* are also key actors; this includes county government departments and national agencies like the National Disaster Management Unit with formal mandates. *External partners including* international organizations, NGOs, and research teams contributing to governance networks also form key polycentric networks that the research aimed to engage.

Social Learning and Experimentation: Our research is built on the premise that uncertainty is inherent in climate adaptation, particularly in a dynamic environment like Mathare. Therefore, the study itself was designed as an iterative process of social learning and experimentation. Acknowledging inherent uncertainties, this principle promotes

continuous learning through systematic monitoring, evaluation, and feedback loops (Folke et al., 2005). Applications include *Participants as co-designers* where community members actively co-design technology rather than serving as passive subjects, experimenting with digital tools and providing continuous feedback. *Iterative processes* where the research adapts are based on findings about tool effectiveness, viewing failures as learning opportunities rather than setbacks. *Learning from Failure*, the research acknowledges that some experiments may fail. A new feature may prove too complex, or a communication channel may be ineffective. This is not seen as a setback, but as a critical learning opportunity that informs the next phase of research and development. *Institutional Flexibility and Adaptability* that involves governance systems' capacity to adjust structures, rules, and processes based on new information and changing conditions (Pahl-Wostl, 2009). Implementation includes *Community-level flexibility* where tech tools enable rapid response through real-time mapping of flood zones and drainage blockages, allowing faster adaptation than static systems. *Integration with formal institutions*, the research explores how the flexibility of these community-led tools can be harmonized with the more rigid structures of formal government. The research explores pathways for community-generated data to inform formal government responses, creating fluid relationships between community-led and official systems.

2.3.2 Climate Resilience Theory

Climate Resilience Theory provides the overarching theoretical foundation for this research, focusing on how systems, be they ecological, social, or coupled socio-ecological systems, respond to and recover from disturbances, and adapt to change (Walker et al., 2004). Originating from ecological studies (Holling, 1973), the concept has evolved significantly to encompass the human dimension, leading to the development of socio-ecological resilience (Folke et al., 2005). This perspective is crucial for understanding informal settlements, which are complex socio-ecological systems facing multiple, interacting stressors. Key constructs within Climate Resilience Theory relevant to this study include *Adaptive Capacity* which is defined as the ability of a system to adjust to actual or expected climate stimuli or their effects (Araya-Muñoz et al., 2016; IPCC, 2014).

In informal settlements, this translates to the capacity of residents and local institutions to modify behaviors, livelihoods, and infrastructure in response to climate risks, such as developing new farming techniques during droughts or constructing elevated homes in flood-prone areas. It involves learning, flexibility, and the ability to innovate (Siders, 2019). *Transformative Capacity* is also a key construct that is being studied, it refers to the ability to create a fundamentally new system when the existing one becomes untenable or

undesirable (Pelling, 2010). It involves addressing the root causes of vulnerability and systemic inequalities rather than merely coping with symptoms. For informal settlements, this could mean advocating for secure land tenure, formalizing services, or shifting governance structures to be more inclusive and responsive.

Coping Capacity is the third construct studied under this theory. It refers to the ability to face and manage adverse conditions, emergencies, or disasters by using available skills and resources (*UNISDR, 2009*). This is often a short-term, reactive response to immediate climate shocks, such as temporary evacuation during floods. While essential, resilience theory emphasizes moving beyond mere coping to building more proactive adaptive and transformative capacities.

The theory highlights that resilience is not a static state but a dynamic process of continuous learning, self-organization, and adjustment in response to environmental and social changes (Folke et al., 2005). For informal settlements, understanding their existing resilience pathways and how they can be strengthened through external interventions is paramount.

2.3.3 Community-Based Resilience

Community-based resilience theory concludes that localized networks, knowledge, and agency are central to surviving and adapting to shocks (Norris et al., 2008). Core components include:

- *Social Capital*: Trust, reciprocity, and collective action within community networks.
- *Local Knowledge:* Indigenous strategies for resource management (e.g., drainage systems crafted by Mathare residents).
- *Empowerment*: Communities as active agents, not passive beneficiaries, in resilience-building.

Technological tools enhance resilience by digitizing local knowledge such as mapping flood-prone areas using QGIS) and strengthening social ties through communication platforms (e.g., WhatsApp groups for disaster alerts). In Mathare, participatory mapping applications such as *MWAMKO* can document informal infrastructure, validate community expertise and inform external interventions. However, technology must complement and not replace existing social networks to avoid eroding trust. Resilience is bolstered when communities co-design governance frameworks. For example, youth-led mapping in Mathare can provide hyperlocal data for adaptive planning, merging technical and contextual knowledge.

2.3.4 Citizen Science and Participatory Action Research

Citizen science engages non-experts in data collection, analysis, and advocacy, aligning with participatory action research (PAR) principles that prioritize equity and co-creation (Bonney et al., 2009; Fals-Borda, 1987). Key aspects include:

- *Empowerment:* Residents gain agency by producing evidence to demand accountability (e.g., air quality monitoring to challenge polluters).
- *Scalability:* Low-cost sensors and mobile apps enable large-scale, real-time environmental monitoring.
- *Action-Oriented Outcomes:* Data directly informs community-led interventions, such as green infrastructure projects.

Projects like "Sensor Journalism" (combining sensors and storytelling) allow residents to document climate vulnerabilities including flooding frequency) and advocate for infrastructure upgrades. PAR frameworks ensure that technological tools align with local priorities, avoiding extractive "helicopter research." Challenges include ensuring data literacy and addressing digital divides like income disparities in technology access.

The theoretical framing of citizen science and Participatory Action Research (PAR) is central to the Mathare study, which seeks to co-produce climate resilience knowledge through equitable and participatory methods. By positioning community members as active agents in data generation and interpretation, the research integrates low-tech tools to document local flood risks and inform collective action. This approach challenges extractive research practices by embedding knowledge production within community contexts, ensuring socially legitimate and action-oriented outcomes.

2.4 Conceptual Framework

The conceptual framework for this study illustrates the hypothesized relationships between catalytic, tech-based participatory methods and enhanced climate resilience within the specific context of Mathare Informal Settlement, underpinned by the theoretical lenses of Diffusion of Innovations (DOI) and Adaptive Governance.

Figure 2.2: Conceptual Framework
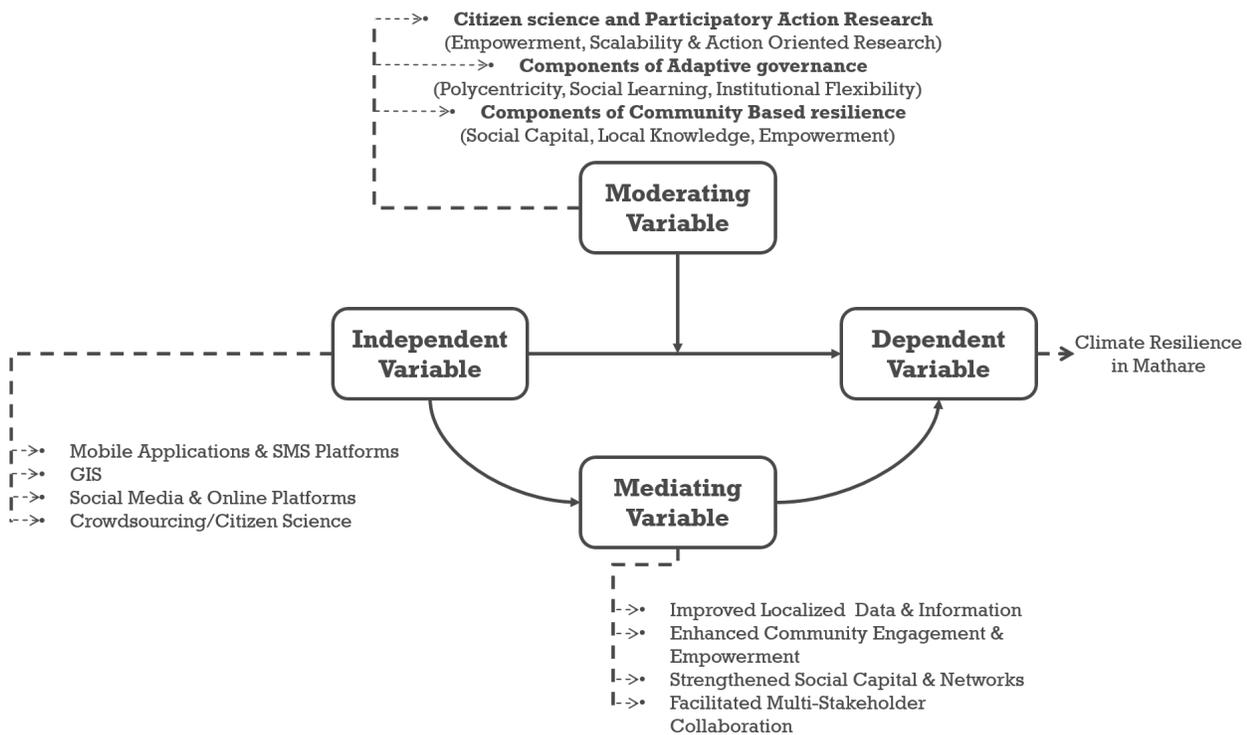
Source: Author conceptualization, 2025

This framework proposes that catalytic tech-based participatory methods directly enhance climate resilience in Mathare informal settlement through four interconnected pathways: generating localized climate risk data, empowering community-led action, strengthening social networks, and enabling multi-stakeholder coordination. These pathways serve as mediating mechanisms that translate technological participation into tangible resilience outcomes, addressing the critical data gaps and governance challenges typical of informal settlements.

However, the effectiveness of these methods depends on two moderating conditions. First, Diffusion of Innovation Theory reiterates that adoption rates hinge on how communities perceive the technology's advantages, compatibility, and ease of use, determining whether these methods achieve widespread, sustained implementation. Second, Adaptive Governance Theory establishes that collaborative, flexible institutional structures are essential for integrating tech-enabled participation into broader planning processes through continuous learning and feedback. When high adoption rates combine with adaptive governance structures, the catalytic effect emerges creating synergistic outcomes that accelerate climate adaptation by transforming residents from passive recipients into empowered agents within responsive, coordinated systems.

2.5 Gaps in the Literature

2.5.1 Identified Gaps

Limited Catalytic integration mechanisms, Literature lacks analysis of how technology and participation combine to create synergistic resilience effects beyond mere co-existence, with specific amplification mechanisms remaining underexplored (World Bank, 2013). *Long-term sustainability factors* are also a key gap identified by this research. Context-specific understanding of socio-economic, cultural, and infrastructural factors influencing sustained use in resource-constrained, digitally divided environments is limited, particularly regarding design features, training needs, and community support systems beyond pilot phases (Horn, 2021; Ouma et al., 2024). *Multi-stakeholder governance frameworks* are also another gap. Clear understanding of governance models, power dynamics, data governance structures, and integration of community initiatives into formal urban planning processes remains insufficient (Trialog, 2024). Lastly, *Context-specific African case studies* where in-depth empirical research from African informal settlements providing actionable insights into co-design, implementation challenges, and socio-technical dynamics proved scarce was also identified by the research study. (Hussainzad & Gou, 2024).

This research provides empirical evidence on how technology integrated with participatory approaches creates a catalytic effect that amplifies community participation and accelerates resilience outcomes in Mathare, analyzing specific operational mechanisms and transformative potential. It critically examines multi-stakeholder collaborations and governance structures that emerge through tech-enabled participatory methods, analyzing how power dynamics are navigated, data is managed, and community-generated information integrates into formal decision-making processes, thereby advancing understanding of adaptive governance in informal urban contexts. By examining user perceptions, digital literacy levels, and community champions' roles, the study contributes practical insights for overcoming digital divides and ensuring intervention longevity. Focusing on Mathare provides detailed, actionable knowledge from a highly vulnerable African informal settlement, offering valuable lessons for informing climate resilience interventions, policy development, and tech-based participatory tool design across similar Global South settings.

3. Methodology

3.1 Research Design

This research employed a mixed-methods framework to respond to the multifaceted challenges of climate resilience in Mathare informal settlement. To meet the study objectives, a combination of quantitative and qualitative methods was applied across different thematic areas of the research including climate risks and lived experiences, flood zone demarcation and proposed use of riparian land, awareness and coping capacity, low-tech participatory tools, co-design and testing of a digital participatory platform, and governance and justice.

Figure 3.1: Methodological process summary

Data Analysis

Research Paper
Preparation and
Dissemination

Data Collection and
Participatory
Mapping(10th to 11th
June 2025)

Co-Creation
Workshop of Low-
Tech Participatory Tool

04

01

07

Reconnaissance &
Research Design (12th
March 2025)

03

05

Development,
Customization and
Training of the Data
Collection Tool (30th
May 2025 to 6th June
2025)

02

06

Refinement of the Low-
Tech Participatory Tool

Source: Author depiction, 2025

Household surveys, administered through the co-created digital tool, generated numerical data on vulnerabilities, adaptive capacities, existing participatory practices, and levels of technological accessibility within the community. This was complemented by semi-structured interviews and focus group discussions, which provided deeper insight into community perceptions, socio-economic realities, and the meanings behind observed trends. Integrating both data forms during analysis enabled triangulation, allowing narrative accounts to elaborate on quantitative findings, while survey trends offered measurable grounding for qualitative observations.

This approach was necessary given the complexity of resilience-building in informal settlements, where physical hazards, social networks, governance dynamics, and evolving technology intersect. In line with established mixed-methods best practice, this design strengthened the credibility and validity of the findings, ensuring that both measurable indicators and lived experiences were captured to support the development of context-sensitive, scalable, and participatory climate resilience strategies.

3.1.1 Sampling Strategy

The sampling framework was designed to balance statistical precision with field-based realities, including population displacement, spatial density, safety considerations, and time and resource constraints. The primary study population for the quantitative component consisted of adult household members residing in flood-affected areas of Mathare. Given the absence of a comprehensive and up-to-date household register and the high density and mobility typical of informal settlements, a spatial stratified random sampling approach was employed.

Mathare was first subdivided by administrative boundaries, specifically the wards of *Mlango Kubwa*, *Mabatini*, Hospital Ward, and *Utalii* Ward, which were identified in previous flood impact assessments such as the Mto Wangu Initiative, 2024, as most affected. A gridded overlay was applied to the settlement map, and grid cells were randomly selected. Within each selected cell, households were then randomly sampled. This method aligns with best practices for sampling in under-enumerated urban settings and helps mitigate bias introduced by convenience or corridor-based sampling approaches.

A sample of 110 households was finalized based on field accessibility and to ensure broad spatial coverage across the settlement. This exceeded the minimum sample size of 98 households initially calculated using Slovin's formula with a 10% margin of error and an accessible target population of approximately 3,900 households (post-displacement) across the five wards:

$n = N / 1 + N(e)^2$

where N= 3,900 and e= 0.1

$n = 3,900 / 1 + 3,900 (0.1)^2 = 98.$

While proportional stratification had initially been planned across the four wards, no household data were ultimately collected from *Utalii* Ward. This limitation is acknowledged in Section 3.6. The final sample is therefore concentrated across the

remaining three wards, allowing for meaningful spatial comparisons while reflecting the practical constraints of fieldwork in informal contexts.

Figure 3.2: Stakeholder Map
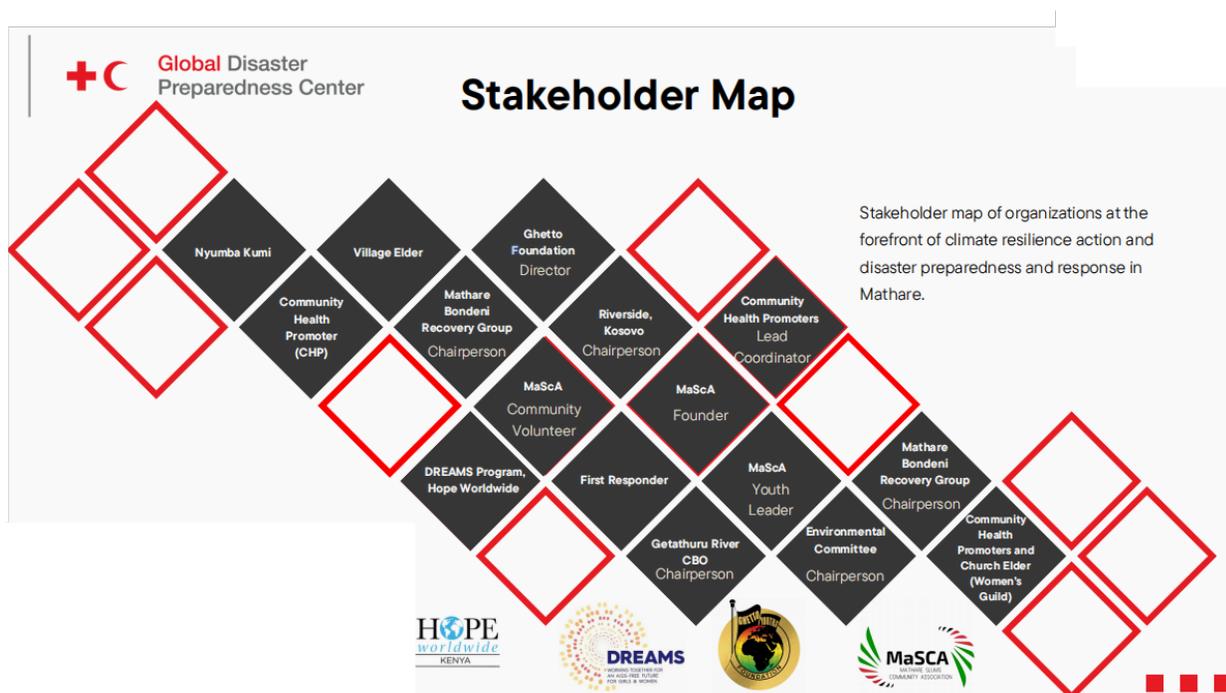
Source: Author's own Depiction, 2025

3.1.2 Mobile App Prototype Co-design and Testing

The MWAMKO platform was developed as a digital participatory tool structured around the three functional modules as elaborated in the first chapter of this research. Its development followed a human-centered, co-design approach to ensure usability, contextual relevance, and scalability within low-resource urban environments.

Stakeholder workshops and prototyping sessions were conducted with community researchers, local residents, and technical partners to inform interface design, question structuring, translation, and participatory features. The Data Collection module was designed to support structured surveys, interviews, geospatial mapping, and multimedia documentation. While SMS/USSD functionality was initially explored to accommodate users with basic phones, resource constraints limited full integration. Instead, an offline caching system was implemented, enabling users to collect and store data including text responses, GPS coordinates, images, and audio without internet connectivity, with automatic synchronization once a connection was available.

The testing of the data visualization and analytics module placed emphasis on simplifying visual outputs to align with varying literacy and digital proficiency levels, without compromising the analytical capabilities required for research and decision-making.

Prototype testing was undertaken in Mathare by trained research assistants and community members. Feedback informed iterative refinements to usability, data validation, language translation, and synchronization protocols. Training sessions strengthened local capacity to use the app for surveys, mapping, and interpretation of visual outputs, enhancing trust and ownership of the process.

The resulting platform demonstrated functional reliability in offline environments, operational flexibility in data-scarce settings, and strong potential for replication in other informal urban contexts.

3.2 Data Collection Methods

Data was collected through complementary qualitative and quantitative approaches designed to respond directly to the study's core research questions on climate risks, resilience practices, governance, and digital tool co-production in Mathare. Each method generated specific types of data aligned with particular thematic and objective-driven inquiries.

Data collection was executed by trained research teams who were often accompanied by community researchers for citizen science and co-production. The methods included structured household surveys, semi-structured interviews with key informants, participatory mapping workshops with integrated Focus Group Discussions, and review of secondary spatial and textual data.

3.2.1 Household Surveys

An online based questionnaire was administered to the 98 sample size, an additional 12 households were strategically identified by the community researchers based on availability and interest to this research study resulting into the 110 households surveyed using the *MWAMKO* mobile platform. Structured household surveys were deployed to gather quantitative data on climate-related vulnerabilities, lived experiences of flooding, coping strategies, and access to technology. These surveys provided evidence for assessing inequalities in awareness, early warning mechanisms, and barriers limiting adoption of resilience-enhancing tools, thereby informing the research objective on vulnerability and adaptive capacity. The survey covered demographic information, housing characteristics, flood/drainage issues, disaster experiences, and perceived capacity to

respond to climate impacts. Each survey was administered by a trained enumerator (often a local community researcher) who read questions in English or Swahili, as appropriate. The app enabled direct data entry, GPS logging, and real-time syncing.

3.2.2 Key Informant Interviews

Semi-structured interviews were conducted with 21 key informants, chosen via purposive sampling to include a range of institutional and community perspectives such as local ward administrators, Community Based Organizations (CBOs), NGO workers, community elders, and technical experts on floods/drainage. Twenty of the interviews were conducted using the MWAMKO platform. The platform presented open-ended guided questions to draw out detailed responses on particular issues, granting the interviewee an opportunity to add information from their knowledge and experiences.

These interviews generated insights into governance dynamics, institutional responses to climate risks, and existing participatory initiatives. These interviews addressed questions on the effectiveness of current participatory approaches, legitimacy of decision-making structures, and justice dimensions of climate adaptation. One interview, due to unexpected technical limitations, was recorded using a digital recorder and transcribed later. Interviews were conducted in English or Swahili, depending on the informant's preference.

The interview guide included questions on local climate-related hazards including but not limited to: Flooding, Landslides, Health risks, Existing resilience efforts, Institutional coordination, and Community priorities.

Each session lasted approximately 45 minutes to 1 hour. Notes and audio for those using the platform were saved with date/time stamps. Informed consent was obtained and recorded for all interviews. The MWAMKO platform's interview mode ensured consistency in questioning and automatically logged each interview's GPS location. These interviews yielded qualitative insights on issues such as institutional roles, historical changes in flood patterns, and community adaptation practices.

3.2.3 Participatory Mapping

Participatory mapping and focus-group discussions (FGDs) were conducted in each target village to engage residents in spatially identifying hazards and co-developing solutions. In group sessions of 6–10 participants (mixed by gender and age), residents were first asked to draw or annotate maps of their local area, highlighting features such as streams, drainage channels, flood-prone zones, and assets (schools, clinics). These hand-drawn

maps were then overlaid and digitized in the MWAMKO application based on GPS data and satellite imagery. Participatory mapping workshops, integrated with focus group discussions (FGDs), were conducted to spatially document community knowledge on flood-prone zones, contested riparian land use, drainage pathways, evacuation routes, and informal risk mitigation practices. These exercises contributed directly to questions on spatial risk perception, proposed uses of the riparian corridor, and the co-production of spatial data for climate-resilient planning.

3.2.4 Secondary Data and Spatial Layers

In addition to primary data, we reviewed secondary sources for background context and spatial analysis. This included high-resolution satellite imagery from Google Earth and OpenStreetMap layers to visualize Mathare's terrain, settlement patterns, and drainage infrastructure. We obtained census and administrative data (population counts, household distribution, ward boundaries) from the Kenya National Bureau of Statistics. Climate model outputs and hazard maps (flood models) from meteorological agencies and academic sources were gathered to understand projected climate impacts.

3.3 Data Analysis Approach

Data analysis proceeded in parallel strands for quantitative and qualitative data, with final synthesis across both.

3.3.1 Statistical Analysis

Survey responses were first cleaned and coded in Excel. Descriptive statistics of percentages, means, and ranges were computed to characterize household demographics, exposure to hazards, and adaptation measures. Cross tabulations were used to explore relationships such as comparing flood impact and vulnerability by age group. Simple inferential tests (Chi-square or t-tests) were conducted where appropriate to check for significant differences. Quantitative analysis also included generating bar charts and frequency distributions from the MWAMKO data via Excel. The results provided a numeric baseline of community conditions such as the percentage of households affected by flooding, and common livelihood sources.

3.3.2 Qualitative Coding

Transcripts of the 21 key informant interviews and notes from FGDs were analyzed using thematic coding. Using an inductive approach, researchers read all transcripts and assigned open codes to segments of text reflecting issues like "community capacity," "drainage

problems," or "governance challenges." Codes were then grouped into higher-level themes following Braun & Clarke's six-phase framework for thematic analysis that encompasses familiarization, coding, and theme identification. Multiple researchers coded independently to enhance reliability. Discrepancies were resolved through discussion. Key themes included local perceptions of climate risk, barriers to action, and suggested solutions. Representative quotes were selected to illustrate each theme. This qualitative analysis illuminated the reasoning behind survey findings; for instance, why some households reported feeling vulnerable and surfaced nuances such as cultural factors affecting participation that numbers alone could not capture.

3.3.3 GIS Spatial Analysis

Geospatial analysis was performed by importing MWAMKO-collected points (households, interview locations, voted design sites) into QGIS along with secondary layers (roads, streams, elevation, ward boundaries). We mapped flood risk areas by overlaying survey reports of flooding with official floodplain data. Point-density analyses highlighted neighborhoods with the highest concentration of reported hazards. The geotagged votes from participatory mapping were visualized to identify which riparian design options were most preferred in different areas. QGIS tools were also used to produce final maps for the report. Spatial filters allowed the research team to cross-examine data by location or demographics. By integrating quantitative and qualitative inputs in a common map space, GIS analysis helped identify spatial patterns and opportunities for targeted interventions.

3.4 Ethical Considerations

The study adhered to rigorous ethical standards throughout all phases. Informed consent was obtained from every participant after enumerators explained the study's purpose verbally and through digital forms. Participation was voluntary, with participants free to skip questions or withdraw at any time.

Confidentiality was maintained through several measures: participants were assigned anonymous ID codes with no personal identifiers stored; GPS coordinates were generalized to neighborhood level for public reporting; and all data files, cloud servers, and audio recordings were password-protected with access limited to the core research team. Recordings were destroyed after transcription.

Community entry protocols were observed by obtaining approvals from village elders, local chiefs, and community-based organizations. Surveys were conducted privately, and research assistants received training on neutral, non-leading questioning to minimize interviewer bias. Teams traveled in pairs and maintained regular communication with a

base coordinator for safety; notably, safety concerns led to the exclusion of Utalii Ward from fieldwork. All findings are presented in aggregated form to protect individual privacy.

3.5 Study Limitations

This study faced several constraints affecting scope and generalizability. Security concerns led to the complete exclusion of Utalii Ward, creating a geographic gap that biased findings toward areas with better security and established community structures. The household sample size (n=110), while adequate for descriptive purposes, limited statistical power for detecting sub-group differences. Purposive sampling introduced potential selection bias toward visible stakeholders, and the absence of county or national government representatives left institutional perspectives underrepresented.

Technological constraints fundamentally shaped participation. The *MWAMKO* platform's smartphone and data connectivity requirements created inherent exclusions in the context of uneven device ownership, with connectivity issues occurring in 31% of sessions.

The absence of low-tech channels such as SMS or USSD, largely due to budget constraints, may have limited participation among older and more vulnerable residents, skewing engagement toward younger, digitally literate users. This highlights both a methodological limitation and a wider challenge inherent in technology-mediated participation. Future platform design should therefore prioritize inclusive communication strategies that integrate multiple entry points to reach diverse community segments.

The time-limited, cross-sectional design precluded assessment of long-term adoption patterns or sustained usage. Data collection immediately following major flooding (April-May 2024) captured acute crisis concerns rather than long-term resilience priorities. Self-reported data introduced potential recall and social desirability bias, while lack of unified disaster recording systems caused reporting inconsistencies.

A critical conceptual limitation emerged: 63.3% of community members were unfamiliar with "climate resilience," revealing a disconnect between research frameworks and local conceptualizations. Finally, Mathare's characteristics as Kenya's oldest informal settlement with established community structures limit generalizability to similar large, established urban settlements rather than newer or less organized contexts. Despite these limitations, mixed-method triangulation enhanced data quality and mitigated individual-method weaknesses.

4. Results and Findings

4.1 Respondent and Stakeholder Profiles

4.1.1 Ward-Based Distribution and Demographics

The response rate from the study comprised of 110 households and 21 key informants across Mathare Distribution: Mlango Kubwa Ward 39.8% (n=44), Mabatini Ward 35.0% (n=39), Hospital Ward 25.2% (n=27). Utalii Ward had no representation due to security constraints. This may slightly limit the spatial representativeness of the findings. However, given the ward's similar physical and socio-economic characteristics to the sampled areas, the results remain generally indicative of its situation.

Figure 4.1: Data Collected by Ward
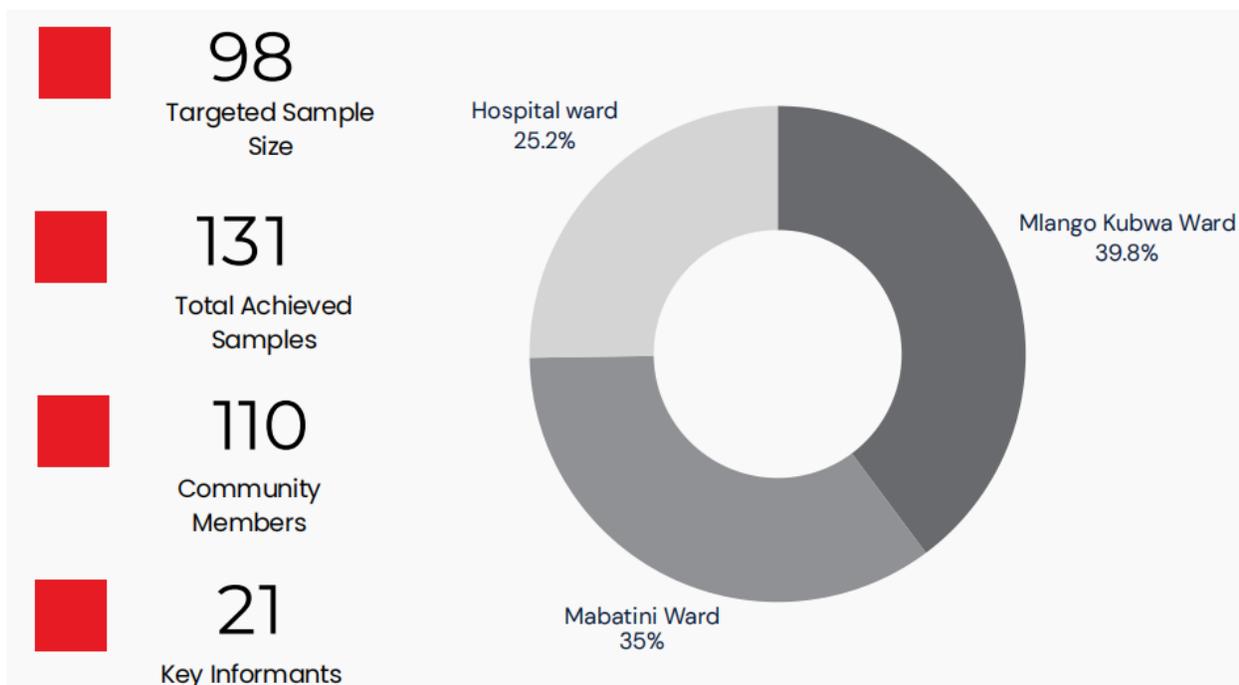
Source: Field Survey, 2025

4.1.2 Age Demographics and Settlement Duration

The age distribution analysis revealed important demographic patterns among study participants. According to Field Survey, 2025, the modal age group comprised individuals aged 30 to 39 years, representing 32 respondents or 29.1% of the sample. The mean age

of participants was 35 years, indicating a predominantly youthful population. The age range extended from 18 to over 60 years with representation across all age brackets, while youth representation (ages 18-29) accounted for 25 respondents or 22.7% of the total sample.

Figure 4.2: Age Distribution of Respondents
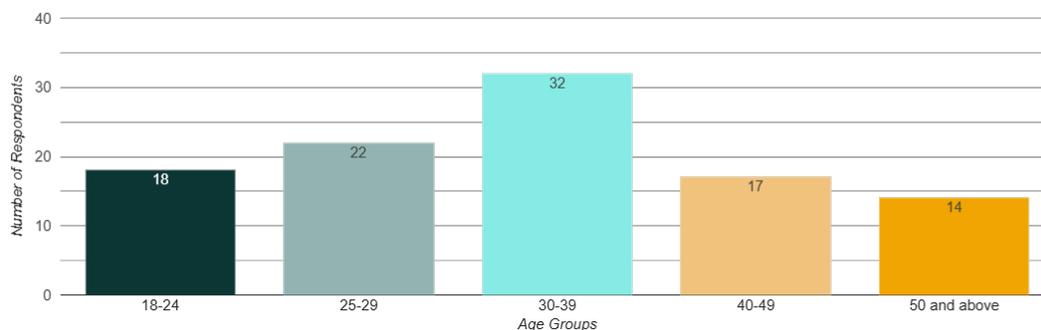
Source: Field Survey, 2025

Settlement duration data indicated that participants had lived in Mathare for an average of 6.8 years. The majority of residents, representing more than 60% of respondents, were long-term residents who had lived in Mathare for over 10 years. Recent arrivals, defined as those residing for less than 2 years, comprised 14 respondents or 12.7% of the sample.

Figure 4.3: Age Groups and their settlement duration in Mathare
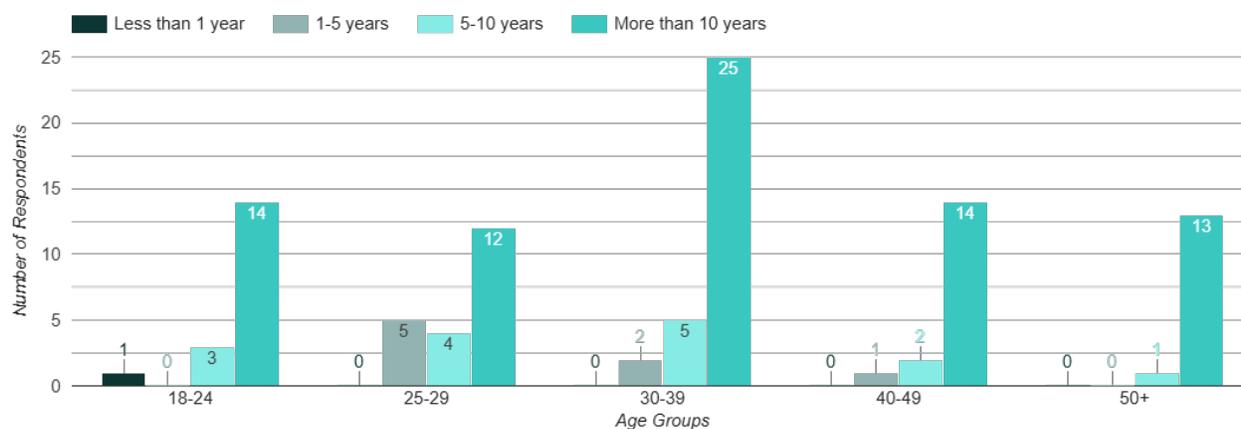
Source: Field Survey, 2025

4.1.3 Community Awareness

When asked whether they had heard the term *climate resilience*, 62 respondents (63.3%) indicated they had not, while 36 (36.7%) reported familiarity with it, reflecting limited

awareness of formal climate terminology. However, 76 respondents (80.9%) reported having experienced forced eviction or relocation due to flooding. This contrast highlights a gap between conceptual awareness and lived experience, suggesting that while community members may lack exposure to technical climate terms, they possess substantial firsthand knowledge of climate impacts.

Issues that can be categorized as climate-induced problems were identified as being widespread, with flooding being the most commonly experienced climate impact. Specifically, 85 out of 110 respondents, representing 77.3% of participants, reported experiencing flooding in their area.

Fires also emerged as a major community concern, with 49 respondents (44.4%) reporting damage to their homes or surroundings. Although the study did not determine the specific causes of these fire incidents or establish a direct link to climatic factors, respondents identified them within the broader category of climate-related problems. This, when considered alongside the finding of the limited awareness of formal climate resilience terminology. It indicates that while community members experience and report diverse environmental hazards, their conceptual understanding of how these relate to broader climate dynamics remains limited.

Figure 4.4: Climate problems experienced by respondents
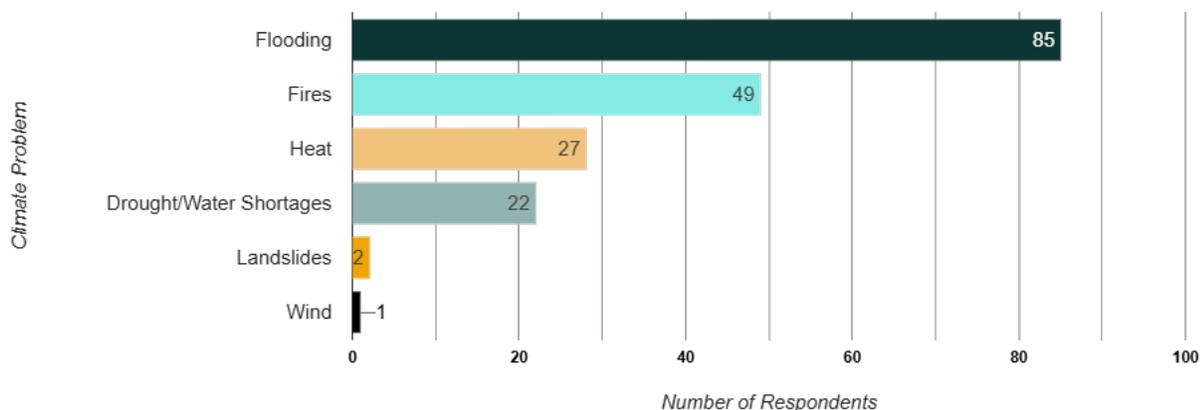
Source: Field Survey, 2025

Seasonal awareness patterns emerged clearly from the data collected through the Field Survey. April and June were consistently identified as the most difficult months, representing peak flooding periods for the community. The data revealed a strong correlation between reported flooding incidents and rainy seasons, demonstrating sophisticated local understanding of climatic patterns.

Figure 4.5: Most severe months for climate related problems
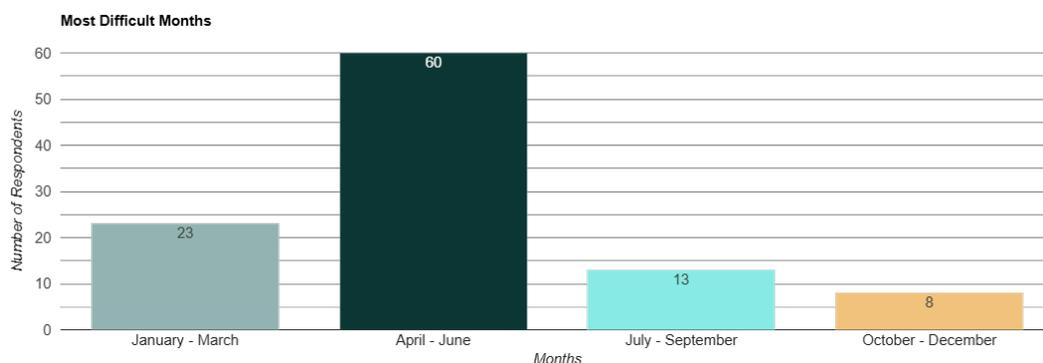
Source: Field Survey, 2025

4.1.4 Stakeholder Network Analysis

The stakeholder mapping exercise successfully identified 15 key organizations and individuals actively involved in climate resilience activities within Mathare. Community-based organizations formed a crucial component of this network, including the Mathare Bondeni Recovery Group, Getathuru River CBO, Kosovo Community Group, and Mathare Social Change Alliance (MaSCA). These organizations represent grassroots-level climate action and community mobilization efforts.

Formal governance structures identified through the platform included village elders, Nyumba Kumi leaders, and environmental committee chairs, representing traditional and government-recognized leadership systems at the local level. External partners working in the area comprised Hope Worldwide, the DREAMS Program, Community Health Promoters, and various church-based organizations including Women's Guild groups. Notably, respondents did not identify any county or national governance structures as part of their stakeholder network, revealing a significant governance gap that could impede institutional coordination and hinder the long-term integration of community-based climate resilience efforts into formal adaptation plans. This diverse yet locally concentrated stakeholder ecosystem demonstrates the complex governance structures operating in informal settlements while highlighting the critical need for strengthening multi-level engagement that bridges community initiatives with higher-level government structures to develop effective and sustainable climate resilience initiatives.

4.2 Flood Hazard Mapping
4.2.1 Community-Reported Flood Experiences

The flood hazard analysis conducted through the MWAMKO web-based platform revealed critical patterns of vulnerability across Mathare's landscape. High frequency flood areas were consistently identified as riparian zones along the Mathare and Gitathuru rivers, with seasonal patterns showing peak flooding during the April-June rainy season. According to the platform data, impact severity was substantial, with 85 respondents representing 77.3% of participants directly affected by flooding events.

The spatial distribution analysis, conducted using QGIS as an open-source co-design tool, identified several distinct high-risk zones based on accumulated community experiences, with the participatory mapping process directly operationalizing the 3iF framework's emphasis on inclusive infrastructure development that integrates all voices and needs through collaborative co-production processes involving government, academia, and civil society stakeholders. Primary flood zones encompassed areas within 15 meters of river channels, where residents reported the most frequent and severe flooding incidents. Secondary impact areas included low-lying areas characterized by poor drainage systems, while flash flood corridors were identified along steep slopes that channel water toward residential settlements during heavy rainfall events.

4.2.2 Infrastructure-Related Flood Factors

Community mapping exercises revealed critical infrastructure deficits contributing significantly to flood vulnerability throughout the settlement. According to the Field Survey, 2025, drainage infrastructure challenges were pervasive, with blocked or inadequate drainage systems identified in 73% of surveyed areas. Informal waste disposal practices leading to channel blockages represent a recurring theme, compounded by the complete lack of formal storm water management systems in most areas of the settlement.

Housing vulnerability patterns emerged as another critical concern through platform documentation. According to the data, 48% of flood-affected respondents lived in temporary structures located within floodplains, making them particularly susceptible to water damage. Inadequate foundation systems unable to withstand water damage were commonly reported, alongside widespread use of poor-quality building materials that increased overall structural vulnerability during flood events.

4.2.3 Community-Identified Flood Zones

4.2.3.1 Participatory Risk Mapping Results

The MWAMKO platform enabled comprehensive community participation in identifying and mapping flood-prone areas based on residents lived experiences and local knowledge. High-risk zones identified through this participatory process included immediate riparian zones experiencing recurring annual flooding, which represented the most consistently reported problem areas across all wards.

Educational infrastructure vulnerability was prominently featured in community mapping exercises, with school environments identified as being at significant risk during flood events. Similarly, health facility surroundings were mapped as critical infrastructure vulnerable to climate impacts, raising concerns about service continuity during emergencies.

Map 4.6: High-Risk Zones in Mathare
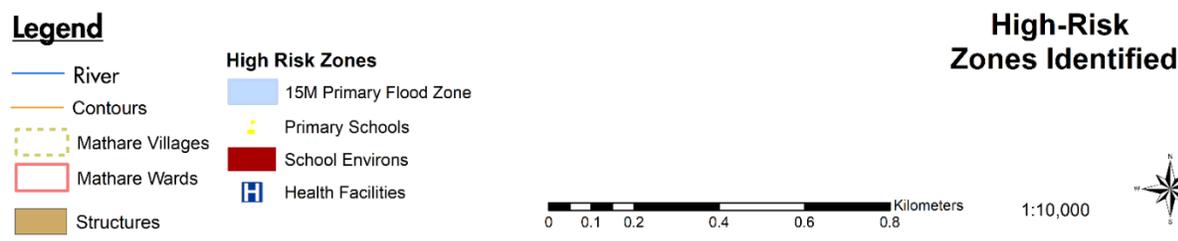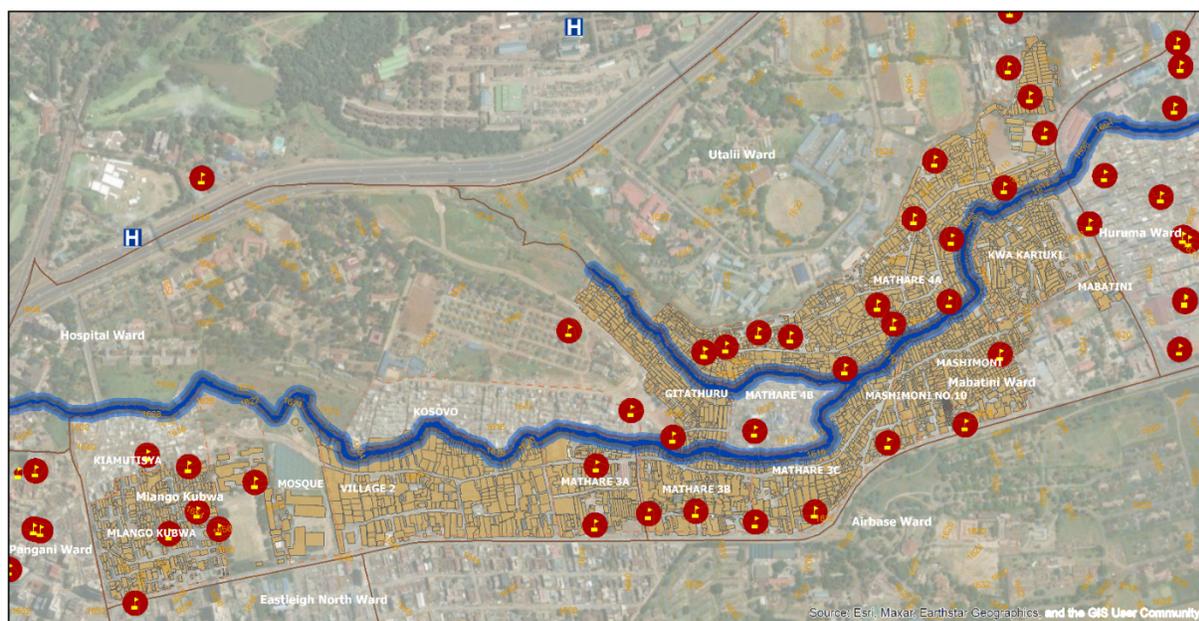
Source: Field data and Google Earth, 2025

4.2.3.2 Community Coping Mechanisms

Residents demonstrated remarkable ingenuity in developing various adaptation strategies to manage flood risks. Traditional flood management approaches documented through the questionnaires included improvised sandbag barriers using locally available materials, elevated storage systems for household goods, and sophisticated community early warning systems operating through existing social networks. Temporary relocation to higher ground during peak flood seasons represented another commonly employed strategy.

Collective action initiatives emerged as particularly important coping mechanisms within the community. According to platform documentation, residents regularly organized community river cleaning exercises, implemented informal drainage improvement initiatives, and provided mutual aid during flood events. Knowledge sharing about safe areas and evacuation routes occurred through established social networks, demonstrating the community's capacity for self-organization in response to climate challenges.

4.2.4 GIS-Verified Flood Risk Areas

4.2.4.1 Spatial Analysis Integration

The integration of community-identified flood zones with formal GIS analysis provided a comprehensive and validated risk assessment for the settlement. According to the MWAMKO web-based platform, there was remarkably high correlation, exceeding 80%, between community-identified flood zones and topographical low points identified through satellite imagery analysis. This validation demonstrated that community knowledge accurately identified micro-drainage patterns that remained invisible to conventional satellite imagery interpretation.

Local flood timing predictions developed by residents aligned closely with official meteorological data, further confirming the reliability of community knowledge systems. The combination of participatory mapping and GIS analysis revealed 15 critical flood-prone micro-zones within the study area, while elevation gradient analysis confirmed community-identified flow patterns. Infrastructure proximity analysis conducted through the platform highlighted particularly vulnerable facilities requiring priority attention in resilience planning efforts.

4.2.4.2 Riparian Reserve Boundary Mapping

The MWAMKO platform facilitated collaborative mapping of riparian reserve boundaries, enabling community participation in identifying current flood extent within these critical zones. The MWAMKO platform facilitated collaborative mapping of riparian reserve

boundaries, enabling community members to identify and validate current flood extents within these critical zones. Of the respondents, 45.8% agreed that the mapped riparian zone accurately reflected their flood experiences over the years, while 54.2% disagreed. Among those who disagreed, 35.3% felt that the 30-metre riparian reserve prescribed by the Water Resources Authority (WRA) and recently enforced by the government during the 2024 clearance of structures along the Mathare River was excessive and should be reduced to 15–20 meters. A further 31.4% stated that floodwaters do not reach that distance, and 15.7% reported that the actual flood extent is between 10–15 meters. The MWAMKO platform also facilitated the collection of geographical coordinates marking the highest flood extents, which were subsequently visualized through its data visualization module.

4.3 Web-Based Platform Usage

4.3.1 User Feedback and Suggested Improvements

4.3.1.1 Community Feedback Analysis

Community feedback gathered through the MWAMKO web-based platform highlighted both its strengths and areas for improvement. Users appreciated its intuitive interface, effective visual mapping tools, and the inclusion of local language support particularly Sheng which enhanced accessibility and engagement. Offline functionality was also highly valued, especially in areas with unstable internet connectivity.

However, participants identified several areas for enhancement. They recommended expanding multimedia storage capacity to better support documentation, adding more local language options beyond Sheng, and introducing real-time notification systems for community alerts integrated with existing communication channels.

Stakeholders further emphasized technical and functional upgrades to improve inclusivity and resilience outcomes. Priorities included strengthening offline capabilities to cover all platform features, extending language support to include Kikuyu, Luo, and other local dialects, and introducing a simplified interface for elderly users and those with limited digital literacy. Additionally, integrating early warning systems with weather data, resource mapping for evacuation planning, progress tracking for resilience initiatives, and advocacy tools to facilitate engagement with government agencies were strongly recommended.

4.3.1.2 Sustainability and Scaling Recommendations

Community ownership strategies were identified as essential for long-term platform sustainability. Recommendations included transferring platform management responsibilities to established community-based organizations, establishing local technical support networks, and developing community-led training programs for new users. These approaches would ensure continued platform operation beyond the initial research period. Sustaining the MWAMKO platform beyond the research phase requires embedding it within existing governance frameworks. This could be achieved through partnerships with county and national agencies such as the National Disaster Management Unit (NDMU) and the Water Resources Authority (WRA), alongside collaboration with local NGOs and community organizations. Institutionalizing platform outputs through formal data-sharing agreements and integrating community-generated data into urban planning and disaster management processes would enhance its long-term relevance. Policy frameworks promoting participatory digital governance, supported by county Information and Communication Technology (ICT) and climate adaptation budgets or development partnerships, would further ensure its continuity and scalability to other settlements.

Replication framework development was recommended to enable platform adaptation in other informal settlements. This included creating standardized toolkits for platform customization, developing comprehensive training modules, and establishing partnerships with technology providers for sustainable hosting arrangements.

4.4 Participatory Mapping Outputs

Figure 4.8: Community Co-Designed Vision for Riparian Restoration in Mathare
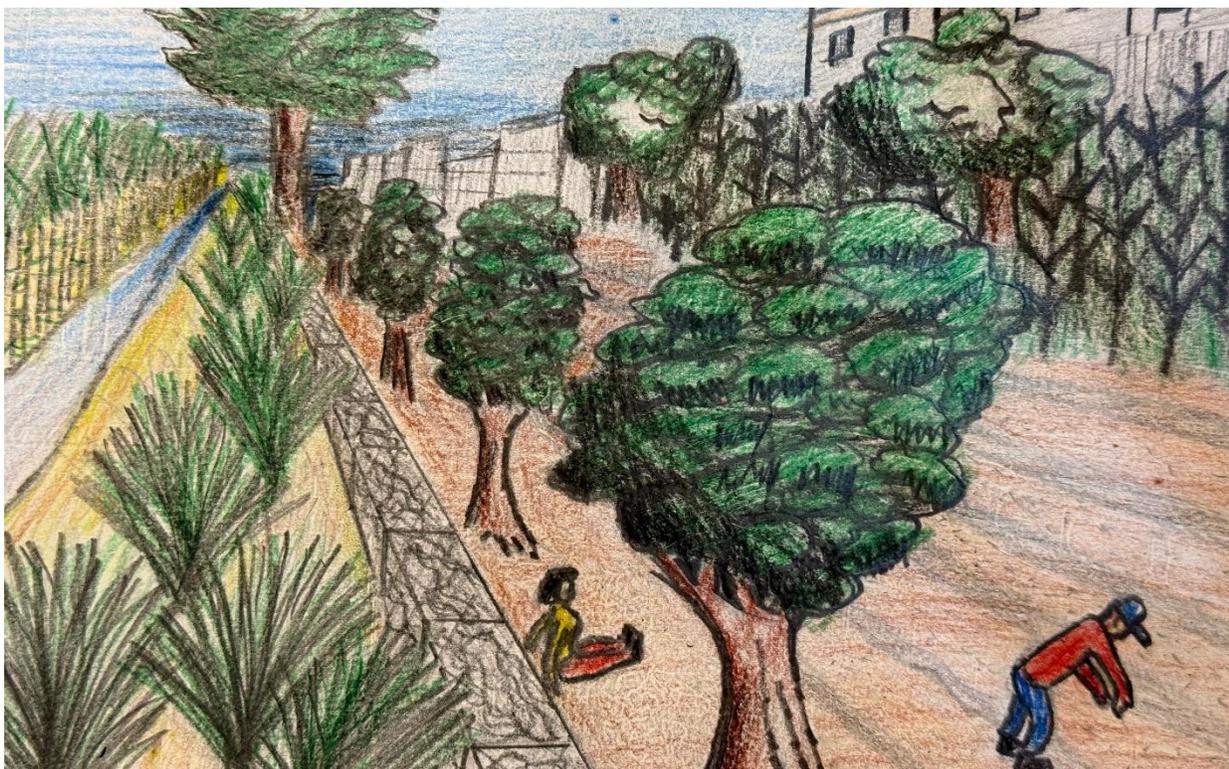
Source: Author Depiction from Community vision, 2025

This participatory sketch drawn during the participatory mapping exercise referenced in the methodology illustrates the community's proposed design for rehabilitating the river riparian zone. Vetiver grass is selected for its deep root system and minimal maintenance needs, while bamboo is proposed to reduce bank erosion and mitigate flooding impacts. The design reflects local aspirations for a safe, green, and multifunctional public space that enhances resilience while restoring ecological integrity.

4.4.1 Sources of Information

The platform revealed that digital and traditional media, alongside direct community gatherings, are the most effective channels for disseminating information on climate resilience within the study area. The figure shows the community's response on their best sources of information on climate resilience.

Figure 4.9: Best sources of information on Climate Resilience

Best Sources of Information on Climate Resilience
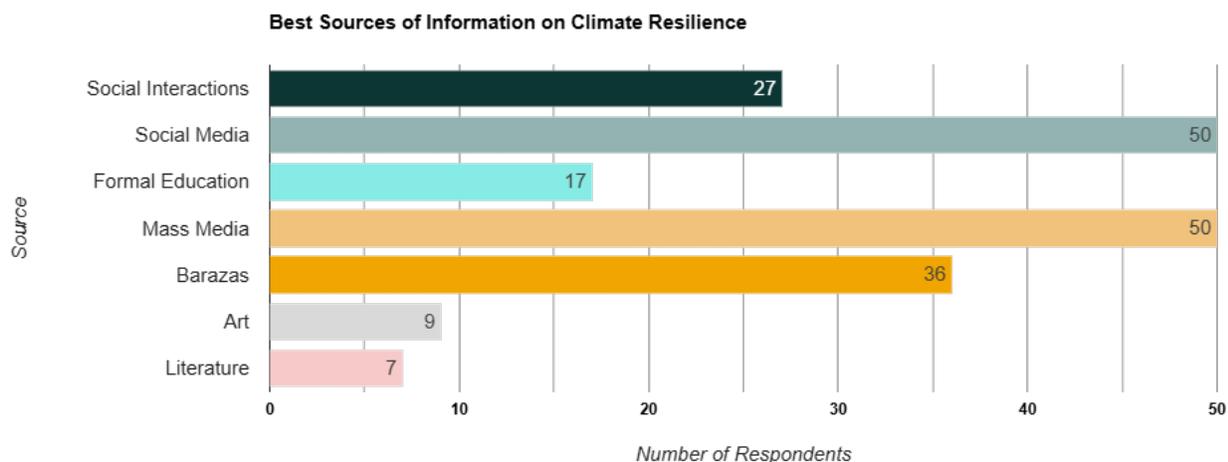
Source: Field survey, 2025

The most effective sources identified by the respondents were:

1. **Social Media Platforms**: This highlights the pervasive influence of platforms like Facebook, WhatsApp, Twitter (X), and possibly TikTok in current information exchange, particularly among younger and more digitally connected demographics. Its reach is wide, and information can spread rapidly.
2. **Mass Media Platforms**: This refers to traditional media like radio, television, and newspapers. Despite the rise of digital, mass media remains a powerful and trusted source, especially for reaching a broader and perhaps older audience.
3. **Community Gatherings (Public *Barazas*):** This underscores the continued importance of face-to-face interaction and community-led dialogue. *Barazas* allow for two-way communication, questions and answers, clarification, and the building of trust through direct engagement with local leaders and project implementers. They also cater to those with limited access to media.

Other sources of information include:

1. **Social Interactions**: This speaks to the power of word-of-mouth, peer-to-peer learning, and the influence of trusted individuals within social networks. Information shared this way often has higher credibility.
2. **Formal Education**: Indicates that schools and educational institutions play a role in shaping understanding, albeit likely a slower and more systemic one.
3. **Art and Literature**: While perhaps less direct for immediate information dissemination, this points to the potential of creative and cultural expressions (e.g., songs, plays, stories) to convey complex messages about climate change and resilience in an engaging and memorable way.

4.4.2 Community Efforts

The study revealed the following community efforts in a bid to combat and adapt to climate change:

1. **Tree Planting Along the River Bank (Riparian Restoration):** This is a crucial nature-based solution that helps to reduce soil erosion as well as create a microclimate within the area.
2. **Urban Agriculture in an Effort to Reclaim the Riparian Reserve:**
3. **Community Cleanup Activities Organized by Local Groups, Foundations, and NGOs:**
   - **Climate Resilience Contribution:** While seemingly simple, these activities have profound impacts on climate resilience, particularly in Mathare:
     - **Flood Risk Reduction:** Clearing solid waste, debris, and blockages from rivers and drainage channels directly prevents flash floods and reduces their severity. Blocked drains are a primary cause of localized flooding in urban informal areas.
     - **Disease Prevention:** Stagnant water from blocked drains and uncollected waste creates breeding grounds for vectors of diseases (e.g., malaria, cholera) that are often exacerbated by warmer temperatures and altered rainfall patterns. Cleanups reduce these health risks.
     - **Improved Sanitation and Hygiene:** Better waste management leads to a healthier living environment, which is crucial for community well-being in the face of climate stressors.
     - **Building Social Cohesion and Capacity:** These activities foster a sense of collective responsibility and strengthen community networks. The involvement of local groups like Ghetto Foundation and Mathare Bondeni Fire Committee demonstrates existing community capacity and leadership in addressing local environmental challenges.

Most impactful climate resilience initiatives are tree planting and waste management collection.

Figure 4.10: Most Impactful Climate Resilience Initiatives

Most Impactful Climate Resilience Initiatives
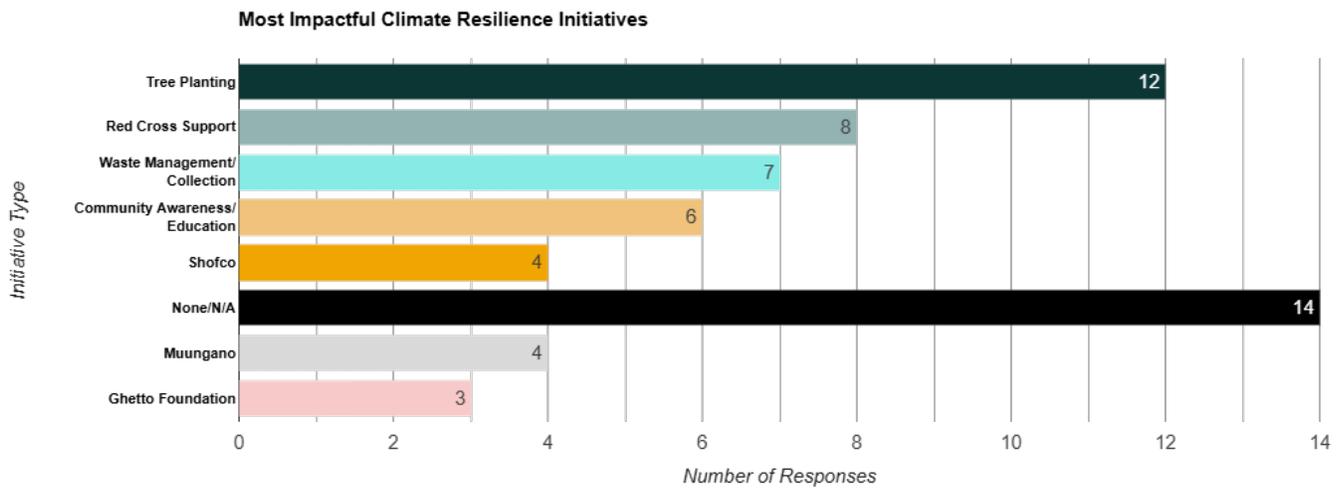
Source: Field Survey, 2025

4.4.3 Opportunities for Stakeholder Collaboration

The study revealed that majority of the residents were familiar with digital mapping and communication tools such as SMS Alerts and mapping apps such as google maps. Other tools include web browsers and USSD code.

Figure 4.11: Familiarity with Mapping and Communication Tools
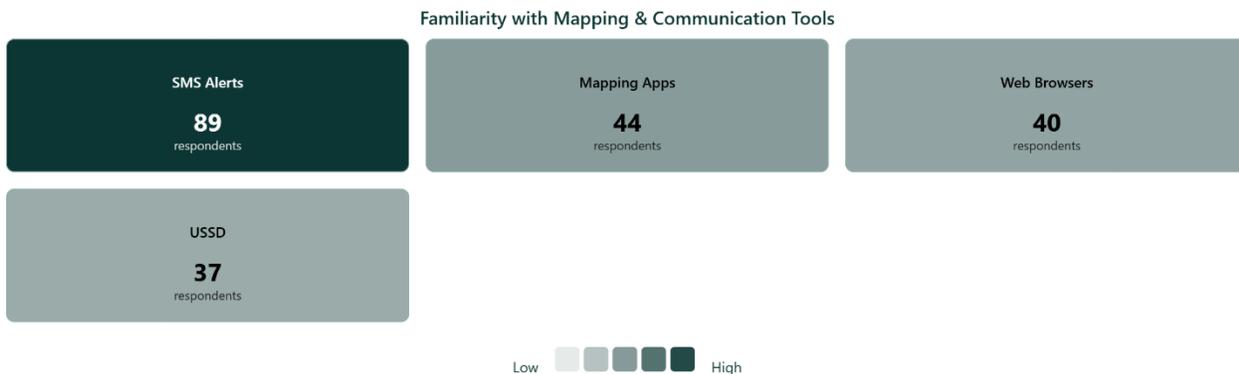
Source: Field Survey, 2025

This opens up a significant avenue for innovation and effective climate resilience and disaster risk strategies. This goes beyond just disseminating information and speaks to the community's capacity for engaging with digital platforms for various purposes. Additionally, the respondents recommended the following features to be included in the participatory tool:

- Climate and hazard information systems
- Public participation and community engagement
- Technological access, language inclusivity, and user experience
- Disaster preparedness and emergency response
- Climate change adaptation and preparedness
- Urban planning and land use management
- Economic resilience and livelihood support
- Health and social science resilience

Figure 4.12: Tool features for climate planning

Tool Features for Climate Planning
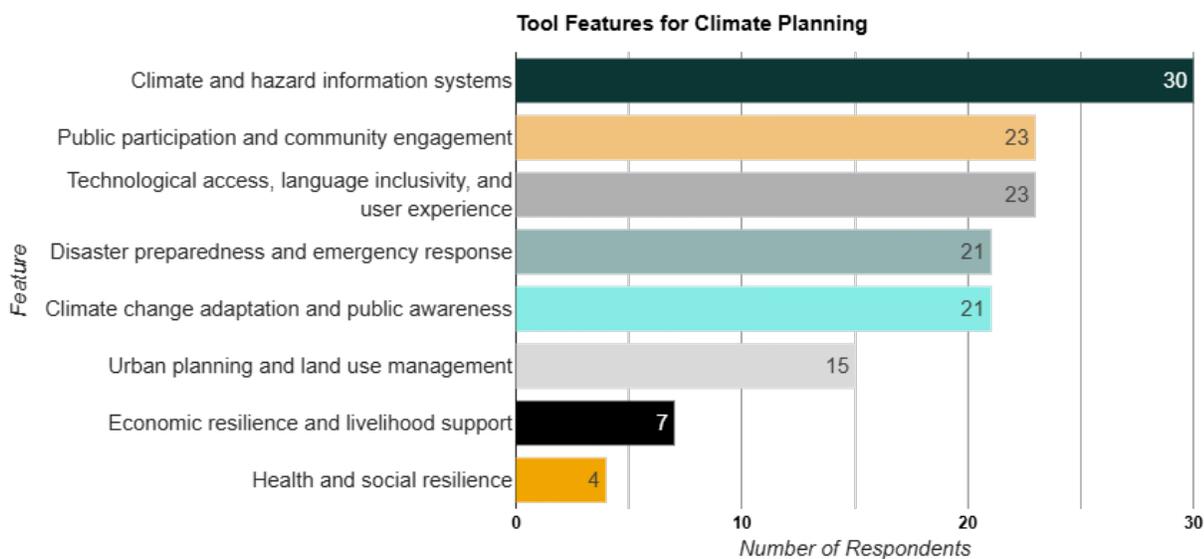
Source: Field Survey, 2025

The residents additionally expressed interest in using the tool not only for receiving alerts but also for ensuring that the information generated through the platform informs local planning, emergency response, and government interventions. While users valued alerts for personal preparedness, their stronger motivation stemmed from the potential of the tool to amplify community voices and influence formal decision-making processes affecting their settlement.

Figure 4.13: Community motivation for using the platform

Motivation to Use the Tool
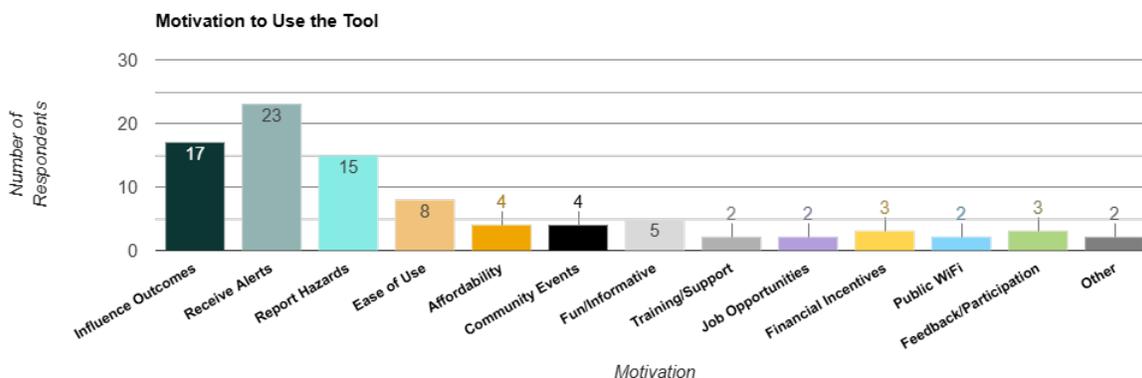
Source: Field survey, 2025

However, some expressed concerns over data privacy, the cost implications of using the participatory tool, false reporting, value realization, fear of surveillance, user friendliness, poor network coverage, and device accessibility as shown in the figure below. Data privacy was the most raised concern amongst the respondents, signaling the need to adhere to data privacy and protection laws.

Figure 4.14: Priority Concerns before launch
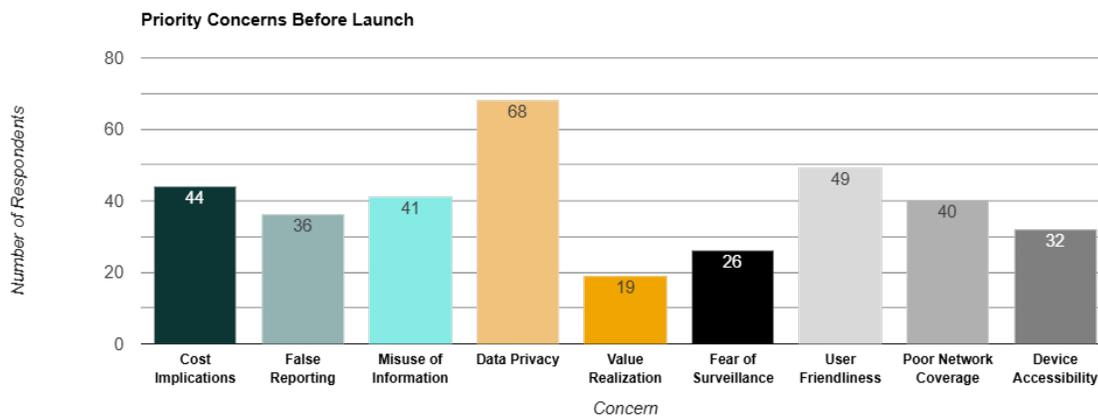
Source: Field Survey, 2025

The successful implementation of this low-tech tool depends entirely on robust, collaborative stakeholder engagement. The field survey offers a prime opportunity to forge these partnerships:

- *Community Members and Local Leaders*: As the ultimate beneficiaries and first responders, their local, traditional, and experiential knowledge is crucial. They are essential for identifying specific vulnerabilities and co-designing truly appropriate solutions.
- *Local Community-Based Organizations (CBOs) & NGOs:* Organizations like Ghetto Foundation, Mathare – Bondeni Fire Committee, Muungano Wa Wanavijiji, and Akiba Mashinani Trust are vital intermediaries and implementers. They already have established trust and deep contextual understanding on the ground.
- *Nairobi County Government:* This body holds significant power over urban planning, infrastructure, and resource allocation. Their buy-in is non-negotiable for scaling up local efforts and integrating the tool into broader development plans.

5. Discussion And Implications

5.1 Interpretation of Findings

5.1.1. Overall Interpretations

The study illustrates how digital tools, when co-designed and locally embedded, can catalyze inclusive urban governance and enhance climate resilience in structurally marginalized environments and additionally support the notion that resilience is a dynamic process influenced by inclusive governance, technology, and local agency rather than a fixed attribute. By demonstrating how digital tools can simultaneously stimulate all three resilience capacities, the Mathare scenario lends empirical substance to the theory. The results support DOI theory in a high-impact, low-tech setting. More significantly, they expand the idea by demonstrating how adoption in underrepresented communities is influenced by trust, data ownership, and ethical design. These factors that are frequently overlooked in the mainstream DOI literature.

5.2 Empowerment, Data Ownership, and Local Knowledge

The study demonstrates that community empowerment through digital knowledge systems significantly enhances climate resilience. Partnerships with grassroots organizations, such as SHOFCO and MaSCA, validate the community's invaluable contribution to adaptation efforts (Pelling & High, 2005). Residents possess a unique, context-sensitive understanding of local flood dynamics and weather patterns, which is a critical resource for early warning and climate monitoring (Ziervogel et al., 2017). Integrating this indigenous and experiential knowledge via techniques like participatory mapping enables the co-production of climate data, filling existing gaps and fostering context-appropriate adaptation strategies (Colenbrander et al., 2017).

The expansion of digital data collection in climate resilience research underscores the critical need for robust governance mechanisms. Consistent with previous studies, this research highlights persistent gaps concerning data ownership, control, and the equitable distribution of benefits, all of which are essential to safeguarding community interests (Taylor, 2017). These findings point to the importance of rethinking data governance within participatory and community-based research contexts. In particular, the concept of data trusts emerges as a potentially transformative framework for managing climate-related data generated by and about Mathare residents. By institutionalizing collective ownership and establishing transparent protocols for data access and use, such trusts could reinforce local control while enabling responsible data sharing across actors engaged in urban resilience planning (Wolff et al., 2016; Stalla-Bourdillon et al., 2020).

5.3 The Role of Technology as a Catalyst

Technology serves as a catalyst in achieving climate resilience, accelerating adaptation and mitigation processes to better resist and recover from climate-related hazards (Davis, 2009). Digital technologies enable real-time analysis and environmental monitoring, providing powerful tools that reduce urban vulnerability across critical domains such as urban flooding adaptation and mitigation, energy access and infrastructure (Aprizal et al., 2025; Mirzaei, 2025).

Specifically, for adaptation, sensor-based monitoring systems like IoT, Digital Twins, and smart agricultural systems leverage big data for real-time environmental analysis and improved resource management. Cities like Rotterdam, New York, and Singapore have successfully integrated these technologies with urban planning and policymaking, strengthening institutional capacities (Aprizal et al., 2025; Mirzaei, 2025).

However, it is worth noting that technological progress not specifically targeted at reducing GHG intensity can paradoxically worsen global warming, and isolated technological solutions are often inadequate for the complexities of interdependent human-technology-environment systems (Alestra et al., 2023; Chien et al., 2022).

5.4 Barriers to Effective Participation

The research identified multiple barriers that constrained effective community participation in technology-enabled climate resilience initiatives within Mathare Informal Settlement. A significant digital divide emerged, characterized by low digital literacy (with 23% of users requiring extensive technical support) and limited smartphone access, especially among the elderly. Infrastructure deficits, including internet connectivity issues (affecting 31% of sessions) and device constraints, fundamentally undermined sustained

engagement. Furthermore, the exclusion of low-tech channels (SMS/USSD) due to budget constraints created an exclusionary effect, contradicting inclusive participatory aims.

A critical governance gap was identified by the complete absence of county or national governance structures in the stakeholder network. This disconnect prevents the institutionalization of participatory processes and the integration of community knowledge into official urban planning. Stakeholder engagement was also fragmented, resulting in weak coordination and duplicated efforts among the 15 identified organizations.

Beyond immediate technological and governance constraints, deeper structural barriers proved most fundamental in shaping the effectiveness of participation. Insecure land tenure emerged as a primary constraint, as the constant threat of eviction reported by 80.9% of surveyed residents undermined long-term community investment in resilience improvements. Equally significant was the systematic devaluation of community knowledge within formal planning processes. Despite participatory mapping demonstrating an 80% correlation with formal GIS analyses, this locally grounded and sophisticated understanding of flood dynamics remained largely excluded from official decision-making.

The research documented that 80.9% of surveyed community members had experienced forced eviction or relocation due to floods, creating a climate of uncertainty that undermined long-term participatory planning efforts. Finally, the study identified systematic devaluation of community knowledge in formal planning processes. Despite residents demonstrating sophisticated understanding of local flood patterns, drainage dynamics, and seasonal variations through participatory mapping exercises (achieving 80% correlation with formal GIS analysis), this knowledge remained marginalized in official decision-making.

5.5 Relevance to Urban Policy and Practice

The research findings carry significant implications for urban policy development and climate resilience practice in informal settlements, both within Nairobi and across similar contexts globally. Digital platforms, when co-designed with communities, can serve as effective bridges between grassroots climate action and formal governance structures.

The effectiveness of the MWAMKO platform utilized by both the research team and the community researchers further illustrates that low-tech participatory tools can function reliably even in resource-constrained environments. The platform's outcomes resonate with the study's insights on the value of accessible, community-anchored digital systems for enhancing citizen engagement and co-production of spatial knowledge. This

convergence underscores the potential of such approaches to strengthen participatory dimensions of urban climate governance and resilience planning.

For policy implementation, the study suggested that governments should establish formal data-sharing agreements with community-based organizations, creating institutional mechanisms for integrating community-generated climate data into official urban planning processes. The high correlation (exceeding 80%) between community-identified flood zones and formal topographical analysis validated that participatory mapping generates scientifically credible data while simultaneously building community capacity and ownership. The research findings directly inform implementation of Kenya's National Disaster Risk Management Bill (2021) and Disaster Management Fund Regulations (2022) by providing evidence-based models for community-led disaster preparedness. The riparian reserve boundary mapping conducted through the MWAMKO platform demonstrated how participatory tools could support government relocation planning processes while simultaneously capturing community input on alternative land use options. This approach offers a middle ground between purely extractive data collection and fully community-controlled planning, potentially reducing conflicts around forced evictions. At the county level, policy should establish community climate data trusts to institutionalize community ownership over climate-related data while enabling transparent, consensual data sharing arrangements (Wolff et al., 2016; Stalla-Bourdillon et al., 2020).

The research findings supported arguments that technology-enabled participation can advance climate justice by centering voices of populations most affected by climate change yet systematically excluded from decision-making. The documentation of how participatory mapping revealed spatial patterns of vulnerability invisible to conventional analysis demonstrated technology's potential for making structural inequities visible and actionable.

5.6 Recommendations for Future Research

Based on identified limitations and preliminary findings, several research directions merit priority attention. Longitudinal studies are critically needed to track technology adoption over multiple years, assess sustained engagement factors, and measure tangible improvements in flood preparedness and community capacity. Comparative research across diverse informal settlements and international contexts would strengthen evidence on transferability, identifying universally applicable principles while documenting necessary contextual adaptations based on size, governance, and infrastructure variations.

Hybrid technological approaches combining smartphone platforms with low-tech systems (SMS/USSD), non-digital methods, mesh networks, and community-controlled open-source platforms require investigation to achieve equitable participation and reduce external technical dependence. Power dynamics and equity analysis must examine whether digital platforms genuinely redistribute decision-making authority or digitize existing exclusions. Research should assess how community-generated data enters formal planning, influences policy decisions and resource allocation, and advances climate justice across demographic groups.

Methodological innovations should develop indicators distinguishing meaningful from tokenistic engagement, explore collaborative data interpretation approaches, and integrate traditional ecological knowledge with scientific data for hybrid resilience planning systems. Financial sustainability models must investigate viable approaches for maintaining platforms and engagement beyond initial project funding, examining scaling pathways and critical success factors.

Institutional uptake research should identify barriers to government adoption, document strategies for integrating community-generated knowledge into formal decision-making, and assess whether participatory data produces tangible policy responses and budget allocations.

6. Conclusion

6.1 Summary of Key Insights

This study examined the potential role of catalytic technology-based participatory methods in enhancing climate resilience in Mathare, Nairobi. The research established that community knowledge is both credible and indispensable as resident-led flood mapping showed over 80 percent correlation with formal topographical data, confirming the scientific validity of local expertise. The MWAMKO digital platform proved effective in mobilizing residents to identify risks, map hazards, and co-design solutions. However, persistent challenges such as digital literacy gaps, connectivity limitations, and concerns over data privacy affected adoption. More critically, the lack of county and national government involvement created a governance gap, constraining the institutional integration of community-generated knowledge into official planning processes.

The theoretical frameworks of Climate Resilience, Diffusion of Innovations, and Adaptive Governance were instrumental in explaining these dynamics. Communities demonstrated adaptive capacities, innovation adoption patterns, and governance complexities that highlight the potential and limitations of technology-enabled participation. These findings

reinforce that resilience in informal settlements is not a static outcome but a dynamic process shaped by inclusive governance, technological innovation, and structural conditions.

6.2 Contributions to Practice and Policy

This research contributes widely to urban climate resilience practice and policy development. First, it provides empirical validation that participatory digital platforms can generate scientifically credible data while empowering marginalized communities. The high correlation between community mapping and formal analysis demonstrates that participation need not sacrifice technical rigor, addressing persistent tensions about balancing scientific validity with inclusive engagement.

Second, the research provides practical insights for designing and deploying participatory platforms in resource-constrained settings. The MWAMKO - Resilience Mtaani platform highlighted that low-tech digital solutions can foster inclusivity but must be complemented with hybrid approaches such as SMS or USSD to bridge digital divides. This offers a blueprint for practitioners and development partners working in similar contexts.

Third, the research operationalized the 3iF framework in informal settlement contexts, demonstrating how conceptual principles translate into implementable interventions. The study validated that Participatory Flood Modeling tactics can combine GIS technology with citizen science to co-create actionable intelligence for targeted interventions. This approach addresses data scarcity while building local capacity for ongoing monitoring.

Fourth, at the policy level, the findings provide evidence to support integration of community-generated data into statutory urban planning and disaster risk management frameworks. This aligns directly with Kenya's National Disaster Risk Management Bill (2021) and Disaster Management Fund Regulations (2022), offering concrete pathways for participatory data to inform decision-making. The study also advances the discourse on climate justice by showing how participatory methods can make visible the vulnerabilities of marginalized groups that formal processes often ignore. For instance, the riparian reserve boundary mapping demonstrated how participatory tools can support government planning processes while capturing community input on alternative land use options, potentially reducing conflicts around forced evictions.

Finally, the research identified critical policy needs including establishment of community climate data trusts to institutionalize data ownership, formal data-sharing agreements between community organizations and government entities, and mechanisms for

channeling   climate finance directly to local levels. These recommendations address systemic barriers preventing community initiatives from achieving scale and sustainability.

6.3 Final Recommendations

Based on the findings, several recommendations emerge for stakeholders at multiple levels.

For government actors, there is a need to institutionalize community-generated data through formal planning frameworks, data-sharing agreements, and participatory governance structures. This should be complemented by policy reforms that address structural barriers such as insecure tenure and forced evictions, which fundamentally undermine resilience-building.

Development partners should prioritize long-term investment in institutional and community capacity building to strengthen the foundations for sustained climate adaptation. Short-term interventions, including pilot initiatives, should be strategically aligned with broader adaptation objectives and embedded within locally led processes that promote learning, innovation, and scaling.

To avoid the pitfalls of helicopter research where external actors conduct isolated, short-term projects with limited local engagement, adaptation initiatives should center local knowledge systems, participatory co-production, and long-term partnerships with local institutions. Adopting such an incremental adaptation pathway ensures that investments deliver immediate benefits while progressively advancing toward systemic, context-specific, and locally owned resilience outcomes. Support for hybrid digital and low-tech participation models is essential to ensure inclusivity. While the research does not yet provide conclusive evidence that such participatory digital platforms can be sustainable or continually used, it highlights their potential as evolving mechanisms for integrating local and scientific knowledge and fostering collaboration. Accordingly, investments should focus on strengthening local ownership and governance structures around participatory platforms, including community-managed technology centers and subsidized connectivity, to create the conditions under which long-term sustainability might emerge.

For community organizations, stewardship of participatory platforms is critical to sustain engagement and ensure data sovereignty. The establishment of climate data trusts could safeguard community-generated information and strengthen bargaining power in negotiations with state and non-state actors.

For researchers, there is a clear need for longitudinal studies to track adoption trajectories and resilience outcomes over time, as well as comparative studies across informal

settlements to test scalability and context-specific adaptations of catalytic participatory methods.

The case of Mathare demonstrates that technology alone does not deliver resilience; rather, it becomes catalytic when embedded in broader efforts to democratize governance, redress systemic inequities, and amplify community agency. Participatory platforms such as MWAMKO - Resilience Mtaani can make marginalized knowledge visible, foster co-production, and facilitate collaboration across governance levels. However, their transformative potential will remain constrained without political will, structural reforms, and institutional recognition of local agency.

The promise of catalytic resilience lies in convergence, where technology amplifies local voices, where governance structures legitimize community knowledge, and where resilience planning is rooted in principles of justice and equity. Only through such convergence can informal settlements like Mathare transition from being sites of systemic vulnerability to being active agents of climate resilience and urban transformation.

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Appendices

Appendix A: Site Gallery

Appendix B: Key Informant Interview Survey Questionnaire

Catalytic Tech-Based Participatory Methods to Build Climate Resilience Locally: A Case Study of Mathare Informal Settlement, Nairobi, Kenya

This research addresses the urgent need to enhance climate resilience in informal urban settlements by transforming traditional top-down planning approaches. Centered on Mathare, one of Nairobi's largest informal settlements, the project evaluates existing participatory methods and introduces innovative techniques to empower community members in climate adaptation planning. By actively involving local residents, urban planners, and other stakeholders, the study seeks to bridge the gap between expert-driven decision-making and community insights.

Note: Please provide detailed information and specific examples whenever possible.

General Information:
Section I: General Information
Date of the Survey: ....
Name of the respondent: ....
Age: ....
Ward/ Village administered: ....
Email Address and Mobile Number: ....

Have you noticed any changes in the riverbank or water course over time along Mathare river?
....
Are there policies or frameworks that support (or hinder) community participation in climate planning? If yes, state them
....
In your opinion, how can the government collaborate with communities in planning for relocation due to climate related events?
....
Are there any existing community guidelines that regulate activities carried out within riparian reserves? If yes, please highlight the key provisions of the guidelines
....
What locally-led initiatives/projects are you aware of whose objective is climate change mitigation in Mathare?
....
Which of the stated initiatives has been most impactful in sensitizing the residents about community- led climate adaptation?
....

What ways do you currently engage the community in the activities of your organization?
....

How have you infused low-tech participatory methods (e.g. WhatsApp groups or online surveys) in engaging them?
....

Have you been involved in projects where technology was used to engage the community in Mathare, if yes, what tools were used and how?
....

In your experience, how common is the use of digital tools for mapping and communication applied in informal settlements? Please elaborate
....

What challenges are faced in implementing technology driven participation processes (internet access, literacy, distrust, financial constraints) in informal settlements?
....

How do you coordinate with NGOs/CBOs to avoid duplication of efforts in Mathare?
....

What mechanisms exist to ensure climate adaptation plans align with the priorities of informal settlement residents, rather than top-down agendas?
....

What role do traditional or informal governance structures (e.g., community elders, resident associations) play in shaping locally-led climate resilience?
....

How do you engage with relevant stakeholders e.g. national agencies or international actors (e.g., UN-Habitat) to advocate for informal settlement needs in climate policy?
....
....

How do the existing climate resilience projects address vulnerabilities (e.g., spatial location, gender, age, disability, poverty) in informal settlements?
....

If a mobile or web-based tool was developed to support climate planning in Mathare, what should it include?
....

What would make it easier for more residents to use technology for engagement
☐ Language options
☐ Trainings
☐ Public Wi-Fi
Other...

What would motivate residents to use such a tool (e.g., ability to influence outcomes, receive alerts, report hazards)?
....

What critical concerns (e.g., data privacy, misuse, misinformation) should be addressed before launching such a tool?

Appendix C: Community Members Interview Survey Questionnaire

Catalytic Tech-Based Participatory Methods to Build Climate Resilience Locally: A Case Study of Mathare Informal Settlement, Nairobi, Kenya

This research addresses the urgent need to enhance climate resilience in informal urban settlements by transforming traditional top-down planning approaches. Centered on Mathare, one of Nairobi's largest informal settlements, the project evaluates existing participatory methods and introduces innovative techniques to empower community members in climate adaptation planning. By actively involving local residents, urban planners, and other stakeholders, the study seeks to bridge the gap between expert-driven decision-making and community insights.

Note: Please provide detailed information and specific examples whenever possible.

General Information:
Section A: General Information
Date of the Survey: ....
Coordinates: ....
Ward administered: (select one)
☐ Mlango Kubwa Ward

☐ Mabatini Ward

☐ Hospital Ward

☐ Utalii Ward

Village administered: ....
Name of the respondent(optional): ....
How long have you lived in Mathare?

☐ <1 yr

☐ 1-5 yrs

☐ 5-10 yrs

☐ >10 yrs

Gender: ....
Age:

☐ 18-24

☐ 25-29

☐ 30-39

☐ 40-49

☐ 50 and above
Number of household members: _____ adults, _____ children (<18)

Section B: Climate Risks & Experiences

What climate-related problems have you experienced recently?

☐ Flooding

☐ Heat

☐ Landslides

☐ Water shortages

☐ Fires

Others_____

Which year did this climate-related event occur most severely? _____

Which months are most difficult due to these problems?

☐ Jan- March ☐ April–June   ☐ July –Sept ☐ October–December

In the past 2 years, how often did flooding affect your household?

[ ] Never [ ] Once [ ] 2-3 times [ ] 4+ times

What were the main damages from flooding? (Tick all)

[ ] Property loss

[ ] Health issues

[ ] Displacement

[ ] Lost income

[ ] Water contamination

Have you faced forced relocation/eviction due to floods or "riparian reserve" actions?

[ ] Yes [ ] No → If Yes: How did this impact your family? _____

Have you joined community groups addressing floods/evictions?

[ ] Yes [ ] No → If Yes: Which activities? (e.g., clean-ups, protests, planning meetings)

How effective are current community efforts against floods? (Scale: 1=Not helpful → 5=Very helpful)

[1]

[2]

[3]

[4]

[5]

Rank methods you've used to share ideas with leaders: (1=Most used, 4=Least used)

___ Barazas (community meetings)

___ WhatsApp groups

___ Door-to-door campaigns

___ Youth/elders' forums

What prevents your participation?

[ ] Time

[ ] Safety

[ ] No information

[ ] "Leaders don't listen"

[ ] Other

In your opinion, which age group is most affected by climate related events and how? _____

☐ Below 18

☐ 18-35

☐ 36-59

☐ 60 and above
What do you/your neighbors do during heavy rain or flooding to avoid loss and damage?
Capture any infrastructure deficiencies or river conditions in your area: (allow selection of multiple images) –
Cross-check photo capture option in chrome browser (Raphael)
Blocked drains/sewers
Poor building materials (mud houses, etc.)
Polluted/blocked rivers
Other

Section C: Flood Zone Demarcation & Proposed Use of Riparian Land

Does the current demarcation of the riparian zone present a true reflection of your flood experience over
the years?
☐ Yes
☐ No, explain_____

In your estimation, how far from the edge of the river do you consider to be the highest point of flooding?
(Capture the GPS Point)
In your opinion what would be the most accurate way of defining the riparian zone across informal
settlements in Nairobi?
What are the current activities taking place in and near the Riparian Reserve in this village?
☐ Farming
☐ Community parks
☐ Public Toilets (Temporary)
☐ Children play areas
☐ Jogging tracks
☐ Walking lanes
☐ Outdoor gymnasiums
others _____
What activities would you prefer to see in the newly cleared riparian reserve aligned with the objective of
environmental conservation and community well-being?

Section D: Awareness & Coping Capacity
Have you heard the term "climate resilience"?
☐ Yes ☐ No
If yes, what does it mean to you? _____
What have been your best sources of information on climate resilience
☐ Mass media (music, radio, television, podcasts)
☐ Social media (Facebook, tiktok, twitter, Instagram, LinkedIn, etc.)
☐ Art (murals, paintings, graffiti)
☐ Literature (newspapers, comics, books)
☐ Formal education
☐ Community organizations (SDI, SHOFCO etc.)

☐ Barazas

☐ Social interactions (family, friends)

☐ others_____

What local knowledge/initiatives help your community cope with climate related issues?

Which of the above-mentioned initiatives has been most impactful in building community-led climate resilience? Explain_____

Is your community prepared for future floods/extreme weather?

☐ Yes ☐ No ☐ Not sure

What more is needed? _____

Section E: Low-Tech Participatory Tools

Which mobile communication device/gadget do you use?

☐ Smartphone

☐ Basic phone (calls/SMS)

☐ I do not have a phone

How would you prefer to report climate incidents?

☐ SMS

☐ USSD menu

☐ QR scan

☐ Paper form

☐ Call a trained volunteer

☐ Community/Social Halls/booths

Are there any current digital tools or platforms that help you to receive alerts on hazards or share feedback publicly?

☐ Yes, state them _____

☐ No

It is assumed that digital tools improve efficiency in sensitizing and disseminating information on climate resilience. To what extent do you agree with this assumption?

☐ Strongly disagree

☐ Disagree

☐ Neutral

☐ Agree

☐ Strongly agree

Would you act on alerts (e.g., heavy rain warnings)?

☐ Yes

☐ No, why? _____

What alerts would you like to share or receive?

☐ Weather

☐ Health

☐ Service disruptions

☐ Safety tips

☐ Community events

What would make it easier for more residents to use technology for engagement?

☐ Language options

☐ Trainings

☐ Public Wi-Fi

Other _____

What is your preferred language for platform content?

☐ English

☐ Kiswahili

☐ Sheng

What climate related information would you like to access from a digital platform?

☐ Flood reporting

☐ Infrastructure maintenance

☐ Hazard maps

☐ Policy documents

☐ Funding schemes

☐ Case studies and best practices

Section F: Co-Designing and Testing a Digital Participatory Tool

How familiar are you with use of the following tools for mapping and communication?

☐ Mapping apps (e.g. Google maps etc.)

☐ SMS alerts

☐ USSD

☐ Web browsers (e.g. Google Chrome, Firefox etc.)

If a mobile or web-based tool was developed to support climate planning in Mathare, what should it include?

What would motivate residents to use such a tool (e.g., ability to influence outcomes, receive alerts, report hazards)?

What would be your priority concern that should be addressed before launching such a tool?

☐ Data privacy

☐ Misuse of information

☐ User friendliness

☐ Cost implications

☐ Poor network coverage

☐ Device accessibility

☐ Fear of surveillance

☐ False reporting

☐ Value realization of the tool

Section G: Governance & Justice – ADD THIS SECTION

Rate responses to floods/evictions:

Local Leaders | Poor Fair Good |

County Govt.| Poor Fair Good |
NGOs | Poor Fair Good |
How much say do residents have in redevelopment plans?
[ ] None [ ] A little [ ] Some [ ] A lot
Should climate solutions prioritize those most affected
 [ ] Strongly agree [ ] Agree [ ] Disagree

Closing:
Asante sana! Your voice shapes solutions.