

A COMPARATIVE FLOOD RISK ASSESSMENT OF MONGLA AND SHARANKHOLA UPAZILA USING AHP-GIS INTEGRATION

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ABSTRACT

Flooding is one of the most frequent and severe natural hazards in the coastal region of Bangladesh, where low-lying terrain, tidal incursion, and frequency of tropical storms enhance the degree of susceptibility. Mongla and Sharankhola Upazilas in Bagerhat district experience recurrent inundation driven by tidal surges, river overflow, and intense monsoonal rainfall, with exposure amplified by fragile geomorphology, inadequate drainage, and limited infrastructural resilience. An integrated Analytic Hierarchy Process (AHP) and Geographic Information System (GIS) approach has been developed to comparatively assess the flood risk of these two upazilas, which is presented in this paper. The study integrates flood hazard and vulnerability to produce composite risk maps that are intended to aid local disaster management and planning. This was carried out by relative weight assignment of flood-controlling parameters through expert assessment and generating spatially explicit hazard, vulnerability and composite risk maps using GIS overlay analysis. The results show that in Mongla the two major factors that drive vulnerability are distance from roads (38%) and literacy rate (31%) which suggest that accessibility and educational awareness increase flood susceptibility but hazard is mainly determined by rainfall with average annual rainfall (37%) and drainage density (25%) being the most significant variables. In Mongla, about 59 % of area comes under moderate to high flood risk, and almost all of the unions are flood prone. However the unions of Chandpi and Sonailata have been identified as most at risk. On the other hand, Sharankhola's vulnerability is dominated by literacy rate (37%) and population density (24%), indicating the significance of social preparedness and population concentration, whereas distance from rivers (32%) and drainage density (25%) controlled the hazard in this upazila. While moderate-risk zones occupy the majority of Sharankhola (31.43%), Southkhali and Royenda unions are identified as high priority zones concerning flood risk. Overall, this AHP-GIS based analysis provides a spatially explicit decision support framework that facilitates the identification and prioritization of high risk unions, supports the improvement of flood early warning and preparedness measures, and provides guidance for the development and execution of resilient infrastructure interventions.

Keywords: *Flood risk assessment; Analytic Hierarchy Process (AHP); Geographic Information System (GIS); Hazard mapping ; Vulnerability mapping*

1. INTRODUCTION

Flood is one of the most devastating natural disasters in the whole world which can result in massive loss of lives, destruction of property as well as economic destabilization (Kader et al., 2024). The risk of flooding is also particularly high in the southern part of Bangladesh due to its low topography, strong tidal effect, and its closeness to the Bay of Bengal (Md. S. Ali & Hossen, 2022; S. Ali et al., 2012). Within this region, Mongla and Sharankhola Upazilas in Bagerhat district undergo repeated floods triggered by tidal waves, heavy rainfall, river overflows, and cyclonic occurrences (Das et al., 2016). These areas have been affected by a number of disastrous floods in the past that have increased their susceptibility. The occurrence of severe cyclones like Sidr (2007) and Aila (2009) caused extensive inundation, massive displacement, destruction of key infrastructure, and significant economic losses in these areas (Roy & Blaschke, 2015; Soeb et al., 2023). More recent happenings such as Super Cyclone Amphan in 2020 and seasonal floods that occur have also caused further erosion of community resilience (Hassan et al., 2020). These occurrences demonstrate the interplay between natural hazards and socioeconomic factors, highlighting the need for a thorough assessment of flood risks that integrates both hazard intensity and community vulnerability.

Most GIS-based flooding studies in Bangladesh have used hydrological model and few studies have utilized systematic multi-criteria frameworks like Analytic Hierarchy Process (AHP) (Chowdhury, 2024). Many studies have focused primarily on physical hazard parameters, with limited attention to socio-economic vulnerability indicators that shape the real magnitude of disaster impacts. In the case of Mongla and Sharankhola, in particular, the existing literature is mostly focused on cyclone damage, embankment breach, salinity challenges, though it does not provide a multi-criteria and comparative flood risk analysis that identifies the most vulnerable unions in these upazilas (Hasan et al., 2020). This disparity underscores the need for an integrated AHP–GIS technique. The AHP presents a stepwise approach to decision-making where different hazard and vulnerability parameters are allocated quantitative weights to in accordance with the judgement of experts (Chakraborty & Mukhopadhyay, 2019). Combined with GIS, AHP enhances the spatial evaluation of flood susceptibility and community vulnerability by implementing the basic risk function: $\text{risk} = \text{hazard} \times \text{vulnerability}$ (Danumah et al., 2016). With this, the goal of the current study is to conduct a comparison of flood risk analysis of the upazilas of Mongla and Sharankhola to enhance the disaster mitigation and climate adaptation planning. The explicit aims are: (i) to generate spatial hazard and vulnerability maps via the integration of hydrological, topography, and socio-economic data within a GIS framework, and (ii) to produce flood risk maps for the identification of prioritized intervention areas. This analysis identifies high-risk unions, facilitates focused disaster planning, and supports adaptive actions to enhance community and infrastructure resilience.

2. METHODOLOGY

2.1 Study Area

The study area Mongla and Sarankhola Upazilas, are described in the section below, and the locations are shown in Figure 1.

2.1.1 Mongla Upazila

Mongla Upazila under the Bagerhat District, comprises the administrative units of Burirdanga, Chandpai, Chila, Mithakhali, Mongla Port Paurashava, Sonailtala, and the Chandpai Range within the Sundarbans as per community report on Bagerhat. It lies between 21°49'–22°33' N latitude and 89°32'–89°44' E longitude, bordered by Rampal upazila to the north, Morrelganj and Sharankhola to the east, the Bay of Bengal to the south, and Dacope to the west (Hossain et al., 2016). It is a high flood risk area due to its geographical location near the coast and its river systems.

2.1.2 Sharankhola Upazila

Sharankhola Upazila in Bagerhat District occupies the southern part of Bangladesh, lying between 22°13' and 22°24' N latitude and 89°46' and 89°54' E longitude. Administratively it comprises the

unions of Dhansagar, Khontakata, Rayenda, and Southkhali, together with part of the Sundarbans Reserve Forest. Studies identify Sharankhola as among the most disaster-prone upazilas in Bagerhat due to embankment breaches, recurrent inundation and river dynamics that exacerbate coastal vulnerability (Malaker et al., 2022).

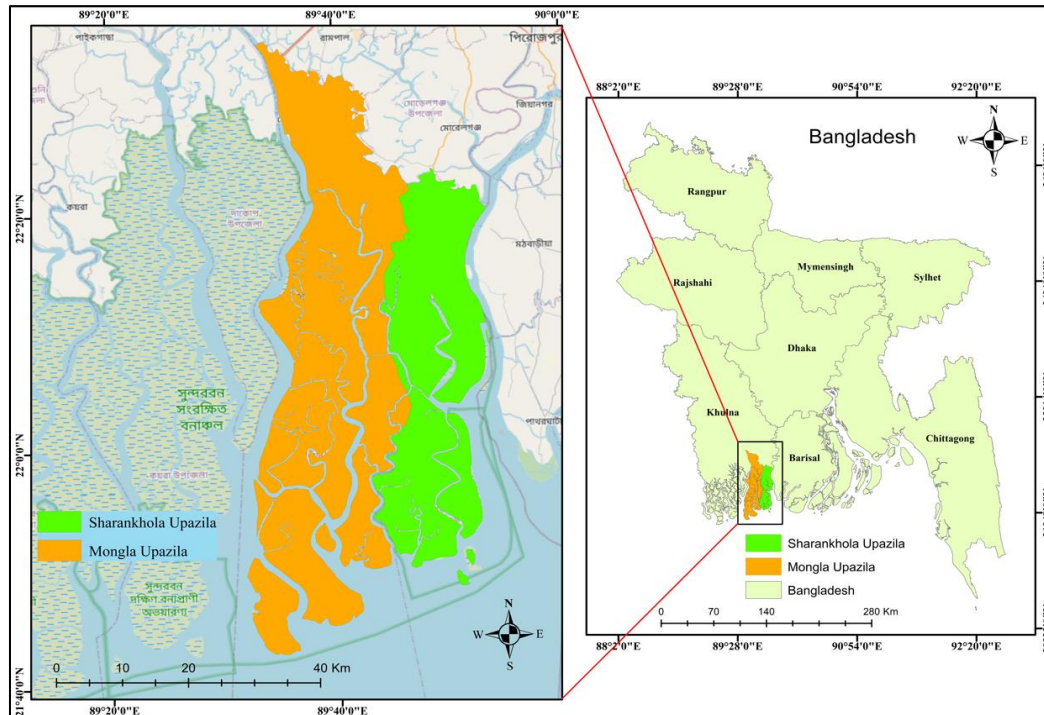


Figure 1: Location of the study area

2.2 Methodological Workflow

The overall methodological framework of this study is illustrated through a flowchart presented in Figure 2.

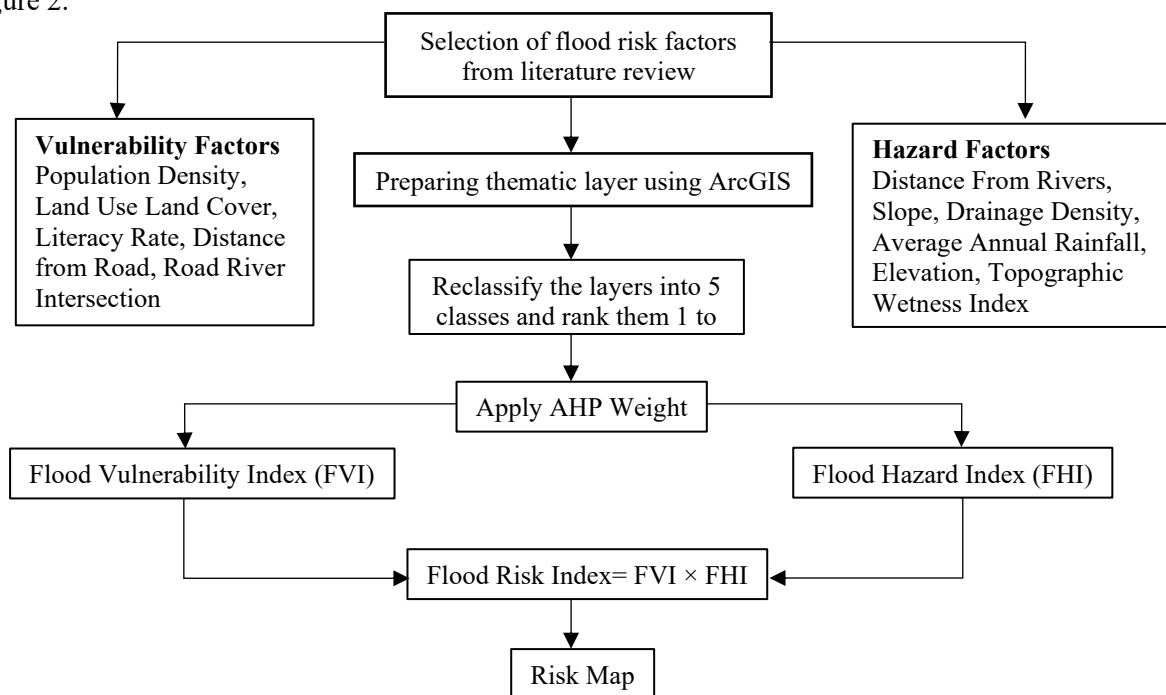


Figure 2: Flowchart Showing the Methodology of the Study

2.3 Data and Materials

All of the factors for the hazard and vulnerability index were chosen based on the literature review and the definition of hazard and vulnerability (Mokhtari et al., 2023). The factors and their sources are given in Table 1.

Table 1: Different Factors with Their Sources and Types

Index Name	Factors	Data Type	Data Source	Resolutions
Hazard Index	Distance from Main Rivers (Dri)	Polygon vector	LGED Shapefile	—
	Slope (S)	Raster	DEM (2024) from US Geological Survey (USGS)	30 m × 30 m
	Drainage Density (DD)	Raster	DEM (2024) from US Geological Survey (USGS)	30 m × 30 m
	Average Annual Rainfall (R)	Grid Raster	Center for Hydrometeorology and Remote Sensing (https://chrsdata.eng.uci.edu/)	0.04mX0.04m
	Elevation (E)	Raster	DEM (2024) from US Geological Survey (USGS)	30 m × 30 m
	Topographic Wetness Index (TWI)	Raster	DEM (2024) from US Geological Survey (USGS)	30 m × 30 m
Vulnerability Index	Population Density (PD)		Population and Housing Census 2022	—
	Land Use Land Cover (LULC)	Raster	Sentinel-2 Land Cover Explorer	10 m × 10 m
	Distance from Road (DRo)	Polygon vector	LGED Shapefile	—
	Road–river intersection (RR)	Polygon vector	LGED Shapefile	—
	Literacy rate (LR)		Population and Housing Census 2022	—

2.4 Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) is a popular multi criteria decision making (MCDM) technique developed by Saaty (1977). It offers a methodical framework for assessing and ranking alternatives according to various criteria by organizing complex problems into a hierarchical model that includes a goal, criteria, sub-criteria, and alternatives. This technique has been extensively used to provide weights to the decision-making factors (Chakraborty & Mukhopadhyay, 2019). The technique utilizes paired comparisons and a hierarchical framework to assess scenarios in which relative significance is dictated by the decision maker's evaluation. The consistency ratio (CR) is computed to verify the coherence of assessments. This is a vital element of the AHP process. For each combination of criteria, one choice is given a score ranging from 1 (equal important) to 9 (great importance), while the other option receives the reciprocal of this number (Table 2). In this study, school teachers, NGO workers, and AHP experts

provided their judgment on the relative importance of one indicator over another, and based on their judgment, pairwise comparison matrices were prepared both for the hazard

Table 2: Saaty Scale of Preference between Parameters (Saaty, 1988)

Intensity Importance	Explanation
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2, 4, 6, 8	Intermediate values

and vulnerability index (Tables 3-6). After that a single consolidated pairwise comparison matrix was formed for each upazila by making geometric mean of the pairwise comparison matrices. The results were tested using the Consistency Ratio (CR). Consistency Ratio (CR) below 10% is acceptable according to Saaty (Saaty, 1977). All the calculation for getting the AHP weight value were done using excel tool (Goepel, 2013).

Table 3: Pairwise comparison matrix (consolidated) for hazard index in Mongla (CR=1.6%)

	Dri	S	DD	R	E	TWI
Dri	1.000	2.330	0.390	0.296	2.129	1.760
S	0.429	1.000	0.285	0.258	0.810	0.857
DD	2.565	3.511	1.000	0.566	2.378	2.822
R	3.380	3.873	1.767	1.000	4.267	3.274
E	0.470	1.235	0.421	0.234	1.000	1.282
TWI	0.568	1.167	0.354	0.305	0.780	1.000

Table 4: Pairwise comparison matrix (consolidated) for vulnerability index in Mongla (CR=3.2%)

	PD	LULC	DRo	RR	LR
PD	1.000	0.926	0.297	2.579	0.332
LULC	1.080	1.000	0.230	3.161	0.435
DRo	3.371	4.348	1.000	3.809	1.143
RR	0.388	0.316	0.263	1.000	0.238
LR	3.008	2.300	0.875	4.198	1.000

Table 5: Pairwise comparison matrix (consolidated) for hazard index in Sharankhola (CR=0.8%)

	Dri	S	DD	R	E	TWI
Dri	1.000	4.884	1.251	1.091	4.284	4.867
S	0.205	1.000	0.257	0.475	0.860	1.028
DD	0.799	3.884	1.000	1.147	2.952	3.770
R	0.917	2.104	0.872	1.000	2.539	2.611
E	0.233	1.162	0.339	0.394	1.000	1.364
TWI	0.205	0.972	0.265	0.383	0.733	1.000

Table 6: Pairwise comparison matrix (consolidated) for vulnerability index in Sharankhola (CR=3.6%)

	PD	LULC	DRo	RR	LR
PD	1.000	4.141	0.818	4.425	0.490
LULC	0.242	1.000	0.351	2.646	0.292
DRo	1.223	2.847	1.000	3.386	0.527
RR	0.226	0.378	0.295	1.000	0.210
LR	2.040	3.424	1.897	4.762	1.000

2.5 Flood Hazard Index (FHI)

Hazard refers to a natural, physical phenomenon capable of causing damage through river overflow and floodwater spread (Mokhtari et al., 2023). Six parameters-Distance from rivers, slope, drainage density, average annual rainfall, elevation, and Topographic Wetness Index (TWI) were selected to develop the hazard index. After preparing all layers of the parameter using ArcGIS (version 10.7.1), each parameter layer was classified into five categories using the Natural Breaks (Jenks) method. The classes were reclassified and ranked from 1 (very low) to 5 (very high). AHP-derived weights were then assigned to

each parameter, and a weighted overlay was performed in ArcGIS after standardizing all layers to the WGS 1984 UTM Zone 45N coordinate system. After that the Flood Hazard Index (FHI) was calculated using the equation (1) (Radwan et al., 2019).

$$FHI=W1 \times Dri + W2 \times S + W3 \times DD+ W4 \times R +W5 \times E + W6 \times TWI \quad (1)$$

Where W1, W2... .. were the AHP weight values and Dri=Distance from Rivers; S= Slope; DD=Drainage Density; R=Average Annual Rainfall; E=Elevation and TWI=Topographic Wetness Index.

2.6 Flood Vulnerability Index (FVI)

Vulnerability indicates the degree to which natural phenomena could foreseeably impact assets and is a crucial component of risk, as it determines whether exposure to a hazard actually constitutes a risk (Ouma & Tateishi, 2014). Population Density, Land Use Land Cover (LULC), Distance from Road, Road River Intersection (RR) and Literacy Rate were chosen for vulnerability index. After preparing all the parameter layers, each parameter was classified and ranked similarly to the hazard index. Next, AHP weight values were assigned to each parameter, and a weighted overlay was applied using ArcGIS to calculate the Vulnerability Index. This time also all the layers must be in the same coordinate system. The Vulnerability Index was determined using the equation (2) (Radwan et al., 2019).

$$FVI=W1 \times PD+ W2 \times LULC+ W3 \times DRo+ W4 \times RR +W5 \times LR \quad (2)$$

Where W1, W2... .. were the AHP weight values, and PD=Population Density; LULC= Land Use Land Cover; DRo=Distance from Road; RR=Road River Intersection, and LR= Literacy Rate.

2.7 Flood Risk Map Generation

Risk pertains to the potential loss of life, harm to individuals, damage to property, and financial disruption caused by natural catastrophes (Merlotto et al., 2016). It is generally defined as the interaction between hazard and vulnerability; hence, flood risk is calculated as their product (Ouma & Tateishi, 2014). The Risk Index was derived in ArcGIS using the equation (3).

$$\text{Risk Index} = \text{Hazard Index} \times \text{Vulnerability Index} \quad (3)$$

The resulting flood risk map was intersected with union shapefiles for each upazila to identify the high risk unions, which were classified into five categories: very low, low, moderate, high, and very high.

3. RESULTS AND DISCUSSION

For Mongla, the AHP analysis showed that distance from roads was the most highly weighted parameter (38%) among the vulnerability factors, followed by literacy rate (31%) and Land Use Land Cover (13%), while less weightings were assigned to population density and road river intersection each 12% and 6%, respectively. This indicates that the low educated and access restricted communities are more susceptible to floods. In contrast, for Sharankhola, literacy rate (37%) had the highest contribution to vulnerability followed by population density (24%) and distance from roads (23%). Previous study on Coastal region of Bangladesh showed similar socio demographic characteristics (Bhuiyan & Dutta, 2012), pointing out that social preparedness and population concentration strongly influence flood exposure and susceptibility. Less weightings were assigned to LULC and road river intersection each 10% and 6%, respectively. All the vulnerability index factor's maps for Mongla and Sharankhola Upazilas are shown in figure 3 and figure 4 respectively. In case of hazard parameters, average annual rainfall (37%) dominated the flood hazard in Mongla, indicating a primarily rainfall-induced hazard regime. Prior studies in the coastline area indicated that monsoon precipitation, in conjunction with tidal backwater effects, exacerbates surface flooding in low-lying regions (Auerbach et al., 2015). Drainage density (25%) and distance from rivers (14%) were the next influential parameters, while it was distance from river (32%) followed by drainage density (25%) and average annual rainfall (21%) for Sharankhola. These findings suggest that Sharankhola's flood hazard is primarily influenced by river proximity and drainage characteristics. The other hazard parameters in Mongla include elevation (9%), TWI (8%) and slope (7%) while the other hazard parameters in Sharankhola include elevation (8%), slope (7%) and TWI (7%) indicating less importance in flood risk. All the hazard index factors maps for Mongla and Sharankhola Upazilas are shown in figure 5 and figure 6 respectively. Spatial flood risk

analysis (Figure 7) further shows that in Mongla, moderate-risk (29.66%) and high risk (29.32%) zones dominate, while low risk (28.95%), very low-risk (7.93%), and very high-risk (4.15%) zones are distributed unevenly. This indicates that about 59% of the total area falls under moderate to high flood risk. Similarly, the flood risk map (Figure 8) reveals that Sharankhola is largely characterized by moderate-risk areas

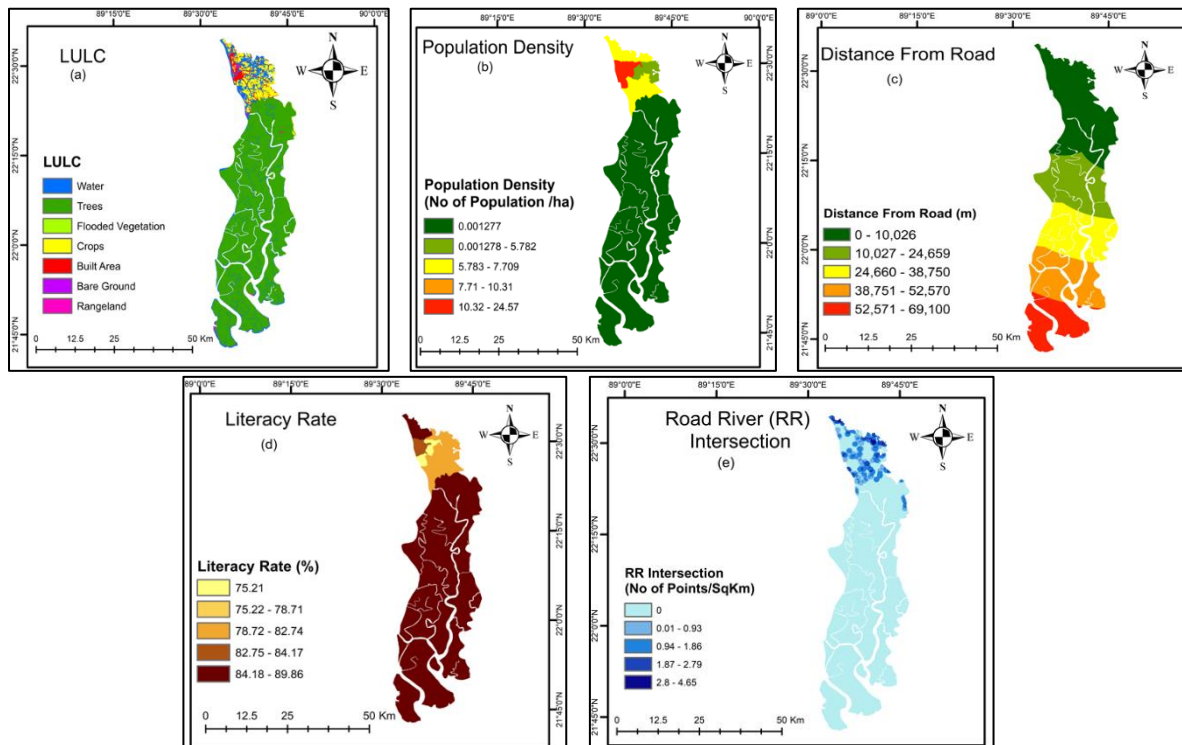


Figure 3: Vulnerability Index Factors Maps For Mongla Upazila

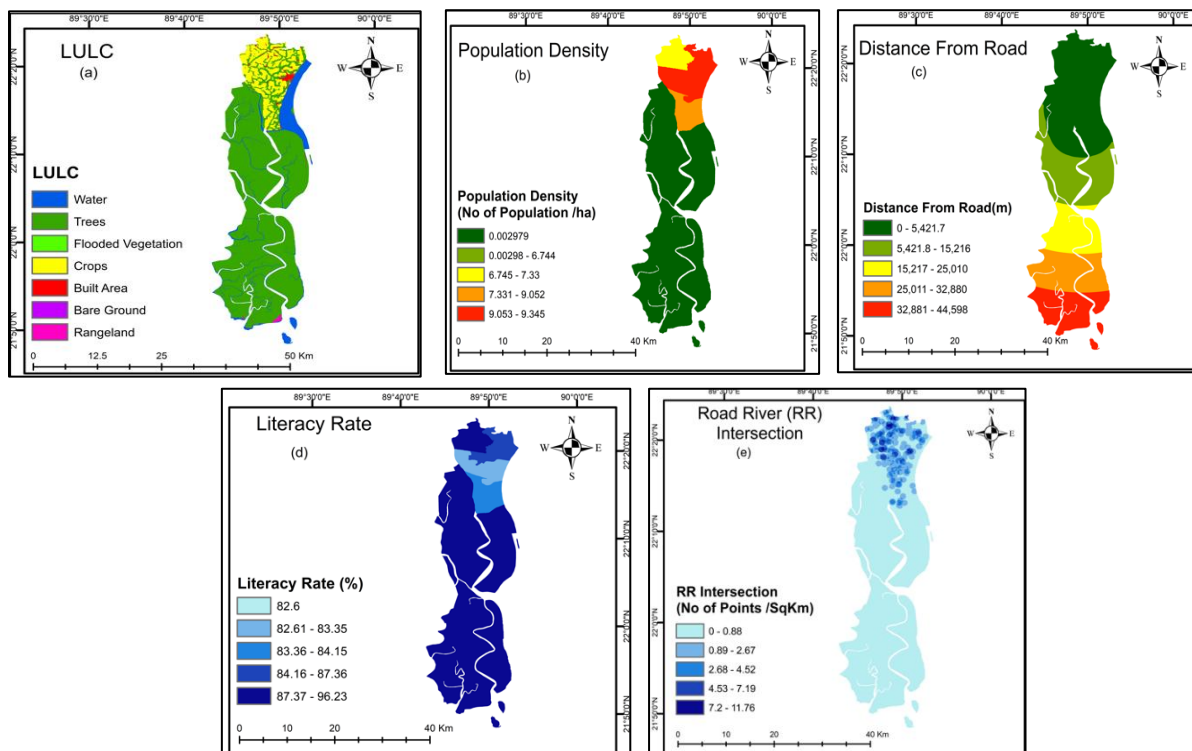


Figure 4: Vulnerability Index Factors Maps For Sharankhola Upazila

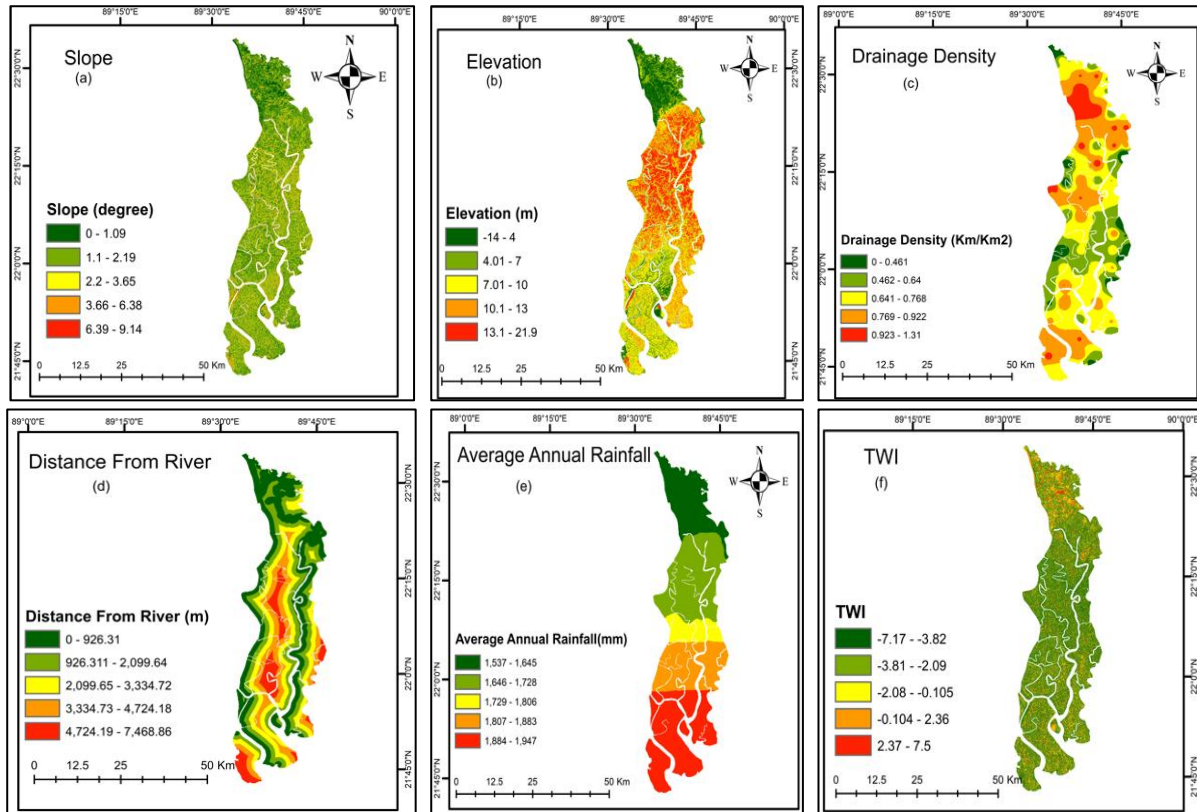


Figure 5: Hazard Index Factors Maps For Mongla Upazila

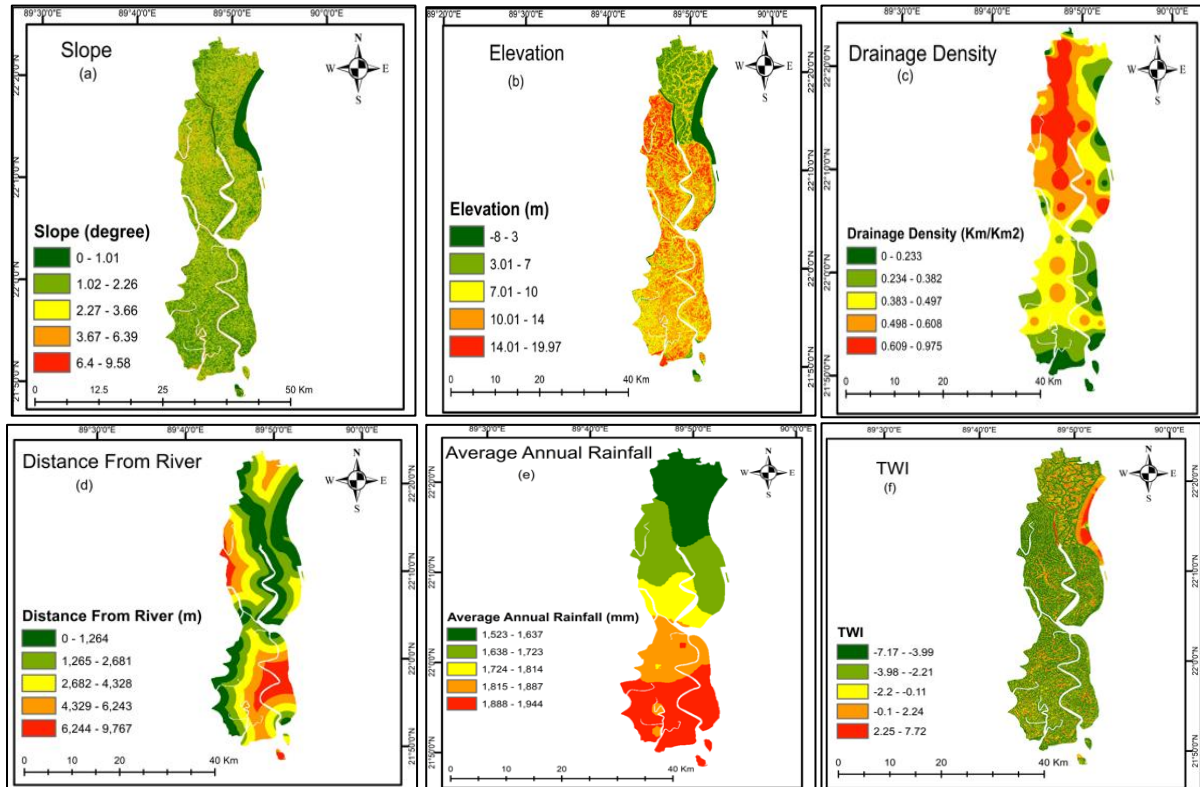


Figure 6: Hazard Index Factors Maps For Sharankhola Upazila

(31.43%), followed by low (29.35%) and very low (22.41%) zones. That means most of the areas in the Sharankhola Upazila fall within very low to moderate flood risk zones. On the other hand, High and

very high-risk categories cover 11.48% and 5.33% of the area, respectively. Figure 9 indicates that in Mongla Upazila, most areas in Chila, Burirdanga, and Sundarban unions fall within high flood risk zones, while the majority of Sonailtala Union lies in the very high-risk category. Figure 10 shows that

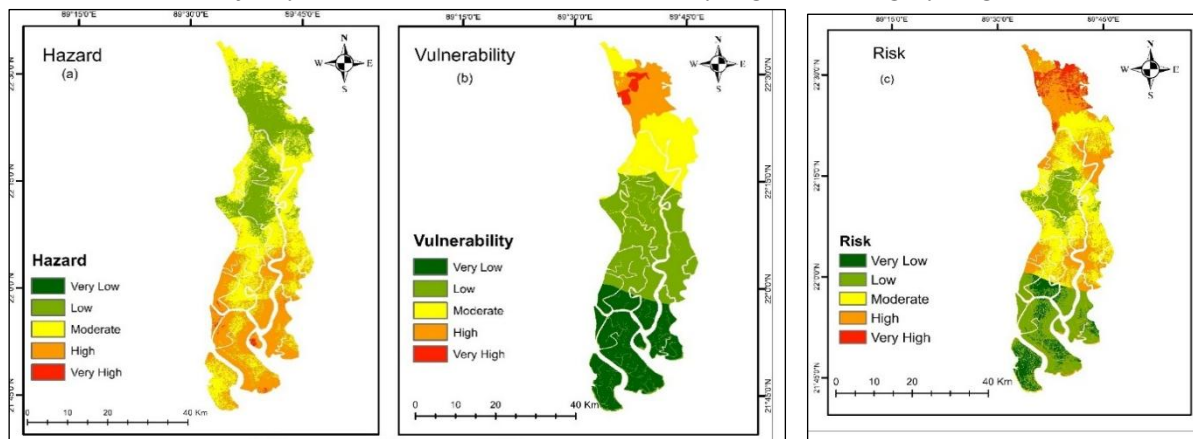


Figure 7: Mongla Upazila (a) Hazard Map (b) Vulnerability Map (c) Flood Risk Map

almost all unions in Mongla are flood-prone, with Chandpi (100%), Sonailtala (99.88%), and Chandpi Range (22.61%) within combined high and very high-risk classes. That means Chandpi, Sonailtala unions are of critical concern for flood risk management. From a previous research on this Upazila it was found that the most flood frequency occurred unions were north-east of Burirdanga, north-west of Sonaitala, east of Mongla Port Pourashova, north-west of Mithakhali, north of Chandpi indicating that almost all unions were flood prone (Adnan et al., 2020) . In Sharankhola, Figure 11 reveals that most areas of Southkhali Union are under high-risk zones, while Royenda Union is dominated by very high-risk areas. Figure 12 further shows that 97.71% of Southkhali Union and 93.7% of Royenda Union, along with 41.26% of Dhansagar Union and 0.03% of Sundarban (Reserve Forest) fall within combined high and very high-risk categories. So Southkhali and Royenda unions are of critical concern. Similarly previous flood risk analysis on Sharankhola upazila revealed that the Southkhali union was the most risky union due to flood as its risk score is 1.43 which is the highest among the risk score values of

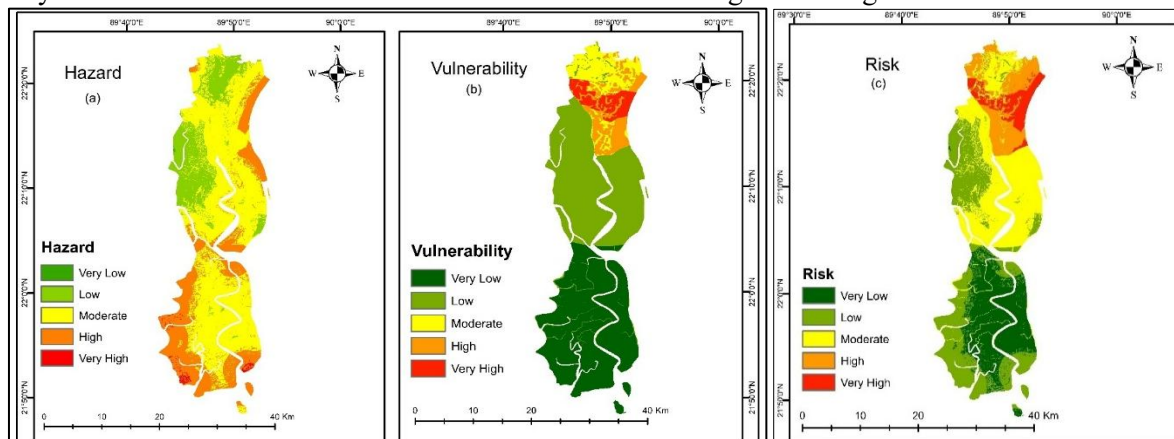


Figure 8: Sharankhola Upazila (a) Hazard Map (b) Vulnerability Map (c) Flood Risk

other unions (Jahid, 2013). Overall, these patterns indicate that Mongla’s elevated flood risk arises from its low-lying topography, intense rainfall, and infrastructural exposure related to its port and industrial landscape, whereas Sharankhola’s vulnerability is driven by its proximity to major rivers, high population density, and dependence on climate-sensitive livelihoods. Due to the significant impact of drainage density, both Upazilas consistently exhibit hydrological sensitivity (Akter et al., 2025). The integrated AHP–GIS approach thus effectively delineated spatially explicit flood risk zones, identifying critical areas for targeted adaptation and resilience planning.

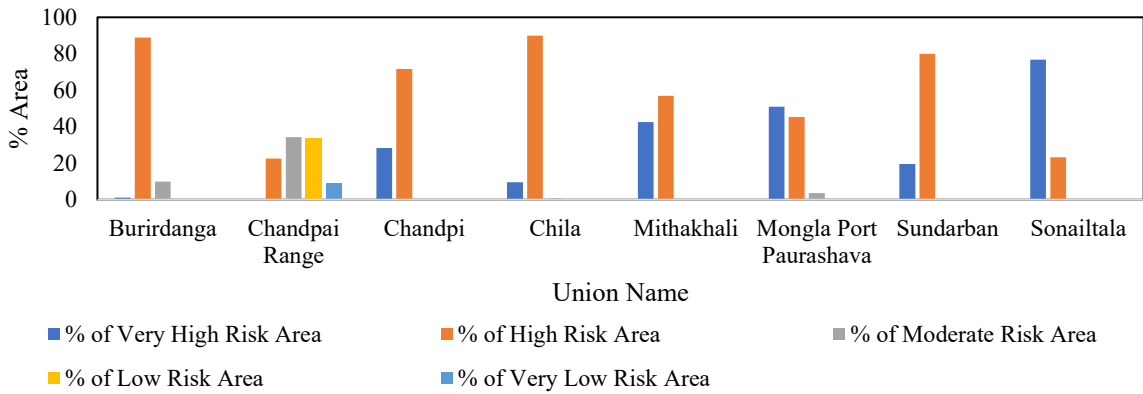


Figure 9: Percentage Distribution of Flood Risk Categories Across the Unions of Mongla Upazila

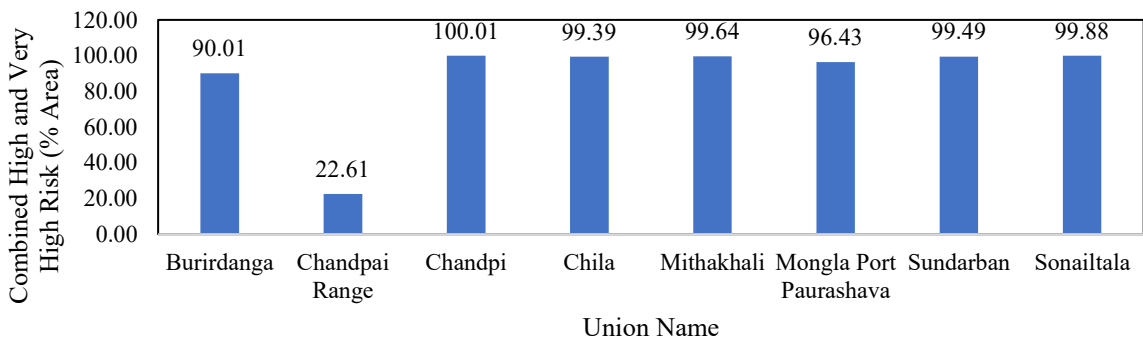


Figure 10: Percentage Distribution of Combined High and Very High Risk Areas in Mongla

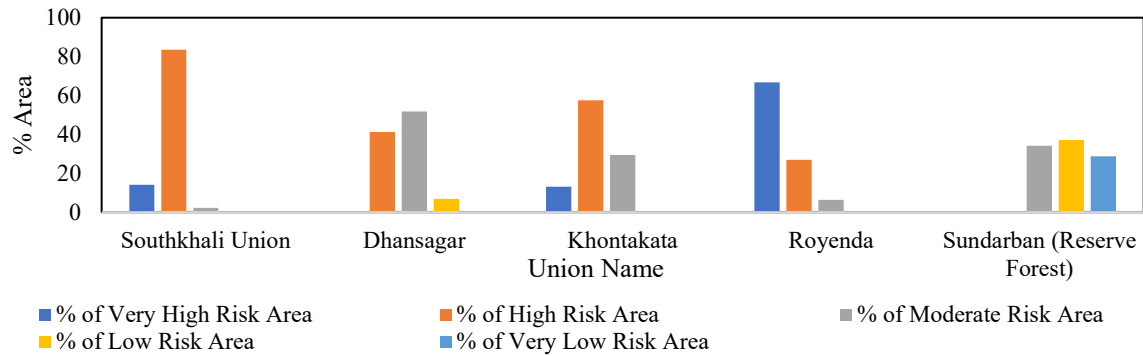


Figure 11: Percentage Distribution of Flood Risk Categories Across the Unions of Sharankhola Upazila

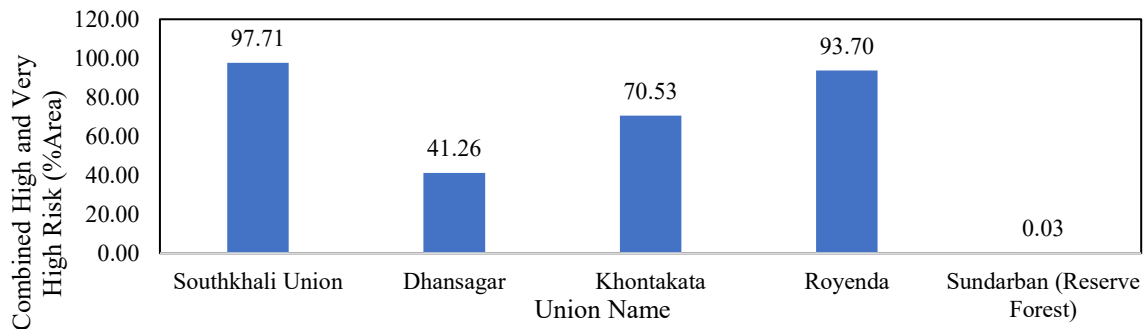


Figure 12: Percentage Distribution of Combined High and Very High Risk Areas in Sharankhola

4. CONCLUSION

The AHP-GIS based flood risk analysis delineated the spatial variability of the flood risk across Mongla and Sharankhola Upazilas, which offered important observations of the dynamics of flood risk in the southern coastal Bangladesh. The results indicated that the hydrological and infrastructural exposures, such as high rainfall, low-lying terrain, and port and industrial exposures were the main factors to Mongla's flood risks. On the other hand, the vulnerability of Sharankhola is mostly due to location close to the rivers, high population density and low literacy rate which signifies that social and geomorphological factors have a significant role in shaping the exposure to flooding. As the analysis of the two upazilas showed, 59% of the Mongla is located in the zone of moderate-high flood risks, and only 16.81 % of Sharankhola is put in the zone of high and very-high risks, which has resulted in significant spatial difference to be attributed to the local environmental and socio-economic factors. The prone areas which were identified as the critical ones were Chandpi and Sonailta in Mongla and Southkhali and Royenda in Sharankhola and actions were taken to ensure flood resilience by improving infrastructure. The results of this study give scientific basis on how the local authorities and policymakers will be able to organize their resources effectively, adopt effective flood control mechanisms, and enhance community readiness on a union level. Nonetheless, there are some weaknesses which impact the accuracy of the results of this study. The omission of other biophysical and environmental factors like Normalized Difference Vegetation Index (NDVI), Modified Normalized Difference Water Index (MNDWI), lithology and soil type together with lack of ground truth validation can have affected the general accuracy of the model. Further research is required to include these factors in incorporating higher-resolution data and massive field validation to further improve flood risk mapping. In spite of them, it can be stated that the AHP-GIS integration is a credible and flexible model and can be applied to other coastal upazilas, which will lead to the development of a regional database of flood risks and direct sustainable resilience planning throughout coastal Bangladesh

DECLARATION OF USE OF AI

The authors used AI-based tools, including ChatGPT and QuillBot, solely for language related assistance such as grammatical correction, sentence restructuring, and paraphrasing to improve clarity and readability. No AI tools were used in the research design, data analysis, methodology, or interpretation of results.

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