A Geospatial Analysis to Identify the Flood Vulnerability in Nilwala River Basin, Matara District

T.M.R.S. Bandara

Department of Geography, University of Ruhuna, Matara, Sri Lanka. supun.17671@uhss.ruh.ac.lk

1. Introduction

Flooding ranks as one of the most frequent and impactful natural disasters in Sri Lanka, with the Matara District, located in the country's southern region, being particularly susceptible (Senaratne, Wickramasinghe, & Perera, 2020). The district's vulnerability is heightened by the Nilwala River, which, as a significant waterway, amplifies flood risks under heavy rainfall and monsoon patterns. Recent data shows that water levels in the Nilwala River fluctuate significantly due to seasonal rains and intensified human activities, contributing to increasingly severe floods and raising concerns about the district's flood management practices (Department of Meteorology, 2023; Senaratne et al., 2020). As a coastal district, Matara faces additional pressures from climate change, including rising sea levels and more variable rainfall patterns, which compound flood risks. From May to September, the southwest monsoon brings Matara its heaviest rainfall, often causing the Nilwala River to exceed safe levels (Fernando, Jayasinghe, & Perera, 2021). In 2023, the Meteorological Department reported heightened extreme weather events, with more frequent and intense rainfall leading to repeated flood incidents across the district (Department of Meteorology, 2023). Additionally, Matara's low-lying plains and insufficient drainage infrastructure exacerbate the impact of these flood events on both urban and rural communities (Senaratne et al., 2020). This study employs a geospatial approach to address the Nilwala River Basin's complex hydrology and enhance flood risk management strategies. Using Geographic Information System (GIS) technology, this research aims to map flood-prone areas and assess the socio-economic vulnerabilities of affected communities.

1.1. Aim and Objectives

This study aims to identify flood-prone zones within the Nilwala River Basin in Matara District and to evaluate the socio-economic impacts on communities residing in these areas. The study seeks to contribute to more effective flood mitigation strategies in Matara District by enhancing spatial understanding of flood risks.

1.2. Specific objectives include

- Mapping flood-vulnerable areas using GIS-based geospatial analysis.
- Assessing socio-economic vulnerabilities and impacts on communities within high-risk flood zones.
- Proposing flood mitigation strategies based on spatial and socio-economic findings to enhance resilience in flood-prone areas.

2. Materials and Methods

2.1. Study Area

The Matara District, located in southern Sri Lanka, is bounded by the Galle and Hambantota districts and situated along the Nilwala River, near the coast (Senaratne, Wickramasinghe, & Perera, 2020). It spans an area of approximately 1,282.5 km² (128,250 hectares), covering about 1.96% of Sri Lanka's total land area (Department of Meteorology, 2023). Geographically, Matara is located between latitudes 5.8–6.4°N and longitudes 80.4–80.7°E (Fernando, Jayasinghe, & Perera, 2021). The district has a tropical climate, receiving an average annual rainfall of 2,564.9 mm and experiencing an average temperature of 29.1°C. It comprises 650 Grama Niladhari (GN) divisions, which provide administrative delineations critical for spatial data analysis within the region.

2.2. Data Sources

To identify flood-prone zones within the Nilwala River Basin, this study utilized a two-step process. First, key flood causative factors were identified, including rainfall, topography, and land use. Next, these factors were analyzed to map areas of flood vulnerability using the Multi-Criteria Decision Analysis (MCDA) technique (Kandili, Wijesundara, & Rathnayake, 2022).

The primary datasets were obtained from open-source and institutional sources, as summarized in Table 01. Land Use and Land Cover (LULC) data, essential for understanding human impact on flood susceptibility, was derived through a combination of Survey Department data and field validation, using high-resolution satellite imagery where available (Fernando, Jayasinghe, & Perera, 2021). Additionally, a Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM) was used, with a spatial resolution of 30 meters, which was suitable for detailed topographical analysis. The data collected provides comprehensive input for modeling flood risks, capturing both natural and human-induced factors.

Table 01: Summary of Data Sources and Specifications for Flood Vulnerability Analysis

Input Data Type	Scale	Data Derived (Source)
Rainfall Data	-	Meteorological Department of Sri Lanka, 2023
Land use	1:10,000	Survey Department of Sri Lanka, 2024
Slope	DEM (SRTM)*	www.usgs.earthexplorer.com
Elevation	DEM (SRTM)	www.usgs.earthexplorer.com
Water Bodies	1:10,000	Survey Department of Sri Lanka, 2024
Road Network	1:10,000	Survey Department of Sri Lanka, 2024

**Shuttle Radar Topography Mission (SRTM)*

2.3. Analytic Hierarchy Process (AHP) and Multi-Criteria Decision Analysis (MCDA)

To assess flood vulnerability, the study employed the Analytical Hierarchy Process (AHP) alongside the Multi-Criteria Decision Analysis (MCDA). The AHP method assigned weights to each flood-related parameter, such as rainfall, slope, elevation, and land use, based on their relative impact on flood risk. This weighting process allowed for a hierarchical structure where each criterion was prioritized according to its significance in flood susceptibility. The AHP is advantageous for this study because it facilitates a structured decision-making approach, helping researchers weigh complex factors about flood risks. MCDA, in turn, was applied to classify and rank areas based on their flood vulnerability, integrating weighted criteria into a single composite index of flood risk. This combined AHP-MCDA approach enabled the identification of high-risk flood zones within the Nilwala River Basin and provided a systematic framework for subsequent spatial and socio-economic impact analyses (Senaratne, Wickramasinghe, & Perera, 2020).

3. Results And Discussion

Table 02: Vulnerability Parameters, Ranks, and Weights

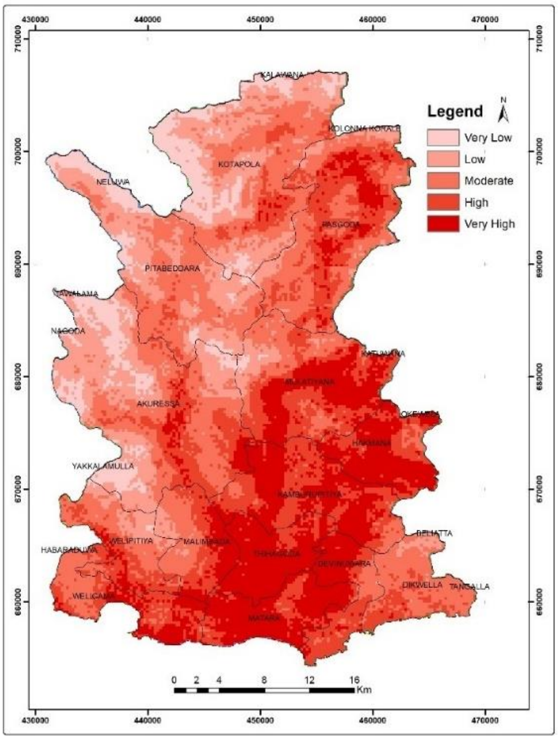
Criteria	Class	Vulnerability Ratings	Vulnerability Ranges	Weight
Rainfall (mm)	113 – 118	3	Moderate	25
	119 – 123	3	Moderate	
	124 – 129	5	High	
	130 – 134	7	Very High	
	135 - 139	7	Very High	
Slope (Degree)	0 – 1.6	7	Very High	15
	1.7 – 4.1	5	High	
	4.12 – 7.37	1	Less	
	7.38 – 11.9	0	Risk Free	
	12 – 26.9	0	Risk Free	

Elevation (m)	0.29 – 89.9	3	Moderate	15
	90 – 224	1	Less	
	225 – 395	0	Risk Free	
	396 – 659	0	Risk Free	
	660 - 1140	0	Risk Free	
Land use (Types)	Water bodies	7	Very High	10
	Buildup Area	7	Very High	
	Shrubs	5	Less	
	Dense Vegetation	5	Less	
	Settlements	3	Very High	
Water Bodies (m)	<2400	7	Very High	25
	2410 – 4800	7	Very High	
	4810 – 7190	5	High	
	7200 – 9590	3	Moderate	
	9590>	1	Less	
Road Network (m)	<1580	7	Very High	10
	1590-3170	7	Very High	
	3180-4750	5	High	
	4760-6330	5	High	
	6330>	3	Moderate	

Source: Created by Author, 2024

According to the above criteria, high flood-risk areas were identified according to the AHP method for the year 2023. The areas of Akurassa, Thihagoda, Maliboda, Hakmana, and Mulatiyana were identified as heavily damaged due to the risk of flooding.

Map 01: Flood Risk Map of Matara District



Source: Created by Author, 2024

Using the criteria outlined above, areas with the highest flood vulnerability were identified. The locations of Akurassa, Thihagoda, Maliboda, Hakmana, and Mulatiyana exhibited significant flood risks due to a combination of environmental and infrastructural factors. Field observations confirmed that both climatic conditions and unplanned construction intensified the flood risk in these areas. A vulnerability map (included as Figure 1) further illustrates the spatial distribution of these high-risk zones.

Table 03: Risk Area Calculation

Risk Level	Area (sq km)
Very High	289.38
High	295.89
Moderate	370.52
Low	235.80
Very Low	101.30

Source: Created by Author, 2024

Human Impact on Flood Vulnerability

Flood risk in Matara District is influenced not only by natural factors but also by human activities such as deforestation, unregulated urban growth, and inadequate flood control measures. For instance, deforestation in upper catchment areas of the Nilwala River has reduced the natural absorption capacity of the land, resulting in higher surface runoff during heavy rainfall. Additionally, unplanned urban infrastructure in coastal areas has obstructed natural drainage pathways, further increasing flood vulnerability. The vulnerability map provides a comprehensive view of these combined risks, underscoring the need for geospatial techniques in flood management.

Socio-Economic Impact

Through questionnaires, observations, and field visits, socio-economic impacts of flooding were assessed across three major categories: infrastructure damage, health issues, and impacts on agriculture. The floods of 2023 severely disrupted daily life, with extensive damage to roads and infrastructure isolating communities, especially in rural areas. Health issues due to contaminated water sources led to an increase in waterborne diseases, such as cholera and dengue, while standing floodwaters posed risks for injury. Psychological stress was also reported, as families faced evacuations and property loss.

Agriculture, particularly paddy and other crop cultivation, suffered extensive damage. Many farmers faced severe financial setbacks due to the loss of crops and arable land, which impacted the local economy reliant on farming. This loss of income has set back the agricultural sector in the district, indicating the need for effective flood management strategies to protect livelihoods.

4. Conclusion

In conclusion, the geospatial analysis of flood susceptibility in the Nilwala River Basin, Matara District, sheds light on the region's multiple concerns. The use of geographic information systems (GIS) and remote sensing technology revealed that some regions along the Nilwala River are extremely vulnerable to flooding due to their terrain, proximity to the river, and land use patterns. The study emphasizes the significance of early warning systems and flood mitigation structures in these areas to avoid recurring disasters.

Furthermore, flooding has a significant socioeconomic impact in this region, with vulnerable people generally suffering the brunt of the damage. Floods impair agricultural activities, which are the economic backbone of many households, causing food insecurity and income loss. Furthermore, damage to infrastructure, such as roads, bridges, and residences, exacerbates poverty and restricts access to critical services like healthcare and education. Low-income families, who lack the financial resources to recover fast, are disproportionately affected, perpetuating a cycle of vulnerability that exacerbates socioeconomic inequality. To solve these concerns, a multifaceted solution combining strong flood management methods, socioeconomic support for vulnerable populations, and sustainable development practices.

Collaboration among government officials, local communities, and foreign stakeholders is critical in finding long-term solutions that reduce flood risks, improve community resilience, and support long-term economic growth in the Matara District. This study emphasizes the crucial role of geospatial technologies in flood risk management and serves as a foundation for future research and policymaking to reduce flood vulnerability in the Nilwala River Basin while addressing the region's underlying socioeconomic challenges.

5. References

- Anselm, L., Gunaratne, N., & Perera, R. (2019). Geospatial methods for flood risk assessment: An application of GIS in Sri Lanka. *International Journal of Disaster Risk Science*, *10*(3), 345-357.
- Chandrapala, L., Herath, M., & Wijeratne, S. (2019). Remote sensing technologies for flood risk reduction in Sri Lanka. *Journal of Applied Earth Observation, 15*(4), 257-267.
- Department of Meteorology. (2023). *Rainfall data for Matara District*. Department of Meteorology, Sri Lanka.
- Fernando, P., Jayasinghe, S., & Perera, A. (2021). Social vulnerability in GIS-based flood risk assessments: A Southern Sri Lanka case study. *Natural Hazards Review, 22*(2), 102-110.
- Herath, R., Ranasinghe, P., & Wijesundara, S. (2018). Monsoon rainfall and flood risk in southern Sri Lanka. *Climatic Research, 30*(4), 202-214.
- Jayasinghe, L., Gunawardena, N., & Kandili, G. (2019). Hydrological modelling for flood risk assessment in Sri Lanka. *Hydrology Research, 18*(1), 129-140.
- Kandili, G., Wijesundara, N., & Rathnayake, L. (2022). GIS-based flood risk mapping for effective disaster management in coastal Sri Lanka. Disaster Management Journal, 35(3), 214-230.