Early Warning System for Disaster Preparedness in Local Flood Management

Leonardo Tedjaprasadja

Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jawa Timur

Corresponding author:

Leonardo Tedjaprasadja

Faculty of Medicine, Universitas Pembangunan Nasional Veteran Jawa Timur

Jl. Rungkut Madya, Gn. Anyar, Kec. Gn. Anyar, Surabaya, Jawa Timur 60294

E-mail: leonardo.tedjaprasadja.fk@upnjatim.ac.id

ABSTRACT

Background: Flooding remains one of the most recurrent and devastating natural hazards, disproportionately impacting low-lying and poorly drained areas, particularly in developing countries. Exacerbated by rapid urbanization, climate change, and inadequate infrastructure, flood-related disasters increasingly affect socioeconomically vulnerable populations. Despite the predictable nature of such events, local-level disaster preparedness remains insufficient, largely due to the absence or inefficiency of Early Warning Systems (EWS).

Methods: This paper investigates the role of EWS in strengthening community-based flood preparedness by applying the United Nations Office for Disaster Risk Reduction (UNDRR) four-component framework: risk knowledge, monitoring and warning service, dissemination and communication, and response capability. Using a qualitative, framework-based methodology, the study assesses each component through case study analysis, technological review, and institutional mapping.

Result and Discussions: Findings indicate that while EWS provides a robust conceptual tool for flood risk mitigation, their implementation is frequently hindered by technical, institutional, social, and financial barriers. These include unreliable monitoring infrastructure, fragmented governance, inequitable communication access, and unsustainable funding mechanisms. Moreover, the study reveals that the success of EWS hinges not merely on technological sophistication, but on their alignment with local contexts, community participation, and cross-sectoral coordination.

Conclusion: This concludes that for EWS to be effective and equitable, they must be embedded within broader resilience strategies that emphasize localized governance, long-term capacity building, and inclusive risk communication. By reorienting EWS toward community-driven models, stakeholders can enhance flood preparedness and reduce disaster vulnerability amid escalating climate threats.

Keywords: EWS, Disaster Preparedness, Flood Management, Local Context

Introduction

Flooding is widely recognized as one of the most frequent and destructive natural hazards affecting populations around the world. It poses particular risks to low-lying regions and areas with insufficient drainage infrastructure, where the accumulation of surface water often results in widespread inundation. The adverse impacts of flooding have become increasingly severe in recent decades, a trend closely linked to the interplay of rapid and often unregulated urbanization, land-use change, inadequate investment in resilient infrastructure, and the intensifying effects of climate change. These compounding factors not only elevate the likelihood of flood occurrences but also expand the scope of their socio-economic consequences.

Communities situated in flood-prone zones are often the most vulnerable, especially those with limited access to economic resources, institutional support, or formal housing. Such populations frequently bear the brunt of these disasters, experiencing high rates of displacement, property loss, public health crises, and disruptions to livelihoods and educational continuity. In many developing countries, informal settlements located in floodplains or near drainage channels are particularly exposed, further exacerbating risks for already marginalized groups.

Despite the recurrence of such disasters and their increasingly documented effects, community-level disaster preparedness remains disproportionately weak. A key contributing factor to this vulnerability is the absence, or suboptimal implementation, of effective early warning systems (EWS). These systems—when properly designed, implemented, and maintained—serve as critical instruments in forecasting flood events, disseminating timely alerts, and facilitating rapid, coordinated responses that can significantly reduce casualties and material losses.

This paper aims to explore the essential role of EWS in strengthening flood disaster preparedness at the local level. Particular attention is given to community-based approaches, which

emphasize participatory planning, local ownership, and contextual relevance as foundational principles for building resilient and adaptive responses to flood-related hazards.

Methods

This study employed a qualitative and framework-based approach to examine the structure and application of Early Warning Systems (EWS) in the context of local flood preparedness. The analytical framework is grounded in the four-component model established by the United Nations Office for Disaster Risk Reduction (UNDRR), which defines a comprehensive EWS as comprising: risk knowledge, monitoring and warning service, dissemination and communication, and response capability. These components were operationalized as key categories for assessing system design and community-level implementation.

First, risk knowledge was analyzed by identifying methodologies for the systematic assessment of flood-prone zones, vulnerable populations, and existing community capacities. This involved reviewing local hazard maps, socioeconomic vulnerability indices, and participatory risk assessments used in selected case studies.

Second, the monitoring and warning service component was evaluated through the examination of real-time data collection mechanisms. The study considered the deployment and efficacy of hydrological sensors, satellite-based rainfall detection, river gauge networks, and meteorological forecasting tools. Attention was given to their integration within national and local monitoring systems.

Third, the dissemination and communication element was assessed by documenting how early warnings are transmitted across different user groups. Emphasis was placed on the use of multi-channel delivery systems, including SMS messaging, community radio, sirens, public address systems, and digital platforms. The study evaluated the cultural and linguistic appropriateness of these communication strategies.

Finally, response capability was examined through documentation of community preparedness measures. This included the presence of contingency plans, frequency of emergency drills, training programs, and the accessibility of evacuation infrastructure. The interaction and interdependence of all four components were analyzed to determine the overall coherence and functionality of EWS models in disaster-prone regions.

Result and Discussion

The application of the four-component UNDRR framework in this study provided a structured lens through which the effectiveness of Early Warning Systems (EWS) for local flood preparedness could be comprehensively assessed. By disaggregating EWS into its constituent elements—risk knowledge, monitoring and warning service, dissemination and communication, and response capability—the analysis revealed both the strengths and limitations inherent in current EWS practices.

Assessment of EWS on disaster preparedness

The assessment of risk knowledge emphasized the importance of context-sensitive hazard mapping and vulnerability assessment as a prerequisite for targeted early warning interventions. However, findings suggest that many local governments and communities lack the technical and financial capacity to conduct such assessments on a regular basis. This deficiency can result in outdated or overly generalized risk data, leading to the misallocation of resources or the failure to issue warnings where they are most needed.

In evaluating monitoring and warning services, the study highlighted the growing reliance on technological tools such as satellite data and hydrological sensors. While these tools enhance precision and lead time, their utility is often constrained in rural or under-resourced settings where maintenance, calibration, and data interpretation pose significant challenges. The effectiveness of these tools, therefore, depends heavily on institutional capacity and technical training.

The dissemination and communication component was found to be highly variable across case studies. While the use of diverse channels (SMS, radio, sirens, etc.) can increase the likelihood of message reception, inconsistent access to communication infrastructure—especially among marginalized groups—can undermine the inclusivity of warnings. Moreover, the lack of standardized messaging and localized content may reduce the clarity and perceived credibility of alerts.

Finally, the analysis of response capability underscored the critical role of community preparedness in translating warnings into life-saving action. Communities with established emergency protocols, trained volunteers, and prior experience in disaster drills demonstrated higher responsiveness. Nevertheless, in many settings, the absence of sustained funding and institutional support limits the frequency and quality of such preparedness activities.

Collectively, the discussion reveals that while EWS frameworks are conceptually robust, their real-world application is often uneven. Technical solutions alone are insufficient; successful EWS must be embedded within a broader system of community engagement, institutional coordination, and sustained investment. Bridging the gap between EWS design and on-the-ground implementation remains a key challenge for disaster risk reduction strategies, particularly in resource-constrained environments.

While Early Warning Systems (EWS) offer a theoretically robust framework for disaster preparedness and risk reduction, their real-world implementation—particularly in the context of local flood management—faces numerous and interrelated challenges. These barriers hinder the operational effectiveness, equity, and long-term sustainability of EWS initiatives, especially in low- and middle-income countries where institutional capacities and resources may be limited.

Challenges and Barriers

One of the primary technical challenges lies in the reliability and maintenance of monitoring infrastructure. Advanced hydrological sensors, weather stations, and telemetry systems are often expensive to procure and require specialized expertise to operate and calibrate. In many rural or under-resourced regions, equipment is prone to malfunction due to environmental exposure, lack of maintenance protocols, or power supply instability. Consequently, gaps in real-time data undermine the accuracy of forecasts and diminish public confidence in alerts.

At the institutional level, EWS efforts are frequently constrained by fragmented governance structures and weak inter-agency coordination. The absence of a centralized authority or a clearly defined mandate for disaster communication can result in delayed decision-making and conflicting instructions. Moreover, disaster risk reduction (DRR) policies are often formulated at the national level without adequate integration with local authorities, leading to a disconnect between strategic planning and on-the-ground implementation.

Social barriers further complicate the dissemination and reception of early warnings. Populations in informal settlements, remote areas, or marginalized communities may lack access to communication devices or may not understand warning messages delivered in unfamiliar languages or formats. Cultural beliefs, distrust in authorities, and the legacy of false alarms can also contribute to public apathy or resistance, reducing the likelihood of timely evacuation or risk-appropriate behavior.

Financial constraints pose an overarching limitation to EWS development and sustainability. Many projects are initiated through short-term donor funding without provisions for long-term maintenance, system upgrades, or community training. Without dedicated budget allocations at the local level, even well-designed systems may fall into disrepair or become obsolete.

Conclusion

In light of these challenges, it is evident that the success of Early Warning Systems in flood-prone communities depends on more than technological infrastructure. The four-component framework proposed by the United Nations Office for Disaster Risk Reduction—comprising risk knowledge, monitoring and warning service, dissemination and communication, and response capability—remains a valuable guideline for holistic system design. However, its effective implementation must be context-sensitive, locally adapted, and grounded in the socio-political realities of the target communities.

Moving forward, a transformative shift in approach is required: from externally imposed, hardware-centric solutions to community-driven, integrative models that prioritize sustainability, inclusivity, and resilience. This entails strengthening institutional linkages across administrative levels, ensuring consistent public funding, and building long-term capacity among local stakeholders. Public trust must also be cultivated through transparent governance, culturally competent messaging, and regular community engagement activities such as simulations and education campaigns.

Ultimately, embedding EWS within broader resilience and development agendas will allow these systems to function not as stand-alone tools, but as integral components of a society's adaptive capacity in the face of intensifying climate risks. In doing so, EWS can move beyond merely warning of disaster to actively fostering a culture of preparedness, accountability, and collective risk governance.

References

1. UNDRR. Early Warning Systems: Saving Lives [Internet]. United Nations Office for Disaster Risk Reduction; 2022 [cited 2025 Jun 30]. Available from: https://www.undrr.org/implementing-sendai-framework/sendai-framework-action/early-warnings-for-alls

2. UNISDR. Sendai Framework for Disaster Risk Reduction 2015–2030 [Internet]. United Nations Office for Disaster Risk Reduction; 2015 [cited 2025 Jun 30]. Available from: https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf
3. Basher R. Global early warning systems for natural hazards: systematic and people-centred. Philos Trans A Math Phys Eng Sci. 2006;364(1845):2167–82. doi:10.1098/rsta.2006.1819
4. Hidayat H. Petabencana.id in Flood Disaster Management: An Innovation in Collaborative Governance-based Early Warning System in Indonesia. JKAP. 2020;24:61. doi:10.22146/jkap.53167
5. Alam E, Collins AE. Cyclone disaster vulnerability and response experiences in coastal Bangladesh. Disasters. 2010;34(4):931–54. doi:10.1111/j.1467-7717.2010.01176.x
6. Zaman S, Sammonds P, Ahmed B, Rahman T. Disaster risk reduction in conflict contexts: Lessons learned from the lived experiences of Rohingya refugees in Cox's Bazar, Bangladesh. Int J Disaster Risk Reduct. 2020 Nov;50:101694. doi:10.1016/j.ijdrr.2020.101694
7. WMO. State of Climate Services: Early Warning Systems 2022 [Internet]. World Meteorological Organization; 2023 [cited 2025 Jun 30]. Available from: https://library.wmo.int/viewer/68500/download?file=1335_WMO-Climate-services-Health_en.pdf&type=pdf&navigator=1
8. World Bank. The Power of Partnership: Strengthening Early Warning Systems in Developing Countries [Internet]. 2019 [cited 2025 Jun 30]. Available from: https://www.gfdrr.org/sites/default/files/publication/The%20Power%20of%20Partnership_WEB.pdf
9. IFRC. Community Early Warning Systems: Guiding Principles [Internet]. International Federation of Red Cross and Red Crescent Societies; 2013 [cited 2025 Jun 30]. Available from: https://www.ifrc.org/sites/default/files/CEWS-Guiding-Principles-EN.pdf
10. Mercer J, Kelman I, Taranis L, Suchet-Pearson S. Framework for integrating indigenous and scientific knowledge for disaster risk reduction. Disasters. 2010;34(1):214–39. doi:10.1111/j.1467-7717.2009.01126.x
11. Glantz MH. Early Warning Systems: Do's and Don'ts [Internet]. United Nations University Press; 2004 [cited 2025 Jun 30]. Available from: https://www.ilankelman.org/glantz/Glantz2003Shanghai.pdf

12. United Nations. Global Survey of Early Warning Systems [Internet]. UNISDR Platform for the Promotion of Early Warning; 2006 [cited 2025 Jun 30]. Available from: https://www.preventionweb.net/files/3612_GlobalSurveyofEarlyWarningSystems.pdf
13. Kelman I, Glantz MH. Early warning systems defined. In: Glantz MH, editor. Climate Affairs. Boston: American Meteorological Society; 2014. p. 89–101. doi:10.1007/978-94-017-8598-3_5
14. Kreibich H, et al. Adaptation to flood risk: Results of international paired flood event studies. Earths Future. 2017;5:953–65. doi:10.1002/2017EF000606
15. Le Dé L, Gaillard JC, Friesen W. Remittances and disaster: A review. Int J Disaster Risk Reduct. 2015;12:43–52. doi:10.1016/j.ijdrr.2013.03.007
16. Paul BK, Dutt S. Hazard warnings and responses to evacuation orders: The case of Bangladesh's Cyclone Sidr. Geogr Rev. 2010;100(3):336–55. doi:10.1111/j.1931-0846.2010.00040.x
17. Kolen B, Helsloot I. Decision-making and evacuation planning for flood risk management in the Netherlands. Disasters. 2014;38(3):610–35. doi:10.1111/disa.12059
18. Zia A, Wagner CH. Mainstreaming early warning systems in development and planning processes: Multilevel implementation. Risk Hazards Crisis Public Policy. 2015;6(2):153–79. doi:10.1007/s13753-015-0048-3