Flood Risk Reduction Using Integrated Community-Based Disaster Risk Management and Geo-Spatial Approaches in Gin River Basin, Sri Lanka

Hansi Piyumi Nisansala

Oceanographic Institute of the University of Sao Paulo
Corresponding Author's Email: hansipiyuminisansala@gmail.com

Abstract

Floods present considerable risks to the sustenance of livelihoods, infrastructure, and social fairness within the Gin River Basin, Sri Lanka, necessitating an integrated methodology for efficient risk mitigation. This article investigates the implementation of Community-Based Disaster Risk Management (CBDRM) combined with geospatial techniques to reinforce community resilience and involvement in reducing flood hazards. Encompassing an area of 932 square kilometers, the research site displays various climatic conditions impacted by monsoons and diverse topography spanning from mountainous forested inclines to agricultural floodplains. The methodology involved the selection of 100 households and stakeholders for data collection through quantitative surveys and qualitative interviews, focusing on demographic characteristics, livelihood trends, flood impacts, and coping strategies. Data was acquired from both primary and secondary resources, encompassing governmental publications and hydrological observation stations. The Delphi method was employed to enhance the CBDRM model customized for the area. The investigation pinpointed crucial socio-economic variables influencing community engagement in flood risk governance. The outcomes of the study underscored the recurrent flood occurrences intensified by climate variations, underscoring the necessity for a multifaceted strategy encompassing both physical and non-physical interventions. The strategy for lessening flood risks integrates traditional local knowledge, participatory risk evaluations, and sophisticated geospatial technologies like OpenStreetMap for instantaneous flood delineation. Proposed physical interventions involve the establishment of new sluices, refurbishment of pump houses, and the erection of flood embankments, while non-structural actions emphasize prompt warning systems, land utilization supervision, and community enlightenment. This holistic approach accentuates the significance of community responsibility, regional proficiency, and sustainable developmental techniques in augmenting flood resilience. The findings aim to enhance the wider conversation on disaster risk reduction and provide practical solutions for managing flood hazards in the Gin River Basin.

Keywords: CBDRM, demographic, DELPHI, flood hazards, flood resilience

Introduction

The Millennium Development Goals (MDGs), adopted globally in 2000, highlight the importance of addressing vulnerability, disaster management, and risk assessment in

development (WMO, 2017). Disasters, both large and small, can undo years of progress, severely impact livelihoods, and increase the risk of extreme poverty, disease, and poor health. Floods, in particular, are frequent hydrological disasters causing significant economic damage, threatening human lives, and disrupting infrastructure. Their impacts on businesses, public services, and the environment exacerbate social and economic inequalities, affecting community resilience and participation in flood-risk management. Effective community involvement in disaster risk reduction (DRR) requires understanding the socio-economic factors influencing participation, such as poverty, education, and access to services (Ashvin et al., 2021).

This paper attempts to address the importance of enhancing community resilience is underscored by Sri Lanka's experience in DRR over the past two decades. Despite traditionally high resilience, government and civil society efforts have primarily focused on preparedness and recovery, affecting attitudes and knowledge about disaster risk (David, 2021). Community-based institutions play a crucial role in managing flood risks, with indigenous knowledge providing valuable coping strategies. For instance, in Bangladesh, communities adapt by raising houses and storing emergency provisions. Sri Lanka, frequently affected by floods, experiences significant disruptions and damage during monsoon seasons (Pakneshan et al., 2023). Understanding the magnitude and frequency of floods is essential for effective planning and management. Models like the disaster-resistant and disaster-resilient communities emphasize minimizing vulnerability and enhancing community participation in DRR efforts (Chamal et al., 2023).

Research objectives

The main objective of this study is to determine Flood Risk Reduction using integrated Community-Based Disaster Risk Management and Geo-spatial Approaches in GIN River Basin, Sri Lanka. The sub-objectives of the study are to analyze the flood risk reduction in the Gin River area, prepare a flood risk reduction plan using integrated community-based disaster risk management (CBDRM) and geospatial approaches, and to align the CBDRM with a suitable existing model of flood risk reduction.

Study area

The study area, as delineated by latitudes 6°18'-6°24'N and longitudes 80°19'-80°35'E, encompasses the Gin catchment, situated between longitudes 80°08'E to 80°40'E and latitudes 6°04'N to 6°30'N, covering an estimated area of 932 square kilometers. The climatic conditions in this region are shaped by the influence of the southwest monsoon (May to September) and the northeast monsoon (November to February), interspersed with inter-monsoon showers

during the remaining months. Precipitation levels exhibit variation in accordance with elevation, ranging from more than 3500 mm annually in the upper regions to below 2500 mm in the lower areas. (Salajegheh, 2013) The catchment area, entirely situated within the wet zone, showcases mountainous forested slopes in the higher elevations, while the middle and lower parts feature human habitation, agricultural activities, and forested areas. Thawalama, positioned in the mid-section of the catchment, primarily comprises human settlements and cultivated lands within the expansive floodplain of the Gin River (Wickramaarachchi, 2016). This zone borders the Sinharaja Rain Forest, a designated natural world heritage site, and incorporates anthropogenic practices like tea and rubber cultivation, domestic gardens, and regenerated forests.

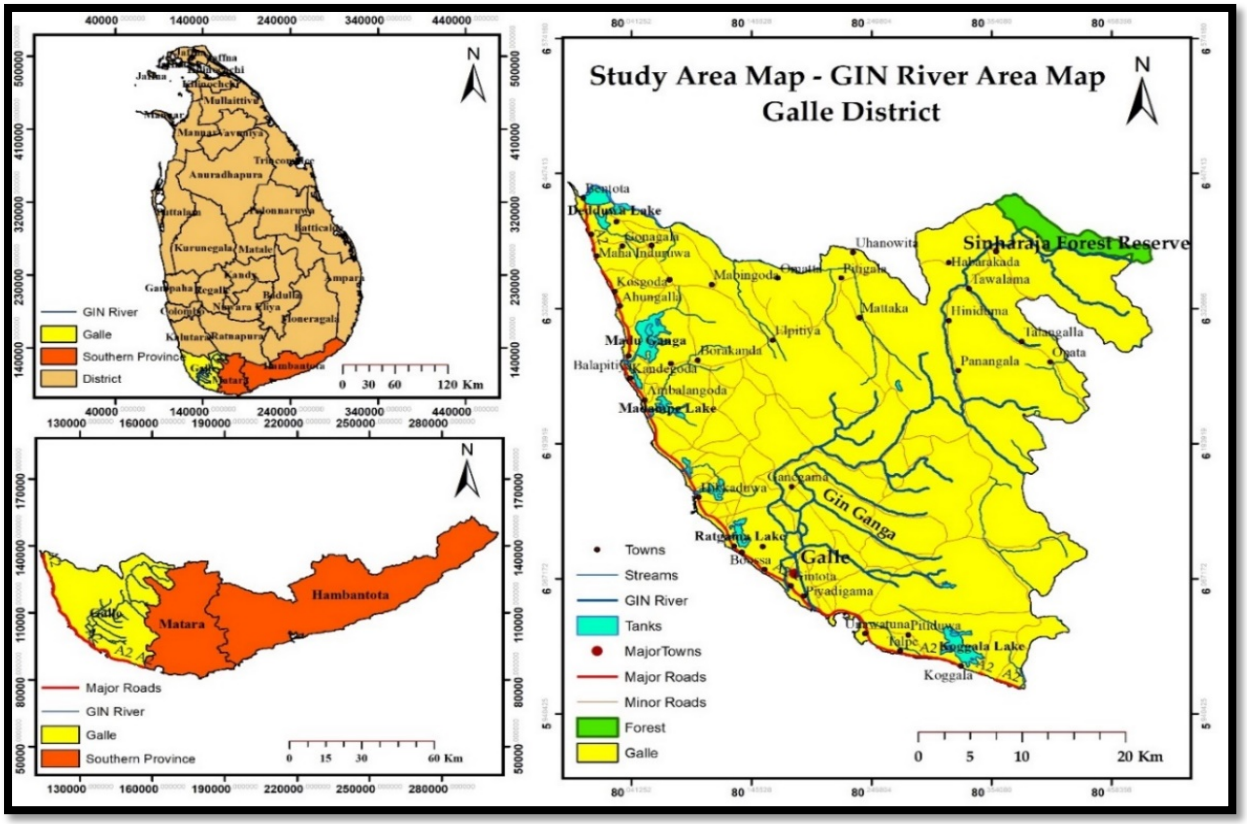

Figure 1: Study Area Map

Topography

The geographical features of the locality are defined by steep-sided, northwest-oriented strike ridges and valleys, characterized by basement rocks comprising highly resistant Precambrian metamorphic formations. The flow patterns of tributary streams are influenced by geological formations, where smaller streams rely on seasonal precipitation, whereas larger streams exhibit perennial flow. The Gin River basin, classified as a fifth-order stream, spans an area of 947 square kilometers with a river length of 112 kilometers, originating from elevated terrains exceeding 1300 meters (Kumari et al., 2018).The data for this research endeavor was

obtained from the hydrological monitoring station at Thawalama (6°20'33"N, 80°19'50"E), covering an upstream catchment area of 470 square kilometers. (Dennis et al., 2019). The average annual precipitation within the catchment region is around 3,200 mm.

Material and Methods

The methodology involved purposively selecting 100 households, institutions, community leaders, and practitioners at household, district, and community levels due to time and financial constraints. Both quantitative and qualitative approaches were used to study community-based disaster risk management (CBDRM), focusing on disaster preparedness and recovery. Data collection methods included narrative literature review, secondary data (e.g., government reports), and primary data (e.g., interviews, focus group discussions, key informant interviews, and field observation). The Delphi technique was employed in three stages to refine the final CBDRM model for the Gin River basin (Hua et al., 2020).Quantitative data was gathered through household questionnaires covering demographics, livelihood patterns, flood impacts, vulnerable groups, and coping strategies. Qualitative data was collected via key informant interviews with district-level stakeholders, NGOs, religious institutions, and community representatives, discussing topics such as livelihood patterns, income sources, flood impacts, vulnerability causes, coping strategies, and development options (Ekeu-Wei, (2018).

Data Analysis

The disaster risk reduction method consists of six consecutive steps that can be used either in advance of or during a disaster to lower risks in the future. Each stage develops from the one before it and leads to additional action. The stages in the disaster risk reduction process are given in the figure below:

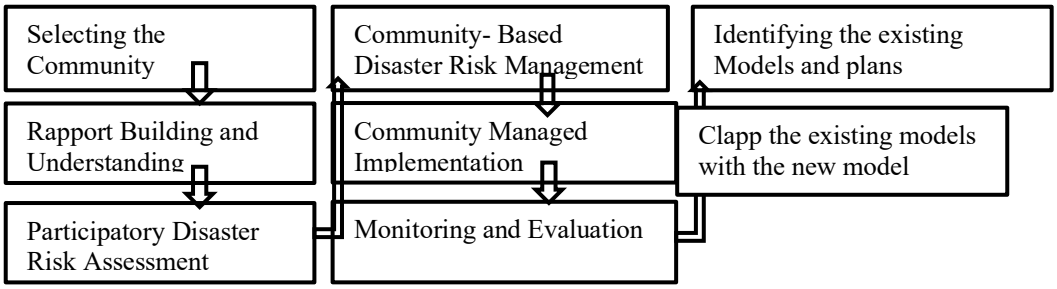

Figure 2: Disaster Risk Reduction Process (Adpc 2006)

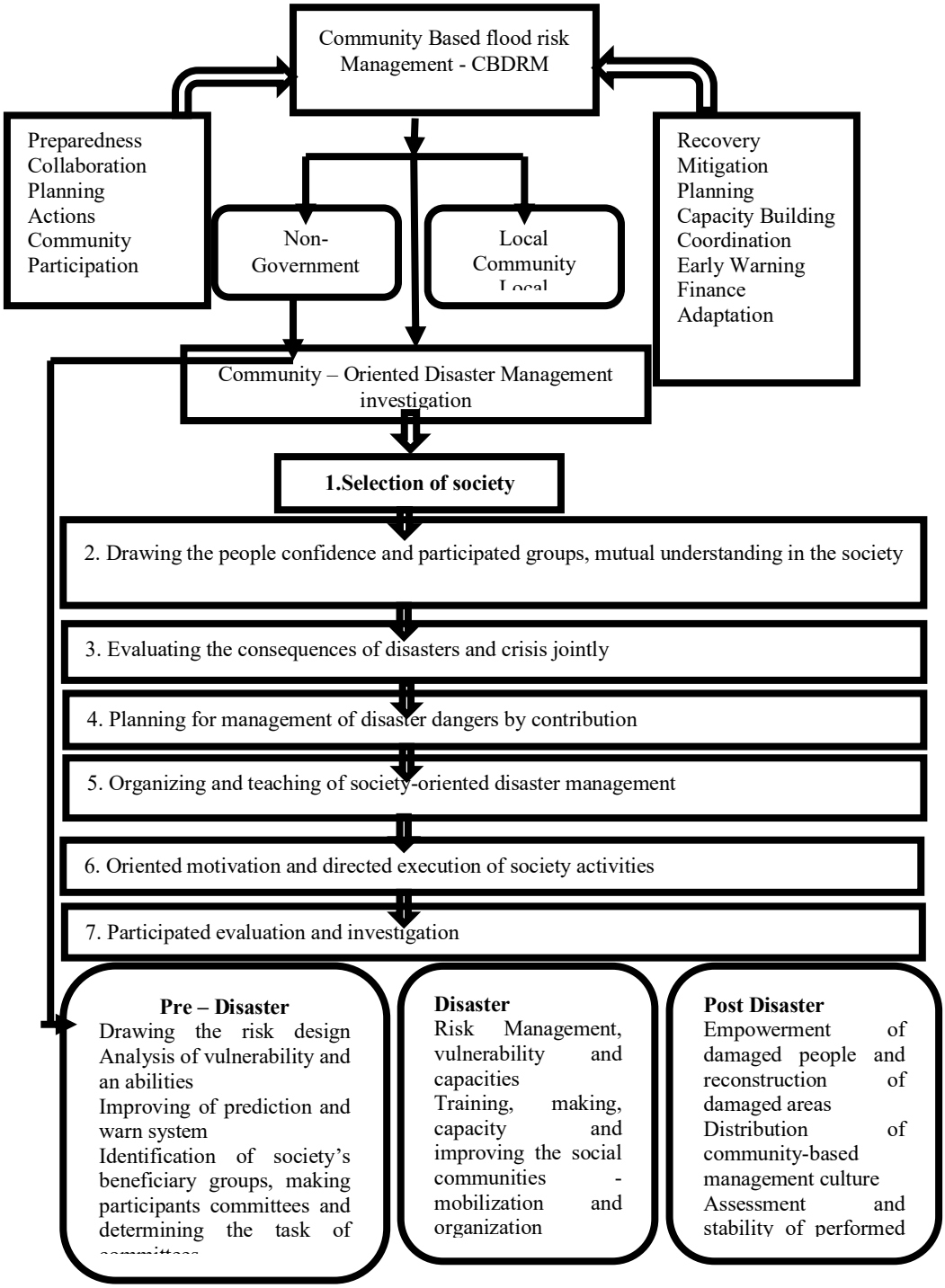

Figure 3: Methodological Framework

Results

However, the area is prone to recurring flood events, posing significant challenges to both the local communities and infrastructure. As climate change exacerbates weather patterns, the vulnerability of this region to flooding has become more pronounced, necessitating comprehensive studies and interventions to mitigate these risks (JMMU et al., 2020).

Several research endeavors have underscored the multifaceted aspects of flood risk within the GIN River basin. These studies often investigate the complex interplay of environmental factors, land use practices, hydrological patterns, and anthropogenic influences contributing to the heightened flood vulnerability. They explore diverse methodologies encompassing hydrological modeling, spatial analysis, and socio-economic assessments to understand the dynamics of flood occurrences and their impacts on the region. Furthermore, the GIN River basin has witnessed various efforts aimed at flood risk reduction and management. These initiatives span a spectrum from structural interventions such as embankments and reservoirs to non-structural measures like community-based preparedness and early warning systems. The effectiveness of these strategies, their sustainability, and their alignment with local socio-economic contexts form pivotal focal points in the ongoing discourse on flood risk reduction in this region (Kanchana et al., 2020).

This paper aims to synthesize and critically analyze existing research on flood risk reduction in the GIN River area of Sri Lanka. By examining the current state of knowledge, identifying gaps, and evaluating the efficacy of mitigation strategies, this study seeks to contribute to the ongoing dialogue on enhancing resilience against flooding in this ecologically rich and socially vibrant region.

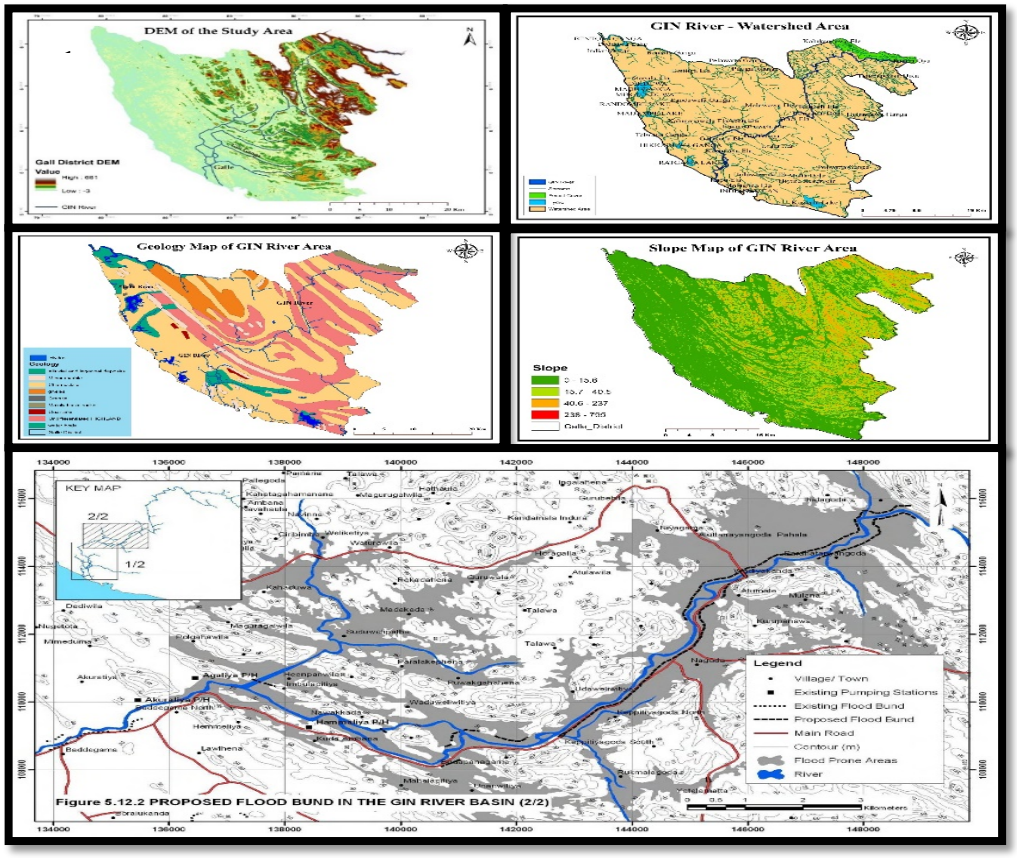

Figure 4: Gin River Area Dem, Gin River Watershed Area, Gin River Slope Map, Gin River Area Geology Map, Flood Prone Areas In Gin River Map

Society Participation

As per the definition provided by the World Health Organization (WHO) in 2002, community participation is characterized by individuals actively engaging in decision-making processes, identifying pertinent issues, and executing development policies and services (WMO. 2017). This approach enables individuals to exert influence on the design of development initiatives, decision-making processes, and the allocation of resources. Participation involves collaborative decision-making and societal supervision, covering all essential activities required to address present needs. It capitalizes on the inherent capacities of individuals, granting them the ability to effectively oversee their health and manage their lives through the acquisition of knowledge, skills, and self-assurance (Sadegh Nejad, 2009). To participate people in society, the different roles are determined for people which are as fallow:

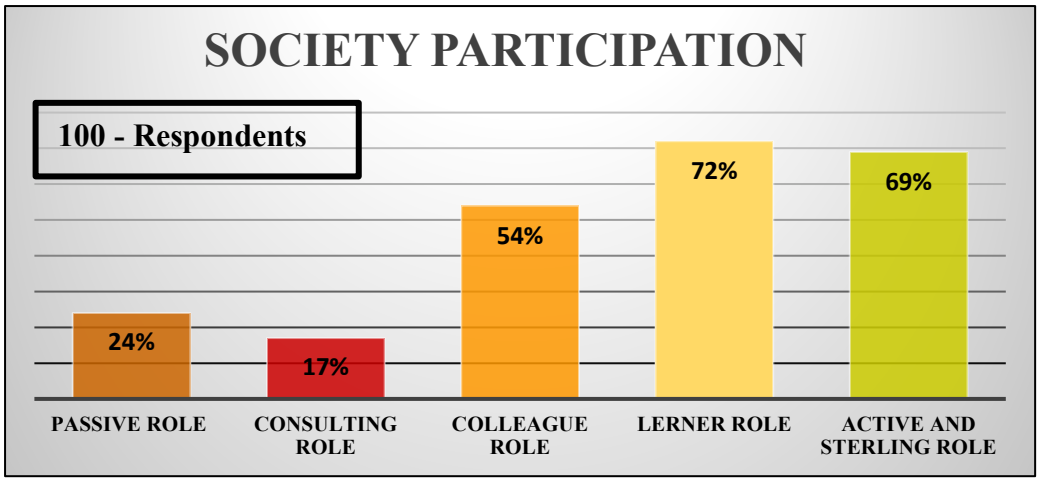

Figure 5: Society Participation (Source- Compiled by Author, 2022)

- **Passive role:** fallowing and obeying of rules and plans of decision makers and lawmakers
- **Consulting role:** using of people views
- **Colleague role:** people cooperation in management processes
- **Lerner role:** learning knowledge and necessary skills for people interventions
- **Active and sterling role:** people cooperation as a partnership (Jahangiri, 2010)

In flood analysis within the GIN River area, various socio-economic factors significantly impact both the vulnerability of communities to floods and the subsequent recovery and resilience-building efforts (Rojanamon et al., 2009).

Community-based flood disaster risk management is crucial in Sri Lanka to enhance resilience and preparedness against the frequent flood hazards that pose a threat to the nation. The damage inflicted on structures and infrastructure by floods underscores the necessity for integrating disaster risk reduction (DRR) mechanisms within the current systems. Despite the advocacy for sustainability by the Green Building Council of Sri Lanka, the complete integration of DRR into its framework remains incomplete. Consequently, Community Disaster Management Committees (CDMC) are being formed in at-risk areas such as the Gin River region. (Perera, B, H, N., Wickramaarachchi, N, C., 2022) These committees offer DRR information, carry out vulnerability assessments, and provide training for effective disaster preparedness and response. Furthermore, there is a development of multi-stakeholder networks to facilitate the exchange of knowledge between government bodies and flood-prone communities.

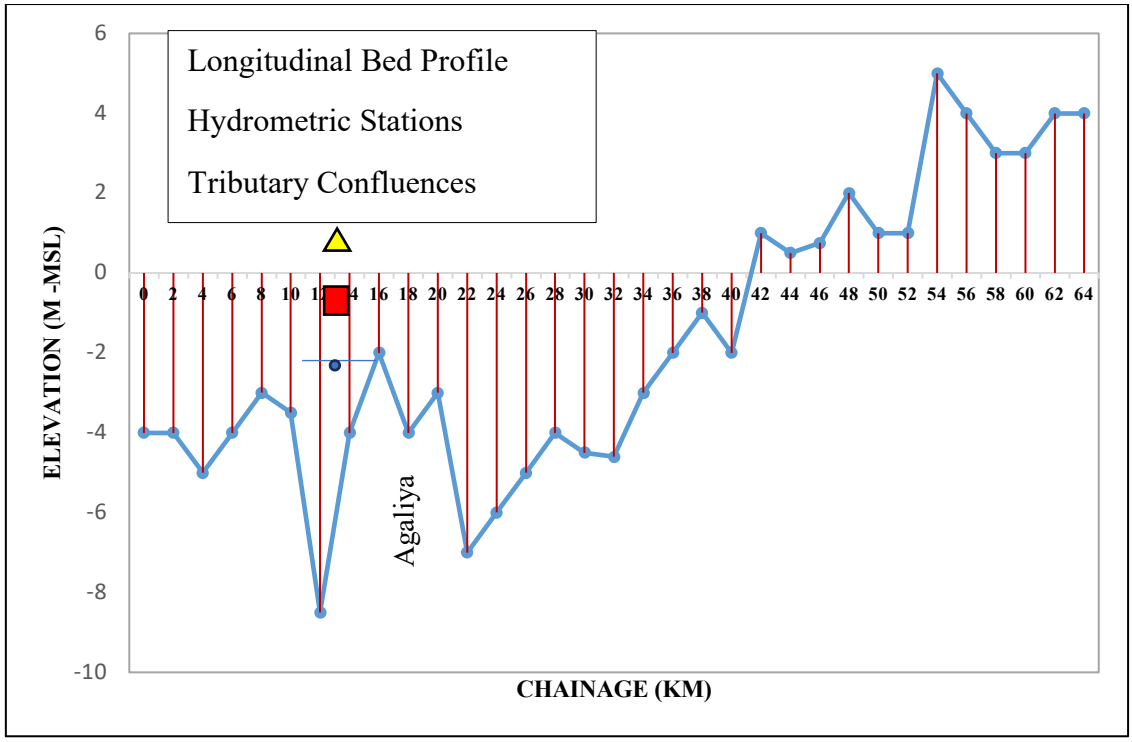

Figure 6: Longitudinal Profile of Gin River (Source: LHI, 2021)

Diverse methodologies are being utilized to effectively involve communities in flood disaster risk management. These methodologies encompass Participatory Risk Assessment (PRA), Vulnerability and Capacity Assessment (VCA), community hazard mapping, and the establishment of community-based early warning systems. Additional strategies include simulation drills, workshops for capacity enhancement, formulation of community-based disaster management plans, and mobilization of local resources. Attention is also given to gender and social inclusivity, the reinforcement of local institutions, nurturing partnerships, promoting sustainable livelihoods, and engaging communities in recovery and rehabilitation endeavors. These strategies underscore the significance of community ownership and empowerment, utilizing local expertise to bolster flood disaster resilience in Sri Lanka.

Existing flood management Master Plan Gin River Basin

Structural Measures

Table 1: Proposed Major Structures in Master Plan (Gin River)

	Kind of structure	Major dimensions
Short Term	1. New sluices	9 nos.
	2. Rehabilitation of existing pumps	10 pump houses
	3. Mound dike	A=51,000 m^2 (3 sites)

Plan	4. Flood bund	Left bank (L=8,360 m, H=5.4m) Right bank (L=7,620m, H=5.3m)
Long Term Plan	5. Flood bund (heightening)	Left bank (L=8,360 m, H=6.6m),Right bank (L=7,620m, H=6.3m)
	6. New pump house	8 nos.

Non-structural Measures (To proceed in parallel with the short-term plan)

Table 2*:* Non-Structural Measures to be promoted (Gin River) (Source: JICA Study Team)

Measures	Major Items
1. Early warning and monitoringsystem	- 8 rain gauge stations - 5 hydrometric stations
2. Restriction of further development in urban area	- Management and monitoring of land use - Prohibiting housing development in flood prone area - Flood zoning with hazard mapping,
3. Promotion of water-resistantarchitecture	- Heightening of building foundation - Construction of column-supported - Housing, change to multi-storied housing - Water proofing of wall/housing materials, etc.
4. Promotion of flood fightingactivities	- Information dissemination in the communities - Evacuation to safer area, - Removal of properties in house/building, etc.
5. Resettlement	- Mound dike
6. Institutional strengthening ofimplementing agency	- Consensus building for project implementation - Integration with urban development and land use development plans

Flood Risk Reduction Plan Using the Cbdrm and Geospatial Approaches

A plan for reducing the risk of floods has been examined in Sri Lanka using the Community-Based Disaster Risk Management (CBDRM) and geospatial methods. The focus of the research was to identify areas that are vulnerable to flooding and develop models to

evaluate the levels of flood risk. The studies integrated different criteria, such as the built environment, physical environment, and socio-economic environment, to categorize vulnerability and assess the levels of risk (Reaves, 2013). Open-Source applications, like OpenStreetMap (OSM), were employed to gather on-site information and identify areas that are inundated by floods. (Dr.Sanjar Salajegheh, 2013) Advanced models were utilized to assess the advantages of local infrastructure adaptation measures and determine the costs of not responding to changing flood risks (Gireesan, 2013). The spatial variations of drought and flood hazards were also analyzed in the Northern Region of Sri Lanka. These studies offer valuable insights and tools for the development of effective plans to reduce flood risks using CBDRM and geospatial approaches in Sri Lanka.

Creating a flood risk reduction plan for the Galle District in Sri Lanka using integrated Community-Based Disaster Risk Management (CBDRM) and geospatial approaches involves a comprehensive and collaborative process. Here's a general outline of the steps Researcher identified by the outputs (Pacific et al., 2008).

Step 1: Understand the Context

Risk Assessment: Conduct a detailed risk assessment of flood-prone areas in the Galle District. This includes identifying vulnerable communities, assets, infrastructure, and natural features that are at risk.

Step 2: Engage Stakeholders

Stakeholder Mapping: Identify and engage key stakeholders, including local communities, government agencies, NGOs, academic institutions, and private sector entities.

Step 3: Data Collection and Analysis

Geospatial Data Collection: Gather geospatial data such as elevation, land use, drainage systems, and flood history. This data will be essential for creating flood hazard and vulnerability maps.

Step 4: Community Participation

Participatory Mapping: Involve local communities in mapping flood-prone areas, safe shelters, evacuation routes, and critical infrastructure. Their knowledge is crucial for accurate planning.

Step 5: Risk Mapping

- Flood Hazard Mapping: Use geospatial data to create flood hazard maps indicating areas at risk of flooding based on elevation and historical flood patterns.
- Vulnerability Mapping: Combine socio-economic data (population density, poverty rates, etc.) with flood hazard maps to identify vulnerable communities and assets

Step 6: Risk Assessment

Integrated Risk Assessment: Combine hazard and vulnerability information to assess the overall flood risk in different areas of the district.

Step 7: Strategy Development

- Community-Based Strategies: Collaborate with local communities to develop strategies tailored to their needs. This could include early warning systems, community training, evacuation plans, and resource mobilization.
- Infrastructure Improvement: Identify critical infrastructure in flood-prone areas and develop plans for upgrading or relocating them.

Step 8: Early Warning Systems

Community Early Warning Systems: Design and implement community-based early warning systems that utilize both modern technology and local knowledge.

Step 9: Capacity Building

Training and Workshops: Conduct capacity-building workshops to enhance community members' skills in disaster preparedness, response, and first aid.

Step 10: Monitoring and Evaluation

Implementation Monitoring: Continuously monitor the implementation of the flood risk reduction plan and gather feedback from the community.

Regular Review: Regularly review and update the plan based on new data, lessons learned, and changes in the flood risk landscape.

Step 11: Collaboration and Coordination

Stakeholder Coordination: Ensure effective collaboration among all stakeholders involved in the plan's implementation.

Step 12: Public Awareness and Education

Community Outreach: Conduct public awareness campaigns to educate the community about flood risks, safety measures, and the importance of their participation.

Step 13: Documentation and Reporting

Figure 7*:* Identified Flood risk reduction plan for the GIN River Area

Communities and institutions involved in disaster management were forced to take proactive measures to lessen the impact of disasters due to the rising trend of disasters. The Sri Lankan government and other DM actors have begun to recognize the Community Based Disaster Risk Management (CBDRM) method as a fundamental tactic for increasing community capacity and resilience. The Government Road Map and the National Disaster Management Plan have designated Sri Lankan Red Cross Society as one of the primary actors in delivering CBDRM measures (Mohamed et al., 2023).

In accordance with the framework established by the government, SLRCS CBDRM interventions concentrated on conducting participatory risk profiling through evaluations of hazard, vulnerability, and capability, followed by the creation of community risk reduction plans, forming community groups to serve as village disaster management committees, training and outfitting local reaction teams, Identifying and implementing small-scale, community-managed mitigation activities, conducting simulation exercises and drills, installing signboards to indicate safe evacuation routes, executing DM awareness campaigns, and distributing information, education, and communication materials are just a few examples (Miyami et al., 2022).

The CBDRM program includes a school programming that is put in place to foster a culture of readiness within the school community. This entails the creation of a school-based disaster management unit, the creation and training of safety teams, the creation of plans and maps for the reduction of disaster risk at the school level, the execution of disaster mitigation and preparedness operations at the school level, and the conducting of practice drills.

Combining the Gin River Cbdrm Process with Existing Cbdrm Approach Model

The harmonization of the GIN River Community-Based Disaster Risk Management (CBDRM) approach with the participatory methodologies of the Participatory Learning and Action (PLA) model presents a compelling opportunity to fortify community resilience, instigate sustainable solutions, and cultivate an all-encompassing flood risk reduction strategy within the GIN River basin of Sri Lanka. (Wickramaarachchi, 2016) The GIN River CBDRM approach, tailored to the region's specifics, lays the foundation by engaging local stakeholders, leveraging community insights, and pinpointing flood vulnerabilities unique to the basin. (Kodikara et al., 2019). This initiative champions community involvement and context-sensitive strategies to mitigate risks.

Conclusion

In conclusion, the objectives set forth to analyze flood risk reduction in the GIN River area have paved the way for a holistic approach towards managing and mitigating potential flood hazards. By employing integrated Community-Based Disaster Risk Management (CBDRM) techniques alongside geospatial methodologies, a comprehensive flood risk reduction plan has been crafted. This plan considers the unique vulnerabilities of the GIN River area and harnesses suitable existing models of flood risk reduction, thereby fostering a proactive and adaptive strategy aimed at enhancing resilience and ensuring the safety of the communities within this region against the threat of floods.

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