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Why Are Community-Based Early Warning Systems Inadequate? A Case Study of the Licungo River Basin, in Mozambique

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Abstract This study examined the effective implementation of a community-based early warning System (CBEWS) as an early evacuation tool in at-risk communities in the Licungo River Basin Mozambique. Using the United Nations Office for Disaster Risk Reduction (UNDRR) framework, this study evaluated the effectiveness of the CBEWS, focusing on the identification of factors that impede its functionality. The research employed a qualitative approach, conducting one-on-one interviews with key stakeholders at the national, provincial, and district levels, and group discussions with community members in the Licungo River Basin. Interviews and group discussions were conducted in Portuguese and Echuabo, facilitated by a local translator, and included a diverse representation of community members and leaders. The results revealed that the four pillars of the UNDRR framework - risk knowledge, monitoring and warning, communication and dissemination, and response capacity - lacked interdependence, resulting in the CBEWS failing to effectively facilitate early evacuation. Specifically, the study identified several critical factors: a lack of trust in the early warning system, inadequate monitoring and warning systems, communication challenges, and insufficient response resources. Additionally, the lack of social capital significantly affected community members' willingness to implement and respond to CBEWS warnings and voluntarily evacuate. These findings highlight the need to address social capital and use incentive-based approaches to enhance the effectiveness of the CBEWS. Therefore, promoting strategies that strengthen social capital and incorporate incentives is essential to ensure community engagement and effective evacuation.

Keywords: Licungo River Basis, Flood evacuation, Community-based early warning system, UNDRR framework

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1. INTRODUCTION

Natural hazards have had a substantial impact on Mozambique making it one of the nation's most severely affected by natural disasters worldwide. According to the INFORM Risk Index for 2021 and the Global Climate Risk Index for 2021, Mozambique face severe weather-related hazards and climate-related impacts from global warming (Aleksandrova, 2021; Eckstein et al., 2021). Different types of natural hazards are frequently registered in the country, including floods, cyclones, droughts, coastal erosion, rising water levels, earthquakes, and soil salinisation (Brida et al., 2013; National Institute for Disaster Management (INGC), 2014)

Floods are more likely to occur in Mozambique owing to its geographical configuration. As a coastal country, it is the gateway for many rivers that flow from inland countries to the Indian Ocean, including Tanzania, Malawi, Zimbabwe, Zambia, and South Africa (Duvail et al., 2017; Wesselink et al., 2015). Furthermore, several of its major rivers cause cyclical flooding,including Zambezi, Limpopo, Save, Buzi, and Pungue the intensity of which varies depending on rainfall in inland countries and the magnitude of tropical cyclones (Brida et al., 2013; Manjate et al., 2009). In addition to these international rivers, Mozambique also has a considerable number of flood-prone rivers.

Effective community-based early warning systems (CBEWSs) play an important role in reducing the risks posed by natural hazards in at-risk communities, particularly in developing countries such as Mozambique. A CBEWS is "an early warning system where communities are active participants in the design, monitoring and management of the early warning system (EWS), not just passive recipients of warnings" (Tarchiani et al., 2020). A CBEWS is a tool that assists in early evacuation (Macherera & Chimbari, 2016). Its implementation can substantially reduce disaster risk and loss of life, livelihood, and health, as well as the economic, physical, social, cultural, and environmental assets of individuals, businesses, communities, and countries (Wahlström, 2015).

Mozambique began implementing CBEWSs in the early 2000s when severe, deadly floods struck the areas of Maputo, Gaza, and Inhambane (Lumbroso et al., 2008). To mitigate disaster risks in flood-prone and cyclone-affected areas, the Mozambican government implemented a comprehensive approach for the most vulnerable communities situated along international rivers and coastal regions. However, Mozambique continues to suffer from significant human losses caused by repeated flooding, such as the 2019 cyclone Idai which killed over 1500 people, and resulted in hundreds missing (Mutasa, 2022; Nhamo & Chikodzi, 2021).

The policy framework for disaster risk reduction (DRR) in Mozambique is guided by the Master Plan for Disaster Risk Reduction 2017-2030 and the Law on Disaster Management (INGC, 2020). The Master Plan outlines the strategic vision for DRR, emphasizing the importance of strengthening early warning systems and enhancing community resilience. It aims to integrate DRR into sustainable development policies and planning to, ensure a proactive approach to managing disaster risks (Ministros, 2017). The Law on Disaster

Management provides the legal foundation for DRR activities and establis the roles and responsibilities of various stakeholders, including government agencies, local communities, and international partners. This law mandates the development and implementation of EWS across the country, prioritizing the involvement of local communities in disaster preparedness and response (INGC, 2020).

This study aims to explore why the CBEWS in Mozambique does not adequately reduce human loss based on a case study of the Licungo River Basin (LRB), which is located in central Mozambique and is prone to severe floods and cyclones. The remainder of this paper is organized as follows. Section 2 reviews the existing literature on CBEWSs. Section 3 introduces the United Nations Office for Disaster Risk Reduction (UNDRR) framework used as the analytical model and describes the methods used in this study. Section 4 provides an overview of the LRB, detailing its geographic and socioeconomic vulnerabilities as well as the impact of recent flooding events. Section 5 presents the field research results and identifies the factors that hinder the effective functioning of the CBEWS based on the UNDRR framework. Section 6 discusses the findings in the context of the existing literature. Finally, Section 7 concludes the paper and provides policy recommendations.

2. LITERATURE REVIEW

2.1 Concept and Significance of Community-Based Early Warning Systems

Many definitions of early warning systems have emphasized the vital role of community participation and have been supported and promoted by international frameworks and organizations, including the Sendai Framework for Disaster Risk Reduction (SFDRR) and the UNDRR. Macherara and Chimbari (2016) emphasized that community members are not passive recipients of warning signals at the local level, but are active participants throughout the entire process, starting from hazard identification and the formulation of EWS. In this participatory approach, community members play critical roles in the design, monitoring, and management of the EWS. Their involvement ensures that the system is tailored to the specific needs and context of the community, thereby enhancing its effectiveness and relevance in mitigating disaster risks (Hallegatte et al., 2016; Macherera & Chimbari, 2016; Marchezini et al., 2018).

Researchers agree that the active participation of local community members is necessary to ensure the efficacy of CBEWSs. Therefore, CBEWSs should be developed with careful attention to local contexts, with the primary outcome of incorporating CBEWSs being to provide communities at risk of disasters with the necessary information, knowledge, technologies, and skills to prepare for, mitigate, and respond to hazards and their effects (Macherera & Chimbari, 2016).

In the development of the CBEWS concept, two distinct approaches have emerged: the top-down approach, known as the ”first-mile” hazard-centered EWS, and the bottom-up approach, referred to as the “last-mile” people-centered EWS (Tarchiani et al., 2020). The first approach focuses on the collection, analysis, and processing of data and early warning messages to ensure that the CBEWS has accurate and timely information to initiate the warning process (Tarchiani et al., 2020; Uprety et al., 2018). It involves gathering data from meteorological agencies, satellites, sensor networks, and other monitoring systems, which are then evaluated, verified, and transformed into actionable warnings for decision making (de Leon, 2012; Tarchiani et al., 2020). In contrast, the “last-mile” approach represents the final stage of the information flow, where the early warning messages generated are effectively communicated to and received by at-risk communities (Smith et al., 2017; Tarchiani et al., 2020; Udu-gama, 2008). This phase is responsible for disseminating warnings to at-risk communities and facilitating their understanding and appropriate response. This involves the communication and delivery of warning messages through channels, such as sirens, mobile phones, community leaders, and local networks, including indigenous knowledge (Smith et al., 2017; Udu-gama, 2008).

The top-down and bottom-up approaches are not mutually exclusive; rather, they can be integrated to create a collaborative and feedback-driven cycle within the CBEWS (Marchezini et al., 2018; Sim et al., 2017; Tarchiani et al., 2020). Thus, the components within the CBEWS exhibit interdependence and rely on one another to ensure the overall effectiveness of the EWS (Sim et al., 2017; Tarchiani et al., 2020). Without a robust first mile, characterized by accurate and reliable information, the CBEWS would lack the foundation necessary for generating meaningful warnings (Collins, 2009; Tarchiani et al., 2020). Similarly, without an effective last mile, the warnings produced by the system would fail to reach and resonate with at-risk communities, rendering early warning efforts ineffective (Sufri et al., 2020; Tarchiani et al., 2020).

The CBEWS approach has been widely implemented and is considered around the world to be an effective method for reducing disaster risks at the community level, particularly in African countries, where people are more vulnerable to natural hazards. This has attenuated risks associated with natural disasters, including tropical cyclones, floods, droughts, tsunamis, and landslides (Braimoh et al., 2019; Cross & Societies, 2009; Golding, 2022; Mark et al., 2019). Studies in Africa have demonstrated that CBEWS can foster disaster risk reduction and management objectives by providing timely warnings to communities before disasters occur, thus saving lives and minimizing economic losses (Braimoh et al., 2019). Moreover, it can facilitate the development of effective communication channels between communities, local government, and other stakeholders involved in disaster risk management by promoting collaboration and coordination (Golding, 2022; Macherera & Chimbari, 2016; Sufri et al., 2020). Therefore, CBEWSs are cost-effective approaches that rely on local knowledge and resources, making them suitable for low-cost implementation and maintenance (Gladfelter, 2018). This aspect renders CBEWSs particularly appropriate for developing countries such as

Mozambique, which face financial constraints in disaster risk reduction (Lumbroso, 2018; Macherera & Chimbari, 2016).

The UNDRR suggests four pillars necessary for effective early warning systems: risk knowledge, monitoring and warning, communication and dissemination, and response capacity (Tarchiani et al., 2020). Some studies have evaluated the early warning systems in action based on the framework, whereas others have proposed a variety of technical and socio-political recommendations to improve the effectiveness of CBEWSs and facilitate early evacuation based on the framework. Researchers have actively sought to comprehend the impact and interrelationships among the pillars of the UNDRR framework as well as the influence of each component on the community (Macherera & Chimbari, 2016; Marchezini et al., 2018; Tarchiani et al., 2020).

For instance, Tarchiani et al. (2020) applied the UNDRR framework to evaluate EWS for floods along the Sirba River in Niger, emphasising the need to integrate hydrological forecasts and observation methods with community monitoring and preparedness systems. Similarly, Chinguwo (Chinguwo & Deus, 2022) revealed how the adverse consequences of a lack of capacity and essential resources hampered the operation of the UNDRR framework pillars in Malawi. Despite the Malawian government's endeavors to sustain the system, enhance the capacity of local communities, and implement more advanced technological solutions, this study revealed the prevalence of implementation failures in the CBEWS approach. These failures stemmed primarily from limited government funding and bureaucratic challenges encountered in the implementation process. Lumbroso (2018) examined the impact of government funding on the effectiveness of a CBEWS in Uganda, and indicated that the absence of sufficient financial resources allocated by the government hampered its effectiveness. Lumbroso (2018) suggested that effective flood EWSs for African countries, including Uganda, require the establishment of a robust scientific and technical foundation and prioritization of the protection of those at risk. Additionally, governments must allocate adequate funds to cover the recurrent costs of CBEWS implementation to ensure sustainability and long-term success (Lumbroso, 2018).

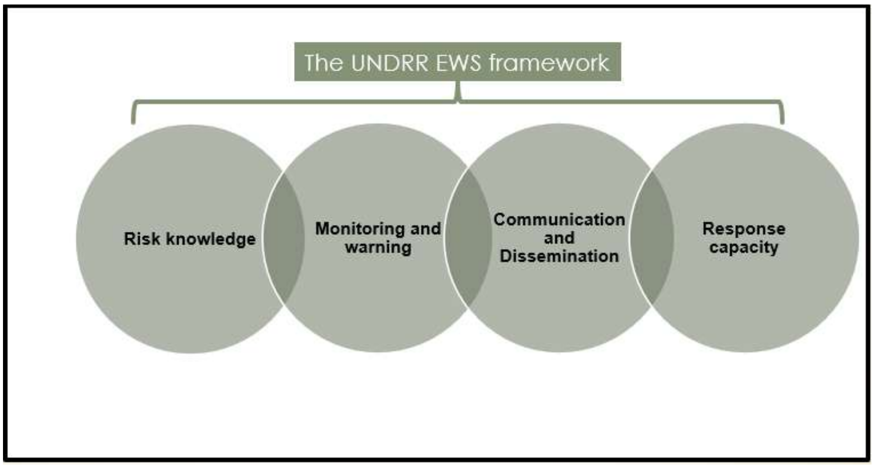
Notably, the utilization of CBEWS for flood evacuation in Mozambique, particularly in national rivers, has not been extensively studied in the existing literature. Most studies have primarily focused on the application of CBEWS to international rivers, which introduces complexity to these issues. These studies were mainly conducted in English by researchers from neighboring countries such as South Africa, Zimbabwe, Malawi, Tanzania, and Zambia (Manyena, 2013; Maripe et al., 2022; Wabanhu, 2017) and examined river basins such as Zambezi, Limpopo, Save, and Buzi, which span multiple countries and flow into the Indian Ocean (Kgomongoe & Meissner, 2003; Tumbare, 2005). However, the Licungo River, a national river in Mozambique, presents an appropriate case study for uncovering the inherent challenges in CBEWS implementation. Despite the involvement of the Mozambican government, international organizations, and non-governamental organizations (NGOs) in conducting institutional surveys on national rivers, the findings are not publicly available, resulting in a scarcity of research and limited understanding of CBEWS implementation in Mozambique, both at the national level and in the LRB.

3. RESEARCH METHODS

The research methodology was structured around the four pillars of the UNDRR framework: risk knowledge, monitoring and warning, communication and dissemination, and response capacity. To achieve a comprehensive understanding of the CBEWS in the LRB, we employed a combination of both individual and group interview.

3.1 Analytical Model: UNDRR Framework

The UNDRR framework consists of four essential pillars that guide the development and implementation of effective early warning systems: 1) risk knowledge, 2) monitoring and warning, 3) communication and dissemination, and 4) response capacity (Sufri et al., 2020; Tarchiani et al., 2020) (Figure 1). According to the UNDRR and SFDRR frameworks, a successful EWS depends on the positive interplay among its pillars, meaning that failure to manage one component will lead to the failure of the entire system (Tarchiani et al., 2020).



Source: Adapted from UNDRR Framework

Figure 1. The UNDRR Framework for the Early Warning System

Risk knowledge is integral to empowering communities to prepare for and proactively respond to floods. By gaining a comprehensive understanding of flood hazards and the associated risks and vulnerabilities, communities can foster a collective awareness that strengthens their ability to mitigate and manage these challenges. Utilizing risk knowledge and available resources and capacities, communities are equipped to implement appropriate preventive measures and respond effectively (Smith et al., 2017; Sufri et al.; Tarchiani et al., 2020).

Monitoring and warnings are essential to establish early warning and monitoring stations that are strategically positioned upstream to promptly detect and signal the onset or likelihood of a flood (Smith et al., 2017; Tarchiani et al., 2020). By employing monitoring and warning technology, communities can effectively notify downstream residents and initiate pre-flood evacuations (Macherera & Chimbari, 2016). Moreover, it is crucial to establish a clear threshold that triggers flood alerts to ensure that all community members, including the CLGRD, are aware of and understand the agreed-upon criteria. They must monitor and detect floods proficiently to consistently provide accurate, timely, and reliable warnings. Importantly, the concept of CBEWS does not restrict monitoring functions to the government exclusively, but shares it with the local community, which can monitor the level of water locally.

Communication and dissemination are critical for delivering warnings and messages to the at-risk individuals. The messages produced by either the government or the community must be disseminated through an information network to at-risk people. To ensure the effectiveness of a CBEWS, information must be clear, easily comprehensible, and disseminated through various sources and channels, including text (short message system (SMS) or bulletin), verbal/audio (radio, siren, telephone, or megaphone), and visual (television, flag, or sign) methods (Sufri et al., 2020; Tarchiani et al., 2020). Flood-warning information should encompass relevant details, such as location, scale, potential impact, probability, mitigation measures, and recommended response actions, including evacuation routes and designated shelters, which are valuable for community members (Smith et al., 2017; Sufri et al., 2020). Moreover, it is vital to communicate flood hazards to the most vulnerable segments of the community, including women, children, older adults, and individuals with disabilities or impairments.

Response capacity is necessary to implement appropriate actions when people receive warning messages. This pillar includes not only physical equipment such as boats and shelters but for collective and individual disaster education programs, engaging local leaders and volunteer organizations for flood management, and ensuring appropriate community response to flood-warning messages (Macherera & Chimbari, 2016). Developing well-defined contingency plans based on available resources and clarifying the roles of community segments, including local authorities and NGOs, further strengthen flood responses. Continuous evaluation and improvement through disaster education campaigns, drills, and feedback mechanisms can refine response strategies. Additionally, addressing the needs of vulnerable populations, such as people with disabilities and older adults, by including them in disaster training enhances overall preparedness (Sufri et al., 2020; Tarchiani et al., 2020).

These key elements from the UNDRR framework were used as the basis for structuring the interview questions and group discussions to ensure a comprehensive assessment of the CBEWS in the LRB, as shown in Table 3.

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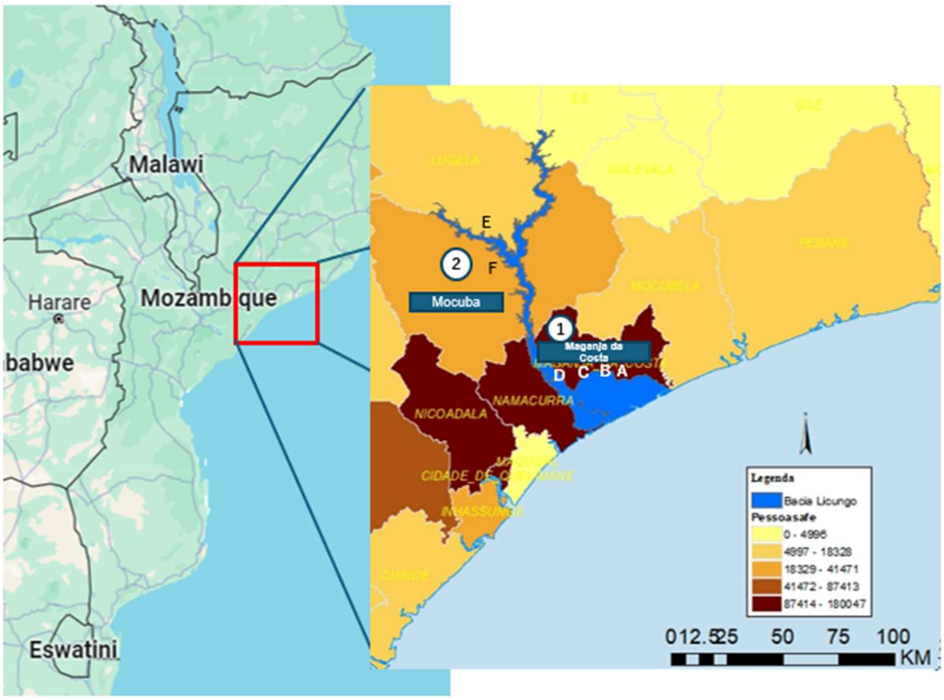
3.2 Target Area and Communities Characteristics

The target area of this study is the LRB, specifically focusing on two districts: Maganja da Costa, in Nante communities, and Mocuba, in Mocuba-Sede Communities, as seen in Figure 2. These districts were selected based on their high flood risk, significant historical flood impact, socioeconomic diversity, and varying evacuation behaviors, which provide a comprehensive understanding of the factors influencing the effectiveness of CBEWS.



Source: Google Maps (left) and data provided by INGD in 2023 (right).

Figure 2. Target communities in Maganja da Costa (A, B, C, and D) and Mocuba (E and F) in the Licungo River Basin

Nante communities, known as Baixo Licungo, in the Maganja da Costa District are lowland and wetland areas located downstream of the Licungo River, spanning 2,873 km² with a population of 144,974 and a density of 50.5 inhabitants per km² (Instituto Nacional de Estatisicas (INE), 2017). This district is frequently affected by floods and serves as the epicenter of major flooding events, particularly those in 2015 and 2022. The community relies primarily on subsistence agriculture and fishing, making it highly vulnerable to flood.

Mocuba City in Mocuba District is the largest city in the LRB, covering 8,773 km² with a population of 399,551 and a density of 45.5 inhabitants per km² (INE, 2017). It serves as the main hub of the region and is strategically located at the confluence of several rivers, thereby increasing the flood risk. The regional water management directorate ARA-Norte is located in Mocuba and provides real-time flood information to the districts within the LRB.

For ethical purposes, the selected communities in Nante were classified using codes (A, B, C, and D) and Mocuba City (E and F) -see Figure 2 and Table 1- to protect the privacy and

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confidentiality of the participants, maintain ethical standards, and build trust with them. All the target communities are in wetland areas near the banks of the Licungo River, which exacerbates their vulnerability to flooding. Below is a detailed table of the characteristics of the target communities in these districts:

Table 1. Characteristics of the communities in the target area

District	Community Code	Shelter Type	Main Occupations	Impact and Relocation
Maganja da Costa (Nante Communities in Baixo Licungo)	Community A	Primary school	Farmers, fishers, small businesses	Relocated in 2015 and maintain houses in farming areas
	Community B			
	Community C	Open space with tents provided by Government and NGOs		Significant impact in 2015 and 2022, not relocated due to lack of land in the high-ground zone.
	Community D	Primary school		Not relocated, affected in 2015, not affected in 2022
Mocuba City	Community E	Primary school	Farmers, fishers, commerce	Affected in 2015, not affected in 2022. Relocated from riverbank to elevated area in Lugela
	Community F	Various shelters (schools, markets, churches, mosques)	Farmers, nurses, teachers, police	Affected in 2015, and 2022, not relocated

3.3 Individual Interviews

We conducted individual interviews with key stakeholders at various disaster management levels in Mozambique. These interviews aimed to gather in-depth insight into the implementation and challenges of CBEWS. This interview format was designed to include individuals who were most relevant to the study, specifically in the Maputo and Zambezia Provinces. Interviews were conducted between August and September 2022. In Maputo, interviews were conducted with the following key governmental organizations operating at the national level.

1) The national water management authority: Department of River Basins Management (DGBH), at the National Directorate of Water Resources Management (DNGRH).

2) The national disaster management authority:

- The National Center for Emergency Operations (CENOE), and
- The National Division of Disaster Prevention and Mitigation (DPM) of the National Institute for Disaster Management and Risk Reduction (INGD).

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In Zambezia Province, which encompasses the LRBs, interviews were conducted with representatives from the provincial office of government agencies and local governments as follows:

3) The provincial disaster management agency: The provincial INGD located in Quelimane, the capital city of Zambezia Province (see Figure 3),

4) The regional water management agency: Northern Regional Water Administration (ARA-Norte) under DNGRH based in Mocuba City.

5) The local government: District Administrator and Chief of the Administrative Post of Nante in the Maganja da Costa District.

Source: Photo taken by the authors during field research

Figure 3. Interview held at INGD delegation in Quelimane - Zambezia Province

3.4 Group Interviews

Group interviews were conducted with at-risk communities in the Nante Administration Post in the Maganja da Costa District, and Mocuba communities, in Mocuba District, within the LRB to gather insights into the CBEWS implementation. Participants were selected to ensure diversity and included both sex (men and women), local disaster management committee members, local government representatives, and traditional leaders. Recruitment was facilitated by local government representatives who obtained permission from traditional leaders, as required for any community gathering activity in Mozambique.

Table 2 summarizes the entities and individuals interviewed in both the one-on-one and group interviews during the research process. The first author conducted the interviews in Portuguese, and a hired translator facilitated communication by translating into the local language Echuabo and back into English, enabling the second author to participate.

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Table 2. People and institution interviewed during field research

Level	Entity/Individual	Representative Interviewed	Total People Interviewed
Individual interview			
National	INGD: CENOE and DPM–Maputo DNGRH–Maputo	High-level employees Chief of National Department	2 1
Province	Provincial COE–Zambezia	Key informants	1
District	ARA-Norte–Mocuba District: Maganja da Costa	Key informants District administrator	1 1
Locality (Local office of District government)	Locality: Nante (Baixo Licungo)	Chief of Locality	1
Group interviews			
Community	CLGRDs and selected community members, including local and traditional leaders in Mocuba and Maganja da Costa	All members (two CLGRDs in Mocuba and six in Maganja da Costa)	15–18 members/groups

The questions were administered in Echuabo (the local native language) and translated into English or Portuguese by a hired translator. The meetings were held in public places designated by traditional leaders to ensure a neutral and accessible environment for all participants (see Figure 4).

Source: Photo taken by the authors during field research

Figure 4. Group discussion held in Nante involving local government representatives, traditional leaders, local committee for disaster management, and other community members

The discussions were facilitated by the research team and an INGC district representative (one in each district: Maganja da Costa and Mocuba), following a structured guide focusing on the key topics of the UNDRR framework: risk knowledge, monitoring and warning, communication and dissemination, and response capacity (see Table 3).

Table 3. Key questions for the group interviews summarized by the UNDRR Framework

UNDRR Pillar	Key Elements	Interview Questions	Main Discussion Topics
Risk Knowledge	Understanding flood risks, community vulnerability, and risk perception	What are the main flood risks identified in the Licungo River Basin? How do communities perceive these risks?	Community awareness and understanding of flood risks Historical flood events and their impact
Monitoring and Warning	Effectiveness of monitoring systems, methods of disseminating warnings	How effective are the current monitoring systems in place? What methods are used to disseminate flood warnings?	Experiences with past flood events; Effectiveness of existing warning systems; Reliability and maintenance of monitoring equipment
Communication and Dissemination	Channels used for communication, clarity of messages, and the community's ability to understand warnings	What channels are used to communicate flood warnings to the community? How clear and understandable are these messages?	Challenges in communicating and understanding flood warnings Preferred communication methods and channels
Response Capacity	Community preparedness, availability of resources, implementation of response plans	What measures are in place to ensure community preparedness and response to flood warnings? What resources are available to support these efforts?	Community preparedness and response to warnings Availability and effectiveness of response resources Suggestions for improving community response

3.5 Ethical Considerations

This research involved interviews with human adults who serve in disaster management as professionals or volunteers. No private information was collected; hence the individuals included in the data were not be identified. All questions in the interviews were benign. The interviewees were voluntarily informed about the purpose of the study, and their oral consent was obtained.

4. OVERVIEW OF THE TARGET AREA: THE LICUNGO RIVER BASIN

4.1 Geographic and Socioeconomic Vulnerabilities of the Licungo River Basin

The LRB in Mozambique is renowned for its significant flooding events and unique geography, making it a critical area for studying CBEWS. Situated in the savanna region with an even topography, the basin transitions from tropical vegetation to open plains towards the Indian Ocean (Cea et al., 2022; INGC, 2022; Timberlake et al., 2009). Low-lying areas such as Mocuba, Namacurra, and Maganja da Costa experience annual flooding due to their proximity to the river's descent from the Namuli Mountains 2000 m above sea level to the Vila Valdez estuary at sea level (INGC, 2022). Periodic high tides in the Indian Ocean affect the course of rivers, leading to overflows and floods in the densely populated plains (Cea et al., 2022; INGC, 2022).

It spans approximately 343 km and descends from the mountains, plateaus, and plains before reaching the Indian Ocean (Cea et al., 2022; Nzualo & Silvestre, 2019). The basin varies in altitude from over 1000 m to 200 m above sea level, with tributaries such as the Lugela, Raraga, and Mabala Rivers originating from similar topographical regions. Lowland areas, such as wetlands and grasslands, frequently obstruct river flow due to sediment accumulation from highland and mountainous areas (Cea et al., 2022; Chiarelli et al., 2021).

The primary tributary, the Lugela River, significantly influences the flow dynamics through its steep descent. During the rainy season, the river experiences substantial water flow, leading to rapid increases in the runoff velocity of the Licungo River, causing severe flooding downstream in Namacurra and Maganja da Costa (Chiarelli et al., 2021; INGC, 2022; Timberlake et al., 2009). The LRB receives the highest amount of rainfall compared with other river basins in Mozambique, with central and northeast regions experiencing precipitation exceeding 2000 mm (INGC, 2022). Factors such as tropical cyclones, orographic precipitation, the flat terrain of the basin, and inadequate drainage infrastructure contribute to flooding, making the LRB highly susceptible (Cea et al., 2022; INGC, 2022; Nzualo & Silvestre, 2019).

Most LRB communities are located in wetlands near the Licungo Riverbanks, which are classified as high-risk areas (INGC, 2022; Nzualo & Silvestre, 2019). These communities predominantly rely on subsistence agriculture, fishing, and small-scale farming, with livelihoods centered around natural resources. Urban centers serve as central business districts, while peripheral zones house many slums where residents are primarily in the low or middle-income classes (INE, 2017). These urban areas face challenges related to inadequate sanitation facilities and fragile sewage networks, which contribute to urban flooding (Nzualo & Silvestre, 2019).

The socio-economic structure of LRB communities is characterized by high levels of poverty, limited access to education and healthcare, and inadequate infrastructure (INE, 2017). Traditional leadership plays a crucial role in community governance, with local leaders and elders pivotal in decision-making processes, including those related to disaster preparedness and response (Artur, 2013; INGC, 2022; Koivisto & Nohrstedt, 2017). The cultural fabric of these communities is rich, with practices and beliefs that significantly influence their perceptions of and responses to natural hazards (Cea et al., 2022; INGC, 2022). Recurrent floods exacerbate the challenges faced by these communities, threaten lives and disrupt livelihoods, leading to cycles of vulnerability and resilience (Cea et al., 2022; Queba, 2022).

The LRB encompasses ten districts, constituting 42% of all the districts in Zambezia Province, with four of the five municipalities located within the basin (INE, 2017). It is the most densely populated basin in the country, with 57.3 inhabitants per square kilometer and the majority are young individuals, accounting for over 70% of the population (Cea et al., 2022; INE, 2017; INGC, 2022). Zambezia Province, with 5,164,732 inhabitants, had 62% of its population living below the poverty line in 2015, with agriculture and fishing as primary income sources (INE, 2017). While Portuguese is widely spoken among urban residents, most of the population speaks their native languages, and there are high illiteracy rates in rural areas (INE, 2017).

4.2 Impact of the 2015 and 2022 Floods

Historically, the LRB has experienced significant flooding events that have profoundly affected the local population, infrastructure, and economy (Garrote, 2022). The vulnerability of a basin to flooding is well-documented as it is one of the 11 basins in the country that is most exposed to flood damage (Cea et al., 2022; Salvucci & Santos, 2020). Over the last 52 years, the Licungo Basin has experienced catastrophic floods in 1970, 1984, 1995, 1998, 2014, 2015, 2019, and 2022 (Cea et al., 2022). Among these, the 2015 floods were the most severe in terms of material, economic, and human life damages. This event was associated with the tropical cyclones Chedza and Bansi, which brought heavy rainfall of 700 mm in January in Mocuba. Over two days, from January 11th to 12th, the water depth exceeded 12 m at the Mocuba gauging station (flood threshold of 3.5 m).

The human impact was substantial. The INGC of Mozambique reported that the 2015 floods caused 155 deaths. A rapid assessment following the floods indicated that approximately 326,000 people had been affected. Approximately 30,000 houses, 2,362 classrooms, and 17 health units were either partially or totally destroyed. Additionally, 104,430 hectares of crops were lost, impacting 102,000 farmer households. The cost of damages was estimated to be approximately $371 million, or 2.4% of GDP, with recovery and reconstruction costs at $490 million.

In January 2022, Cyclone Ana brought heavy rainfall to the LRB, resulting in another severe flooding event. An average of 200 mm of rain fell basin-wide in a single day, with some areas receiving up to 350 mm (Cea et al., 2022). This intense rainfall pushed the Licungo River's levels beyond the flood threshold of 3.5 meters at the Mocuba gauge, leading to widespread flooding, especially in the lowland districts of Maganja da Costa, Namacurra, and Nicoadala

(Canhanga et al., 2020; Garrote, 2022). The floods affected more than 141,483 people and caused 25 deaths. In addition to fatalities, many individuals were injured or left homeless. More than 7,700 homes and 2,457 classrooms were destroyed and 70,982 hectares of agricultural land were inundated (Cea et al., 2022). The floods also damaged 23 water supply systems, 144 power poles, and 2.275 km of roads, severely disrupting food supply chains and leading to immediate food security issues and widespread displacement (Cea et al., 2022; Singh & Schoenmakers, 2023).

Historical analysis of the period from 1950 to 2008 showed that floods have occurred every 2.6 years in the LRB. This implies that the Licungo River is expected to exceed the flood alert level every 2 to 3 years (Garrote, 2022; INGC, 2014). Very large floods, exceeding 1.5 times the flood stage, occur much less frequently, approximately once every 15 to 20 years (INGC, 2014).

The flood event in January 2015, which had the highest recorded magnitude, is a notable example of such an extreme event. These geographic and socioeconomic factors are essential for understanding disaster prevention strategies in Mozambique, which are categorized into four levels of flood response (Garrote, 2022; INGC, 2014). Table 4 summarizes these levels, the actions taken at each level, and the historical frequency of floods in the Licungo River Basin.

5. RESULTS AND ANALYSIS: FACTORS PREVENTING EFFECTIVE CBEWS IMPLEMENTATION

During the interviews, we focused on the factors that influenced the four key pillars of the UNDRR framework. In the following sections, the factors associated with each section of the analysis are indicated in bold. These factors will help highlight the main findings and insights related to each pillar of the CBEWS framework in the context of the LRB in Mozambique.

5.1 Risk Knowledge

Our interview results indicate that while communities in the LRB possess a certain level of awareness of flood risks, this knowledge is primarily based on past experiences and indigenous knowledge. As one community elder in Nante explained,

"*We know the floods will come because our ancestors have told us how to watch the river and the sky. But sometimes, the warnings from the authorities are too late or not accurate, such as the 2015 massive floods*" (A member of Community E, Group Interview, September 8, 2022).

Table 4. Flood response levels of Licungo River Basin

Flood Response Level	Description	Actions Taken	Frequency in Licungo River Basin
Level 1 (Low Risk)	Minor flood events with minimal impact on communities.	Regular monitoring, community awareness, dissemination of precautionary information, and equipment maintenance.	Floods occur on average every 2.6 years, expected to exceed flood alert level every 2-3 years.
Level 2 (Moderate Risk)	Floods causing moderate damage to infrastructure and agriculture.	Heightened monitoring, increased frequency of warnings, preparation for possible evacuation, and mobilization of temporary shelters and emergency supplies.	Very large floods (exceeding 1.5 times flood stage) occur about once every 15-20 years.
Level 3 (High Risk)	Severe floods with significant potential for damage to property and risk to lives	Pre-emptive evacuations, deployment of emergency response teams, coordination with local and international organizations, implementation of detailed evacuation plans, and continuous updates to the community.	January 2015 flood was the highest recorded magnitude. Approximately every 50 years (assumed)
Level 4 (Extreme Risk)	Catastrophic flood events pose a severe threat to life and extensive damage to infrastructure.	Declaration of a state of emergency, large-scale mandatory evacuations, extensive rescue and relief operations, high-alert emergency services, and rapid dissemination of information.	Approximately every 100 years (assumed)

Source: Adapted from INGD (2014) and Cea (2022)

However, despite concerted efforts made by the CLGRDs to develop disaster awareness campaigns and map risk zones and vulnerabilities, a gap remains in effectively conveying the true extent of flood risks, including frequency, intensity, and magnitude, faced by these communities. Consequently, existing flood risk knowledge among community members relies primarily on their own personal experiences and the oral transmission of knowledge passed down from previous generations, drawing upon wisdom accumulated over time.

According to an INGD report (INGC, 2022), floods occur in the LRB every two years on average. These floods were estimated to correspond to level 1 and 2 scenarios, with recurrence intervals of 10 and 25 years, respectively. Our focus group discussion with the CLGRD in Mocuba District revealed that the level of community preparedness aligned with the flood recurrence interval. Many individuals residing in the LRB were familiar with these flood scenarios. As one CLGRD member noted:

"We have learned to expect these smaller floods and have adapted our responses accordingly" (A member of Community F, Group Interview, September 8, 2022).

Similar observations were made in Maganja da Costa, particularly in communities within the Nante administrative post, with a notable lack of preparedness for the more severe Level 3 and 4 scenarios, which have recurrence intervals of approximately 50 and 100 years, respectively.

Interviews conducted with members of the Northern Regional Water Administration (ARA-Norte) in Mocuba City provided further support for our findings. They reported that a rare and severe flood occurred in the LRB in 2015, which was the most destructive and deadly event in the history of the area. This flood corresponds to a Level 3 scenario with a recurrence interval of 50 years. Furthermore, a representative from the INGD in Mocuba and Maganja da Costa demonstrated that residents of the downstream districts, including Lugela, Mocuba, Namacurra, and Maganja da Costa, were unable to respond effectively to the disaster. One representative stated,

"During the 2015 floods, we saw that many people did not have the means or the knowledge to evacuate in time. The warnings were there, but the response was not sufficient" (A member of Community B, Group Interview, September 7, 2022).

It is clear that the residents of the LRB are predominantly **trapped in the experiences** and ancestral knowledge of navigating floods. Their understanding of floods was primarily based on **direct observation** and intergenerational transmission. They lack access to scientific data that can support the possibility of future changes in flood patterns, including shifts in intensity, frequency, and magnitude, due to climate change. This reliance on traditional knowledge leads to the perception that flood occurrences will remain consistent, as their ancestors had also encountered floods of similar magnitude. Consequently, floods are regarded as a recurring part of the community's life cycle. Many community members view the flood hazard as an "intermittent visitor" that temporarily disrupts their daily lives but ultimately recedes, allowing normalcy to resume. Thus, enhancing the risk knowledge among community members, including the incorporation of scientific data and climate change projections, is essential for a more comprehensive understanding of flood risks. This knowledge can empower communities to take proactive measures and effectively respond to future floods.

5.2 Monitoring and Warning

Individual interviews with the related organizations revealed that the community monitoring and warning system for floods in the LRB relied on two main sources: local flood detection systems and national CENOE warning systems. The local flood detection system, also known as the community monitoring and warning system, relies on the activities of CLGRD, which monitors river gauges. These river gauges consist of coded steel bars installed along the Licungo River banks (see Figure 5) and automatic sensors connected to sirens. Government agencies, such as the INGD, ARA-Norte, DNGRH, and NGOs, such as Mozambique Red Cross and Fundo de Desenvolvimento da Comunidade, provide most of the monitoring and warning equipment.

Source: Photo taken by the authors during field research

Figure 5. The ARA-Norte river gauges in use in Nante (left) and Mocuba city (right) in the LRB.

Local monitoring systems, such as river gauges and automatic sensors, face significant challenges. A representative of ARA-Norte stated the following:

"We have faced significant challenges in maintaining the monitoring equipment due to limited financial support and frequent vandalism" (A member of Community A, Group Interview, September 7, 2022).

This lack of reliable monitoring has undermined the community's trust in the warning system. Interviews with CLGRD representatives in Mocuba and Maganja da Costa, revealed that automatic sensors were rendered inoperable because of **vandalism**, which was predominantly carried out by local individuals with past flood experiences. This suggests a lack of perceived value and trust among local people in the EWS equipment, likely stemming from recurrent exposure to floods.

In addition to using local river gauges, community members relied on indigenous knowledge, including observing the behavior of animals such as hippopotamuses, ants, and frogs, as well as river water characteristics and debris along riverbanks, to anticipate floods. A community member from Maganja da Costa mentioned:

"We look at how the animals behave. If the frogs are moving to higher ground, we know the floods are coming" (A member of Community A, Group Interview, September 5, 2022).

Although not as reliable as scientific monitoring systems, these indicators showcase the community's deep connection with their environment and their accumulated wisdom over generations which serve as supplementary sources of flood information.

The CENOE warning system which is connected to INAM, DNGRH, and ARA-Norte, plays a crucial role in real-time monitoring and issuing warnings to at-risk communities in the LRB. However, interviews with representatives from DNGRH, CENOE, and ARA-Norte highlighted certain limitations. One of the main challenges is the accuracy and speed of the system, which are not on par with those of developed countries. Moreover, existing monitoring and warning materials are susceptible to damage and are recurrently washed away by frequent floods in the LRB. This hampers the reliability of the system and delays the provision of timely and accurate warnings to communities. Financial constraints also hinder improvements, as DNGRH and ARA-Norte lack the resources for prompt replacements and investment in highly sophisticated technologies. Collaborative efforts with the government, NGOs, and international organizations have been made to establish and maintain the system. Nevertheless, **the uncovered maintenance costs** and operational challenges remain significant barriers to the full implementation and effectiveness of the CENOE.

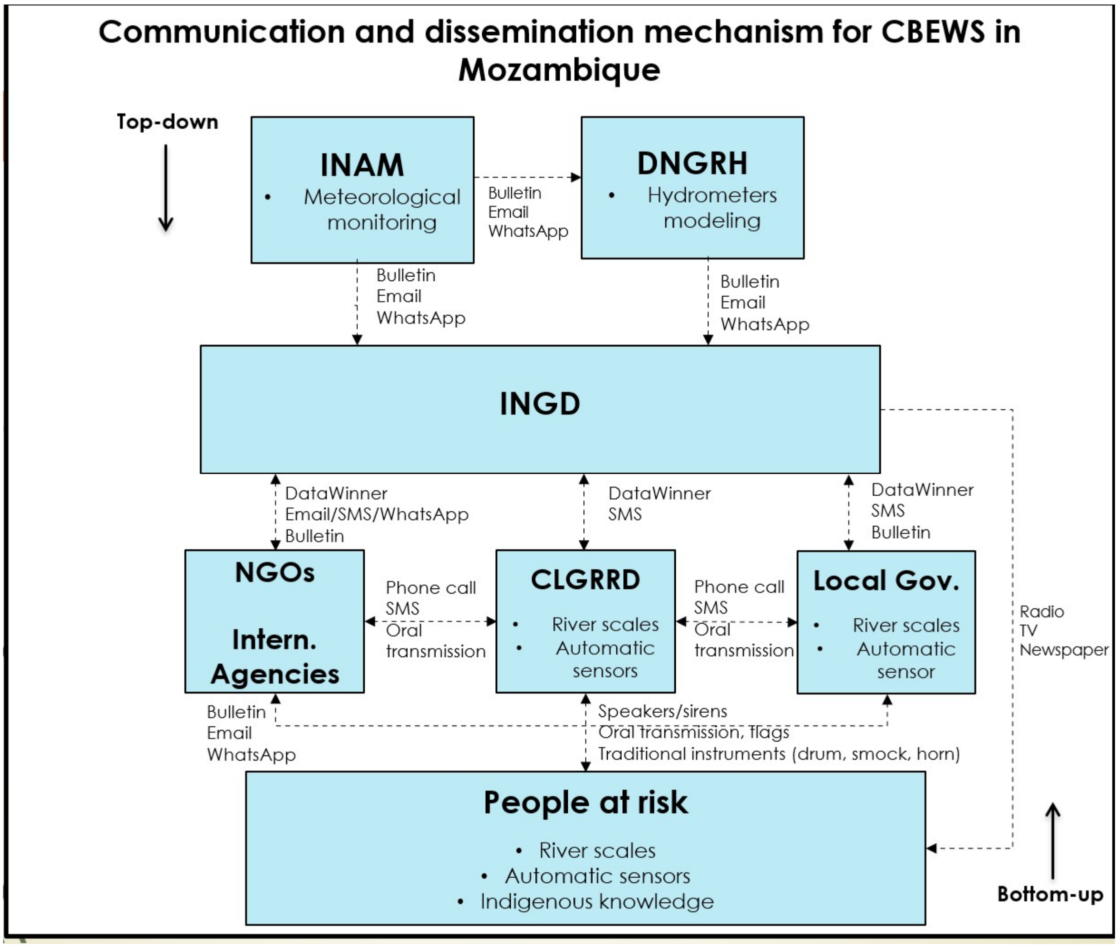
Local and national monitoring and warning systems are not regarded as effective triggers for initiating community evacuation. Despite receiving warnings from the CLGRD, indigenous knowledge-based signs, and the CENOE, the interviewed people said they did not evacuate until they saw an extremely high water level or even started inundating their houses, which means they acknowledged the danger through **direct observation**. Consequently, local and national monitoring and warning systems alone fail to prompt timely community evacuations.

At the national, regional, and local levels, the government's existing EWS partially meets community evacuation requirements, but this is hindered by inadequate technology, which affects its speed and accuracy. However, certain challenges have arisen that can affect the effectiveness of CBEWS. Notably, some communities **lack monitoring capabilities by the local government**. In Mugoloma, the Nante administrative post monitoring the Licungo River poses difficulties owing to transportation constraints. Government caretakers must walk 10 km daily to collect data from the river gauge (Figure 5 left side) and transmit them by SMS to the regional office of ARA-Norte in Mocuba City. Moreover, some agents lacked mobile phones or sufficient phone credit, which hampered data transmission.

5.3 Communication and Dissemination

In Mozambique, particularly in the LRB, communication and dissemination mechanisms follow a comprehensive approach that combines top-down and bottom-up strategies. Warning information is disseminated to community members through two main channels: (1) the government and (2) CLGRDs. The government channel functions as the formal source of warning information, which is generated at the top by the INAM and DNGRH and subsequently transmitted to communities via the national CENOE and the provincial and district Emergency Operation Centers (COEs). The distribution of this information to CLGRDs is typically facilitated by local authorities and NGOs; however, community members can also receive it through various channels, such as SMS, radio, television, and the DataWinner platform (the DataWinner platform operates as a collaborative information-sharing hub, simplifying the distribution of early warning messages, details on damages, and recommended actions for communities in the context of disaster emergencies, utilizing mobile phone technology).

In the second channel, CLGRDs play a crucial role in providing community warning information. These committees serve as the main sources of local warning messages and employ a range of communication channels to relay information to community members. Among the methods utilized are oral communication, sirens, loudspeakers, coloured flags, and traditional instruments, such as horns, fires, smocks, and drums, as shown in Figure 6. At the community level, the system is designed to operate autonomously in the absence or failure of communication channels at the national level. It utilizes existing local resources, including indigenous knowledge, to effectively communicate and disseminate warning messages to at-risk communities.



Source: the authors

Figure 6. Integrated top-down and bottom-up communication and dissemination mechanism of CBEWS in Mozambique. Source: the authors.

According to our interview with CLGRD members from Maganja da Costa and Mocuba, there was a **lack of local information technology** to communicate and disseminate disaster warnings in many communities we visited. For instance, the community radio station in the Nante administrative post has been unable to broadcast for five years owing to a technical breakdown. Another issue was the effectiveness of the DataWinner messages sent directly to local and traditional leaders as well as to CLGRD members' mobile phones, by the CENOE. The CLGRD reported that the mobile phones used for communicating warnings were provided by the government or NGOs. Nevertheless, many communities in these areas lack access to electricity and are unable to charge their phones, and most phones are broken. Furthermore, government-issued messages are solely in Portuguese, neglecting the fact that a significant proportion of the population is illiterate and incapable of comprehending or translating the messages into their local languages. During a group discussion in Mocuba, a CLGRD member highlighted the following:

"The messages we receive are often in Portuguese, which many of our elders do not understand. We rely on our community leaders to translate and disseminate the warnings, but this process can cause delays" (A member of Community C, Group Interview, September 7, 2022).

Consequently, the **language barrier** renders most residents unable to understand critical warning information delivered through the national warning system. Furthermore, DataWinner messages typically provide the magnitude of the hazard, location, and evacuation orders. They lack detailed preventive information, such as the duration of a flood or its impact on at-risk communities, as well as specific recommendations, such as the location of shelters, evacuation routes, or suitable means of transportation.

5.4 Response Capacity

The group interviews revealed the notable engagement of CLGRDs in flood preparedness activities. However, this approach has limitations. Although all the CLGRDs had emergency plans for the flood season, they did not consider specific flood scenarios or quantitative damage estimation. Therefore, the plan lacks feasibility, for example, in terms of the capacity of evacuation shelters and availability of transportation means, considering the number of people at risk. The CLGRD members were also full-time farmers; therefore, resource constraints and time limitations hindered regular disaster education campaigns and drills. In some communities, mock flood drills have not been conducted over the past two years, prioritizing post-flood recovery efforts and sustaining families through agricultural practices.

An assessment of the visited communities showed a **lack of response resources** to be mobilized in the event of massive flood hazards in the LRB. Building community response capacity is critical for effective disaster risk reduction. An INGC district representative noted:

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"Our role is to work closely with the communities to implement DRR programs, but we need more resources and training to be truly effective" (A member of Community E, Group Interview, September 8, 2022).

Interviews with CLGRD representatives revealed uncertainty regarding the quantity and types of resources required for an effective response. While certain resources, such as canoes, evacuation routes, and shelters are present, they are typically utilized only when the flood situation becomes critical, and they may not be sufficient to evacuate all residents living in high-risk areas of the LRB. Community members from the Nante administrative post expressed a preference for remaining in flood-prone areas rather than utilizing the available resources for evacuation. A local leader in Nante expressed concerns about **the lack of incentives for early evacuation**,

"People are afraid to leave their homes and fields because they fear losing everything. We need to find ways to assure that our livelihoods will be protected after the evacuation" (A member of Community D, Group Interview, September 6, 2022).

This reluctance stems from their **fear of losing harvest, farmland, and livestock**, which are their main sources of income and livelihood, as the communities in the LRB rely heavily on seasonal agriculture. Consequently, they are discouraged from leaving their production sites for extended periods, resulting in suboptimal implementation of evacuation and contingency plans.

Land ownership presents a significant challenge for smallholder farmers in Mozambique, including those in the LRB (Almeida & Jacobs, 2022; Jacobs & Ribeiro de Almeida, 2020; Veldwisch et al., 2013). Mozambique, a socialist country in the past, has a legacy of public land ownership and no farmer has official legal tenure on their land, except when it is a widely recognized fact that the farmer has occupied and used the land. Evacuating to safe zones would mean relinquishing rights to their property, potentially leading to redistribution or retention by the government owing to its flood-prone nature. This leads to the lack of incentives to leave the land for evacuation during floods.

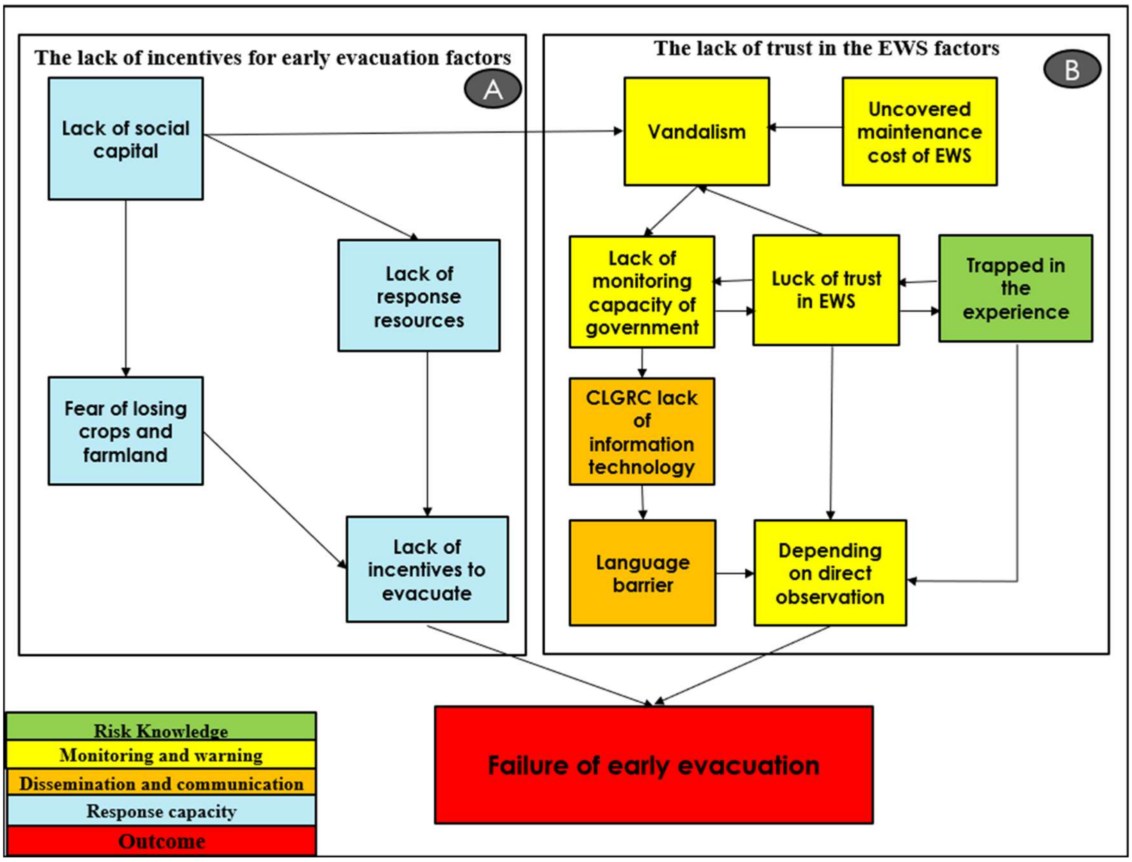
In addition to the institutional background of disincentives, the fear of losing the assets during evacuation is also attributed to the **lack of social capital** within the community. During the interview we suggested that they share their harvest. It is interesting to note that, as a coping strategy, some residents said that they often hide their possessions in trees and stay until floodwaters recede.

5.5 Hypothetical Structural Modeling of the Preventive Factors

Through a comprehensive analysis of the obstructing factors that impede the functionality of CBEWS based on the UNDRR framework, this study builds a hypothetical structure for the identified preventive factors. The term "hypothetical" indicates that the structure suggested here does not have strong evidence nor is it derived from an established analytical method. However, the model was based on logical deductions from the interviews, as explained in this section. We believe that the model is worth suggesting to identify the root causes of the failure of the CBEWS and to serve as a basis for further in-depth research.

The proposed hypothetical structure is shown in Figure 7. Each factor identified in the interviews, denoted in bold , is represented by an individual rectangles. We identified two categories of preventive factors that obstruct the effectiveness of the CBEWS pillars in the LRB: (A) lack of incentives for voluntary early evacuation and (B) lack of trust in the EWS.

Category (A) is influenced by concerns about the potential loss of harvest, livestock, and farmland, as well as the lack of response resources. Community members in the LRB prioritize safeguarding their economic resources in response to early warnings and perceive the risks as uncertain based on their experiences and indigenous knowledge. Moreover, the lack of adequate response resources further diminishes their motivation to evacuate early, as they perceive a lack of support to mitigate potential losses.



Source: the authors

Figure 7. Factors affecting the community-based early warning system in the LRB.

Category (B) reflects a lack of trust in the effectiveness and reliability of the CBEWS. Community members' experiences and limited understanding of evolving risks, local governments' lack of monitoring capacity, and lack of information technology at the community level contribute to this lack of trust. Language barriers and incidents of vandalism targeting monitoring equipment further erode trust. Consequently, community members approach early warnings with skepticism and reluctance, relying on their own direct observations and experiences, which may not always provide accurate or timely information. This undermines the credibility and impact of the CBEWS as an effective early evacuation tool.

6. DISCUSSION

Based on field interviews, the findings of this study highlight several critical factors affecting the effectiveness of CBEWS in the LRB in Mozambique. These include a lack of trust in early warning system, inadequate monitoring and warning systems, communication challenges, and insufficient response resources. Additionally, the study identified a significant impact of social capital on community members' willingness to respond to CBEWS warnings and evacuate voluntarily.

These results were consistent with those of other African studies. For instance, Chinguwo and Deus (2022) examined the implementation of early warning systems in Malawi and found that limited government funding and bureaucratic challenges impeded the operation of the UNDRR framework pillars. Similarly, Lumbroso (2018) highlighted the lack of financial resources as a significant barrier to the effectiveness of early flood warning systems in Uganda. Both studies emphasize the importance of adequate funding and robust institutional support, which align with our findings on the need for better resource allocation and infrastructure maintenance in Mozambique.

The role of social capital in disaster preparedness and response has been documented in other regions. Aldrich and Meyer (2015) argue that social networks, norms, and trust within a community significantly enhance resilience and collective action during disasters. This is consistent with our findings that the lack of social capital in LRB communities discourages individuals from taking appropriate protective measures and relying on early warning systems. However, it is worth emphasizing that the process of social capital is quite different. Our finding is that a lack of social capital may create an insecure environment during disasters and, hence, hinder early evacuation.

In contrast, some studies have shown varying degrees of success in implementing CBEWS, depending on the local context. For example, Tarchiani et al. (2020) reported successful integration of community monitoring and preparedness systems in Niger, emphasizing the need for tailored approaches that consider local cultural and social dynamics. This suggests that while the UNDRR framework provides a valuable structure, its implementation must be adapted to the specific needs and conditions of each community. Our study also highlighted the importance of clear and effective communication channels. Similar challenges were observed by Smith et al. (2017), who noted that communication barriers often undermine the effectiveness of early warning systems. Ensuring that warnings are clear, understandable, and disseminated through the preferred channels is vital for a timely community response.

Therefore, the consistency of our findings with existing literature underscores the need for a more effective CBEWS that incentivizes communities to evacuate by building trust and social networks. This, also highlights the need for tailored strategies to address the unique challenges faced by each community. By promoting social capital, improving resource allocation, and enhancing communication, the effectiveness of CBEWS in the LRB and similar contexts can be significantly increased.

7. CONCLUSION

We examined the factors influencing the effectiveness of the CBEWS in the LRB in Mozambique. By analyzing the key variables associated with the four pillars of the UNDRR framework, this study shed light on the obstructing factors that impede the functionality of the system and its ability to facilitate voluntary early evacuation. The findings reveal that the implementation of CBEWS in the LRB faces significant obstacles, primarily related to community members' reluctance to evacuate when national and local flood warnings are issued. Hesitancy to evacuate in a timely manner places community members' lives and livelihoods at risk. Factors such as a lack of trust in the EWS and the fear of losing crops and farmland contribute to this delay. Furthermore, this study highlights the potential role of social capital as a factor underlying these challenges. The absence of trust and weak community bonds discourage individuals from taking appropriate measures and relying on the EWS.

To address these issues and enhance the effectiveness of CBEWS in the LRB, several recommendations are proposed. First, it is essential to prioritize interdependence among the CBEWS pillars and ensure seamless integration. This entails adopting a comprehensive approach that encompasses risk knowledge, monitoring and warning, dissemination and communication, and response capacity, in alignment with the UNDRR framework. Moreover, it is recommended that the "incentive" component be incorporated as a fifth pillar of the UNDRR framework to further strengthen the system. This pillar emphasize the importance of securing tangible incentives for community members to encourage early evacuation. Effective incentives could include safeguarding livelihood assets and offering compensation for losses. Tangible incentives, including insurance schemes for land and crops and the construction of community-built evacuation towers, should be considered to provide economic security, protect community assets, and incentivize individuals to prioritize their safety through early evacuation. Furthermore, establishing of a bank storage facility to promote the sharing of livelihood and livestock resources among community members could enhance trust and promote mutual support during emergencies. Ensuring the continued operation of the CBEWS infrastructure requires addressing the challenge of maintenance costs. To achieve sustainability, it is crucial to explore viable funding mechanisms that can support the regular maintenance of the system. This may involve establishing partnerships with local NGOs operating in the LRB, fostering collaborations with local governments and the private sector, or devising innovative financing models within communities. By securing the maintenance resources, the CBEWS in the LRB can maintain its effectiveness over time, offering reliable early warning services to the community. Moreover, it is important to not only provide knowledge but also promote scientific understanding among local community members regarding flood EWS. Explaining the scientific principles behind the system, emphasizing the significance of timely responses, and educating community members on the potential consequences of delayed evacuation can foster a deeper appreciation of the EWS. This scientific understanding would enable community members to make informed decisions about current weather patterns and future severe floods based on evidence, thereby increasing their willingness to respond promptly to warnings and prioritize their safety.

Second, building social capital is necessary for effective CBEWSs, which aligns with the research conducted by Shoji and Murata (2021). This is not an easy task, as the lack of social capital in Mozambique's rural communities is rooted in the violent conflicts that occurred between 1977 and 1992 (Schindler, 2010). However, CLGRD could play an important role by implementing a participatory approach to disaster risk management, which is essential for building social capital and enhancing community resilience (Lundgren & Strandh, 2022). This involves engaging local communities in decision-making, promoting collaboration among stakeholders, and empowering community members for disaster preparedness and response. To protect farmers' rights, governance structures should be established and risk zone mapping should be incorporated to identify flood-prone areas and land ownership. Proactive measures by the local government should ensure that at-risk residents possess the necessary land ownership documents and safeguard their rights and interests. Additionally, establishing a centralized bank storage facility would foster trust and resilience within the community, allowing collective storage and resource sharing during floods. By pooling resources, community members can effectively mitigate flood impact and cultivate a sense of collective responsibility and support. These initiatives preserve individual livelihoods and enhance community trust, cohesion and resilience. Proactively addressing land ownership and providing shared resources empowers community members to navigate floods, thereby ensuring long-term sustainability and well-being in the face of natural disasters.

This study has some limitations. First, the research was conducted solely in the LRB of Mozambique, which may limit the generalizability of the findings to other river basins, regions and countries. The CBEWS approach can be influenced by various contextual factors, such as socio-cultural dynamics, geographical conditions, and institutional capacities, which may differ in other settings. Therefore, caution should be exercised when extrapolating these findings to other regions. Further research in diverse geographical contexts is necessary to validate the effectiveness of the CBEWS approach.

This study relied on self-reported data and qualitative observations, which are subject to bias and limitations associated with participant recall or interpretation. While these methods provided valuable insights into the lived experiences and perspectives of the interviewed institutions and community members across LRB, future research could benefit from

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incorporating quantitative methods and conducting larger-scale surveys to validate and complement the present findings.

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APPENDIX

Appendix A: Reference List of Group Interview

1. Community A (September 5, 2022): Group interview. Nante, Maganja da Costa, Mozambique.
2. Community B (September 7, 2022): Group interview. Nante, Maganja da Costa, Mozambique.
3. Community C (September 7, 2022): Group interview. Nante, Maganja da Costa, Mozambique.
4. Community D (September 6, 2022): Group interview. Nante, Maganja da Costa, Mozambique.
5. Community E (September 8, 2022): Group interview. Mocuba City, Mocuba, Mozambique.
6. Community F (September 8, 2022): Group interview. Mocuba City, Mocuba, Mozambique.

Appendix B: List of Abbreviations

ARA-Norte: Northern Regional Water Administration

CBEWS: Community-Based Early Warning System

CENOE: National Center for Emergency Operations

CLGRD: Local Disaster Management Committee (Comitê Local de Gestão e Reducao de Risco de Desastres)

COE Province or District Emergence Center

CVM: Mozambique Red Cross (Cruz Vermelha de Moçambique)

DNGRH: National Directorate of Water Resources Management (Direcção Nacional de Gestão de Recursos Hídricos)

DPM: National Division of Disaster Prevention and Mitigation (Divisão Nacional de Prevenção e Mitigação de Desastres)

EWS: Early Warning System

INAM: National Institute of Meteorology (Instituto Nacional de Meteorologia)

INE: National Institute of Statistics (Instituto Nacional de Estatística)

INGC National Institute for Disaster Management

INGD: National Institute for Disaster Management and Risk Reduction (Instituto Nacional de Gestão de Calamidades)

LRB: Licungo River Basin

NGO: Non-Governmental Organization

SMS: Short Message Service

UNDRR: United Nations Office for Disaster Risk Reduction

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