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Flood Risk and Resilience in the Greater Sylhet Region: A Disaster Management Perspective

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Abstract

Bangladesh is one of the world's most watery and riverine regions where three of the Earth's mighty rivers flow majestically, inundating stretches of its area. The Greater Sylhet region of Bangladesh faces severe and recurrent flood hazards due to its unique haor basin geomorphology, proximity to the Meghalaya Plateau, and complex hydrology influenced by transboundary rivers. This study provides a comprehensive disaster management perspective focusing on flood with historical analysis, hydro-climatological drivers (including monsoon patterns, transboundary inflows, ENSO), and geomorphological influences. It characterizes prevalent flood types, details their devastating socio-economic and environmental impacts, and reviews structural and non-structural mitigation strategies, incorporating insights from recent susceptibility assessments. The study underscores the necessity of Integrated Flood Risk Management (IFRM), emphasizing enhanced forecasting, risk-informed land use, ecosystem-based approaches, community preparedness, and transboundary cooperation to build resilience in this highly susceptible region.

Keywords: Hazard, Haor Basin, Flash Flood, Riverine Flood, Disaster Management, Hydro-climatology, ENSO, IOD, Water Governance, Climate Change Adaptation, Flood Susceptibility.

JEL Classification: Q54, Q57, R11, R58

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1.0 Introduction

Flooding represents one of the most pervasive and damaging natural hazards globally, and Bangladesh is widely recognized as one of the world's most flood-prone nations (Nizamuddin, 2001). Within Bangladesh, the Greater Sylhet region, encompassing the districts of Sylhet, Sunamganj, Moulvibazar, and Habiganj, stands out due to its exceptional vulnerability. This susceptibility stems from a unique combination of factors: its geographical setting as a vast, low-lying tectonic depression known as the haor basin, its location adjacent to the steep Meghalaya Plateau which generates intense orographic rainfall, and its role as a drainage outlet for major transboundary river systems like the Surma and Kushiyara which feed into the larger Meghna system (Ahmad et al., 2001), alongside significant interannual hydro-climatic variability influenced by large-scale phenomena such as the El Niño-Southern Oscillation (ENSO) (Wahiduzzaman et al., 2021; Chowdhury, 2003; Hossain et al., 2001).

The region consequently experiences recurrent and often devastating floods, primarily manifesting as extensive monsoon riverine inundation and increasingly frequent and severe flash floods originating from the upstream hills (Dewan, 2015). These flood events inflict substantial tolls, including loss of life, displacement of communities, destruction of critical infrastructure, crippling economic losses, particularly in agriculture, and significant environmental degradation (Nizamuddin, 2001). The severity and potential increase in frequency of extreme events, such as the catastrophic floods of 1987, 1988, 1998 (Nizamuddin, 2001), and 2022, underscore the urgent need for effective disaster management strategies tailored to the region's specific challenges (ReliefWeb, 2022; IPCC, 2021).

This study provides a comprehensive overview of flood hazards in the Greater Sylhet region from a disaster management perspective. It synthesizes knowledge by examining historical contexts, analyzing hydro-climatological causes, and incorporating recent quantitative assessments of flood susceptibility. The study also characterizes prevalent flood types, details their adverse effects, and reviews structural and non-structural flood control measures. Furthermore, this study combines geospatial analyses to enhance the understanding of flood resilience and inform evidence-based disaster management in the vulnerable Sylhet region.

2.0 Aim and Objectives

The primary objective of the present study is to enhance flood resilience in the Greater Sylhet region of Bangladesh by increasing understanding of flood hazards, utilizing historical data, hydro-climatological analysis, and recent assessments to inform disaster management.

3.0 Objectives:

1. To characterize the flood hazard in the Greater Sylhet region by analyzing its historical context, hydro-climatological drivers, and prevalent flood types.
2. To assess the region's vulnerability by mapping flood susceptibility and documenting the significant socio-economic and environmental impacts.

3. To review existing and potential flood mitigation strategies to inform a more integrated approach to disaster management.

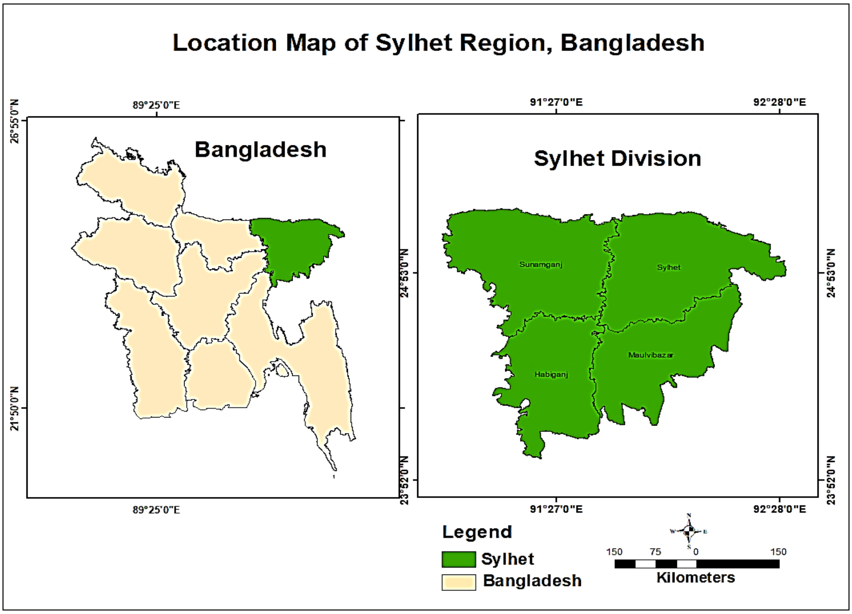

Figure 1: Location Map of Sylhet Region, Bangladesh. *(Source: Prepared by the author.)*

4.0 Historical Overview of Floods in Sylhet

Northeastern Bangladesh's Sylhet region frequently floods due to its geographical location, monsoon climate, and major rivers, including the Surma and Kushiyara. These events have caused significant historical, social, and economic damage, highlighting the area's vulnerability and the crucial need for effective flood management strategies.

4.1 20th Century Events

1974 Flood: One of the most devastating floods in Sylhet's recent history occurred in 1974, affecting millions and causing severe damage to infrastructure and agriculture. It was part of a larger pattern of flooding across Bangladesh that year (Nilufar, 1985).

1987 Flood: While specific Sylhet impacts require detailed local verification, this was a major national flood event noted for its extensive damage across Bangladesh (Nizamuddin, 2001).

1988 Flood: One of Bangladesh's worst floods occurred in 1988, affecting over two-thirds of the country (including Sylhet) and causing widespread devastation. Synchronized river peaks contributed to its severity, prompting major humanitarian responses and leading to the Flood Action Plan (FAP) for improved management (Nizamuddin, 2001; Ahmad et al., 2001)

1998 Flood: Another disastrous flood hit the region nationally, noted for its long duration (over two months in many areas) and extensive damage, affecting agriculture and displacing many families (Nizamuddin, 2001; Ahmad et al., 2001).

4.2 21st Century Events

2004 Flood: Heavy monsoon rains led to significant flooding across Bangladesh, including Sylhet, resulting in displacement, crop losses, and infrastructure damage (NASA, 2004).

2007 Flood: In August 2007, Sylhet experienced severe flooding, impacting millions and leading to at least 192 deaths. The crisis resulted in widespread waterborne diseases, prompting the deployment of over 2,500 medical teams to address health concerns (WHO, 2007).

2010 Flood: Heavy rains and rising river levels contributed to extensive flooding in parts of the region, highlighting ongoing vulnerability (IFRC & BDRCS, 2010).

2020 Flood: Torrential rains, particularly during the monsoon, led to significant flooding in Sylhet and neighboring areas, causing damage to homes, schools, and agricultural land, impacting thousands (FFWC,2020).

2022 Flood: In 2022, catastrophic flooding in Bangladesh, characterized by intense pre-monsoon flash floods and severe riverine flooding in June, devastated the Sylhet and Sunamganj districts. This disaster destroyed homes, infrastructure, and agriculture, displacing millions and prompting a significant humanitarian response (Tuli et al., 2024).

2024 Flood: The IFRC's July 2, 2024, report highlights severe flooding in Sylhet, Bangladesh, resulting from heavy rains on June 18-19. The northeastern Haor region and Cox's Bazar were heavily affected, resulting in casualties and displacing over 1.6 million people. Key rivers exceeded danger levels, stranding 371,000 individuals and leading to the relocation of 4,000 to shelters. The report underscores the urgent need for humanitarian assistance amid ongoing climate vulnerabilities.

4.3 Morphology and Hydrology of the Study Area

The Sylhet region's environmental characteristics, crucial for understanding its flood proneness, are dominated by the interplay between its distinct morphology (landforms) and hydrology (water systems). Geospatial analysis provides quantitative insights into these features and their contribution to flood susceptibility.

4.4 Morphology (Landforms and Structure)

The landscape of the Greater Sylhet region is unique, featuring large low-lying areas surrounded and dotted with hills (Rashid, 1991). Nationally, floodplains cover approximately 80 percent of Bangladesh, resulting from the deposition of sediments from the Ganges, Brahmaputra, and Meghna river systems (Ahmad et al., 2001). This setup significantly influences how water moves and contributes to floods in Sylhet, as quantified by recent susceptibility analyses (Shadmaan & Hassan, 2024).

4.5 Dominance of the Haor Basin

The main feature is the Haor Basin, a vast, low-lying, saucer-shaped area covering over 4,500 sq. km. It's filled with many large wetlands called Haors and smaller water bodies called Bils (Rashid, 1991). These depressions, known nationally by various names such as Haors, Beels, and Baors, are characteristic features of Bangladesh's floodplains and play a crucial role in storing floodwater (Ahmad et al., 2001). Some parts are extremely low (below 3m). Rivers have built up higher banks called 'Kandha' (up to 12m high in the east) (Rashid, 1991). This basin acts like a giant bowl, collecting water and is known to be slowly sinking due to geological activity, which will cause it to sink even lower over time (Rashid, 1991).

4.6 Presence of Uplands

Surrounding and within this low basin are the Uplands. To the north are the foothills of the high Meghalaya Plateau. To the south and east are several hill ranges extending from Tripura, India, with some peaks exceeding 300m in height. Inside the region, there are also areas of slightly higher ground called the Sylhet High Plains and scattered small hills known as 'Tilas' (up to 92m high). These hills are the source of rivers and streams flowing into the basin (Rashid, 1991). These northern and eastern hill areas occupy about 12 percent of Bangladesh's total area (Ahmad et al., 2001).

4.6 Riverine Landforms

The Sylhet region's landscape is dominated by rivers like the Surma and Kushiara, alongside numerous smaller channels. These waterways carve the terrain, creating features such as old river bends (cutoffs) and building natural levees known as 'Kandha', which slope into back-swamps or depressions like haors (Ahmad et al., 2001). Where streams descend from hills, they deposit sand and gravel, forming alluvial fans. The density of the drainage network varies, influencing runoff concentration and potential overflow. Proximity to rivers is critical; areas within 1km of major channels in the Sylhet district received the highest flood susceptibility rating (Shadmaan & Hassan, 2024). The drainage system is generally well-defined and entrenched, particularly evident in winter (Rashid, 1991).

4.7 Active Sedimentation and Ongoing Erosion

Rivers carry lots of mud (sediment) from the hills, which fills up the haors and riverbeds, reducing their capacity to hold or carry water. At the same time, erosion wears down the hills over long periods (Rashid, 1991)

4.8 Land Use/Land Cover (LULC)

Land Use/Land Cover (LULC) has a significant influence on flood patterns in Greater Sylhet, affecting runoff and infiltration. Analysis by Howlader et al. (2024) for the 2000-2022 period reveals an increase in urbanization (more built-up areas) and a decrease in wetland cover within a landscape dominated by crops, water bodies, and trees. This shift exacerbates flood risk, as expanding impervious urban surfaces accelerate runoff while diminishing wetlands reduce natural floodwater storage capacity. Consequently, these LULC changes, particularly urbanization and wetland loss, are key factors contributing to increased flood vulnerability in the region (Howlader et al., 2024).

In short, Sylhet's landscape is defined by the contrast between the vast, sinking Haor Basin and the surrounding hills, which are shaped by its river systems and constantly altered by sinking, sedimentation, and erosion. These morphological features are intrinsically linked to its hydrological behaviour.

5.0 Hydrology (Water Systems and Processes)

The hydrology of the Sylhet region is fundamentally shaped by its basin morphology, proximity to the Meghalaya Plateau, and monsoon climate, resulting in a complex and dynamic water system.

5.1 High Rainfall

High rainfall is a primary driver of flood hazards in the Greater Sylhet Region, which receives Bangladesh's highest average annual precipitation (often >4000 mm, reaching ~6000 mm near Meghalaya) (Ahmad et al., 2001; Rashid, 1991). This finding is mainly due to orographic lifting of monsoon winds by the Meghalaya Plateau (Brammer, 2012). Figure 2 illustrates the significant contribution of pre-monsoon (April) rainfall, displaying average accumulated rainfall from 1995 to 2022 across Habiganj, Sunamganj, Maulvibazar, and Sylhet (Data adapted from Akter et al., 2023). The chart highlights substantial inter-annual variability and extreme rainfall events in certain years (2004, 2012, 2017), with Sylhet consistently recording the highest amounts due to its proximity to the Meghalaya hills. This intense rainfall early in the wet season increases river discharge and saturates the catchment, priming the region for severe monsoon flooding and underscoring the critical role of high precipitation events in driving flood hazards.

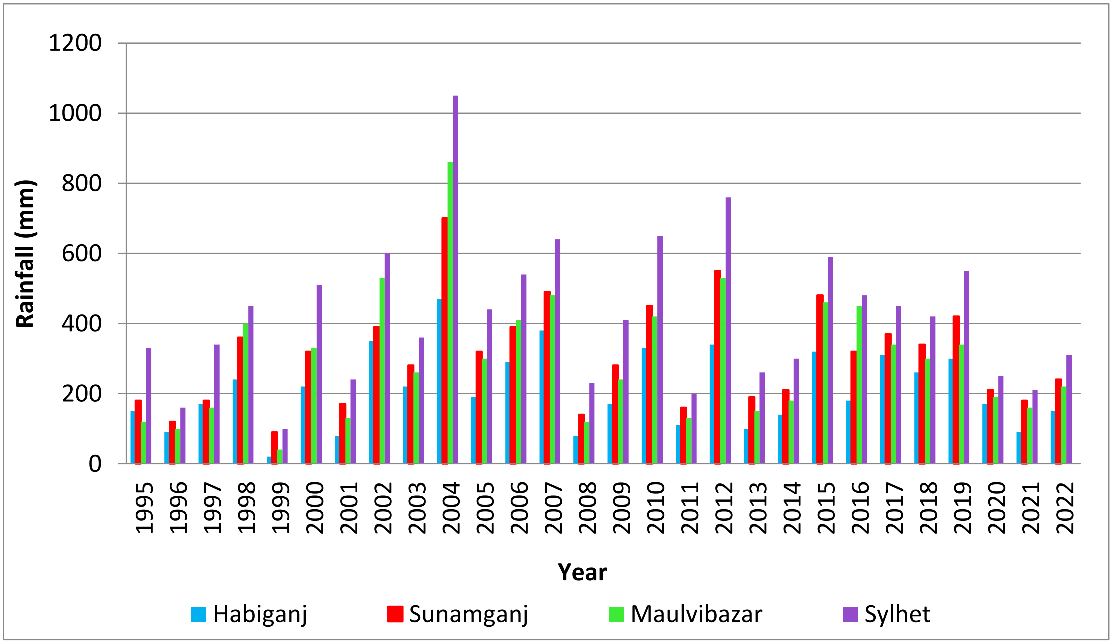

Figure 2: Average April Rainfall in Sylhet (1995-2022). *(Source: Adapted from Akter et al., 2023)*

5.2 River System and Discharge

The dominant river system is the Surma-Meghna. Its primary source is the Barak River, which originates in the Naga-Manipur watershed and carries substantial cross-border flow from India. Within Cachar (India), the Barak bifurcates into the northern Surma and the southern Kushiara Rivers, which form the backbone of the drainage network within Sylhet (Rashid, 1991).

The Surma River generally flows west and southwest, receiving numerous tributaries directly from the Meghalaya Plateau (Lubha, Piyain, Jadukata, Kangsha), which is known for its rapid, flashy discharge that responds quickly to intense rainfall in the hills (Rashid, 1991).

The Kushiara River flows south of the Surma, also receiving tributaries like the Manu, and inputs from the Tripura Hills via its lower course (Gopla, Khowai) (Rashid, 1991).

These rivers exhibit complex patterns of bifurcation (Surma forming the Dhanu/Ghorautra; Kushiara forming the Bibiyana/Kalni) and confluence (Surma and Kushiara meet near Madna; the combined flow eventually forms the Upper Meghna near Kuliarchar). Overall discharge is thus a combination of high local rainfall runoff and significant inflows from upstream catchments in India (Rashid, 1991). The combined system ultimately discharges into the Bay of Bengal through the Lower Meghna estuary (Ahmad et al., 2001).

5.3 Haor Basin Dynamics

Much of the central and western Sylhet region comprises the Haor Basin, a landscape of extensive, low-lying depressions. These function as critical natural flood storage zones, absorbing vast quantities of water during the monsoon from both direct rainfall and overbank flow from the Surma-Kushiara system, forming immense seasonal lakes (Rashid, 1991; Alam & Hossain, 2021). The spatial extent and typical depth of this inundation across the Haor Area are illustrated in Figure 3. This map, derived from the Master Plan of the Bangladesh Haor and Wetland Development Board, categorizes the region based on inundation levels, likely representing typical monsoon water depths. The darkest blue areas, indicating inundation greater than 1.8 meters, are predominantly concentrated in the core haor districts of Sunamganj, Kishoreganj, and parts of Habiganj and Netrakona, highlighting the profound depth of flooding these low-lying basins experience. Areas with inundation between 0.5 and 1.8 meters (medium blue) are also extensive, particularly in Sylhet district and the northern parts of Maulvibazar. Shallower inundation (<0.5 meters, light blue) and areas with minimal to no standing water (dotted white pattern, "0") are more prevalent in the southern parts of Maulvibazar and Brahmanbaria, and along the fringes of the main haor depressions. This zonation visually underscores the haor basin's critical role as a vast natural flood storage zone and directly informs the understanding of flood hazard exposure across different upazilas within the Greater Sylhet region. Their drainage during the dry season is slow and significantly influenced by water levels in the downstream Meghna River, which can exert a backwater effect, impeding outflow. These natural depressions hold significant floodwater, inundating appreciable areas along their periphery (Ahmad et al., 2001)."

5.4 Flood Regimes

Sylhet experiences frequent, varied flooding driven by intense rainfall, high river discharge (local/cross-border), rapid flash floods from adjacent hills, and Haor Basin dynamics. Key flood types include: (a) rapid flash floods near the hills; (b) widespread riverine flooding along major channels; (c) prolonged Haor

Basin inundation; and (d) pluvial flooding when intense local rainfall overwhelms drainage, especially in flat or urban zones (Ahmad et al., 2001).

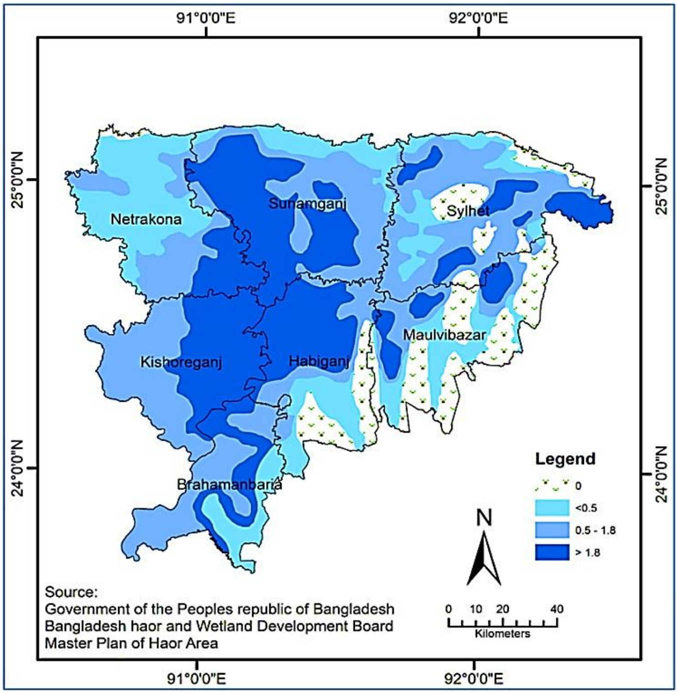

Figure 3: Spatial Distribution of Inundation Levels in the Haor Area of Greater Sylhet. *(Source: Adapted from Chowdhury, 2024; original data from Bangladesh Haor and Wetland Development Board, 2012)*

5.5 Surface-Groundwater Interaction

Monsoon flooding significantly recharges groundwater, which is vital for dry-season Boro rice irrigation and domestic supply. However, sustainable management and quality issues, such as arsenic, are important concerns (Nizamuddin & Chakraborty, 2001; Khuda, 2001).

Morphology and hydrology are interdependent. The low basin shape promotes water accumulation and slow drainage, while adjacent steep hills generate rapid runoff and flash floods. High rainfall and river flows drive landscape modification through sedimentation and erosion. The region's generally flat topography facilitates widespread flood accumulation (Ahmad et al., 2001). Quantitative analysis assesses the contributions of these factors to overall flood susceptibility (Shadmaan & Hassan, 2024).

6.0 Causes and Hydro-Climatological Aspects of Flood, Synchronization of Peaks

The propensity for flooding in the Greater Sylhet region is deeply rooted in its distinct hydro-climatological characteristics and geographical positioning. Understanding these factors, including the phenomenon of peak flow synchronization and the relative importance of different drivers, is essential for comprehending the nature and severity of flood hazards in the area.

6.1 Dominance of the South Asian Monsoon and Heavy Rainfall

The climate of the Greater Sylhet Region is primarily influenced by the South Asian monsoon, which accounts for approximately 80% of the annual rainfall between June and October (Ahmad et al., 2001). This period is characterized by prolonged and intense rainfall across the Surma-Kushiyara catchments, saturating the ground and significantly increasing river discharge, which often overwhelms channel capacity and causes widespread riverine floods (Haque et al., 2025). Figure 4 provides clear visual evidence, starkly showing the Monsoon season (black line) consistently dominating discharge, frequently exceeding 1500 M³/s. This peak flow period directly aligns with the highest risk for major riverine floods. The figure also critically highlights significant year-to-year variability in monsoon discharge, with dramatic peaks (1988, 1993, 1998) contrasting with lower flow years. This variability explains why monsoon flood severity varies significantly from year to year. While less dominant, notable pre-monsoon (orange) and post-monsoon (blue) discharge peaks indicate risks outside the main monsoon, particularly concerning pre-monsoon flash floods. Consistently low winter discharge (green) marks the period of minimal flood hazard (Akter et al., 2019).

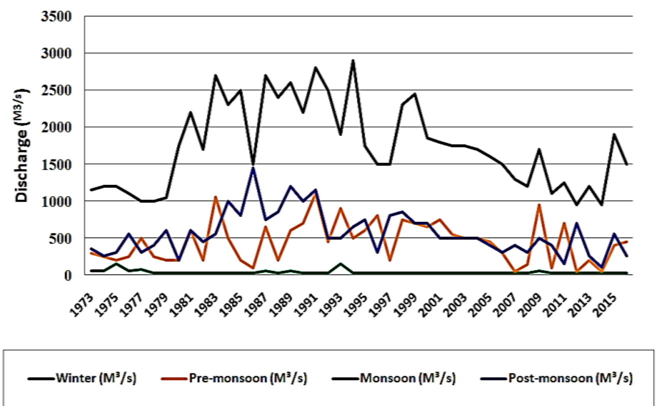

Figure 4: Dominance of monsoon discharge and inter-annual variability shown in seasonal flows (1973-2016) *(Source: Adapted from Akter et al., 2019)*

Complementing the discharge data, Figure 5 presents the observed total seasonal rainfall trends for Sylhet from 1995 to 2022 (Akter et al., 2023). This figure illustrates the distinct rainfall contributions during winter, Pre-monsoon, Monsoon, and Post-monsoon seasons, along with their linear trends. Akter et al., (2023) note a positive tendency of increasing rainfall in the monsoon, pre-monsoon, and post-monsoon seasons for Sylhet, while winter rainfall shows a decreasing trend. The increasing trend in pre-monsoon rainfall is particularly significant for understanding the conditions leading to early flash floods.

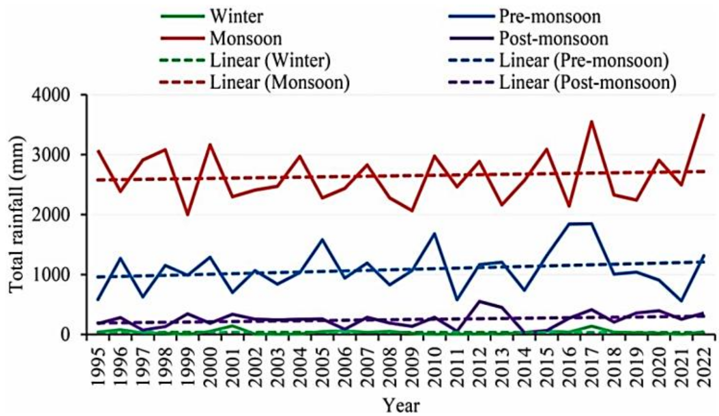

Figure 5: Trends in seasonal rainfall for Sylhet (1995–2022) *(Source: Adapted from Akter et al., 2023)*

6.2 Transboundary Catchment Influence

Sylhet occupies a downstream position within a large international river basin. A substantial volume of the water flowing through the Surma and Kushiyara rivers originates from rainfall occurring in the upstream catchment areas in Meghalaya and Assam, India, primarily via the Barak River and numerous smaller cross-border streams (Dewan, 2015). As noted earlier, over 90% of the annual flow in Bangladesh's major rivers comes from outside its borders (Ahmad et al., 2001). Consequently, hydrological conditions and rainfall patterns within these Indian territories exert a dominant influence on flood levels and discharge characteristics within Sylhet (Mirza, 2011). Land use practices (deforestation or afforestation affecting runoff rates) and any water management interventions upstream inevitably impact downstream flood dynamics.

6.3 Geomorphological Controls

The region's unique topography plays a critical role. The steep gradients of the adjoining Meghalaya hills facilitate extremely rapid runoff, contributing significantly to the 'flashy' nature of floods originating there (Brammer, 2014). In stark contrast, the Sylhet basin itself is a vast, low-lying depression characterized by extensive haors with very gentle slopes (Brammer, 2012). This morphology naturally promotes water accumulation and significantly impedes drainage, leading to prolonged periods of inundation once floodwaters arrive (Banglapedia, 2021). The general flatness of the floodplain landscape means rivers assume a minimum gradient, slowing flow and contributing to inundation (Ahmad et al., 2001). Furthermore, the high sediment load carried by the rivers from the eroding hills leads to deposition within river channels and haors, gradually reducing their capacity to convey water and potentially exacerbating flood heights over time (Islam & Sado, 2000).

6.4 Hydro-Climatological Variability, ENSO Influence, and Climate Change

Flood regimes exhibit significant year-to-year variability, driven by fluctuations in the timing, intensity, and spatial distribution of monsoon and pre-monsoon rainfall. A major driver of this interannual variability is the El Niño-Southern Oscillation (ENSO), a large-scale climate pattern originating in the tropical Pacific with significant teleconnections influencing the South Asian monsoon (Wahiduzzaman et al., 2021; Chowdhury, 2003; Hossain et al., 2001). Specifically, La Niña phases (cooler-than-average central/eastern Pacific sea surface temperatures) are often correlated with enhanced monsoon rainfall across Bangladesh (Chowdhury, 2003; Hossain et al., 2001), increasing the likelihood of severe and widespread monsoon riverine flooding (Wahiduzzaman et al., 2021; Hossain et al., 2001). Conversely, El Niño phases (warmer-than-average temperatures) tend to suppress monsoon rainfall in the region (Wahiduzzaman et al., 2021; Chowdhury, 2003; Hossain et al., 2001), potentially reducing the risk of major riverine floods, particularly during strong El Niño events.

The pre-monsoon period, especially April, is crucial for the onset and intensification of flash floods in the Sylhet haor region. As illustrated in Figure 6, there is a strong relationship between years with excess April rainfall and the occurrence of devastating flash floods between 1995 and 2022. The study by Akter et al. (2023) highlights this connection, finding that an increase in pre-monsoon rainfall can heighten the intensity of flash floods that damage vital crops like Boro rice. Their analysis showed that out of 28 years, 11 experienced excessive April rainfall, with many of these corresponding to high-intensity flood events. Based on this, they suggest that average April rainfall exceeding a threshold of around 400 mm within Sylhet can lead to severe flash floods.

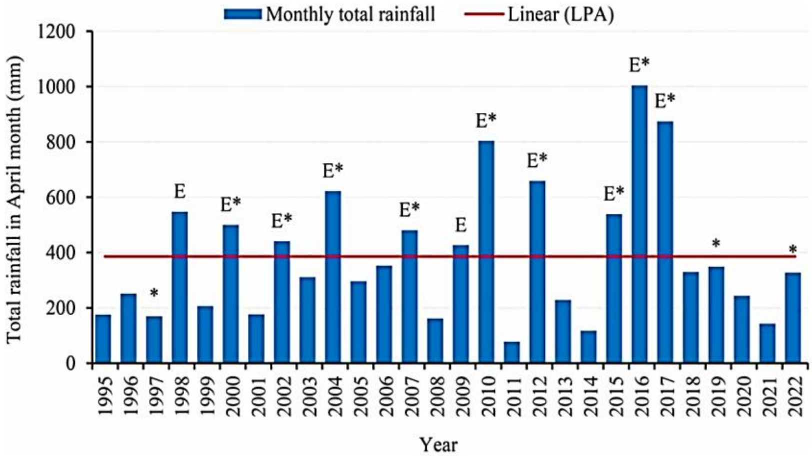

Figure 6: The relationship between high April rainfall and flash floods in the Sylhet region (1995–2022). In the chart E indicates excess rainfall; * indicates high-intensity flash flood years during April; LPA indicates long-period average rainfall. *(Source: Adapted from Akter et al., 2023)*

It is important to recognize that this ENSO-monsoon relationship is complex, with other factors like the Indian Ocean Dipole (IOD) also playing a role (Cai et al., 2015), and moderate El Niño years sometimes paradoxically linked to increased rainfall and flooding in Bangladesh (Chowdhury, 2003; Hossain et al., 2001). Superimposed on this natural variability is the impact of anthropogenic climate change, which is projected to increase the intensity of monsoon rainfall and the frequency of extreme precipitation events, potentially exacerbating flood risks in the future (IPCC 2021; Mirza 2011).

Interestingly, while many expect climate change to bring more intense rain eventually, the actual data for this specific period (1973-2016) showed a statistically confirmed decrease in both rainfall and river discharge at Sylhet. The decrease wasn't constant; rainfall actually rose until about 1990 before starting to fall. The researchers suggest that the observed decline during these years may be an early sign of climate change impacting the local water cycle, but further study is needed to confirm this (Akter et al., 2019).

6.5 Synchronization of Flood Peaks

A critical factor determining the severity of major flood events, particularly in complex river systems, is the synchronization of flood peaks. This phenomenon occurs when peak flows originating from different sources converge simultaneously or within a short time window at a downstream location, such as a river confluence or a flood-vulnerable area. The significance of this timing is underscored by research indicating that river floods become particularly severe when peak flows are not only large but also exhibit a "temporal match" between major contributing rivers (Gädeke et al., 2022). Within the Greater Sylhet region, which forms a key part of the upper Meghna basin drainage system, several synchronization scenarios can substantially exacerbate flood hazards:

6.5.1 Tributary Confluence: The simultaneous arrival of peak flows from major tributaries, such as the Surma and Kushiyara rivers, at their downstream confluence or within the wider Meghna system leads to a compounding effect. This results in a combined discharge and associated water level significantly higher than if the peaks were staggered in time, often causing an "increase in flood magnitude" and potentially an "accelerated flood wave" further downstream (Gädeke et al., 2022).

6.5.2 Upstream Flow and Local Runoff: Severe flooding conditions frequently arise when peak discharge, generated by intense rainfall in the upstream catchments located in India, reaches the Sylhet region concurrently with peak runoff generated by heavy local rainfall within the Sylhet basin itself. This combination overwhelms local drainage capacities.

6.5.3 Flash Flood and Main River Interaction: Flash floods, often originating rapidly from the adjacent Meghalaya hills, can cause significantly more devastation if their arrival coincides with periods of already high water levels in the main Surma or Kushiyara rivers due to ongoing monsoon conditions. The elevated stage in the main rivers impedes the efficient dispersal of the incoming flash floodwater, leading to higher and more prolonged inundation in affected areas.

The devastating 1988 flood across Bangladesh provides a prime example of the impact of peak synchronization, where unusually high peaks on both the Brahmaputra and Ganges rivers coincided, leading to unprecedented water levels in the Padma (Ahmad et al., 2001). While involving different rivers, this illustrates the critical importance of timing. When flood peaks synchronize, the resultant water levels and the spatial extent of inundation are significantly magnified compared to asynchronous events, often producing the "large flooding events" that characterize the region's most severe disasters (Gädeke et al., 2022). Importantly, recent climate projections show a consistent increase in the likelihood of flood peak synchronization occurring between at least two of the three major river systems (Ganges, Brahmaputra, Meghna) (Gädeke et al., 2022). This projected increase in future synchronization poses a significant threat of more frequent large-scale flooding events within Bangladesh. Therefore, understanding and forecasting the potential for peak synchronization is a vital component of effective flood warning and management in the Sylhet region.

6.5.4 Devastating and Adverse Effects of Floods

Floods, the overflow of water onto normally dry land, are a common and destructive global hazard. In Bangladesh, particularly vulnerable regions, such as Greater Sylhet, cause immense economic loss, destroy infrastructure and crops, and impede development (Nizamuddin, 2001).

6.5.5 Loss of Human Life and Injury: The most tragic impact is death (drowning, electrocution, debris) and injury, especially during rapid flash floods common in Sylhet (Brammer, 2014), straining health services.

6.5.6 Displacement and Humanitarian Crisis: Floods force hundreds of thousands from homes in Sylhet, creating vast humanitarian needs in shelters (ReliefWeb, 2022). Associated river erosion worsens homelessness (Nizamuddin, 2001).

6.5.7 Destruction of Infrastructure: Floodwaters destroy homes, businesses, schools, and health facilities. Damage to roads and bridges isolates communities and hinders relief (Islam & Sado, 2000). Power and water systems are frequently disrupted.

6.5.8 Crippling Economic Losses: Floods devastate regional economies, ruining agriculture (crops like pre-harvest Boro rice, livestock, and fisheries) (Brammer, 2014; Ahmad et al., 2001). Businesses halt, and high recovery costs hinder development (Nizamuddin, 2001).

6.5.9 Public Health Crises: Contaminated water leads to waterborne diseases like cholera (Nizamuddin, 2001), while stagnant water breeds vectors. Damaged facilities and disrupted access impede healthcare.

6.5.10 Psychological Trauma: Experiencing floods inflicts significant psychological distress, including anxiety and PTSD, affecting long-term community well-being (Ahmad et al., 2000).

6.5.11 Environmental Degradation: Floods cause soil erosion, transport pollutants, damage aquatic ecosystems, and increase river sedimentation (Brammer, 2014).

7.0 Types of Floods in Sylhet Region

The Sylhet region, characterized by its unique geomorphology, including extensive low-lying haor basins and proximity to the steep Meghalaya hills, experiences several distinct types of flooding:

7.1 Monsoon Floods (Riverine/Fluvial): Seasonal (June-Oct) widespread inundation from heavy monsoon rains over the Meghna system (Surma, Kushiyara) and upstream catchments, causing rivers to overflow banks for extended periods (FFWC, 2020).

7.2 Flash Floods: Rapid-onset floods from intense rainfall, often in adjacent hills (Meghalaya), draining quickly into rivers like Surma and Kushiyara; occurs pre-monsoon (threatening crops) and during monsoon (FFWC, 2020). Ahmad et al. (2001) note that these occur in the pre-monsoon season (April-May), damaging crops.

7.3 Rainfall-Induced Floods (Pluvial): Localized flooding or waterlogging ("Rainfed Flood") due to intense local rainfall overwhelming drainage systems, often worsened when high river levels impede outflow (FFWC, 2020). Ahmad et al. (2001) explain that this is worsened when high rivers impede drainage.

7.4 Urban Floods: Occur in cities due to intense rainfall overwhelming urban drainage, exacerbated by impermeable surfaces (Prokic et al., 2019).

7.5 Accidental/Man-Made Floods: Result from infrastructure issues like embankment failures or roads blocking drainage, causing sudden floods (Ahmad et al., 2001).

8.0 Discussion and Key Findings

A synthesis of the evidence presented reveals that the severe flood risk in the Greater Sylhet region stems from a complex interplay of interdependent factors. This analysis identifies five key findings that collectively explain the region's heightened vulnerability.

First, the region's geomorphology provides the foundation for flooding. The Haor Basin, a vast, low-lying tectonic depression, acts as a natural "bowl" that traps water. This inherent weakness is compounded by ongoing land subsidence and high sedimentation rates, which continually reduce the water storage and conveyance capacity of the area's rivers and wetlands (Rashid, 1991; Islam & Sado, 2000).

Second, the hydro-climatology presents a dual threat. While widespread monsoon rains cause prolonged seasonal flooding, intense pre-monsoon rainfall in April is a critical driver of destructive flash floods that threaten agriculture (Akter et al., 2023). The severity of these events is further modulated by large-scale climate patterns, such as the El Niño-Southern Oscillation (ENSO), which influences monsoon intensity (Wahiduzzaman et al., 2021).

Third, the region is overwhelmingly influenced by transboundary water flows. With over 90% of river discharge originating in upstream catchments in India, flood levels in Sylhet are fundamentally dependent on hydrological events and management decisions occurring outside Bangladesh's borders (Ahmad et al., 2001; Mirza, 2011).

Fourth, the timing of water arrival is a catastrophic force multiplier. The most severe floods occur when peak flows from the Surma and Kushiara rivers, their tributaries, and local runoff synchronize. Climate projections suggest an increasing likelihood of such synchronization, elevating the future risk of large-scale disasters (Gädeke et al., 2022).

Ultimately, these natural vulnerabilities are exacerbated by human activities. Increasing urbanization and the loss of natural wetlands diminish the landscape's ability to absorb excess water, accelerating runoff and exacerbating flood peaks (Howlader et al., 2024).

In conclusion, the study reveals that flooding in Sylhet is a complex phenomenon, not a straightforward issue. It is the result of interconnected geographical, climatic, and anthropogenic pressures that demand a holistic and integrated management approach to build meaningful resilience.

9.0 Flood Control and Mitigation Measures in the Sylhet Region

Effective flood management in Sylhet requires an integrated strategy that combines both structural and non-structural measures, given the diverse flood types and complex hydrology, aligning with standard flood risk mitigation classifications (Minea & Zaharia, 2011).

9.1 Structural Measures: These physical constructions aim to control water flow (Minea & Zaharia, 2011).

a. **Embankments/Levees:** Widely used along major rivers but require high maintenance and risk of breaching. The failure of these structures can lead to sudden and severe inundation of adjacent areas, as shown in Figure 8.

Figure 8: A breach in the Kushiyara River embankment in Zakiganj, Sylhet, caused by heavy rainfall and upstream flows. *(Source: Dhaka Tribune, June 2, 2025).*

b. **River Training/Dredging:** Important for managing high sedimentation to maintain river conveyance capacity, though it is a costly and continuous process. Stalled dredging projects can lead to riverbeds silting up, increasing flood risk (Figure 9).

Figure 9: A dredging project on the Surma-Kushiyara river system designed to reduce siltation and mitigate flooding. *(Source: Voice7 News, August 6, 2025).*

c. **Drainage Improvements:** Vital for addressing waterlogging, particularly in flat, low-lying urban areas and haors where natural drainage is slow**,** Figure 10.

Figure 10: Submerged streets in Sylhet city during the 2022 floods, highlighting the challenge of urban waterlogging. *(Source: Photo by Debashish Debu).*

d. **Flood Proofing & Shelters:** Reducing damage by raising structures and providing safe refuge for displaced populations are essential components of community resilience (Figure 11).

Figure 11: A school building serves as a designated flood shelter for the community during an inundation event. *(**Source:** Dhaka Tribune).*

e. **Reservoirs:** Limited direct control within Sylhet; effectiveness depends on upstream (India) management.

Structural measures are often expensive, require long-term maintenance, and importantly, leave a residual flood risk that cannot be eliminated (Minea & Zaharia, 2011; Kryžanowski et al., 2014).

9.2 Non-Structural Measures: These focus on reducing vulnerability and exposure through policy, planning, and behavioural changes, complementing structural approaches and managing residual risk (Kryžanowski et al., 2014).

a. **Flood Forecasting & Warning Systems:** Critical for preparedness, especially concerning flash floods.
b. **Land Use Planning & Zoning**: Regulating development in flood-prone areas.
c. **Watershed Management & Ecosystem-based Adaptation:** Including haor conservation for natural flood storage.
d. **Preparedness, Awareness & Risk Communication:** Educating communities.
e. **Crop Adaptation:** Enhancing agricultural resilience.
f. **Transboundary Cooperation:** Enhance India-Bangladesh water cooperation for Sylhet flood control, which is vital due to the upstream origins of the rivers (Ahmad et al., 2001). However, progress is often hindered by challenges such as political sensitivities, reluctance to share vital real-time data, competing national water use priorities, and the downstream consequences of upstream infrastructure projects. To reduce flood vulnerability in the Sylhet region, it is essential to overcome these governance obstacles and foster genuine, operational collaboration focused on data exchange, joint forecasting, and potentially coordinated emergency responses.

9.3 Integrated Flood Risk Management (IFRM): For the Sylhet region, Integrated Flood Risk Management (IFRM) offers a strategic framework synergizing structural and non-structural measures into a holistic, continuous, and adaptive approach. It aims to minimize overall flood risk (hazard, exposure, vulnerability) and enhance community resilience, moving beyond isolated interventions (Samuels et al., 2010; Saad et al., 2024).

Key tenets of IFRM for Sylhet include:

a. **Basin-Wide & Transboundary Perspective:** Sylhet's complex hydrology demands a basin-wide view, making transboundary cooperation with India (for data sharing, joint forecasting, coordinated upstream management) and internal cross-sectoral coordination critical.
b. **Balanced Portfolio of Measures:** IFRM advocates a strategic mix of essential structural works (maintained embankments, improved drainage, flood shelters) and robust non-structural measures (effective flood forecasting, risk-informed land-use planning, watershed/haor

conservation, community preparedness, crop adaptation), addressing the residual risks inherent in purely structural solutions.

c. **Risk-Informed & Adaptive Approach:** Decisions are driven by thorough assessments of Sylhet's specific flood hazards, exposure, and vulnerabilities. The strategy must be adaptive, allowing adjustments based on new information, lessons learned, and evolving risks, particularly under climate change.
d. **Stakeholder Engagement & Governance:** Effective IFRM requires participatory governance—involving government agencies, local communities, NGOs, and other stakeholders in planning and implementation—to ensure locally relevant, equitable, and sustainable outcomes.
e. **Full Risk Management Cycle:** It encompasses all phases: prevention (avoiding new risks), protection (reducing existing risks), preparedness (anticipating events), emergency response (managing events), and recovery (learning and "building back better").

Implementing IFRM in Sylhet means transitioning from reactive responses to a proactive, comprehensive risk governance system, leveraging existing initiatives within this integrated framework to build long-term resilience against the region's multifaceted flood challenges (Saad et al., 2024).

10.0 Conclusion

The Greater Sylhet region's vulnerability to flooding, rooted in its unique geomorphological features as a haor basin near the Meghalaya Plateau, demands specialized disaster management strategies. This study shows that while seasonal flooding is normal, the increasing number and severity of floods—such as those in 1988, 1998, and the recent ones in 2022 and 2024 — threaten lives and local communities. Factors such as heavy rainfall, water flow from neighboring areas, and climate change exacerbate flooding. The use of quantitative methods, such as GIS-based multi-criteria analysis, has provided a clearer understanding of these risks, revealing significant spatial variations. The impacts of flooding extend beyond immediate loss of life to long-term economic and environmental damage. Thus, there is a need for more integrated flood risk management strategies, combining structural measures like embankments with non-structural approaches. Strengthening flood forecasting, implementing land-use planning based on risk maps, conserving ecosystems, enhancing community preparedness, and fostering transboundary cooperation are essential for building resilience. With a considerable portion of Sylhet identified as highly susceptible to flooding, it is crucial to prioritize interventions in these vulnerable areas to mitigate future risks effectively.

Authors' Declaration

We declare that the submitted manuscript is our original work and has not been published, nor is it under consideration for publication elsewhere. All sources have been properly cited, and the work is free from plagiarism, falsification, and fabrication. Any use of Artificial Intelligence (AI) tools in preparing this manuscript has been transparently disclosed, and full responsibility for the content rests with the authors.

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