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Strengthening Namibia's Flood Early Warning System through a Critical Gap Analysis

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Abstract: Floods are considered leading hydrometeorological disasters, which are increasing in frequency, intensity and complexity with the evolution of climate change. Their associated impacts have detrimental and often prolonged implications for humankind, especially communities heavily reliant on the natural environment. The development and implementation of effective flood early warning systems (FEWSs) can serve to enhance coping strategies and strengthen the adaptive capacities of target communities while simultaneously minimising flood risks. However, shortcomings related to the lack of information on the operationalisation of these systems, the technical and financial requirements, the challenges faced and the directives related to their implementation have persisted, subverting risk reduction efforts at the grassroots level. Using data from key informant interviews and focus group discussions, this study employed a systematic analysis of the official Namibian flood early warning system based on the system's implementation in Kabbe, Namibia. The study results revealed a need for significant changes across all system components as the FEWS follows a top-down, disintegrated and response-driven approach. Roles are undefined among institutions; funding is inadequate; and community risk perceptions, coping capacities and participation are disregarded. Based on the study findings, the researchers recommend significant changes in the design and application of the system, urging practitioners to recognise FEWSs as the continuous and integrated tools that they are.

Keywords: flood early warning systems; preparedness; disaster risk management; Namibia; gap analysis

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1. Introduction

A total of 223 flood disaster events were recorded across the globe in 2021 [1]. These events surpassed the average number of flood events (163) per annum recorded in the past three decades, a value expected to expand quickly with the effects of climate change. Flooding events have contributed to 9% (104,614) of the global death rate and led to 22% (USD 651 billion) in global economic losses by disaster since 2000 [2]. Africa is the second most affected region by flood hazards globally, recording 748 (23%) flood events, aside from several unrecorded 'mild' events, in the past decade [3,4]. With the observed patterns of sporadic rainfall across the continent, often coupled with inadequate socio-economic capacity, the flood impact in the region is expected to worsen [5]. Within this context, the concern about the risks posed by natural and anthropogenic hazards has exponentially escalated, causing a global shift in focus from post-disaster response to disaster risk reduction (DRR) [6].

Flood early warning systems (FEWSs) form an integral part of this global DRR effort [7], providing systematic and comprehensive strategies that incorporate preparedness and prevention mechanisms for managing hydrometeorological hazards [8]. By effectively harmonising information and communication technology advancements with practical techniques developed under the four pillars of early warning systems, FEWSs have successfully enabled disaster management institutions to mitigate flood disasters [9]. FEWSs,

founded on solid institutional structures, produce timeous and effective hazard predictions, allowing vulnerable communities to respond and minimise the socio-economic and environmental impacts associated with floods [10,11]. Hence, the global call for their development and implementation by the United Nations under target 11.5 of the Sustainable Development Goals and 7 of the Sendai Framework [12,13]. Flood early warning systems are credited for the dramatic decrease in mortality rates by hydrometeorological disasters in some lower-income countries such as Bangladesh, India and Cuba [14]. Following the tropical cyclones and storm surges that resulted in over 300,000 and 140,000 respective deaths in 1970 and 1991, the Bangladeshi government, in collaboration with the Red Crescent Societies, established a cyclone EWS. The system reduced the death toll of an equally intense cyclone, Sidr, to 3500 casualties in 2007 [15]. In 2013, the community-based FEWS developed for the Jiadhal river successfully expedited the evacuation of 25 communities, their livestock and their household assets from impending floods, helping save assets and lives [16]. In Cuba, the early warning systems ensured the early application of protective measures and aided authorities in timeously evacuating 700,000 people, reporting only five casualties [17]. Several other countries use FEWSs [18–20], and extensive legislative progress exists for incorporating them into developmental plans. However, the empirical evidence suggests that these do not always align with the affected communities' natural and socio-economic environments, affecting the response capabilities and flood risk reductions at the grassroots level [21].

This paper presents findings from a study on the critical analyses of the official FEWS in Kabbe, Namibia. The study identifies shortcomings and gaps in the systems' operation and proposes mechanisms for system enhancement for improved flood risk reduction. The paper contributes to the salient literature gap on the holistic assessment of globally standardised early warning systems within the rural African context. Furthermore, the study examines the system from the national to the community level across all four components of an early warning system. The research findings serve as an information source for developing a practical, integrated, participatory and preparedness-driven FEWS. It is hoped that by tailoring FEWSs to target communities' socio-economic and environmental settings, the institutional capacity will be improved to confront future flood hazards effectively.

1.1. Flood Early Warning Systems: A Literature Review

In disaster risk management, a flood early warning system is defined as an information system designed to expedite decision-making to enable vulnerable communities and institutions to mitigate potential damage and losses from impending flood hazards [22]. Four key components comprise a people-centric early warning system: risk knowledge, monitoring and warning services, dissemination and communication and response capability [23]. Flood early warning systems are multi-disciplinary systems that enhance overall flood risk management by strengthening community preparedness, response capabilities and recovery. Although EWSs are integral to effective flood DRR, challenges remain in building robust systems [24].

As flood disasters continue to affect countries with operational FEWSs, the alarming aftermath of these events has led researchers to reflect on the focus, structure and capacity of these systems [25]. Assessments of the nature of hazardous events, their progression and their impacts indicate the need for improved integration within early warning systems [26]. These assessments emphasise that effective hazard risk reduction requires enhanced cooperation amongst stakeholders at national, regional and local levels [27,28]. Accurate forecasting, impact determination, timely warning dissemination and responses are equally critical. As noted by [29], the design and implementation of effective early warning systems are only possible if there is no disintegration between the four components. Any weak link in an early warning system may lead to its failure [30]. Furthermore, other studies [31,32] support this claim while emphasising the need to review operational early warning systems from national to community levels for successful DRR.

Several studies have highlighted the need for implementing people-centred approaches and bottom-up designs for EWS, but publications that systematically analyse the effectiveness of the entire process are rare [32–34]. Furthermore, ref. [32] stated that operational early warning systems require monitoring and review from time to time to keep the systems updated. System reviews identify gaps and help strengthen the system to make it more effective for risk mitigation. This observation proved true in evaluating a flood EWS in Cambodia [35], which identified gaps in warning dissemination and response capabilities. The authors found that the system needed to be tailored to end-users' requirements using a multi-hazard approach for effective operation. Furthermore, [34] recommended incorporating indigenous knowledge into the Belgic EWS to strengthen community understanding and awareness of flood risks. This recommendation was made after finding that community members were unaware they could work with disaster management institutions in dealing with flood hazards, leading to fine-tuned alert thresholds. A review of the Malian FEWS implemented with limited institutional capacity and data from [34] found that rainfall forecasting was unnecessary due to the reliable network of upstream flow gauges, the irrelevance of local rainfall and the slow rise of floods.

In contrast, practice and research studies investigating the efficacy of EWSs from risk identification to the mitigation level are still lacking. While the governance status allows communities to partake in the planning, development and implementation of EWSs, their efficacy has remained relatively unexplored.

1.2. Flood Early Warning in Namibia

In the past, communities in Namibia relied on indigenous methods for flood management [36]. Currently, a national FEWS, operated under the auspices of the Ministry of Agriculture, Water and Forestry (MAWF), exists in addition to these indigenous systems. The MAWF operates the system with assistance from the Department for Climate Change (DCC), the Namibia Meteorological Service (NMS) and the Namibia Water Corporation (NamWater). The DCC and NMS provide climate and weather-related information and services for national and international support, whereas NamWater is in charge of river catchment monitoring. These institutions provide the MAWF with up-to-date climate, weather and rainfall information for flood modelling and forecasting. This information is then forwarded to the Directorate for Disaster Risk Management for validation and then to the Ministry of Information and Communication Technology for dissemination to end-users (Figure 1 [37–39]). The flood early warning system (FEWS) operated across Namibia is a semi-technical system that uses physical observations as a primary forecasting method. Flood routing and initial alerts are determined using rainfall and water level readings obtained from gauges and markers across the Zambezi, Kwando, Chobe and Linyati rivers [40–43].

Although Namibia has an active FEWS in place, the increasing severity and unpredictability of extreme flood events threaten the response-oriented nature of the system. As such, resilience, in terms of preparedness, recovery and response capacity, requires significant improvements if vulnerable communities are to encounter flood hazards effectively. Reviewing the impact level and efficacy of the mechanisms employed to minimise flood impacts is not only relevant to effective community responses but also identifies pathways for resilience building.

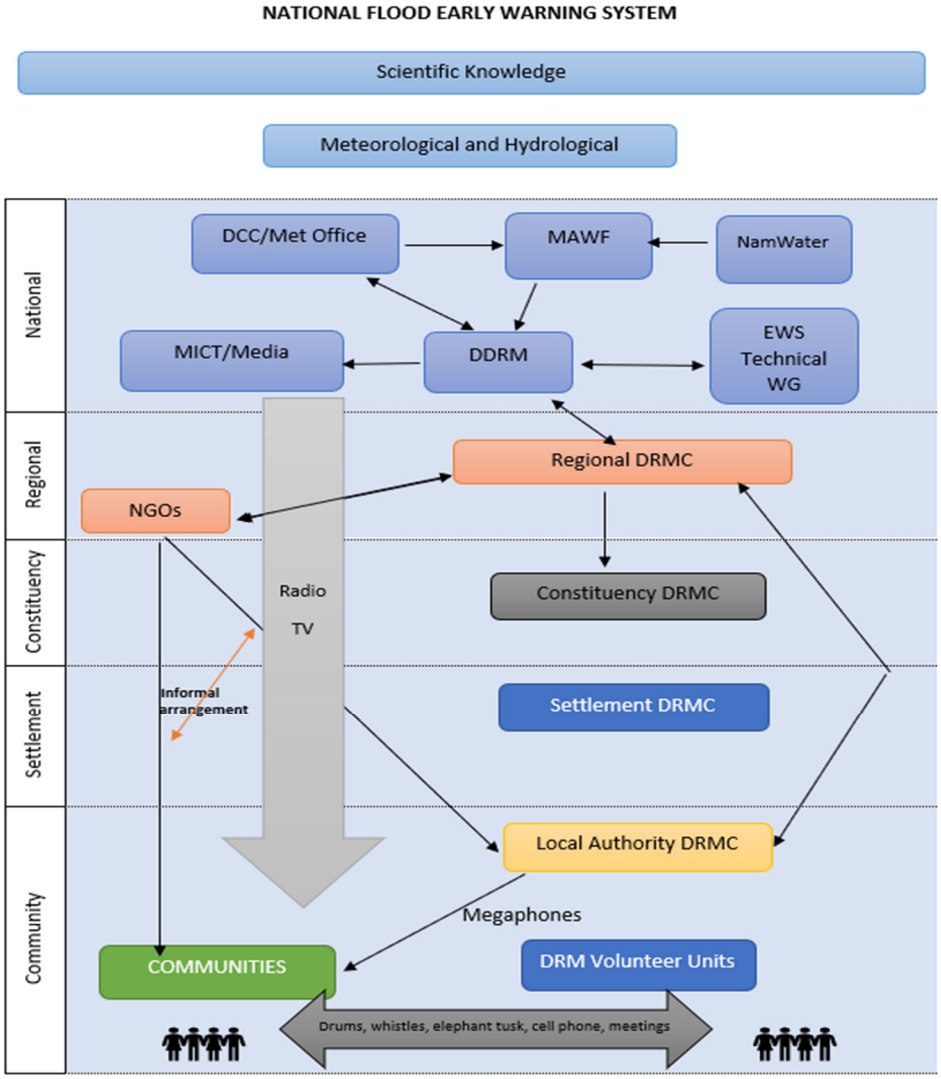

Figure 1. A simplified view of the national flood early warning system in Namibia. Self-illustrated using [44] and research data.

2. Materials and Methods

2.1. Study Area Description

The study was conducted in Kabbe, the most flood-impacted area in Namibia, which comprises several villages with poor and limited infrastructure (Figure 2) [45]. Over 88% of the residents in Kabbe have no access to electricity, 3% are living with disabilities, 16% are below 15 years of age and 58% are over 60. The Kabbe constituency forms part of the Zambezi River basin, covering a surface area of 2135.8 km^2 solely made up of flood plains (over 50% of the flood plains in the Zambezi region) [46]. The area is almost entirely enclosed by two of the country's major perennial rivers, i.e., the Zambezi and Chobe Rivers, and suffers recurrent seasonal, riverine and flash floods, making it the most flood-impacted area [45].

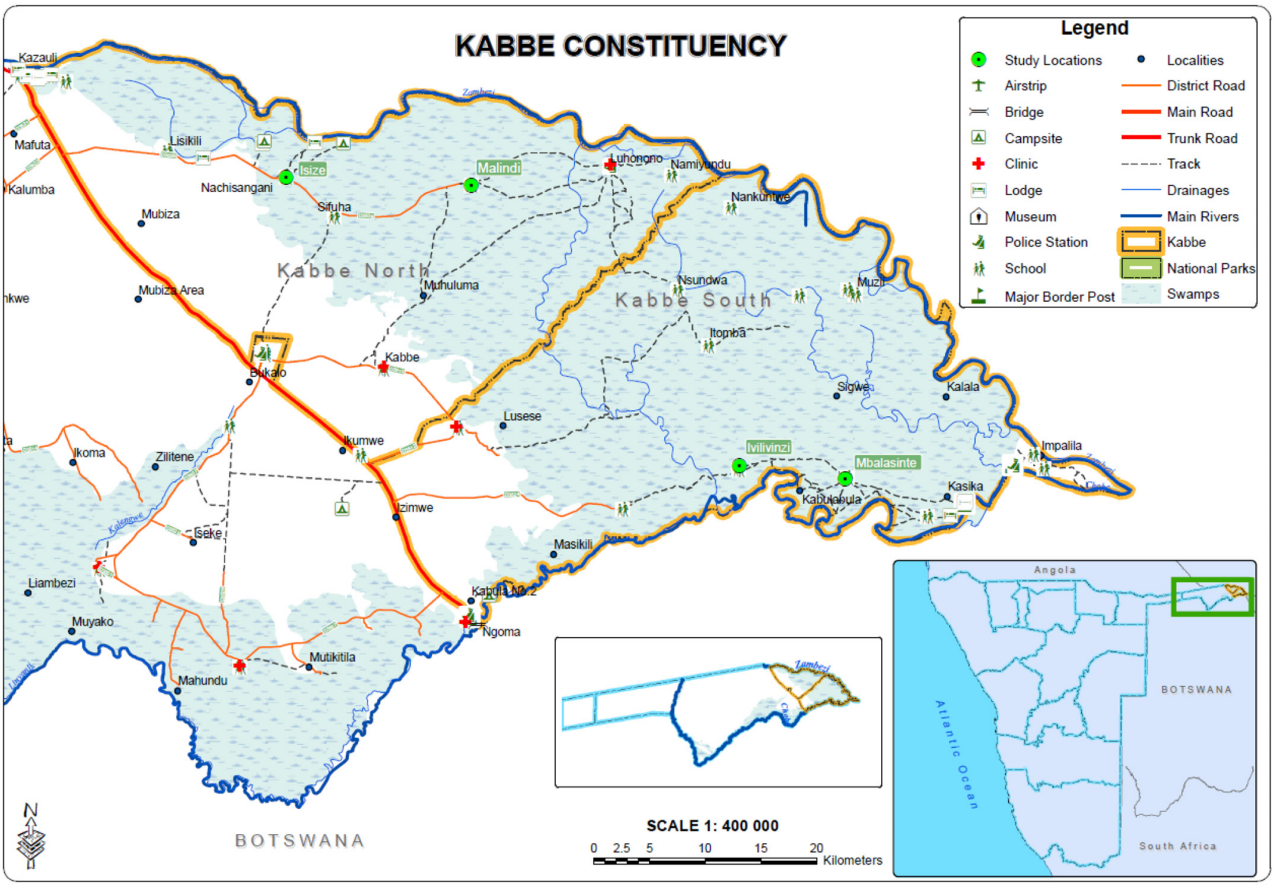

Figure 2. Location of the Kabbe constituency. Self-illustrated using [45].

The population size of the Kabbe constituency, derived from the 2011 Namibia Census Report, was 14,518, with the entire population being rural and 82% being primarily dependent on the environment for their livelihood [47]. Kabbe has been subjected to annual riverine and flash flooding since the 1900s, with the national government requesting international assistance in 2009 and 2011. The area is flooded annually, displacing thousands and resulting in thousands of deaths over the years [41,48]. The most destructive flooding events in Kabbe were recorded in 1958, 1969,1978, 2004, 2007, 2009, 2010 and 2011, with the literature revealing several unrecorded 'high-impact' floods in 1966, 1968, 1970, 1975–1976 and 1979 [49–53]. In 2009, more than 80% of the population in Kabbe was affected by riverine floods, leading to the relocation of over 10,000 people from the floodplain [39]. Although flooding events in 2010 did not require international assistance, residents in Kabbe referred to these floods as being much worse than those experienced the following year [43]. Fifty thousand people were affected in the Zambezi (where Kabbe is located), Omusati, Ohangwena and Kavango regions, of which (16%) were from the Kabbe constituency [41]. Approximately 50% of the residents were affected by floods in 2011, with over 5000 relocated to campsites. The influx of people at the relocation camps resulted in people living in poor sanitary conditions, with insufficient water availability at some campsites for up to six months. Roads were cut off, livestock was left stranded in the floodplains, houses and crop fields were submerged and crop storage was destroyed, exacerbating the ongoing food scarcity issue in the area [50].

2.2. Data Collection and Analysis

Data collection occurred between May and September of 2022 through key informant interviews and focus group discussions in four villages in Kabbe (i.e., Isize, Mbalasinte, Kalumbesa and Ihaha). The two methods allowed for the corroboration, verification and

enhanced credibility of the collected data. Nine (9) semi-structured key informant interviews (KIIs) were conducted with purposively selected officials from governmental and non-governmental agencies involved in flood management. The key informants included officials and technical staff from the MAWF, NDRMC, OPM, ZRC, Kabbe North local authority, Kabbe South local authority and Namibia Red Cross (NRC). The respondents included officials and technicians operating the system at the national, regional and constituency levels. Additionally, eight (8) focus group discussions (FGDs), comprising 7–9 residents, were conducted in the select communities, providing the researcher with a holistic view of the efficacy, degree of reach, information flow, community roles and responsibilities and local awareness and perceptions of the FEWS. The FGDs consisted of village heads, community volunteers, farmers and women's flood committee members. The interview questions for both data collection phases were designed to gather information on FEWS governance, flood risk knowledge and awareness, the flow of relevant information from the national to the community level, flood monitoring, warning dissemination methods, response capabilities, community perceptions on the FEWS and the consideration given to the socio-economic and environmental risk factors in flood-impacted areas. Both thematic and descriptive statistics were used to analyse the data. Using an impact-based scoring system, scores were assigned to each theme based on information from key informant interviews, focus group discussions and field observations made during the research period.

3. Results

The study results are based on the most relevant and recurrent themes observed during the analysis. These results are presented based on system governance and the four elements formulating an early warning system. The results are presented in the order of (1) governance, (2) risk knowledge, (3) monitoring and warning services, (4) communication and dissemination and (5) response capabilities. The findings reveal that the FEWSs contain several gaps across all four components, including governance. Figures 3–7 provide schematic overviews of the system's efficacy for the relevant component, while Figure 8 provides an overview of the system's efficacy based on average scores. The low FEWS scores (Figure 8) corroborate the poor system efficacy, as described by the study participants.

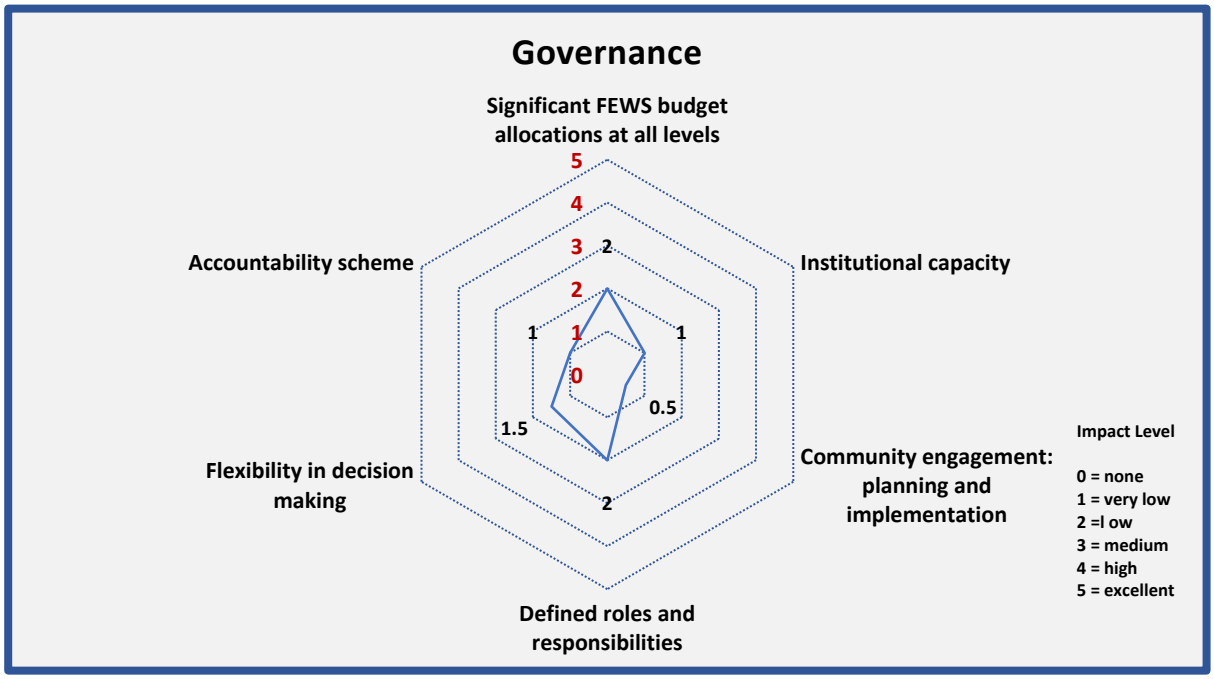

Figure 3. Impact scores for FEWS governance.

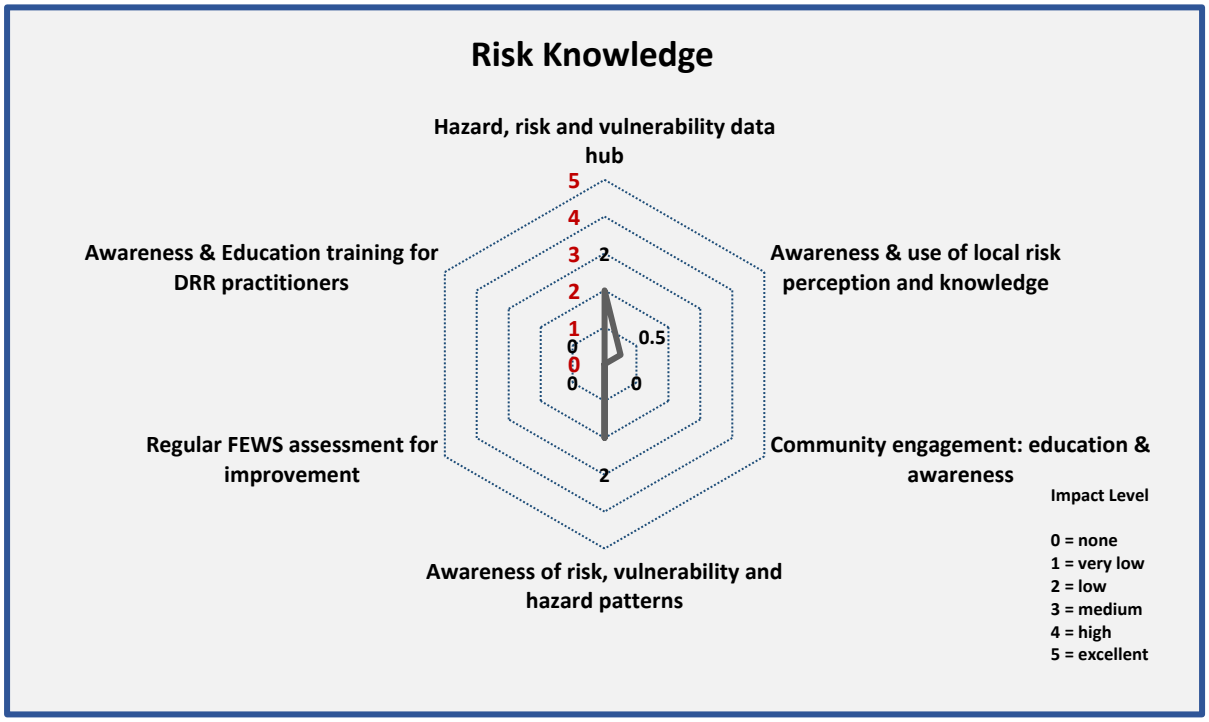

Figure 4. Impact scores for FEWS risk knowledge.

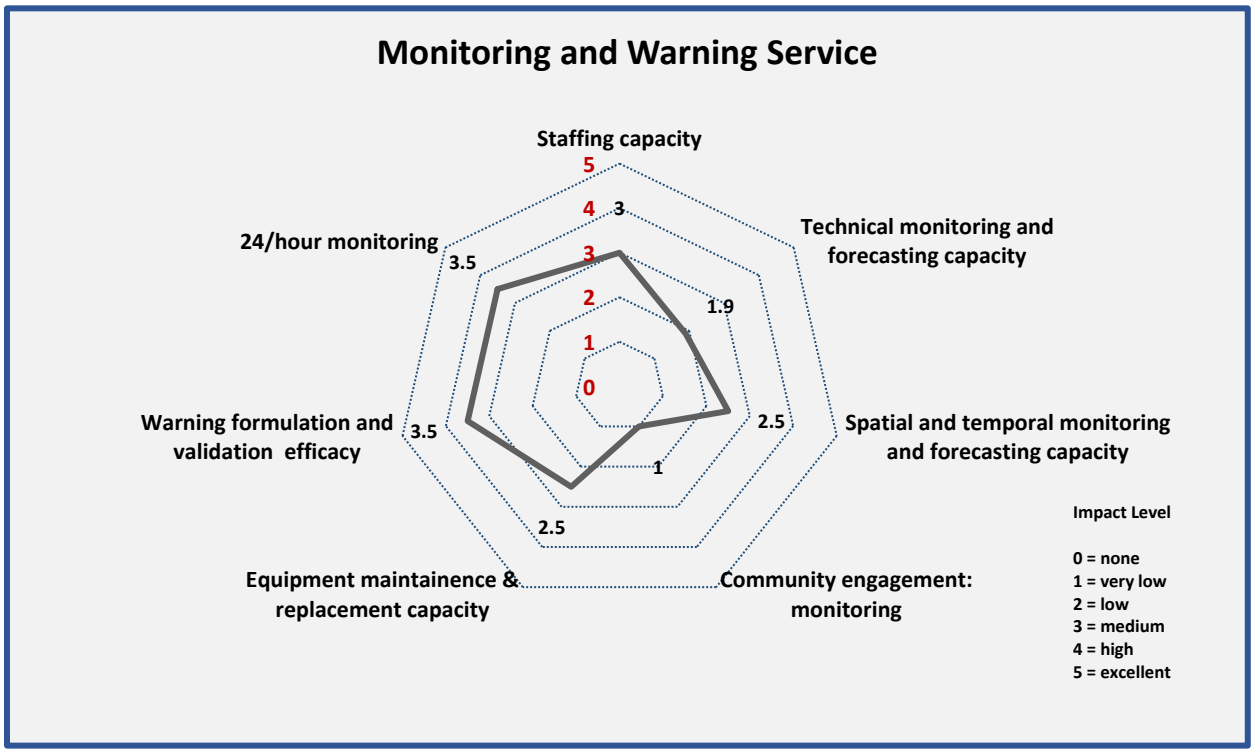

Figure 5. Impact scores for FEWS monitoring and warning services.

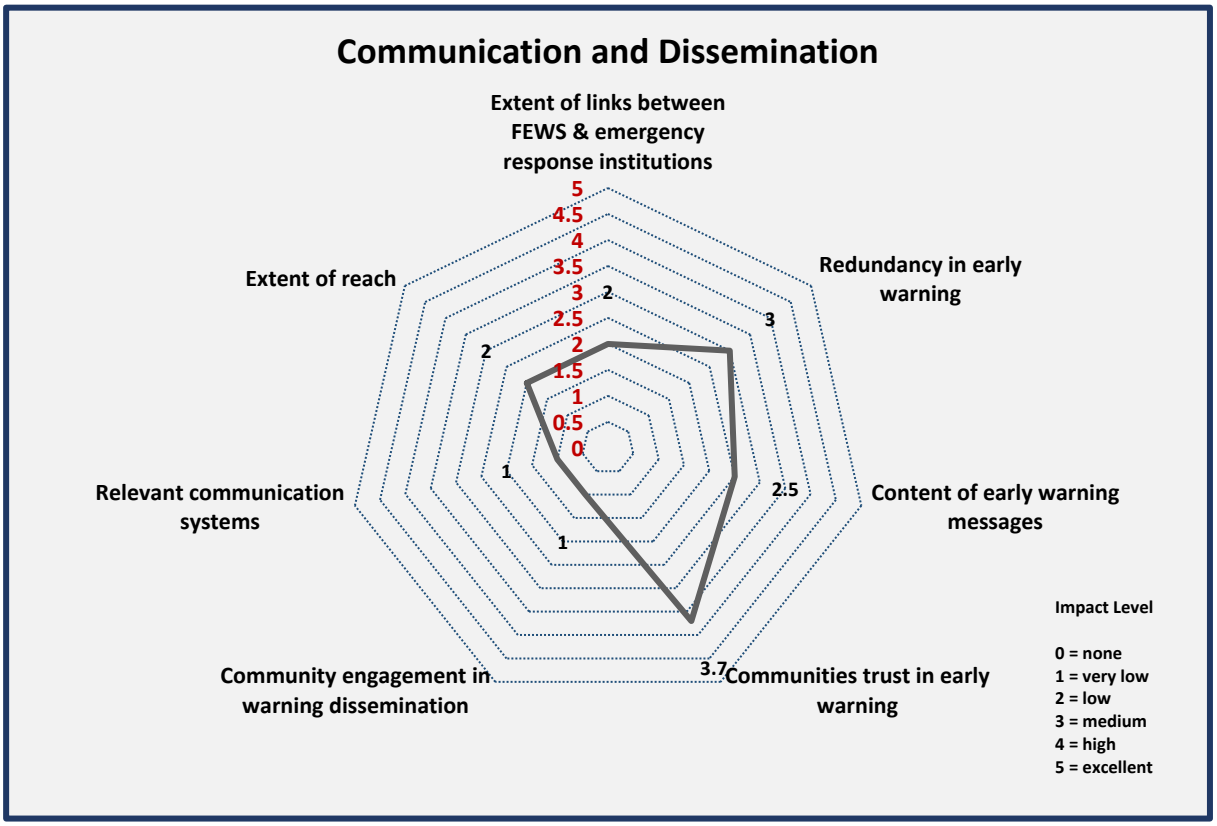

Figure 6. Efficacy scores for FEWS communication and dissemination.

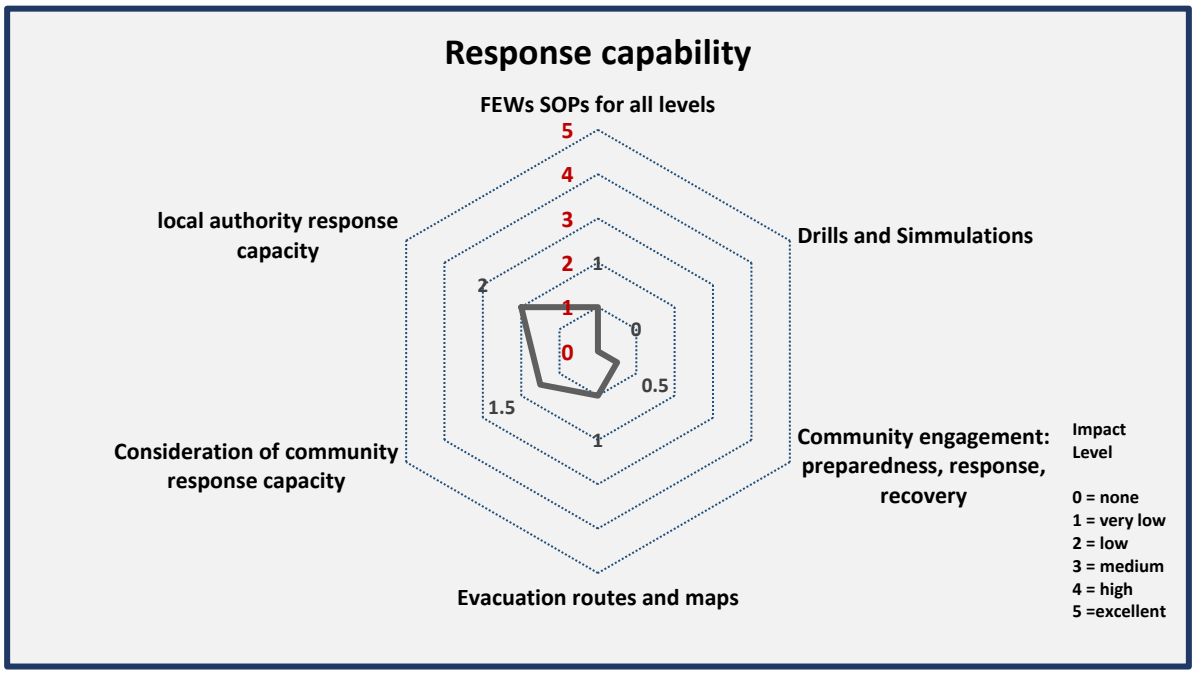

Figure 7. Impact scores for FEWS response capabilities.

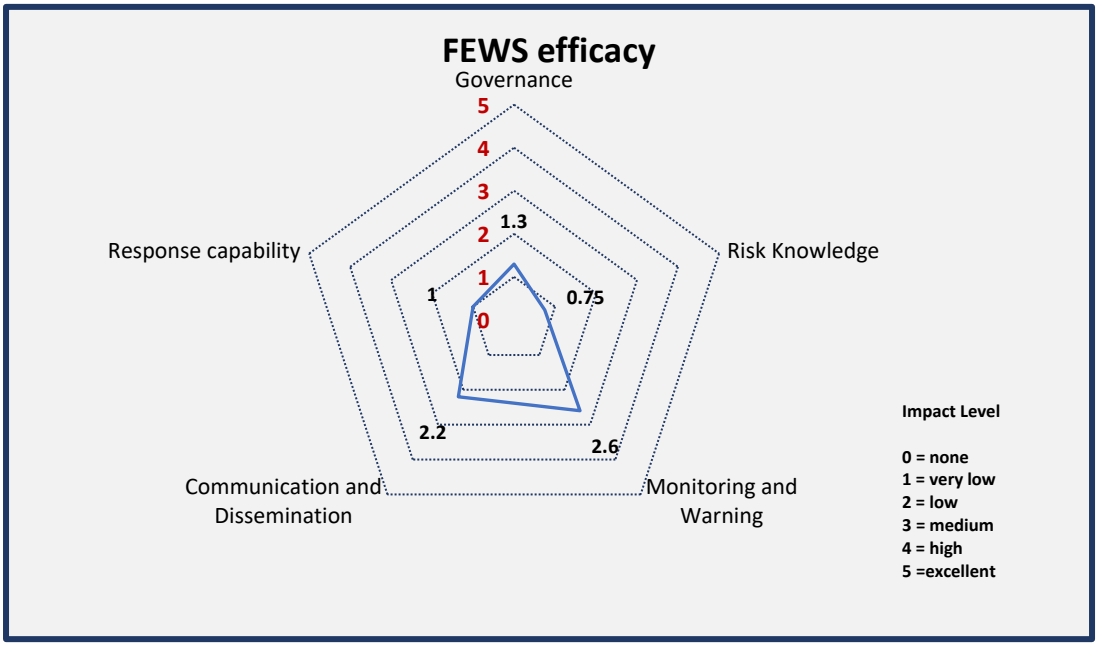

Figure 8. Overall FEWS impact level.

3.1. Governance

The study findings reveal that although technical and DRR institutions collectively serve the FEWS, the roles, responsibilities and accountability are undefined. For instance, although the MAWF is the mandated custodian of the FEWS, the officials seem unsure about their institutional role. As an official from the MAWF stated:

> *"We do the monitoring and forecasting with rainfall and climate data from MSN. However, I would not say we are in charge of the FEWS. We simply provide the DDRM with this information, and they make all the decisions. They say we are in charge, but our role is advisory; we don't make any decisions."*

A DDRM official shared a different sentiment:

> *"We serve a coordinating role; we bring everyone together when a disaster has been declared. We validate and issue warnings via the Ministry of ICT, but the day-to-day running of the system happens at the MAWF. We are only active when it is a national disaster."*

The poor definition of roles highlighted a recurrent trend amongst DRR institutions, revealing a gap in awareness in terms of responsibility and accountability. As an official at the regional office stated:

> *"As a nation, we do not really understand the concept of disaster management. For instance, this region is the most affected by floods, but we do not have a DRM department; we only have one official for DRM and one at the constituency office. Sometimes people even wonder why I am here; I am only active during the flood season."*

Furthermore, knowledge about the roles and responsibilities of FEWS institutions, response plans and the overall existence of a FEWS for flood emergencies is lacking among the public. The decision-making (1.5) and institutional capacity (1) scores were also weak, as decisions about FEWS operations occur at the national level, and not all DRMCs have been established. Past experiences revealed that the structure of command has performed poorly against flood disasters, resulting in avoidable impacts and damage [54]. The causes of failure can be linked to several gaps in this structural assembly, such as the lack of institutional frameworks enabling local authorities to operate the FEWS at the local level. In addition, budgetary allocations and approvals take place at the national level. Nearly

90% of respondents stated that budget allocations for personnel recruitment and training, modernising available systems and developing preparedness and recovery programmes are unavailable. An official at the regional office stated the following:

> *"We have to wait for the MAWF to send us forecasts; sometimes, this is delayed. But it helps that we know each other, so we can call each other directly and intervene even if the official information is delayed."*

Over 80% of the KII respondents agree that funding restrictions are more pronounced at the regional and constituency levels. As a ZRC official lamented:

> *"We only receive money for response efforts, which is not enough. You have to justify every request for funding; if it is not viewed as pressing, it is not approved. So we may plan for community outreach for preparedness training and so forth because these floods occur annually, but if there is no flood, there is no problem. Our hands are tied."*

A DDRM official stated the following:

> *"We do budget allocations at the national level, yes. Regional and local authorities need to motivate funding. Currently, the budget for DRM activities is quite limited, but we are working on it. For now, these authorities just need to tap into their operational budgets."*

3.2. Risk Knowledge

The responses from governmental officials suggest that risk knowledge is the weakest of all four components. Risk information is lagging, as no local or central hubs (0) exist to provide access to hazard, risk or vulnerability information for DRR. Although Kabbe is the most flood-impacted area in the country, over 80% of the key respondents did not know the trends in risks and vulnerabilities in the area. As an MAWF official stated:

> *"I do not know much about Kabbe or the trends in risk or vulnerability; I know that it is above the red line and is the most flood-impacted area in the country, but I do not know anything more about it."*

However, the study found that the residents' awareness of the flood risks, including risk and vulnerability patterns, is very high, based on FGD responses; this information is shared with researchers and sometimes with officials from Namibia Red Cross. As a resident in Kalimbesa stated:

> *"A big flood is always expected every ten years or so; we expect them and prepare. In 2009, the flood was bigger than expected, but we had prepared. In 2011, we expected the floods, but many of us had nowhere to go. The channels were still filled with water from the floods in 2009 and 2010. We know how water behaves, we know what to do, but sometimes it is not enough."*

As a woman from a village DRMC in Mbalasinte stated:

> *"The ones close to the river usually get hit the hardest, and then the water starts flowing down to this side. We gather children, sick, old and blind people and move to some mounds on the higher ground. Even though Kabbe is flat, there are elevated areas where we seek refuge if water levels in the village are high."*

Furthermore, practitioners at the regional level only consider local risk perceptions (0.5). Community engagement, awareness and education training for practitioners and system assessments scored 0, as none of these activities are ongoing. Additionally, over 90% of the FGD respondents acknowledged having no access to risk maps or data from the FEWS.

3.3. Monitoring, Warning Communication and Dissemination

Regarding monitoring and warnings, respondents from the MAWF, OPM and RDMC revealed that although the correct parameters are monitored and warnings are often generated timeously, a sound scientific basis is lacking. However, the system scores for

monitoring and warning services were the highest, indicating that efforts are made in this area. The monitoring and forecasting capacity score (1.9) was attributed to factors such as inefficient personnel, outdated forecasting systems, limited forecasting outputs and inadequate monitoring stations. The spatial and temporal forecasting scored just above having a low impact (2.5), as it extends to the constituency level. As narrated by the MAWF:

> *"Our forecasting capacity is relatively low, as we only rely on rainfall data. We require particular kinds of software to run specific models and to be able to calculate inundation levels, impact the extent and so forth, and we just do not have money for it. We also do not have qualified personnel to operate these systems, so there are a lot of issues."*

The KIIs and FGDs revealed that the residents conduct their own monitoring activities that are not incorporated into the official FEWS. An official from ZRC stated the following:

> *"The MAWF does the monitoring. Unfortunately, there's no formal relationship between our system and residents to monitor. However, they conduct monitoring themselves and share this information among themselves and with the Red Cross. They have my details; sometimes, they will inform me that water levels have risen by this much during the last hour, so it helps."*

A villager in Lusese stated the following:

> *"We do our own forecasting and monitoring using traditional methods and colour sticks given to us by the red cross. We even make our own, and sometimes we call the councillor's office to inform them."*

Additionally, the FEWS in Namibia faces various technical challenges in its operations from national to local levels, such as in data collection, management, synthesis and incorporation into the hydrological modelling process.

The research findings reveal that the challenges faced in warning communication and dissemination (Figure 6) are primarily due to poor coordination between technical, DRR and emergency institutions (2) and poor public engagement (1). Structured coordination is said to be conducted during a declared national disaster. The extent of reach is relatively unknown (2), as no feedback loops exist in FEWS operations. However, the irrelevant communications systems employed (radio, television, websites) during dissemination indicate the limited reach, as they are unbefitting of the rural setting in Kabbe. Based on both KIIs and FGDs, 80% of respondents agreed that communities in Kabbe are ill-equipped to receive alerts and 8% acknowledged receiving warnings on the radio, 94% heard the warnings from fellow villagers based on indigenous systems and 35% agreed that local authorities disseminate warnings with megaphones.

A woman in Lusese stated the following:

> *"We don't always receive official warnings because very few can afford to keep a surplus of radio batteries at all times; some do not even have radios. Electricity is limited, and not many have cell phones."*

Residents with radios acknowledged the redundancy of the warnings (3), while those who receive them trust the warnings (3.7). However, FEWS-trained volunteers do not yet exist to assist with dissemination at the community level, and over 70% of the residents state that these messages are often late. Community engagement scored one on account that the regional and local authority officials engage them unofficially. The EW messages are comprehensible only to practitioners, scoring 1.5. The FGDs revealed that the messages received by residents are different in that they are advisory in nature. As a farmer in Lusese stated:

> *"Sometimes government officials drive through the villages, informing us that water levels are rising and we should evacuate to the upper lands or relocation camps. They do not take us there or send assistance. They announce this and leave."*

3.4. Response Capability

System efficacy in terms of response capability (Figure 7) was found to be inadequate, with scores of 1, 2 and 0 for the availability of standard operating procedures (SOPs), the local authority response capacity and emergency drills and simulations, respectively. Evacuation maps are only developed for disaster-level floods, and response plans only exist at the national and regional levels. As stated by a DDRM official:

> *"We have response plans, but only at the national and regional level. These are only activated depending on the flood magnitude. The Regional DRMC would usually activate their plan during the rainfall season. They cater to the communities in Kabbe.*

A regional DRM official shared the same narrative with a slightly differing sentiment:

> *"We have a response plan, but no drills and simulations are conducted. We simply do not have the budget, even though it is important. Our response plan is not for the constituency or community level; we improvise."*

Residents and officials verified that the local response capacity (1) is disregarded, as narrated by a villager in Ihaha:

> *"Sometimes, the government officials come here to tell us to prepare before the flood and to evacuate. They have a boat that transports us to Katima because we get cut off, but other than that, they only come during elections."*

A local authority official added the following:

> *"It is not that we do not consider the poverty in the area; the people that make decisions higher up do not know Kabbe. They look at a map, see it is a small area, and wonder why we are requesting all these funds; it seems ludicrous. Especially when a flood has not occurred yet, and unfortunately, the people suffer."*

An additional area serving as a significant gap is the lack of community engagement for preparedness and response awareness. The KII and FDG respondents confirmed the sporadic nature of the recovery programs. However, these were undertaken after the flood disaster events of 2009 and 2011.

3.5. Overall System Efficacy

The average impact scores (Figure 8) represent the overall efficacy level of the FEWS against the recurrent flood hazards in Kabbe. As the study findings suggest, the current FEWS does not effectively mitigate flood events in Kabbe. All performance scores were below the medium impact level, suggesting a need for a significant revision of the systems' design and implementation. Although monitoring (2.6) and warning dissemination (2.2) efforts also fell below the medium level, it is evident that efforts are made at the local level. However, significant work must be done regarding the DRM governance (1), risk knowledge (0.75) and response capability (1).

4. Discussion

Based on the study findings, the analysis identified several gaps within the FEWS. The identified gaps are discussed below, with a summary of the gaps and proposed recommendations presented in Tables 1 and 2. The discussion is provided under the designated FEWS study components. Table 1 presents gaps related to the relevant authorities, while the identified gaps related to rural communities are presented in Table 2.

Table 1. Summary of identified FEWS gaps related to authorities and proposed recommendations.

Identified Gaps	Recommendations
Effective EW dissemination to grassroot levels	- Establish methods to address marginalised communities in receiving EWs and make use of current statistics and census reports to monitor the process - Establish a user-friendly interface for EW dissemination by using methods befitting target communities, e.g., sirens, radio, and investing in placing more telecommunication stations in affected areas - Raise awareness among communities on communication systems
Restrictions in communication links	- Use of technological applications to establish communication systems among DRR institutions, with an extension to target communities as far as possible - Establish localised EW communication systems to avoid breakdowns in the hierarchy of EWs dissemination
Lack of and outdatedness of SOPs	- Establish SOPs for all magnitudes of flooding events at all levels of government - Verify SOPs and reviewing roles and responsibilities frequently
Issues in decision-making structures	- Establish a technical advisory committee - Revisit legal and policy provisions to give more autonomy to local authorities and eliminate power struggles between authorities - Ensure that institutional roles and responsibilities are enforced by establishing an accountability system
Poor equipment used for hazard monitoring, forecasting and EW dissemination	- Ensure regular maintenance is carried out and keep an inventory of equipment that needs replacing - Allocate adequate funding for the installation of additional monitoring stations and maintenance of existing stations - Promote the use of more effective alternative methods where technologically advanced equipment cannot be procured
Poor inclusion of communities in FEWS operations	- Create a feedback loop to understand community risk perceptions and vulnerability and FEWS effectiveness - Create mechanisms to involve communities in all stages of the FEWS - Establish platforms to strengthen collaboration between local authorities and communities
Lack of clarity and accuracy in monitoring	- Develop local area modelling to improve flood forecasting accuracy - Enable capacity-building in hazard monitoring and forecasting by hiring experienced staff and regular training
Poor communication speed among DRR institutions and between the public and DRR institutions	- Increase the credibility and clarity of information and using social media platforms for quick dissemination of EWs - Establish reliable communication systems from technical institutions to emergency operating centres (EOCs) and from EOCs to regional and constituency levels - Introduce automated systems for generating and disseminating EWs where applicable, starting at the local level - Combine innovative and traditional mechanisms (e.g., online media briefings followed by emails, phone calls or text messages on significant notices) - Develop stakeholder coordination platforms using social media and quick-access e-bulletins

Table 1. *Cont.*

Identified Gaps	Recommendations
Lack of engagement of local authorities	- Increase funding and human resources, and ensure that DRR is recognised as an institutional and collaborative responsibility at all levels - Enhance the engagement of local actors through revisiting and revising policies - Produce hazard, vulnerability and risk maps at local levels - Establish data and information management systems at the local level
Inaccurate predictions	- Use new technologies for forecasting - Develop local area modelling to improve the accuracy of forecasting
Lack of human resources	- Employ experienced and qualified staff and conduct regular training and capacity-building programmes
Poor planning	- Encourage multi-sectoral approaches for flood mitigation, including revisions of laws and policies - Make use of updated population statistics, scientific research and census information DRR planning - Invest in preparedness training for institutions and residents of at-risk communities
Poor safety in evacuation routes	- Update the templates used for issuing EWs with clear legends and signs - Establish volunteer groups to provide security for women, children and the elderly - Encourage multi-sectoral approaches for evacuation planning - Make use of updated census data and statistics for planning - Develop programmes and social media platforms to update information related to the safety of evacuation routes at the disaster stage
Limited resources in FEWS operations	- Investing in transportation and infrastructure inside shelters - Strengthen logistic supply chains by consolidating all stakeholders from the planning process onwards - Improve links with relief services and develop programmes for camp management and recovery programmes
Inadequate prioritisation of most vulnerable individuals	- Allocate specifically designed areas in safe shelters for people with special needs - Develop and implement humanitarian standards for evacuation camps
Irregularities in the distribution of resources	- Use structured approaches for resource distribution
Lack of education and awareness	- Recruit staff with backgrounds in DRR studies - Develop programmes to educate officials on the socio-economic and environmental capacities of target areas - Develop awareness campaigns on DRR

Table 2. Summary of identified gaps related to community and proposed recommendations.

Identified Gaps	Recommendations
Mistrust of authorities	- Establish mechanisms to measure public trust and take action accordingly - Introduce rating systems for community trust in authorities pre- and post-disaster - Establish a feedback loop for assessing public opinion and rumour monitoring to eliminate false risk warnings
Overconfidence in their traditional knowledge	- Build risk knowledge of community using modern concepts - Use of risk communication strategies to emphasise the danger of the hazard - Incorporate indigenous knowledge and local languages into EW generation and risk awareness campaigns
Reluctance to respond	- Use awareness-building programmes to increase the level of risk knowledge on the impacts of flood disasters
Lack of evacuation training	- Design multi-sectoral evacuation drills and simulation training - Conduct scenario-based drills and training - Conduct an adequate number of drills at the community level - Increase participation in drills by promoting the benefits of effective evacuation
Poor use of available technological platforms for information	- Increase electronic literacy through awareness campaigns - Disseminate EWs through social media targeting specific age groups
Lack of awareness and not following flood guidelines	- Updating school curriculum on risk communication systems - Establishing clear signboards to disseminate proper information in the local language - Use informal education tools - Community-based awareness programmes
Dependence on slower modes of dissemination	- Increase the community awareness of speed communication systems - Establish quick and reliable communication systems from local actors to the community - Set up central community hubs for the maintenance and management of electronic devices, e.g., walkie-talkies, cellular phones, used in EW dissemination
Attachment to personal belongings	- Promote the concept of building back better and the use of evacuation backpacks - Educate on in-house protection strategies for personal belongings; increase elevation to protect goods from floods - Provide resilience training by promoting methods to maximise the beneficial aspects of flooding while maintaining safety
Poor cooperation with local government units	- Create a personal care network - Include local authorities in preparedness activities and evacuation planning - Establish platforms to strengthen collaboration between LAs

4.1. Current Status of the Flood Early Warning System in Kabbe, Namibia

4.1.1. Governance

Undefined institutional responsibility and accountability magnifies the challenges faced in the FEWS operations. The analysis showed that DRR is considered an issue for the national government at the local level; the same is true for the opposite. This realisation is ascribable to the limited mandates and capacity at the local levels, where a single official is assigned per region to deal with all DRR issues. In contrast, the mandate to activate emergency responses lies with the OPM. Additionally, budgetary decisions and approvals occur at the national level, and funds are often disbursed based on flood magnitude.

Inadequate funding is a significant limitation to the sustainability of the FEWS. The gap analysis suggested that the lack of funding limits the preparedness and recovery activities within the system, resulting in discontinuities in operation, insufficient upgrading and advancement of technical equipment and insufficient hiring and training of personnel. Even though early warning systems are considered a continuous process, the FEWS does not have the funds to sustain ongoing operations. Nearly 90% of the respondents state that budget allocations for personnel recruitment and training, modernising available systems and developing preparedness and recovery programmes are unavailable. Funding restrictions are more pronounced at the regional and local levels, which are forced to prioritise funds for response activities.

Additional funding for high-tech computers, observation networks, data management systems and skilled personnel are required to operate and maintain the hydrologic models available to monitoring institutions. Owing to the diversity of the institutions involved in running the FEWS, the lack of information on the implementation and operational costs is an added challenge. Substantial investments require justification, and information on operating the system and the impacts and benefits is widely unavailable. In this case, the data unavailability is due to the lack of a national DRR database that documents and monitors the progress of SDG and Sendai targets, such as reductions in mortality, affected individuals and economic losses. The results of the quantitative economic assessment of the FEWS can assist the government and donors in making informed investments in these systems.

4.1.2. Risk Knowledge

The success of any FEWS depends on having a detailed understanding of the target area's risks [7]. In the case of the Kabbe constituency, a regional-level risk assessment exists, and hazard-prone regions are mapped. However, this information is rudimentary and cannot be used for potential impact assessments. Flood hazard maps produced by the MAWF are not distributed to at-risk communities and only serve at national and regional levels. The evaluation revealed that the vulnerability and risk information collated by the Namibian Vulnerability Assessment Committee (NAMVAC) is sparsely available and not adopted in DRR planning. Additionally, this information is only available at the national level, and there is no local hub for hazard, vulnerability and risk data.

Data availability forms a significant gap in the system, with technical agencies acknowledging that the information required to make informed decisions for forecasting and disseminating timeous warnings is often insufficient. For example, the MAWF indicated their need for high-resolution digital elevation data for inundation mapping and high-resolution satellite-based rainfall information to derive run-off data within the basins to forecast reservoir water levels. This information would enable them to conduct impact assessments in target areas. While individual DRM institutions perform their duties as best they can and share their forecast information, no immediate plans exist within these institutions to develop forecasts that could address the specific needs of other users. Additionally, although the locals are well versed on the risks, vulnerabilities and trends pertaining to these factors, the lack of community engagement to access this information forms another gap.

4.1.3. Monitoring and Forecasting

The use of hydrodynamic models to obtain river discharge data and predict streamflow is a primary activity in flood forecasting [55]. In some instances, flood inundation maps are produced from geo-referenced water surface elevations and used in public awareness efforts and disaster response operations. FEWSs require sound technical capabilities to ensure accurate and timely early warning information. Based on the study results, the FEWS in Namibia faces various technical challenges in its operations from national to local levels, such as in data collection, management, synthesis and incorporation into the hydrological modelling process. The FEWS lags in integrating risk knowledge information observed rainfall records and weather prediction outputs to generate forecasts and remote sensing data. Producing robust flood forecasts, models and hazard maps requires long-spanning data records. In addition, poor data quality and short data records are influenced by poor financial investment, the mismanagement of hydrological networks, equipment damage and weather-related issues. To determine if improvements to modelling tools and procedures are necessary, the operational effectiveness of the flood forecasting system requires frequent evaluation. Although this is crucial, it is not a regular occurrence within the MAWF.

Ground observations remain the primary exercise in flood detection, as the spatial data required for flood forecasting and risk mapping are sparsely available and often incomplete. Additionally, the lack of investment in technical institutions limits the acquisition and operation of model simulations in flood forecasting, restricting outputs for flood risk and hazard mapping. The MAWF revealed that the models used for producing flood early warnings are not accurate or advanced enough for flood impact forecasting, as they lack high-resolution inundation-level data. The lack of trained personnel with technical flood forecasting expertise is another major challenge for the MAWF, limiting the effective operation of the FEWS. Altogether, the analysis revealed that although technically proficient, the forecasters lack knowledge of the downstream response capabilities, including vulnerability levels, risk perceptions, warning communication abilities and flood preparedness. Moreover, although the system depends on ground observations, communities are not enlisted to assist with monitoring, passing up a valuable source for real-time data.

The gaps identified in terms of flood monitoring at all levels of government include ageing, a lack of maintenance and insufficient observation stations and data communication facilities. Additional gaps include the limited technical capabilities, ineffective data sharing and dissemination among FEWS institutions and a shortage of skilled human resources for operating modern computing tools (flood forecasting models, numerical weather prediction, etc.) for accurate prediction and forecast information production.

4.1.4. Warning Dissemination

Based on the set of standard operational outlines of EWSs, effective warning dissemination systems should include a functional telecommunication system that transmits warnings from the central DRR body to national, regional and local authorities, the Namibian Red Cross and communities at risk. The current FEWS disseminates warnings using a "top-down approach". The MAWF alerts the Office of the Prime Minister and they transfer the message to regional and local governments, which then convey it to at-risk communities. The MAWF also uses an electronic bulletin to post updates on observed and expected water levels. However, an advanced nationwide system that alerts people at risk en masse is still pending. The responses suggest that the system widely uses emails and the MAWF flood bulletin (with 700 stakeholders nationwide), followed by radio, SMSs, television and social media for warning dissemination. These methods are unbefitting to FEWS target communities.

Within communities, the dissemination approaches include using community-appointed volunteers, loudspeakers and word of mouth. Due to the rural nature of the communities in the Kabbe constituency, the use of cell phones and electronic devices often proves futile during flood emergencies. The delays between flood forecasts and issued warnings range

from minutes to hours. Day-long delays occur due to the MAWF requiring permission from the OPM to issue notifications. Additionally, the updates are dependent on the level of flood disaster.

Regarding warning capabilities, warning formulation and validation occur at the national level, depending on the level of flood disaster. However, an interpretation of the information is often lacking. Although Namibia has a good communication framework in place, the system generally fails because it does not cater to the rural nature of the target communities. Early warning information does not always reach vulnerable communities and individuals on time. The lack of a round-the-clock operating system is also a significant gap. Round-the-clock flood monitoring only happens during the expected flood season at the national level. Additional gaps in disseminating warnings to the public include the failure to translate generated forecasts and the lack of communication structures in target areas. Residents and officials acknowledge that the sanctioned early warning information flow is low (sometimes it is received and sometimes it does not reach the intended audience). Additionally, warnings should be concise, identify and mention areas at risk, detail probable loss within various timeframes, provide response actions and reach vulnerable communities promptly [56]. However, warnings often take the form of "flood updates", informing residents of rising water levels and possible flood expectations, resulting in misinterpretation and inadequate responses by residents. The fragmented nature of the warnings is because of a lack of SOPs at all levels of government. This observation is consistent with information from state officials and residents who acknowledge that at times, residents wait until flood waters reach their homes before evacuating.

4.1.5. Response Capabilities

Effective end-to-end early warning systems require community acceptance and responsiveness to early warnings [57]. Achieving this requires national and local capacity-building through implementing awareness programmes, disaster preparedness plans and structured training and education by DRM authorities [58]. The assessment results show that in terms of the response capability, the lack of standard operating procedures (SOPs) at the local level, insufficient transportation and funding for public awareness and insufficient response training constitute significant concerns. SOPs are often reserved for 'disaster-level' flood events and are implemented at the national level by the OPM. This lack of local-level planning impedes response activities, as clearance is required from the OPM for emergency support. Due to the limited funds, the ZRC cannot recruit volunteers to assist with evacuations. However, residents trust the warning information received from authorities and personal observations. They often use this information to vacate the floodplains on their own accord. Several members have received evacuation training through past programmes operated by Namibia Red Cross.

The regional council, Namibia Red Cross and residents confirm that communities have opted to take matters into their own hands in recent years and no longer rely on them for evacuations and warnings, a sign of improved community preparedness. Residents rely on each other, community-led committees and volunteer groups to support evacuations. Measures such as temporary relocations, stocking sandbags, digging pathways to redirect flood waters and flood-proofing houses are undertaken well in advance, without governmental support. However, due to their poor economic capacity, residents cannot always take appropriate actions and heed warnings immediately. Furthermore, risk awareness, flood emergency response plans and knowledge about the roles and responsibilities of different FEWS agencies are poor among the public. This lack of information is partially attributable to the irregular awareness programmes; discontinuities in preparedness and response and recovery training; ineffective capacity-building strategies such as drills, workshops and training; and ineffective evacuation procedures magnified by low literacy rates. The population demographics, such as the higher proportion of children and older people (50% in Kabbe) [47], also affect the response rates, as these individuals depend on others for response decisions.

4.1.6. Identified FEWS Gaps and Recommendations

Overall, the assessment revealed gaps in the FEWS from warning generation to dissemination stemming from issues in governance. The issues include a lack of qualified personnel, insufficient reliable information, insufficient equipment, inadequate financial investment and poor collaboration between authorities and communities. Based on these gaps, recommendations for identified gaps related to relevant authorities are presented in Table 1, and those related to communities in the Kabbe constituency are presented in Table 2.

4.2. Study Limitations

The gap analysis of the FEWS naturally had limitations, as it only focused on a single hazard and not the multi-hazard systems addressed by other researchers. Additionally, the assessment covered operations in a single constituency. While flood risks affect several parts of the country, the study's outcome resulted from the views and opinions of communities in the Kabbe constituency. Furthermore, the researcher acknowledges the small sample size of participants. Ideally, ten to fifteen individuals should comprise a focus group discussion [59]. While standard FGD protocols were employed (i.e., adequate information regarding the study objectives, participation, timing and location for focus groups), several FGDs yielded between eight to ten participants. The reduced willingness to participate highlights the difficulties faced in engaging rural communities in research, specifically those reliant on subsistence farming for their livelihood. The difficulties encountered also reflect that communities within the locality engage in similar communication efforts to voice their opinions on flood impacts, i.e., programmes on impact feedback, relief efforts and recovery support. These consultations may have proved futile in the past and reduced residents' interest in the focus groups [60].

5. Conclusions

Flood early warning systems are a paramount fixture of flood-impacted communities, capable of building and strengthening resilience among the most vulnerable groups. If well established, FEWSs save lives, reduce economic loss and emancipate communities, granting them authority over their safety and protection decisions. FEWSs are operational in various countries worldwide; however, information on the nature, development, implementation, operation, benefits and challenges within these systems is lagging. Even more notable is the absence of truly participatory approaches, especially within the rural African context. Effective FEWSs will require DRR practitioners to acknowledge that these systems are developed in partnership with all stakeholders, embedded in communities and discard outdated end-to-end approaches.

This paper attempted to address gaps in the Namibian FEWS in the rural setting of a developing country while using global standards as benchmarks. Several gaps related to structural, financial and technical constraints faced in the system's operation were identified. Additionally, the study found that gaps existed across all four system components and at all levels of operation, including within communities. The study found that the system's efficacy was significantly low, and several changes are required, particularly the adoption of integrated and participatory approaches. National and local governments must consolidate and use the knowledge and expertise of all stakeholders, including researchers, NGOs and target communities, to improve the system's efficacy.

In light of the changing climate, improved flood risk management requires retrospective analyses of flood events and system efficacy associated with the socio-economic risk, vulnerability and capacity of at-risk areas. Ultimately, effective system responses for communities can only be achieved if these needs are understood and prioritised. Practitioners are urged to disregard the notion that an FEWS is a science-based, expert-driven linear tool and to provide the necessary support and resources as defined by those it serves.

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