Chapter 4
Flash Flood Early Warning Systems:
A Critical Review of Their Effectiveness in Reducing Disaster Risks

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ABSTRACT

Flash floods are natural disasters that significantly threaten communities and infrastructure worldwide. Flash flood early warning systems (FFEWS) have been developed to mitigate the negative impacts of flash floods. These systems rely on monitoring and forecasting weather conditions and providing timely warnings to potentially affected communities. However, their effectiveness in reducing disaster risks needs to be better established. This chapter aims to critically review flash flood early warning systems, examining their strengths, limitations, and challenges associated with their implementation and proposing an improved framework and algorithm for an early warning system to mitigate some of the challenges encountered in previous systems. By delving into the current state of these systems, their components, and the factors influencing their effectiveness, this chapter seeks to enhance our understanding of EWS and contribute to developing more robust and efficient strategies for mitigating the impacts of flash floods.

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INTRODUCTION

Flash floods are rapid-onset natural disasters caused by heavy rainfall, often leading to landslides, mudflows, and damage to infrastructure (Sene, 2012; Elkhrachy, 2015). Climate change projections suggest an increase in intense rainfall, potentially exacerbating flash flooding (Zhang et al., 2021). Additionally, urbanization has expanded the vulnerable population. Effective flash flood forecasting requires accurate rainfall forecasts and an understanding of the hydrological processes in catchments. Small catchments are prone to flash floods due to steep slopes, saturated soils, and impermeable surfaces. However, many of these catchments lack monitoring data, posing challenges for hydrological modeling (Hapuarachchi & Wang, 2008).

In March 2023, heavy rains brought relief and devastation to the drought-stricken Horn of Africa (Emily, 2023). While parts of Ethiopia received higher-than-usual rainfall, bringing much-needed respite from the prolonged period of extreme drought, the torrential downpours led to flash flooding in Ethiopia and Somalia. Tragically, several lives were lost, and around 300,000 people were affected by the sudden deluge (Emily, 2023; Crop Monitor GEOGLAM, 2023, June). The juxtaposition of severe drought and destructive floods underscores the unpredictable and extreme nature of weather events in the region.

It is said that Water-related disasters account for a significant 90% of all-natural disasters worldwide, with floods being the most prevalent type of water-related disaster (Perera et al., 2019). Africa bears number two after Asia. Structural and non-structural flood mitigation measures have been implemented to minimize these disasters, but the economic damages caused by floods have continued to increase (Khan et al., 2021).

The situation in the Horn of Africa is not an isolated incident. Eastern Africa has been grappling with the impact of floods, exacerbating vulnerable communities' challenges. Since mid-2022, over 2.25 million individuals in the region have been affected by destructive floods and landslides, further compounding their hardships (Emily, 2023). With the increasing occurrence of flash floods attributed to climate change, anticipating and preparing for such events is crucial to minimize their impacts (Borga et al., 2008; Gaume et al., 2009; Marchi et al., 2010). Forecasting flash floods poses significant challenges due to the explosive nature of rainfall events and the lack of measurement and forecasting in poorly gauged areas. However, radar rainfall observations offer high-resolution data that can improve flash flood early warning systems (FFEWS) by providing quantitative precipitation estimates and forecasts (Hapuarachchi & Wang, 2008).

FFEWS can be categorized as flow-based or rainfall-based. Flow-based systems rely on real-time flow information from river sections, while rainfall-based systems use spatially averaged basin rainfall as the driving variable. The latter method is simpler to implement and has shown the capacity to detect flood events using rainfall threshold exceedances (Corral et al., 2019).

On the other hand, Henao & Zambrano (2022) conducted a systematic review of 19 case studies to compare and analyze methods used for rainfall threshold (RT) estimation in flash flood prediction, focusing on the El Guamo stream basin in Colombia and other regions. The review identifies four types of methods: empirical, hydrological/hydrodynamic, probabilistic, and compound, and discusses their indicators and predicting variables. The study emphasizes the importance of considering local factors when selecting an appropriate method for early warning systems. It also highlights the significance of hydrodynamic models and uncertainty analysis in improving RT-based systems. Challenges in the work include the complexities of predicting flash floods in regions with

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