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Lessons learned: comparing the importance and performance of flood adaptation strategies in resource-limited regions: an analysis of Malawi

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1. Introduction

Flooding encompassing types such as inundation, flash floods, and coastal flooding represents a significant hydrometeorological threat that leads to widespread devastation of human life, livelihoods, and property globally (Abunyewah et al., 2023). Data from the International Emergency Events Database (EM-DAT) indicates a rising trend in both the frequency and intensity of flood events, with over 30% of such occurrences and 40% of the resultant damages taking place in the last decade, signifying a marked increase relative to the previous century (Guha-Sapir et al., 2020). Approximately 1.47 billion individuals are at direct risk of substantial flooding. Notably, 89% of those affected reside in low- and middle-income nations, with 55% primarily concentrated in Sub-Saharan Africa (Rentschler & Salhab, 2020). In Malawi, the lakeshore areas exhibit a pronounced vulnerability to recurrent flash floods, driven by their geographic features and proximity to Lake Malawi. These hydrological events lead to fatalities, community dislocation, and infrastructure degradation, with profound implications for agriculture, which contributes over 30% to the national Gross Domestic Product (World-Bank-Group, 2024). Despite several disaster management frameworks and standards, the effective implementation of disaster management remains a significant challenge (Chong & Kamarudin, 2018), especially in developing regions. Disaster response is becoming problematic as individuals react differently based on their diverse backgrounds and motivations, potentially resulting in disorganized scenarios if not meticulously managed and coordinated (Chong & Kamarudin, 2018).

Nonetheless, considerable literature emphasizes the need to reassess disaster management frameworks, policies, and structures to mitigate bureaucratic impediments and bolster local institutions' capacity to address potential local hazards (Shah et al., 2019). Some studies have also explored the shortcomings in disaster management from a resilience-oriented perspective (Mayer, 2019). In flood management, understanding flood dynamics, community vulnerabilities, and fostering community initiatives is crucial for reducing risks and building resilience. Effectively reducing the vulnerability of marginalized populations hinges on implementing strategic management approaches. By establishing robust disaster preparedness frameworks, communities can significantly diminish the susceptibility of their infrastructure, residences, and populations to the hazards associated with disasters (Cui et al., 2018; Shah et al., 2019). Management strategies extend beyond immediate response efforts to encompass long-term recovery and reconstruction initiatives. By leveraging comprehensive important performance assessment methodologies and incorporating lessons learned from past floods, communities can prioritize investments in resilient infrastructure for urban and rural planning practices that mitigate future risks (Biswas & Nautiyal, 2020). Despite the advances in science and technology that have improved the ability to predict floods in communities (Patel & Yadav, 2023), the implementation of effective management strategies is crucial in mitigating their adverse impacts and safeguarding the lives and livelihoods of vulnerable communities (Paudel et al., 2023). Therefore, discussions on flood disaster management, community participation and adaptation are crucial for society. For instance, developing adaptive capacity can empower communities to identify and respond to disasters (Lin & Lee, 2025). This highlights the importance of people's ability to cope with change and minimize exposure to disasters while effectively mitigating their impacts (Bezboruah et al., 2024).

2. Literature Review

2.1 Community participation behavior in flash-floods prone areas

Public participation is crucial in disaster response efforts (Ali et al., 2019). Specifically, community engagement is essential for enhancing the effectiveness of flood management strategies. Effective flood management strategies rely on active community participation (Hapsari & Zenurianto, 2016). Community participation encompasses the involvement of individuals and groups in planning, decision-making, resource contribution, program implementation, collaboration with specific organizations or activities, equitable sharing of the benefits from developmental programs, and the subsequent evaluation of such initiatives (Cohen John & Norman, 1980). Community participation, while integral to guiding project development and execution, requires a high level of engagement to remain effective. Passive or minimal involvement can hinder the success of these initiatives (Mukerji et al., 2024). Early community involvement significantly mitigates the adverse effects of disasters, ensuring that individuals are informed about every phase of disaster management. This preparedness enhances their capacity to protect themselves, recover, and repair damage caused by disasters. Ultimately, such engagement fosters the development of a safe, self-reliant, and resilient community capable of withstanding future disasters (Nugraheni et al., 2022). Engaging residents and giving them the responsibility for their community's disaster management builds trust, enhances collaboration, and paves the way for more effective disaster management strategies (Lin & Lee, 2023; Ryan et al., 2020). Active community participation forms the foundation of effective disaster management. Communities can harness their unique knowledge, skills, and resources by involving residents to adapt disaster management efforts to their specific needs and priorities (Sufri et al., 2020). This collaboration enhances risk identification, supports affected individuals, and strengthens partnerships with authorities, ultimately fostering more resilient disaster response and recovery (Ryan et al., 2020).

Community participation is especially crucial in post-disaster recovery, particularly for vulnerable populations (Lin & Lee, 2023). Incorporating participatory approaches that account for cultural contexts can significantly improve recovery outcomes. Activities conducted during the pre-disaster phase, such as preparedness training, help strengthen community resilience by covering key areas like evacuation, first aid, and communication. In the recovery phase, providing clear and accessible information empowers communities to make informed decisions and take effective action (Amini Hosseini et al., 2014). Exploring community perspectives on disaster management is vital for understanding participation behavior in flood-prone areas. By delving into attitudes, beliefs, and socio-cultural factors, valuable insights emerge that inform the design of adaptive capacity-building initiatives (Sawaneh et al., 2024). These tailored strategies help address participation challenges, enhance adaptability, and increase engagement, ultimately improving resilience and promoting active involvement in disaster preparedness and mitigation efforts (Lin and Lee, 2022; Lin & Lee, 2023). A summary of existing studies (Anderson et al., 2021; Mukerji et al., 2024) highlights the importance of customizing disaster management efforts through participatory methods tailored to the community's specific needs. Effective recovery efforts after a disaster rely on culturally appropriate, participatory approaches that empower communities. Involving residents in disaster management fosters trust, collaboration, and the development of tailored strategies, making it essential to understand community perspectives for adaptive capacity-building.

2.2 Adaptive capacity in flash-floods prone areas

The Intergovernmental Panel on Climate Change (IPCC) defines adaptive capacity as the ability of various systems, institutions, individuals, and other organisms to adjust to potential damage, seize opportunities, or respond effectively to consequences (IPCC, 2022). This definition highlights the potential for climate adaptation and identifies the factors that can promote or obstruct this process. Within the flood disaster management framework, community adaptive capacity refers to a community's capability to respond efficiently to and adapt to the impacts of flooding (Azad et al., 2020). It is essential to comprehend the specific practices and situational factors that influence the adaptive capacity of vulnerable communities, as this understanding is vital for formulating informed policies and decisions to enhance resilience against disaster impacts. The adaptive capacity of a community is influenced by a myriad of components, including geographical factors, access to knowledge and resources, perceived risks, and institutional support (Jongman, 2018). Additionally, the presence of effective leadership to guide community initiatives during and following flooding events and the ability to obtain external assistance plays a crucial role (Cinner et al., 2018).

Communities can boost adaptive capacity by employing strategies such as advancing education, strengthening communication and collaboration, investing in infrastructure designed for resilience, utilizing advanced technology, incorporating long-term planning into policy frameworks and promoting partnerships among governments, NGOs, and social organizations (Bezboruah et al., 2024; Lin & Lee, 2023). Involving community members in every phase of disaster management planning, preparation, response, and recovery ensures that local needs and priorities are accurately represented in disaster strategies (Cui et al., 2018). This participatory approach has gained global traction due to its effectiveness in addressing the unique needs of local populations (Lorna, 2020). However, a holistic approach linking critical aspects of community adaptive capacity with disaster management is yet to be fully realized. Previous studies have looked into the role of social capital and power structures at household and community levels (Azad & Pritchard, 2023; Meyer et al., 2024), other studies (Bezboruah et al., 2024; Ro & Garfin, 2023) have investigated the role of either community-based non-profit organizations or governments efforts in building adaptive capacity. While the importance of enhancing adaptive capacity in communities is acknowledged, a critical void persists in the collaborative disaster management efforts among communities, governments, and NGOs, particularly in developing nations. The rise in flash flood occurrences in under-resourced regions, such as Malawi, points to a significant gap in research regarding programs designed to enhance adaptive capacity. Much of the existing literature overlooks the insights and contributions of crucial stakeholders, including NGOs, local communities, and governmental organizations, within the Community Based Disaster Management (CBDM) approach. Moreover, there is a pronounced lack of evaluation concerning the effectiveness of disaster management efforts as perceived by these communities, specifically in the context of flash floods. This situation necessitates a comprehensive analysis of the stakeholder roles and their contributions. Evidence suggests that the efficacy of disaster response is significantly linked to the integration and cooperation of governmental and community entities (Raungratanaamporn et al., 2014).

The present research addresses the prevailing conditions in Malawi, a country that grapples with resource scarcity and heightened susceptibility to flooding. The research objectives are threefold: First, (i) it assesses and categorizes various stakeholders based on their perceptions and attitudes toward adaptive capacity programs, utilizing factor analysis and cluster analysis methodologies. In addition, (ii) the investigation delves into stakeholders' views regarding diverse

adaptive strategies implemented within the CBDM framework in the context of flood responses employing the theories of Cinner et al. (2018). This research component is vital for enhancing community-oriented disaster adaptation strategies, ensuring that the specific needs of local populations are prioritized while remaining aligned with overarching disaster management objectives. Lastly, (iii) the study explores critical factors that can promote sustained engagement in flash flood disaster management efforts. Furthermore, through this in-depth analysis, a contextualized adaptive capacity framework is developed to create a solid basis for establishing evidence-based strategies that support collaboration in policy formulation and advance sustainable practices in flood disaster management.

3. Method

3.1 Study location

Malawi's flood vulnerability in Southern Eastern Africa arises from various interrelated factors. The country's geography exposes it to seasonal rainfall and unpredictable weather patterns, resulting in flooding during the rainy season. Climate change intensifies these risks with irregular rainfall, rising temperatures, and increased occurrences of extreme weather events, such as tropical cyclones, which worsen flood severity (Alfieri et al., 2016). Insufficient drainage and limited flood control mechanisms aggravate these challenges, particularly in susceptible regions. Combined with rapid urbanization, informal settlements, poverty, and inadequate disaster preparedness, these factors significantly heighten Malawi's flood susceptibility. From 1946 to 2005, Malawi faced 157 flood events that manifested in various ways, including flash floods and overflowing lakes and rivers in low-lying regions (Pangapanga, 2017). Specifically, between 2001 and 2003, more than 3 million individuals were affected nationwide by these floods, leading to significant displacement.

The displaced households frequently resided in temporary shelters, where access to clean water and proper sanitation was inadequate. These conditions undermined standard hygiene practices, triggering outbreaks of diseases such as cholera. For instance, in 1998/1999 and 2001/2002, with reported cases of over 25,000 and 33,546, respectively, were closely linked to these disasters (Government of Malawi, 2024). Flooding in the country has reached unprecedented levels in 2015, 2019, and 2023. The 2015 floods affected over one million people, causing 230,000 displacements and 170 deaths. In March 2019, *Tropical Cyclone Idai* brought severe flooding, impacting 975,000 individuals and leading to a state of disaster. *Tropical Cyclone Freddy* in March 2023 caused devastating floods, displacing 83,870 people and resulting in over 300 deaths, with 1.3 million needing assistance. The Malawi government, along with donor funds and NGOs, has consistently led efforts in both proactive and reactive flood risk management strategies. The Department of Disaster Management Affairs (DoDMA) primarily drives the institutional framework for disaster risk management. Key national policies, such as the National Adaptation Programme of Action, provide strategic guidance for addressing climate-related risks, including floods (Government of Malawi, 2024). Despite these structures, implementing flood risk management strategies often faces significant challenges, including funding constraints, limited technical capacity, and fragmented stakeholder coordination.

In light of these events, a study was conducted in Malawi's Karonga and Nkhosachota districts to examine the challenges and opportunities of managing flood risks. Karonga, with a population of 365,028 and an area of 3,416 km², faces a 57.1% poverty rate, primarily reliant on agriculture, livestock, and fishing (National Statistical Office, 2019). This district is flood-prone due to rivers like the Songwe and North Rukuru (UNECA, 2015). Nkhosachota, home to 393,077

people, similarly suffers from frequent floods, particularly along the Dwangwa river. In 2024, heavy rains displaced over 6,000 individuals and damaged essential infrastructure.

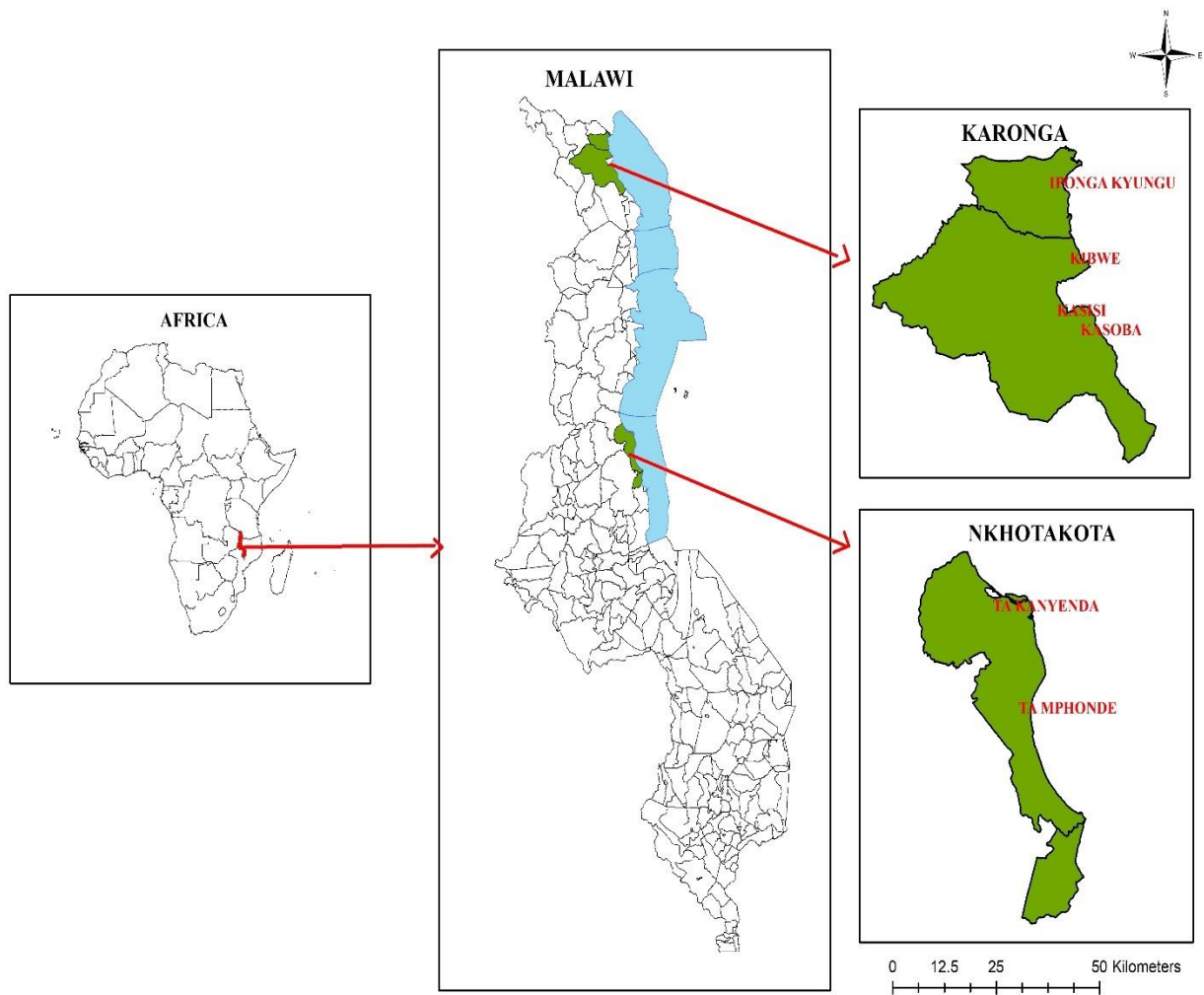


Fig. 1. Location of Karonga and Nkhosakota districts in Malawi

3.2 Study design

This study employs a combined methods approach, integrating quantitative data with qualitative insights to explore the local adaptive capacity for enhanced CBDM concerning flooding. A cross-sectional survey design was employed, focusing on six specific attitude indicators influencing CBDM efforts: the use of flood early warning systems, participation in disaster civic education programs, resource sharing for disaster reduction, involvement in district-level policy formation, engagement in Nature-Based Solutions (NbS) groups, and awareness of perceived disaster risks. The theoretical framework underscores the importance of both physical and non-physical properties (assets), agility to change during disasters (flexibility), robust organizational frameworks (social organization), community education (learning), and resolution autonomy (agency) (Cinner et al., 2018) (Table 1). These components are fundamental in delivering the intricate and dynamic aspects of collaborative flood CBDM, particularly in economically disadvantaged settings. Engaging diverse stakeholders including education specialists, local

government representatives, community leaders, and NGO members in the study was vital for evaluating existing strategies to enhance adaptive capacity and pinpoint areas for improvement (Phan et al., 2023).

The research highlights that participation in CBDM is crucial for building resilience against flooding. Early warning systems enable proactive preparedness to protect individuals and properties while optimizing cost efficiency, particularly in economically constrained areas (Hasan & Islam, 2024). Civic education programs foster self-organization and resilience, enhancing social capital, which is crucial for effective disaster response (Rivera & Nickels, 2014). Resource sharing, such as providing safe refuge and essential supplies, helps minimize vulnerabilities and supports collective recovery efforts (Lin & Lee, 2024). NbS offers sustainable, ecosystem-based disaster risk reduction methods believed to decrease flood volumes and enhance community resilience (Penning et al., 2023). Policies provide structured frameworks guiding organizations in implementing effective disaster mitigation strategies (Mashi et al., 2019). Increased awareness of disaster risks equips communities to adopt timely mitigation strategies, significantly improving adaptive capacity (Sawaneh et al., 2024). (see Table 1).

228 **Table 1** The study's attitude and adaptive capacity dimensions

No	Indicator	Item
Attitude		
1	I often make sure that I have received relevant weather information for my district and local area.	Early warning systems
2	I often attend disaster civic education programs that are organised by either the district or village civil protection group and NGOs.	Disaster civic education program
3	I am willing to share resources and infrastructure towards disaster management to my fellow local members.	Sharing resources
4	I often take part in key decision making processes that involves policy formulation for disaster management.	Policies
5	I am aware of the disaster risks and its associated hazards which prompts me to take necessary actions to reduce the impacts	Impact reduction
6	I am a member of NbS group that works in tandem with various NGOs and GOVT to lessen floods impacts	Environmental mitigation and coping Strategy
Dimension, according to Cinner et al., (2018)	Flood Adaptive capacity strategies	
Asset	Microfinance loans play a crucial role in empowering vulnerable populations by enabling them to diversify their sources of income. These loans allow individuals to invest in income-generating assets and implement strategies for adaptation, which can enhance their economic stability (Naz & Doney, 2022).	<i>Loans.</i>
	Establishing food storage facilities in the uplands for lowland residents is essential for enhancing community resilience against floods. Constructing flood-resistant buildings and elevating stored items effectively protects vital resources and ensures accessibility during crisis situations. Additionally, waterproof storage safeguards food and tools from water damage (Food-and-Agriculture-Organization, 2023). Investing in these facilities is a strategic necessity for sustainable development and disaster preparedness.	<i>Food storage.</i>
Flexibility	Cash-for-Work (CFW) programs in post-disaster recovery serve as a vital mechanism for empowering affected populations to address urgent needs while simultaneously fostering trust and collaboration with	<i>Cash for Work.</i>

	government entities. By involving local communities in essential rehabilitation efforts, such as house reconstruction and infrastructure restoration, these programs not only meet immediate financial demands but also promote social cohesion (Ahmad & Ma, 2020).	
	The implementation of adaptive measures, such as constructing dykes, presents a compelling strategy to mitigate the impacts of flooding and erosion. These interventions have the potential to significantly decrease the number of individuals affected by flooding by up to two orders of magnitude ultimately leading to a remarkable reduction in associated damage costs (Hinkel et al., 2012).	<i>Dykes.</i>
Organisation	Prioritizing information sharing enhances community resilience and fosters collaboration in flood risk management. By providing access to data on vulnerabilities, weather predictions, and infrastructure assessments, communities can empower residents to make informed decisions, ultimately leading to a safer future (Ibrahim et al., 2023).	<i>Information.</i>
	Relocation is a governance strategy to reduce flood risks, with community responses shaped by socio-economic and cultural factors. Its methods evolve over time, influenced by shifting contexts and past lessons (Madhanagopal & Momtaz, 2022).	<i>Relocation.</i>
Learning	Safety emergency drills play a crucial role in promoting disaster awareness among students and the community. By participating in these drills, individuals enhance their preparedness, cultivate a proactive safety culture, and gain valuable insights into potential disaster scenarios (Amini Hosseini & Izadkhah, 2020).	<i>Drills.</i>
	Enhancing public awareness through mass media serves as a powerful catalyst for change. By strengthening perceptions of family and community bonds, this approach encourages participation in recovery activities, civic engagement, altruistic actions, and disaster preparedness. A well-informed public is more likely to unite in times of need, fostering resilience and solidarity (Cheng et al., 2016).	<i>Mass media.</i>
Agency	The integration of diverse knowledge, particularly Indigenous knowledge, with scientific understanding is increasingly crucial (Wang et al., 2019). Despite technological advancements, many African communities still rely on traditional observations—such as cloud patterns, tree behavior, and local flora to predict floods.	<i>Knowledge integration.</i>
	Embracing a holistic strategy in disaster early warning systems requires a change in perspective regarding Indigenous Knowledge Systems (IKS). By supporting local communities and embedding IKS in policy frameworks, we can significantly improve the overall effectiveness of disaster management initiatives.	<i>Change of attitude.</i>

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3.3 Survey implementation and data analysis

From June to September 2024, surveys were conducted in the Karonga and Nkhhotakota districts, engaging 1,012 respondents selected through stratified random sampling to ensure diverse demographics. Initial analyses were performed using SPSS software (version 22), which focused on community's attitudes through factor and cluster analyses. Factor analysis identified correlated variables, reducing the dataset into fewer dimensions (Suryawan et al., 2024). K-Means Cluster analysis identified three distinct clusters of respondents, revealing varied community perceptions and engagement levels regarding flood risks. This clustering technique categorizes data points based on similarity, enabling tailored approaches to flood CBDM (Troccoli et al., 2022). Positive attitudes correlate with increased proactive measures to mitigate flood hazards (Brown & Damery, 2002), making it critical to understand and address these attitudes for effective flood risk management strategies. A matrix framework was applied to evaluate and rank adaptive capacity indicators based on community assessments of importance and performance. This two-dimensional grid allowed for direct comparisons and highlighted critical focus areas. Various statistical tests, including paired sample t-tests and chi-square tests, were conducted at a significance level of $p < 0.05$ and <0.01 to identify significant differences in perceptions across community groups. Mean scores and Z-scores standardized the data, facilitating comparisons across indicators. These scores were plotted on an IPA matrix, divided into four quadrants: Quadrant I (essential), Quadrant II (requires attention), Quadrant III (not critical), and Quadrant IV (overemphasized), reflecting community perceptions regarding the indicators (Martilla & James, 1977). The final phase involved binary choice models to analyze factors influencing community engagement in adaptive capacity strategies for flood resilience, recoding responses into a binary format based on a Likert scale and demographic profiles, which allowed for systematic analysis of engagement in initiatives. The research employed NLOGIT 5 to establish four models using binomial logistic regression, focusing on factors influencing local collaborative CBDM strategies to enhance resilience to flood disasters. By comparing probit and logistic regression techniques, it incorporated importance and performance scores from IPA for deeper insights. Model adequacy was achieved through Log Likelihood Ratio and Akaike Information Criterion, revealing how knowledge, demographics, and attitudes impact these strategies (Sawaneh et al., 2024).

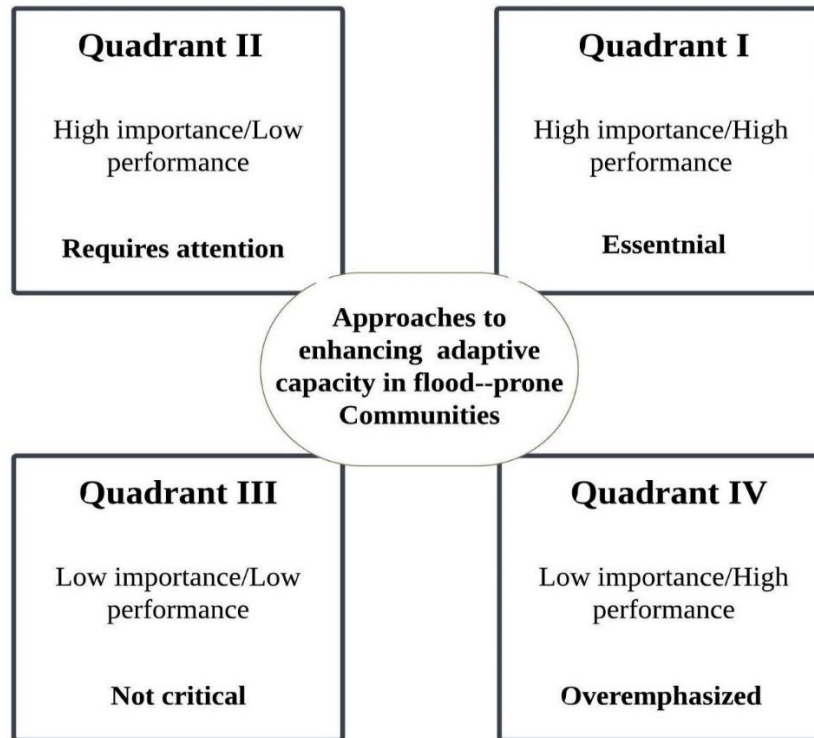


Fig. 2: IPA quadrant grid modified based on the works of (Matilla & James, 1977)

4. Results

This study compellingly argues that grasping community perceptions of flood management strategies is vital, as it uncovers their essential qualities and fosters more effective, context-driven disaster response initiatives. As shown in Table 2, the results from an exploratory factor analysis reveal the connections between various attitudes toward flood disaster management and efforts involved in CBDM. The model accounts for 94% of the total variance. The first identified factor is labelled *Community disaster readiness and action*. Key interactions in this domain encompass (i) adopting and applying early warning systems at both community and district levels, (ii) active participation in disaster educational initiatives addressing hazards and risks, (iii) resource sharing (including shelters and essential post-disaster items), and (iv) contributions to policy development focused on action. The significant factor loadings highlight the essential role of these strategies in shaping community attitudes toward flood disaster management and fostering collaborative engagement in CBDM initiatives. The second identified factor, *Environmental awareness and risk management*, includes indicators focusing on (i) impact reduction, and (ii) environmental mitigation and coping strategies. The impact reduction indicator reflects the community's perceived understanding of flood disaster risks and associated hazards, which drives proactive measures to alleviate potential impacts. On the other hand, the environmental mitigation and coping strategy indicator involves NbS initiatives collaboratively implemented by NGOs and government entities to alleviate flood-related effects. These initiatives encompass activities such as forest restoration, establishment of woodlots, and conservation of water resources.

Table 2 Attitude towards flood disaster management and collaborative efforts in attaining community-based disaster management.

Factor	Indicator	Factor loading	Eigenvalue	Variance Explained (%)	Reliability coefficient
Community disaster readiness and action	Early warning systems usage.	0.980	4.443	74	0.979
	Disaster civic education.	0.941			
	Sharing of resources.	0.969			
	Policies.	0.951			
Environmental awareness and risk management	Impact reduction (NbS).	0.640	1.224	20	0.835
	Environmental mitigation and coping strategy	0.588			

Model properties: Kaiser-Meyer-Olkin Measure of Sampling Adequacy: 0.785, Bartlett's; Test of Sphericity: Approx. Chi-Square 11919.544, (p-value less than 0.001); Total variance explained: 94.451%

Table 3 and Figure 3 present three groups: the High-engagement CBDM group, the Support-level CBDM group, and the Low-engagement CBDM group. These groups exhibit varying levels of involvement with different disaster management strategies and their efforts toward floods impacts. The study assigned these classifications post-hoc based on distinct patterns observed in respondents' engagement with the available strategies and collaborative CBDM initiatives. Before delving into the unique characteristics and behavior of the three identified clusters, it is crucial to clarify that these groups were established based on their responses to six essential attitudes: utilization of early warning systems, involvement in disaster civic education, resource sharing, policy implementation, reduction of impact through disaster risk and hazard awareness, and the application of NbS strategies. These attitudes form the backbone of the study's cluster analysis, enabling the classification of community responses into distinct segments that represent varying levels of engagement and perceptions regarding CBDM.

Table 3 Results of cluster analysis with High engagement CBDM group, Support level CBDM group, and Low engagement CBDM group

Factor	Cluster			F
	Cluster I N=484	Cluster II N=214	Cluster III N=314	
<i>Community disaster readiness and action</i>	0.3244	0.14360	-0.5980	100.298*
<i>Environmental awareness and risk management</i>	0.8866	0.0492	-1.4002	35142.154*
Cluster name	High engagement CBDM group	Support level CBDM group	Low engagement CBDM group	

Note: P is significant at $p < 0.05$

The results of the descriptive analysis indicated significant differences in how each cluster interacted with these six key attitudes, highlighting diverse priorities and needs within the flood disaster community. This categorization sheds light on how different community segments relate to disaster management efforts and their varying interest levels in collaborative approaches to flood CBDM. Understanding these dynamics is vital for developing targeted strategies to increase engagement within each group, particularly in adaptive capacity programs (see Table 4). By recognizing and addressing the unique needs of these segments, we can foster greater participation and ultimately enhance the effectiveness of disaster management initiatives. For instance, individuals in the Support level CBDM group reported high engagement with early warning systems, disaster civic education, resource sharing, and policy enactment mainly due to past flood experiences that prompted them to take action in flood management. This group also demonstrated a stronger willingness to work in tandem with government and NGOs in adaptive capacity strategies aimed at enhancing flood resilience. On the other hand, the High engagement CBDM group, apart from engaging with early warning systems, resource sharing, and policy enactment, made partial contributions to impact reduction through hazard and risk awareness, environmental mitigation, and coping strategies while collaborating closely with the government and NGOs. This group exhibited a proactive approach to disaster management, suggesting sustainable strategies that not only strengthen flood resilience in the short term but also pave the way for long-term risk reduction through coordinated adaptation effort. The Low-engagement CBDM group revealed minimal involvement and perceived willingness to participate in flood CBDM across multiple attitudinal dimensions.

346 **Table 4** Differences in attitude items and selected demographics across the three clusters

Items	Response	High engagement CBDM group (%)	Support level CBDM group (%)	Low engagement CBDM group (%)	Chi-square statistics
Usage of early warning systems	SD	0.0	0.0	9.2	$\chi^2=2024.000$, df=6, p<0.001
	Dis	0.0	0.0	21.8	
	N	0.0	0.0	0.0	
	Ag	0.0	21.1	0.0	
	SA	47.8	0.0	0.0	
Disaster civic education program	SD	47.8	0.0	0.0	$\chi^2=2024.000$, df=4, p<0.001
	Dis	0.0	0.0	0.0	
	N	0.0	0.0	31.0	
	Ag	0.0	21.1	0.0	
	SA	0.0	0.0	0.0	
Sharing of resources	SD	0.0	0.0	12.3	$\chi^2=2024.000$, df=8, p<0.001
	Dis	0.0	0.0	8.8	
	N	0.0	0.0	10.0	
	Ag	0.0	21.1	0.0	
	SD	47.8	0.0	0.0	
Policies	SD	0.0	0.0	0.0	$\chi^2=2024.000$, df=4, p<0.001
	Dis	0.0	0.0	31.0	
	N	0.0	0.0	0.0	
	Ag	0.0	21.1	0.0	
	SA	47.8	0.0	0.0	
Impact reduction through disaster	SD	0.0	0.0	0.0	
	Dis	0.0	0.00	6.9	
	N	43.5	21.1	24.1	
	Ag	4.3	0.0	0.0	

hazards and risk awareness	SA	0.0	0.0	0.0	$\chi^2=211.226$, df=4, p<0.001
Environmental mitigation and coping strategy (NbS)	SD	0.0	0.0	0.0	
	Dis	0.0	0.0	5.5	$\chi^2= 139.693$, df=4, p<0.001
	N	47.0	21.1	25.5	
	Ag	0.8	0.0	0.0	
	SA	0.0	0.0	0.0	$\chi^2= 46.273$, df=2, p<0.001
Working in tandem with government and NGOs	Yes	32.8	16.7	27.7	
Age	18-35 years	19.1	6.9	13.8	$\chi^2= 7.491$, df=2, p<0.001
	36+ years	28.8	14.2	17.2	
Education	Illiterate	0.0	11.1	2.4	$\chi^2= 362.550$, df=2, p<0.001
	Literate	47.8	10.1	28.7	

Note: SA= Strongly agree, Ag= Agree, N= Neutral, Dis=Disagree, SD= Strongly disagree

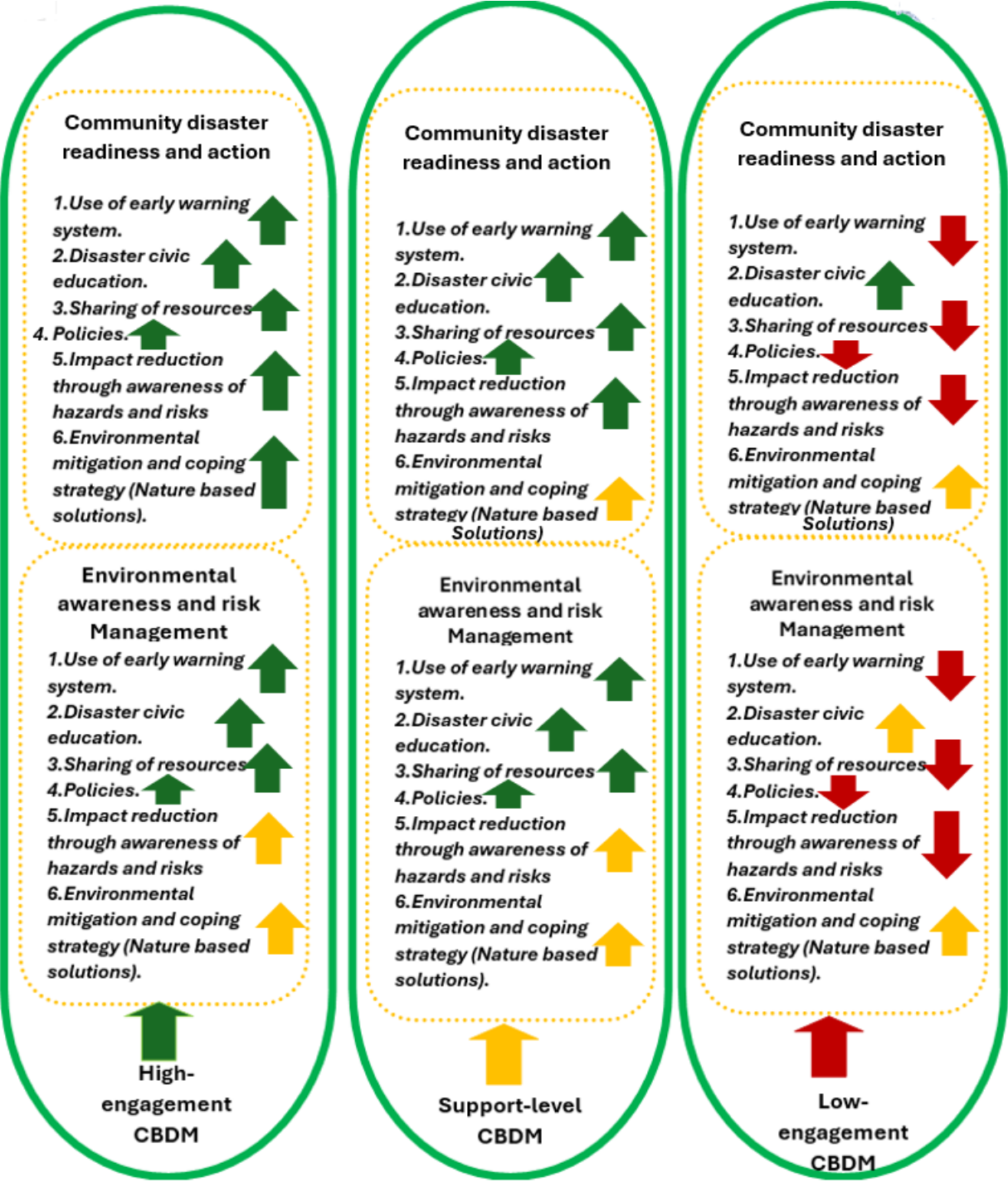


Fig. 3: Visualization of cluster analysis highlighting three distinct classifications

Note Green color represents outstanding performance, yellow indicates adequate performance, and red, highlights areas in need of improvement

The paired sample t-test is a statistical approach for comparing the means of two interrelated samples (refer to Table 5). In this analysis, it was used to evaluate the importance and performance metrics of critical indicators across varying clusters. The results indicated significant variations in the importance and performance values for each key indicator, evidenced by a p-value under 0.01, which confirms statistical significance. Additionally, the paired sample t-test revealed that the rankings of these key indicators differed from one cluster to another, suggesting unique program preferences. To further explore these discrepancies, an importance-performance analysis grid was used to clearly show how key indicators relate to their importance and performance levels across different clusters. Figure 4 highlights the prioritization of specific indicators within flood CBDM. These include the promotion of mass media campaigns (*mass media*), the implementation of emergency drills (*drills*), and the change of attitudes toward integrating Indigenous knowledge systems into policy frameworks (*Change of attitude*). Notably, only the Low-engagement CBDM group agreed that the mentioned indicators are *overly emphasized*, placing them in Quadrant IV. In contrast, indicators such as the provision of construction loans to improve access to social services and shelters (*loans*), promoting construction of dykes to prevent destruction of houses and social services (*dykes*), the establishment of food storage facilities in upland areas for the benefit of lowland residents (*food storage*), the strengthening of knowledge sharing among institutional authorities and community members (*information*) and creating platforms for integrating knowledge systems at policy level (*Knowledge integration*) were identified as crucial. These indicators, along with promoting the collaboration of stakeholders to convince vulnerable communities to relocate (*Relocation*) and the *drills*, are placed in Quadrant II. Interestingly, all clusters agreed on the need to prioritize *loans and dykes*. Meanwhile, the Low engagement and Support level CBDM groups identified *food storage* as requiring more focus. Similarly, the High engagement and Support level CBDM groups agreed on the importance of *information*. The High-engagement CBDM group uniquely emphasized the need to address *relocation* and the conduction of *drills* in schools and communities, signalling these as critical areas needing further attention. The *knowledge-integration* and *relocation* strategies were not considered critical by the Support level and Low-engagement CBDM groups, placing these indicators in quadrant III. Both the High engagement and Support level CBDM groups similarly agreed that *change of attitudes* toward IKS and incorporating their use at the policy level should not be prioritized, resulting in their placement in quadrant III as well. Furthermore, the High-engagement CBDM group viewed *food storage* as a lower priority. In contrast, the Low-engagement CBDM group regarded *information* as a non-essential issue. Both indicators were placed in quadrant III, reflecting a shared view across these groups that these strategies do not require urgent attention. Lastly, all three clusters, the High engagement CBDM, Support Level CBDM, and Low engagement CBDM groups, agreed that promoting cash-for-work programs (*Cash for work*) is essential, categorizing it in quadrant I. The High-engagement CBDM and Support-level CBDM groups also recognize *mass media* as a crucial strategic indicator. However, the Support level CBDM group additionally views *drills* as an essential strategy for disaster preparedness, placing it in quadrant I. This indicates a shared recognition of the importance of community engagement in disaster management, while highlighting some differences in the specific strategies each group prioritizes (see figure 4).

398 **Table 5** Paired sample t-test between Importance-Performance levels of adaptive capacity indicators strategies for each cluster

Indicator		Importance	Rank (I)	Performance	Rank (P)	T-Value	P-value
No.	High engagement CBDM group (n=484)						
1	Provision of construction loans to facilitate access to social services and shelters.	4.776	4	1.4814	7	114.448	0.000
2	Promoting construction of dykes to prevent destruction of houses and social services.	4.927	2	3.824	3	36.861	0.000
3	Promoting cash for work	4.927	2	1.5331	6	41.804	0.000
4	Establishing food storage facilities in the uplands for lowlands residents.	1.3946	9	1.4876	5	-3.024	0.003
5	Strengthening information gathering and sharing among institutional authorities and community members.	4.6777	5	1.6240	4	94.836	0.000
6	Promoting collaboration of stakeholders to convince vulnerable communities to relocate.	4.3781	7	1.5269	6	90.242	0.000
7	Conducting emergency drills in schools and communities.	4.4008	6	4.0000	1	77.520	0.000
8	Enhancing public awareness programs through Mass media.	4.933	1	3.900	2	35.190	0.000
9	Creating platforms for integrating knowledge systems at policy level	4.5393	3	1.2293	10	111.381	0.000
10	Changing of attitudes towards Indigenous knowledge systems and inclusion of its usage at policy	2.000	8	1.384	9	40.287	0.000
	Support level CBDM group (n=214)						
1	Provision of construction loans to facilitate access to social services and shelters.	4.883	3	1.0514	10	120.693	0.000
2	Promoting construction of dykes to prevent destruction of houses and social services.	4.621	6	1.4626	7	21.670	0.000
3	Promoting cash for work e.g., installing sandbags and building community dikes.	4.78	4	4.065	3	11.265	0.000
4	Establishing food storage facilities in the uplands for lowlands residents.	4.9953	1	1.0748	8	211.590	0.000
5	Strengthening information gathering and sharing among institutional authorities and community members.	4.6402	5	1.3972	9	86.980	0.000

6	Promoting collaboration of stakeholders to convince vulnerable communities to relocate.	1.4720	9	1.6682	6	-3.143	0.002
7	Conducting emergency drills in schools and communities.	4.046	7	4.9299	1	-23.196	0.000
8	Enhancing public awareness programs through Mass media.	4.696	2	3.976	4	21.909	0.000
9	Creating platforms for integrating knowledge systems at policy level	1.929	8	1.0748	8	29.421	0.000
10	Changing of attitudes towards Indigenous knowledge systems and inclusion of its usage at policy	1.000	10	1.7150	5	-23.114	0.000
Low engagement CBDM group (n=314)							
1	Provision of construction loans to facilitate access to social services and shelters.	4.6879	3	1.3949	10	91.555	0.000
2	Promoting construction of dykes to prevent destruction of houses and social services.	4.7739	2	1.3248	7	41.617	0.000
3	Promoting cash for work e.g., installing sandbags and building community dikes.	4.955	1	3.929	3	27.588	0.000
4	Establishing food storage facilities in the uplands for lowlands residents.	2.9522	4	1.5605	8	11.510	0.000
5	Strengthening information gathering and sharing among institutional authorities and community members.	1.3535	7	1.5732	9	-4.044	0.000
6	Promoting collaboration of stakeholders to convince vulnerable communities to relocate.	1.4331	6	4.7643	6	-2.825	0.005
7	Conducting emergency drills in schools and communities.	1.1146	8	5.0000	1	-	0.000
8	Enhancing public awareness programs through Mass media.	1.369	5	4.939	4	113.588	0.000
9	Creating platforms for integrating knowledge systems at policy level	2.000	9	3.9904	8	-	0.000
10	Changing of attitudes towards Indigenous knowledge systems and inclusion of its usage at policy	1.000	10	3.990	5	127.581	0.000
						61.499	0.000
						-68.199	0.000

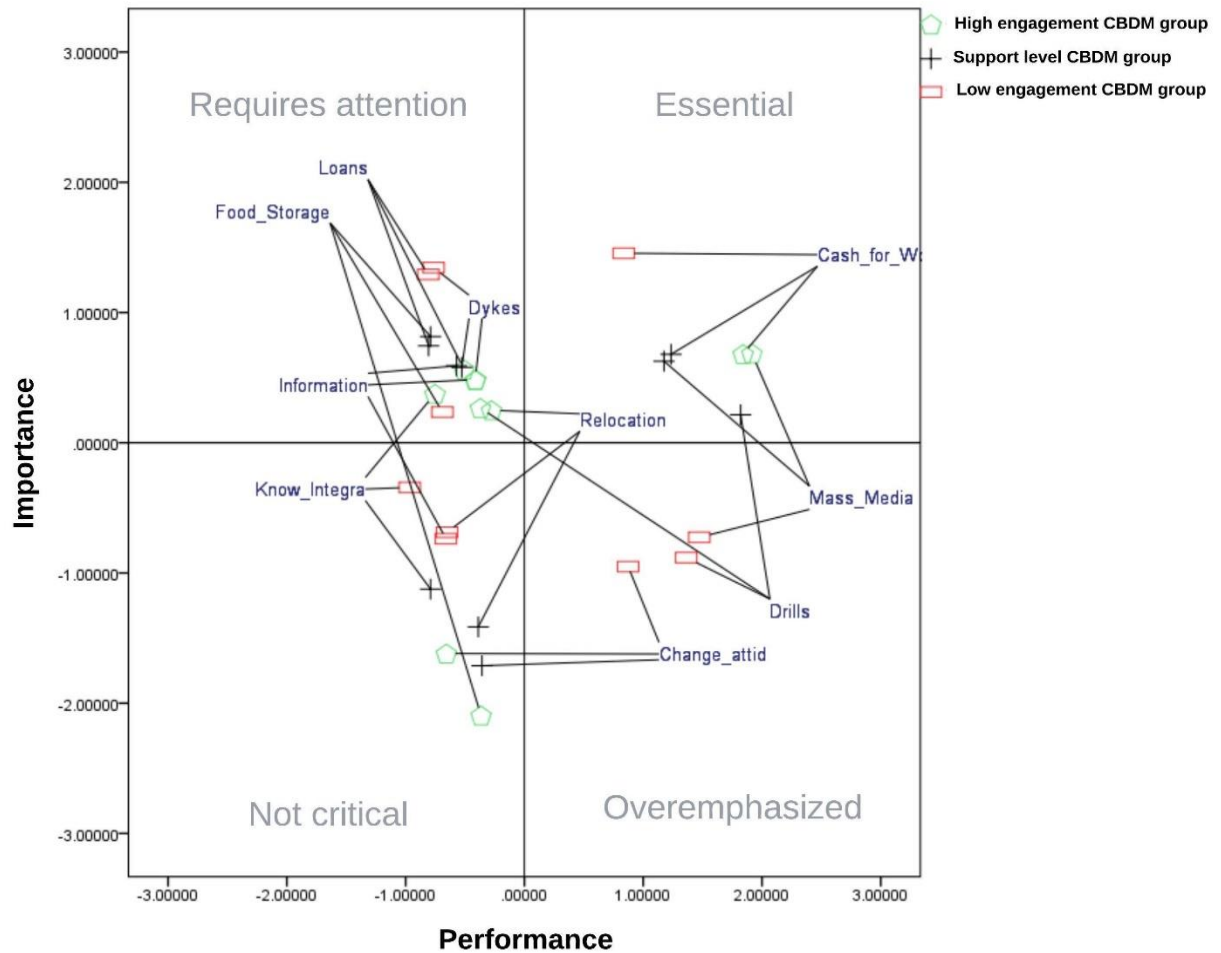


Fig. 4 IPA diagram showcasing adaptive capacity strategy indicators across clusters

Table 6 presents the results from the probit and logit models, which illustrate varying levels of engagement with collaborative adaptive capacity strategies (indicators) designed to achieve flood resilience. The results reveal that resource sharing, participation in policy formulation, impact reduction (i.e., awareness of disaster risks and the ability to take action), and environmental mitigation and coping strategies significantly influence the model ($p < 0.01$). In contrast, early warning systems and disaster civic education do not have a statistically significant effect ($p < 0.1$). Additionally, collaboration with government and NGOs, along with factors such as age and education, show significant positive associations ($p < 0.01$), suggesting a higher level of engagement. Regarding the clusters, the Low-engagement CBDM group exhibits a strong inclination to participate in collaborative adaptive capacity strategies ($p < 0.01$).

Table 6 Probit and logit models assessing the collaborative engagement in the adaptive capacity strategies aimed at floods resilience

Variable name	Probit model				Logit Model			
	(Model I)		(Model II)		(Model III)	(Model IV)		
	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error	Coeff.	Std. Error
Constant	-3.7611***	0.4127	-0.7539	0.5183	-6.5747***	0.7467	-1.3692	0.8999
Use of early warning systems (1 denotes a score more than 3 on Likert scale, otherwise 0)	-0.1461	0.1519	-0.14051	0.1524	-0.2088	0.2648	-0.1966	0.2657
Civic education (1 denotes a score of more than 3 on Likert scale, otherwise 0)	-0.08874	0.1566	-0.01493	0.1529	-0.17823	0.2681	-0.0521	0.2617
Sharing of resources (1 denotes a score of more than 3 on Likert scale, otherwise 0)	-0.7531***	0.1893	-1.1271***	0.24090	-1.3395***	0.3200	-1.999***	0.4152
Policies (1 denotes a score of more than 3 on Likert scale, otherwise 0)	0.45025***	0.1529	0.4705***	0.1537	0.8221***	0.2855	0.8599***	0.2865
Impact reduction (1 denotes a score of more than 3 on Likert scale, otherwise 0)	0.72954***	0.1893	0.7252***	0.1848	1.2853***	0.3333	1.2879***	0.3354
Environmental mitigation and coping strategy (1 denote a score of more than 3 on Likert scale, otherwise 0)	0.33761***	0.1297	0.3663***	0.1308	0.5655**	0.2330	0.6126***	0.2350

Working in tandem with government and NGOs (1 is yes, otherwise 0)	0.6127***	0.1440	0.6174***	0.1449	1.0657***	0.2693	1.0688***	0.2865
Age (1 is 36 years and above, otherwise 0)	0.2865***	0.0977	0.2751***	0.0979	0.5151***	0.1694	0.4962***	0.1698
Education (1 is literate, otherwise 0)	0.8173***	0.2088	0.7871***	0.2004	1.4577***	0.3600	1.4294***	0.3506
Cluster classes (1 is high engagement group, otherwise 0)	-0.5129***	0.1184	-0.5444***	0.1193	-0.8821***	0.2027	-0.9376***	0.2038
Mean Importance of adaptive capacity	1.8146***	0.4470	-	-	3.1472***	0.7583	-	-
Mean Performance of adaptive capacity	-	-	-6.023***	1.2938	-	-	-10.4870**	2.2370
AIC ¹	994.7		988.9		996.2		990.3	
AIC/N	0.983		0.977		0.984		0.979	
LLR ²	118.9		124.7		117.4		123.3	
Chi-square Value	$\chi^2 (12,0.01) = 26.217$							

414 **Note** ***, **, * = Significance at 1%, 5%, 10% level. 1 Akaike Information Criterion, 2 Log Likelihood Ratio

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5. Discussion

5.1 The significance of tailoring adaptive capacity strategies through community engagement

Drawing from the results. The High-engagement CBDM group, the Support-level CBDM group, and the Low-engagement CBDM group represent distinct stakeholder categories within communities, each with unique interests and perspectives regarding strategies to enhance adaptive capacity in flood-prone areas. Communities with low engagement in flood CBDM, often situated near disaster-isolated regions, lack an understanding of the benefits of collaboration due to limited resources and insufficient knowledge about disaster management. Despite this, their proximity to these high-risk areas makes them directly vulnerable to the adverse impacts of floods. Therefore, it is crucial to actively engage these communities in collaborative flood CBDM initiatives and enhance their awareness. The Support-level CBDM group, consisting mainly of smallholder farmers and fishermen, is closely tied to natural resources such as arable land and water from the lake Malawi. Their livelihoods depend on rainfall for agricultural production and the lake for fishing, making them susceptible to flood risks. As a result, they require ongoing access to early warning systems, weather information, and knowledge about potential flood hazards. Involving this group in collaborative flood CBDM strategies is essential for enhancing their capacity to manage floods, reduce risks, and maintain economic stability. The High-engagement CBDM group is well-informed about the significance of risk awareness and preparedness (Gammoh et al., 2023). They understand that enhancing the design and delivery of flood preparedness training and fostering greater trust in governmental communicators can help citizens, including marginalized groups, become better equipped to handle floods. This group is crucial in advocating for collaborative flood CBDM efforts to build adaptive capacity and achieve flood resilience. Their expertise and commitment are instrumental in promoting adopting practices that ensure the long-term sustainability of collaborative CBDM strategies, benefiting both the land and the communities. By implementing collaborative flood CBDM, communities can bridge the gap between locals, planners, and administrators, facilitating the creation of locally driven solutions, the sharing of best practices, the promotion of equitable planning, the formation of grassroots alliances, and the practice of adaptive measures to enhance resilience and sustainable development (Lin & Lee, 2024).

5.2 Community's managerial impact on perceptions of the importance and performance analysis of adaptive capacity strategies

The importance-performance responses revealed that specific adaptive capacity-building strategies such as *drills*, *mass media*, and *change of attitude* were perceived as *overly emphasized* by the Low-engagement CBDM group. The Low-engagement CBDM group faces substantial challenges in building adaptive capacity for effective flood management. High poverty levels within these communities limit access to essential communication tools such as radios, televisions, and smartphones, restricting their ability to receive timely early warnings and critical flood-related information. In addition, knowledge gaps and low awareness diminish their understanding of the importance of *drills*, which are vital for improving preparedness and response to flooding. To foster community engagement and drive behavioral change, agencies should adopt complementary strategies and integrate their use at the policy level. For instance, prioritizing, face-to-face engagement within these strategies facilitates community-led initiatives, bridges existing gaps through openness in sharing views and ideas, and enhances overall resilience (Ryan et al., 2020).

Strategies such as *information* and *relocation* are primarily implemented by social organizations including NGOs. These organizations facilitate skills development and provide financial support at the grassroots level. Surprisingly, both the Low-engagement and Support-level CBDM groups view '*relocation*' as a non-critical issue. This perspective may stem from ineffective risk communication, where the exchange of information failed to generate a positive response. To enhance the effectiveness of flood-related disaster responses, communication and relief efforts should draw upon insights into the communities' prior experiences, perceptions, and communication practices (Wirz et al., 2023).

Additionally, both the High-engagement and the Support-level CBDM groups viewed the need to *change attitudes* toward IKS as a *non-critical issue*. This is because they regard scientific knowledge as a more effective and reliable means of early warning in flood risk management rather than solely relying on IKS. A clear divide between local and scientific knowledge persists, necessitating a critical re-evaluation of community-based approaches to ensure they achieve transformative outcomes (Šakić Trogrlić et al., 2022). Integrating distinctive and context-specific IKS with other evidence-based frameworks could significantly enhance the effectiveness and sustainability of climate change adaptation strategies among these low-income communities (Makondo & Thomas, 2018).

All three groups—High engagement CBDM, Support level CBDM, and Low engagement identified "*Loans*" and "*Dykes*" as requiring attention for building adaptive capacity, especially for vulnerable populations. *Loans* are particularly vital for low-income households, such as smallholder farmers and fishermen, who depend on precarious livelihoods vulnerable to floods. Construction loans are vital for developing robust infrastructure, including housing and hospitals, which are essential for promoting community well-being. Accessible health and psychosocial support services correlate with improved flood resilience, enhancing communities' recovery capacity (Dewa et al., 2022). In Bangladesh, well-managed loan programs have effectively empowered women and fostered collective action for flood adaptation (Naz & Doneys, 2022).

The community's placement of *dykes* as *essential* underscores its ultimate significance. Promoting the maintenance of existing dykes, along with reducing harmful human activities that impact the natural environment that enhances the dykes, should be a focus of public education programs. Dykes play a key role in floodplain management, community protection, and agricultural productivity. By increasing floodplain areas, dykes help reduce flow velocities and volumes, lowering the risks, hydrologic loading, saturation, and overtopping (Smith et al., 2017).

The High-engagement CBDM group highlights "*relocation*" as a priority due to increased awareness of disaster risks from past floods, recognizing the challenges for vulnerable communities. Successful *relocation* efforts can be supported through compensation programs and communication strategies that address emotional and risk-related concerns (Seebauer & Winkler, 2020). In contrast, the Support-level CBDM group emphasizes the importance of reliable disaster "*information*" in building adaptive capacity, essential for improving preparedness and resilience against flood risks. It is critical that educational programs are increased by management towards such efforts. The identification of *CFW* as an "*essential strategy*" emphasizes the role of public works in post-disaster recovery. In Japan, *CFW* positively engaged evacuees in community reconstruction (Nagamatsu, 2014), thereby fostering resilience. *CFW* enables locals to support

their community while obtaining economic relief, making it crucial for management to ensure high performance, especially in resource-constrained developing countries.

5.3 Factors affecting collaborative community engagement to enhance flood resilience

The initiatives from Table 6 promote responsibility and collaboration in flood adaptation; for instance, sharing economy platforms like Airbnb play a crucial role in disaster response by offering essential resources such as shelter and transportation (Wong & Shaheen, 2019). From the results, flood early warning systems often fail to be effective due to a lack of community involvement, leading to mistrust and inadequate addressing of local needs. In addition, financial constraints and poor infrastructure hinder timely warnings, especially for low-income populations (Mwalwimba et al., 2024). Enhancing flood early warning systems requires community integration in system development and securing the necessary resources to address these challenges. Disaster civic and educational programs have shown limited impact on collaborative engagement in flood resilience strategies, possibly due to mismatched content, ineffective communication methods, and personal values (Sawaneh et al., 2024). This highlights the need for better evaluation of program design to align with local cultural contexts. Again, the study demonstrates that age and education are crucial for enhancing community collaboration and adaptive capacity. Older individuals offer invaluable insights from their experiences with floods and traditional coping strategies, while educated individuals excel at identifying vulnerabilities and crafting innovative solutions. Combining the wisdom of experience with the creativity of education is essential for effectively tackling challenges and building stronger, more resilient communities (Liu et al., 2014). The findings reveal that the Low-engagement CBDM cluster is more willing to collaborate than both the Support level and High-engagement CBDM clusters. This may be due to the dire need among the Low-engagement CBDM group to focus on protecting natural resources in isolated areas to secure economic benefits. In contrast, the Support and High-engagement groups prioritize enhancing broader disaster management objectives. This underscores the importance of creating adaptive strategies that address vulnerabilities, promote shared responsibilities, and showcase the long-term advantages of community teamwork in managing flood disasters.

6.0 Conclusion

This study focuses on the critical need to adapt disaster management strategies to community contexts to boost adaptive capacity, especially in developing and resource-limited regions. It uses cluster analysis to categorize community groups involved in flood mitigation efforts. Through IPA, managerial strengths and weaknesses are assessed, while binomial regression reveals key factors for improving regional flood management. The proposed framework delineates straightforward actions for effective implementation. Figure 5 framework illustrates initiatives, such as early warning systems, disaster civic education, sharing of resources, policies, impact reduction through hazards-risk awareness and NbS essential for fostering stakeholder understanding and involvement in adaptive capacity for flood resilience. Effective disaster management requires a solid foundation built on collaboration among local governments, NGOs, and communities. Short- to medium-term actions are essential for initiating proper flood disaster responses. Key activities should focus on establishing emergency communication channels and tailored adaptive capacity programs. The framework also emphasizes long-term strategies

supported by strong policies to increase community resilience against future floods. It identifies three stakeholder groups Low-engagement, Support-level, and High-engagement CBDM groups each with different engagement levels and views on adaptive initiatives, critical for strategy customization. Connecting strategies to importance-performance dimensions shown in the cyclic flow chart aims to optimize adaptive capacity efforts. This approach underscores stakeholder participation and reinforces collaborative flood resilience, especially in resource-constrained settings. The emphasis on educational initiatives to empower local disaster prevention leaders, like volunteers and informed residents, is crucial for fostering long-term commitment. This integrated approach ensures effective disaster management and supplies a customizable framework to tackle regional challenges.

The implications of this study align with several Sustainable Development Goals (SDGs), particularly SDG 11: Sustainable Cities and Communities, by advocating for adaptive capacity strategies and Nature-Based Solutions (NbS) to build resilient, sustainable communities capable of withstanding flood risks. It also supports SDG 13: Climate Action, emphasizing flood resilience, environmental mitigation, and climate adaptation strategies to combat climate change and its impacts. Furthermore, the study advances SDG 17: Partnerships for the Goals, highlighting collaboration among local governments, NGOs, and communities in implementing effective disaster resilience strategies.

The ten indicators employed in this study are all grounded in the five dimensions of adaptive capacity proposed by Cinner et al. (2018). The results obtained from the research in Malawi are compelling; however, it is essential to approach their relevance to other regions and countries with care. Discrepancies in adaptive capacity policies often arise from social and cultural factors, including traditional taboos (Cinner et al., 2018) and socioeconomic differences. Malawi's specific local conditions play a crucial role in shaping its adaptive strategies and the engagement of its communities. By analyzing similar contexts, we can better assess the broader applicability of these findings. Additionally, a global perspective can help identify common themes and regional challenges related to adaptive capacity in the context of disasters such as flooding, as illustrated in Table 7 below.

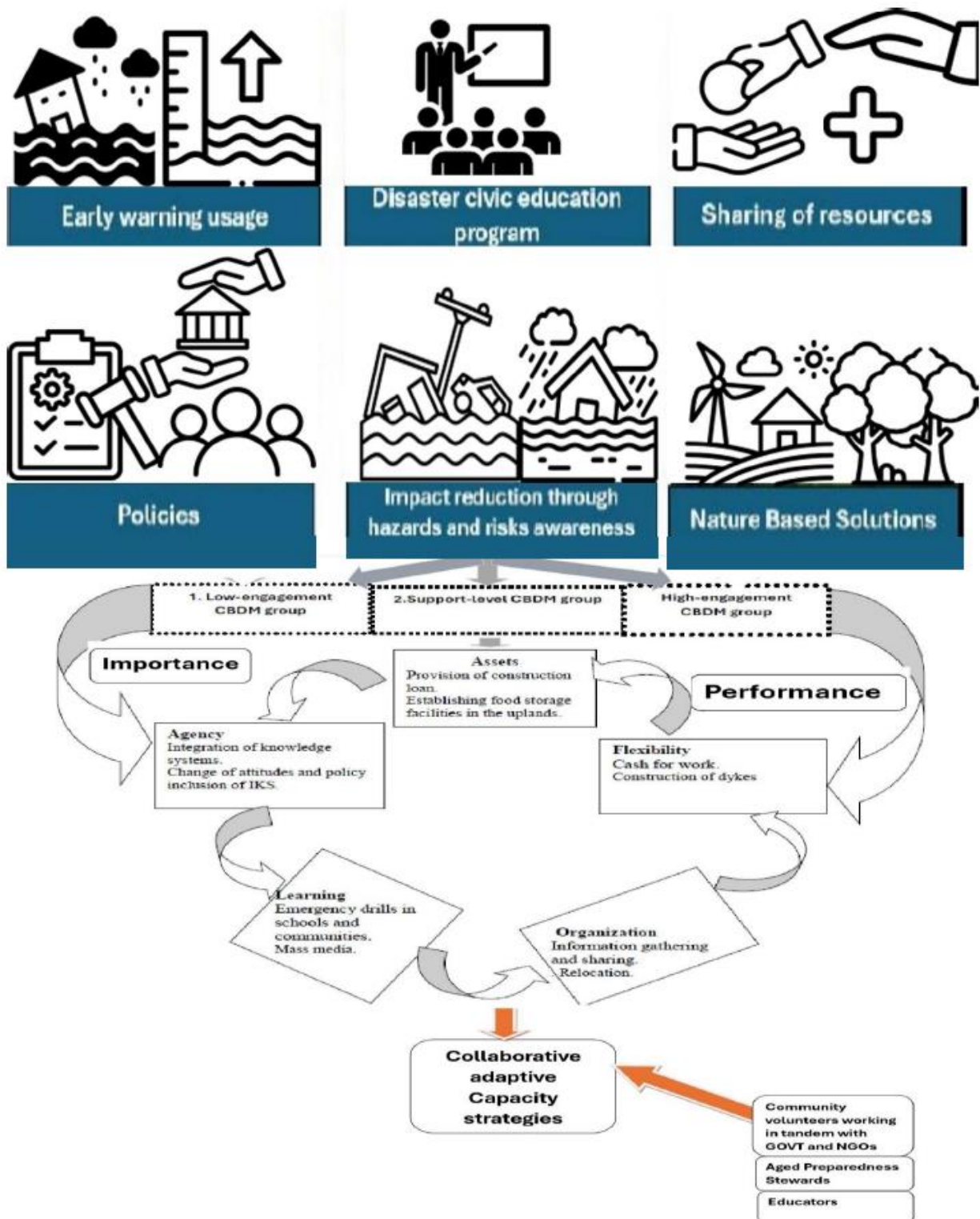


Fig. 5 Framework for strengthening adaptive capacity strategies to enhance resilience against floods.

Table 7: Universalizability of adaptation results

Indicator/Strategy	Malawi	Regional level: Southern African Development Community (SADC)	Similar African countries and other developing nations across the globe	Developed nations globally
Construction loans	Ensures that vulnerable populations have secured financial support for building and improving the standard of houses and shelters.	Enforces adaptive capacity and fulfilment of SDGs by member states (Chikodzi et al., 2024)	Used in Vietnam towards flood disaster adaptation (Anbumozhi et al., 2023)	--
Use of dykes	Needed as a proactive measure to protect homes and critical infrastructure.	Instrumental in controlling the floods and maintaining of Zambezi river for hydro-electric power (Chirashi, 2014)	Used to protect vulnerable populations in Indus Plain of Pakistan (Gul et al., 2024)	Widely implemented in developed countries within the European Union (EU) including Spain, Portugal and Greece (Dottori et al., 2023)
Cash for work	Fosters community engagement and economic gains by offering financial incentives for local disaster prevention participation.	--	Implemented in poverty-stricken regions of Indonesia (Fitritia & Matsuyuki, 2022).	--
Food storage facilities in the uplands	Enhances food security by creating storage options that protect supplies from potential floods.	Maintains a repository of seeds, seedlings, and food for subsequent use (Rakotobe et al., 2016)	Used in the floodplain zones of Brazil (Vieira da Cunha Ávila et al., 2022)	--
Information gathering and sharing among institutions	Strengthen disaster preparedness and response efforts.	Fortify SADC urban resilience against similar developmental challenges (Ndebele-Murisa et al., 2020).	Widely implemented to develop West African cities such as Accra in Ghana (Ibrahim et al., 2023)	Implemented in Texas, USA (Bezboruah et al., 2024)
Relocation of vulnerable communities	Significantly reduces the likelihood of loss of life, property and injury during floods.	Crucial as a last resort measure for authorities aiming to maintain safety in densely populated regions (Stal, 2011).	Highly recommended in Latin America and the Caribbean (Francis, 2021).	Implemented in the United States of America (Pinter, 2021).
Emergency drills in schools and communities	Increase preparedness and ensures that individuals know how to react during emergencies, promoting safety awareness.	Assists in testing and validating the planning assumptions (SADC, 2017).	Implemented in the Philippines (Cubillas et al., 2022).	Widely used in Australia (Dufty, 2018).

Mass media	Educates the public about disaster risks and preparedness strategies, fostering a more informed community.	Helps in regional disaster preparation (Mafofo et al., 2021).	Widely used in Africa (Mafofo et al., 2021)	Implemented in the United Kingdom (UK) (Cologna et al., 2017)
Platforms for integrating knowledge systems at policy level	Creates platforms that combine scientific knowledge with local experience to formulate more comprehensive and effective policies.	Approaches like agroforestry strengthen resilience by lowering the risk of flooding (Madlela, 2022)	Used in the coastal regions of Bangladesh (Choudhury et al., 2021).	Implemented in the Saskatchewan River Delta in Canada (Abu et al., 2020)
Change of attitudes towards Indigenous knowledge systems and inclusion of its usage at policy	Enhances resilience by respecting traditional wisdom and practices still employed in resource-limited districts.	Applied in school curriculum as channels to propel attitude change in policy (Madlela, 2022)	--	Conducted in New Zealand among Indigenous and non-Indigenous tribes (Blackett et al., 2022).

581

582 **Statements and Declaration**

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587 **Credit author statement:** All authors contributed to the study conception and design. Atupele
588 George Msongole– Conceptualization, Formal analysis, Writing – Original draft, Writing -
589 review and editing. Blessings Isaac Kanyangale– Writing – review and editing. Chung-Hung Lee
590 – Formal analysis, Writing – review and editing.

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