Modelling the extreme rainfall and land use land cover change induced flood hazard vulnerability in the north-eastern region of Bangladesh

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Abstract:

Flooding is one of the most common natural disasters throughout the world, leading to the loss of lives and properties. Bangladesh is one of the highly vulnerable countries to climate change-induced flood hazards, due to its location in the Ganges-Brahmaputra-Meghna (GBM) deltaic floodplains with high population exposure. The agro-economically important, haor-dominated Sylhet district in the north-eastern region of Bangladesh has faced devastating floods in recent decades. However, assessing the combined impact of climate change-induced extreme rainfall and anthropogenic forcings-induced land use land cover (LULC) change on the flood-susceptible Sylhet district remains unknown. In this study, the generalized extreme value distribution in rainfall data was adopted to assess the contribution of extreme rainwater to flood hazards. It shows that most of the flood events were enhanced by the excessive rainwater from the upstream. The occurrence of extreme rainfall in the hilly areas of Meghalaya and its rapid runoff over a short period is the main reason for the devastating flood hazards in Sylhet district. The impact of LULC change was assessed using Landsat ETM+ satellite image analysis by adopting remote sensing and Geographic Information System (GIS)-based analytical techniques. The evaluation of the LULC change shows a rapid increase in built-up area during the study period of 2010 to 2022. The remarkable increase was observed in unplanned development of settlement areas, road networks, and construction of infrastructure, most of which have replaced water bodies. The unplanned increase of built-up area and a significant decrease of water bodies highly affect the proper drainage of the rainwater, which enhances the flood hazards. The people's perception analysis shows that the increase of human economic activities and adoption of unplanned development projects are the main reasons for rainfall-induced flood hazards. A significant number of people perceives that the monitoring of extreme rainfall, better management of development projects, and proper drainage are important measures to reduce the combined impact of extreme rainfall and LULC change on increasing flood hazards in the Sylhet district of Bangladesh.

Introduction

The north-eastern region of Bangladesh, especially the Surma river basin area is highly vulnerable to the flood hazards, due to its location in piedmont area of rain-prone Meghalaya Plateau. Agro-economically important northeastern *haor* area of the country has faced devastating floods in recent decades.

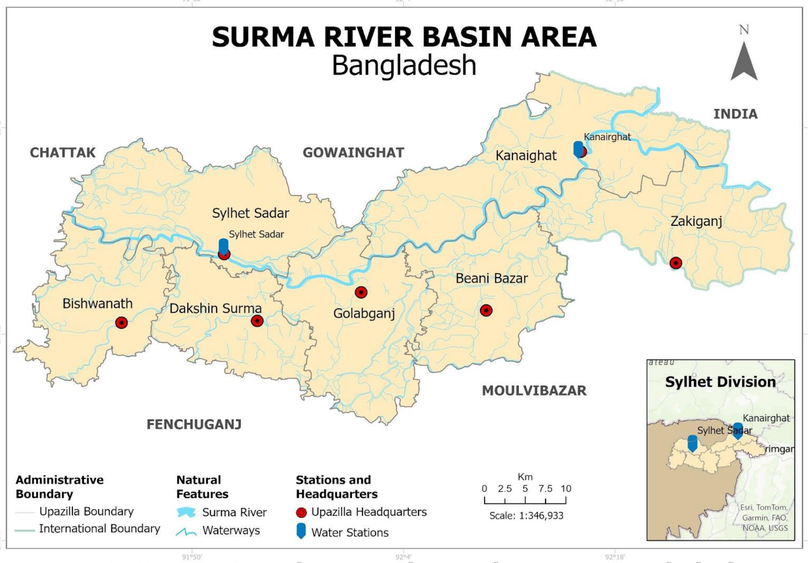


Fig. 1: Surma River basin in the northeastern Bangladesh.

Previous Studies:

✓The faster runoff of heavy rain water from Meghalaya hilly area may influence the flood hazards in this region (Choudhury et al., 2012; Roy, 2013; Akter et al., 2023).

✓A remarkable change in LULC also noticed here during last decade (Islam et al., 2018; Mondal et al., 2022).

➢However, the combined impact of extreme rainfall and anthropogenic forcings induced LULC change to the flood hazards in this area remains unknown.

Objectives

1. Investigate the extreme rainfall events and assess the impacts of LULC change to flood hazards during 2010-2022.
2. Study the combined impact of extreme rainfall and LULC change to the flood hazards in north-eastern Bangladesh.

Data and Methods

Data/Variable		Area	Period	Source
Rainfall	GPM (0.1˚× 0.1˚)	North-eastern Bangladesh (24.30˚-25.45˚N & 90.75˚-92.95˚E)	Daily (2019-2022)	www.gpm.nasa.gov
	TRMM (0.25˚× 0.25˚)		Daily (2010-2019)	www.nasa.gov
LULC	EarthData		2010-2020	www.nasa.gov
Water Level	IWM		Daily (2010-2022)	BWDB
Drainage Density	SRTM DEM 1 ArcSec (30 m)		23-9-2014	www.usgs.gov
Lithology	geo8bg		1997	GSB and USGS

✓Extreme Value Analysis (EVA) with percentiles was used to identify the extreme rainfall event during 2010-2022.

✓Using the threshold of 100 mm/day rainfall, 22 extreme rainfall events were selected

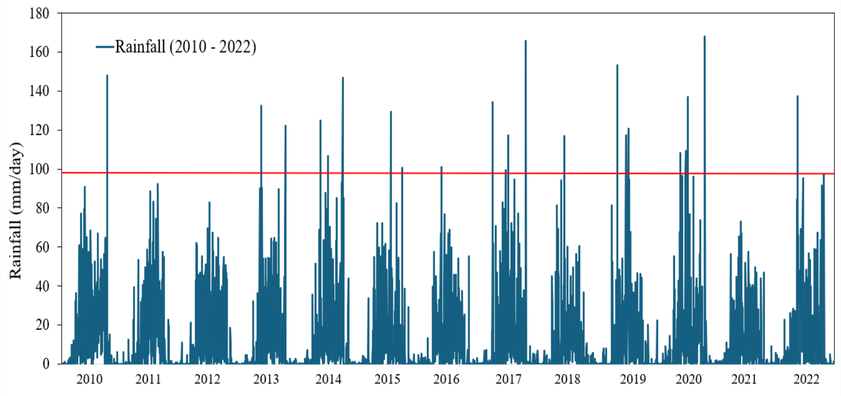


Fig. 2: Daily rainfall over the study area during 2010-2022.

✓GIS was used to analysis the LULC, drainage pattern and lithology in the study area.

Results

Extreme Rainfall Events:

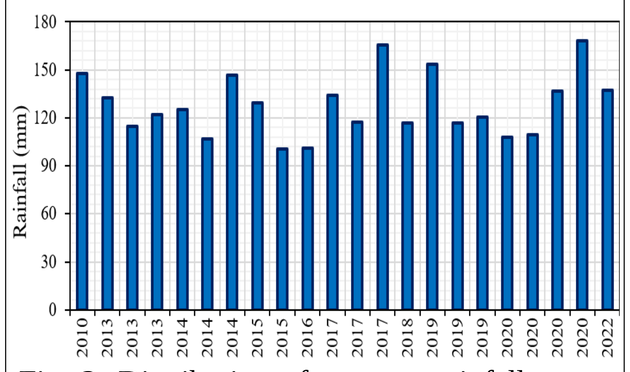


Fig. 3: Distribution of extreme rainfall events during 2010-2022.

✓The frequency of extreme rainfall events are increasing in recent years.

Pattern of Rainfall:

The spatial pattern of rainfall during the selected extreme events:

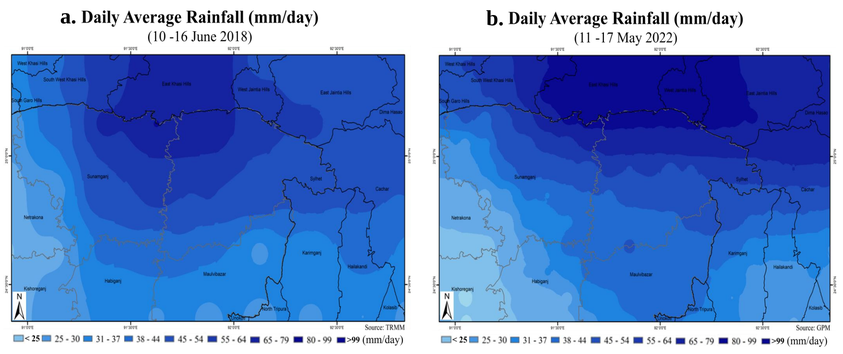


Fig. 4: The seven days average rainfall during the extreme event of 14 June 2018 (a) and 15 May 2022 (b) in the study area.

The study area receives plenty of rainfall during extremes, which may influence the high-water level induced flood hazards.

Water Level:

The water level was investigated to study the flood condition in this region. The following two Stations were considered as representative of the whole study area.

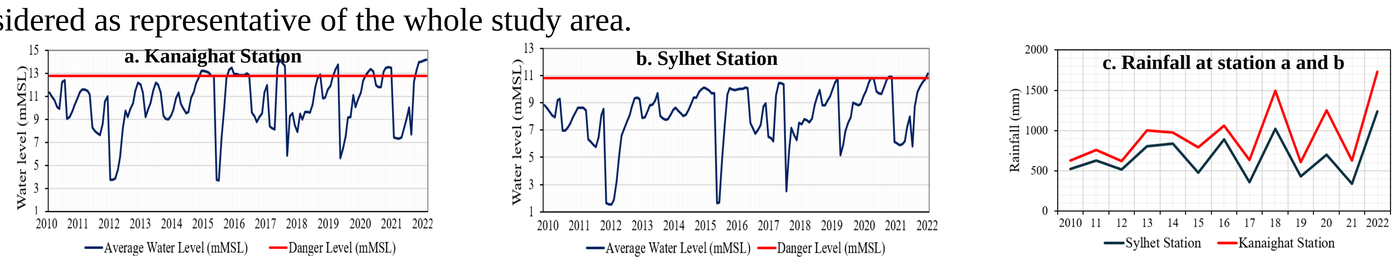
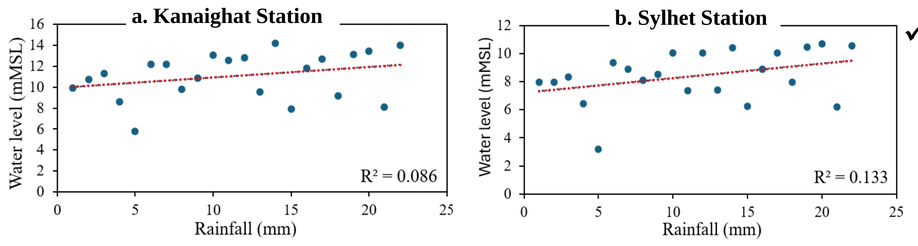


Fig. 5: Daily water level (blue line) for Kanaighat (a) and Sylhet Station (b) during 2010-2022. The red line represents the danger level, corresponding to the flood event. Fig. 5.c represents the rainfall time series of the two

✓For some years the water height reach to danger level, which may enhance by the rainfall.

✓The water height over danger level for many cases at Kanaighat reflets its high rainfall than Sylhet (Fig. 5.C).



✓The significant relationships between the rainfall and water level represents the influence of rainfall to the flood hazards, especially for the many cases of Kanaighat station.

Fig. 6: Scatter plot of water level and rainfall for selected extreme events at Kanaighat (a) and Sylhet (b) station.

Changes in LULC:

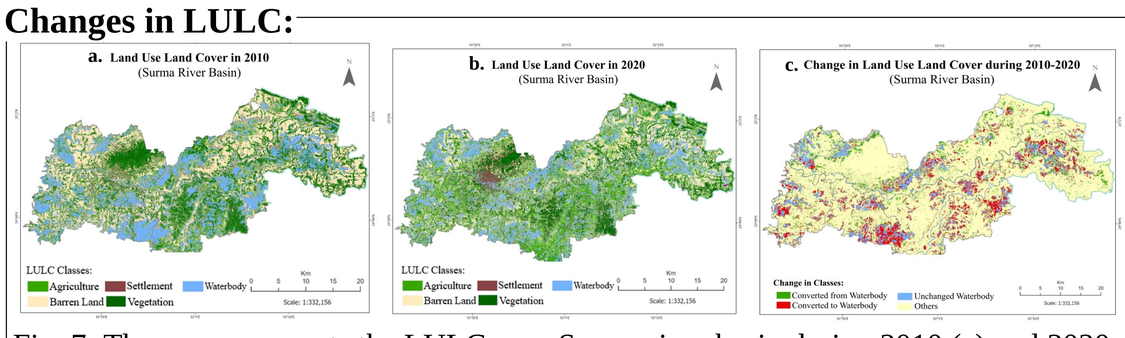


Fig. 7: The map represents the LULC over Surma river basin during 2010 (a) and 2020 (b). Fig. C represents the changes in LULC during 2010-2020.

Table 1:

Classes	Area (km²)	Net Change (Waterbody)
Others	1360.69	−32.21 (km²)
Converted to Waterbody	176.80	
Converted from Waterbody	209.01	
Unchanged Waterbody	171.17	

➢There is a remarkable decrease in waterbody during 2010-2020.

➢The waterbodies act as reservoir of rain water, therefore the reduction in waterbody may enhance the flood.

Discussion

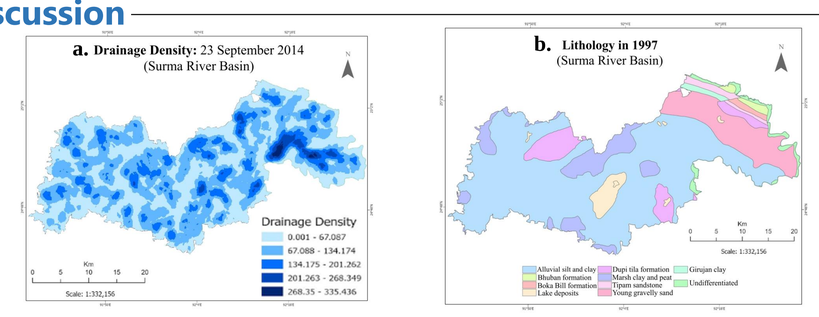


Fig. 8: (a) represents the drainage density of Surma river basin during 23 September 2014. (b) represents the lithology of the Surma River basin during 1997.

➢It assumes that the low drainage with dominance of flood susceptible Girujan clay and recent deposits in lithology also have potential influence to the intensity of flood in this area.

Summary

✓The high-water level during extreme rainfall might enhance the flood hazards in this region.

✓Changes in LULC reduced the area of water reservoirs and affects the drainage of extreme rain water that accelerates the flood hazards.

✓The findings suggest that the proper simulation of extreme rainfall and planned use of land is necessary to control/reduce the impacts of floods hazards in the northeastern region of Bangladesh.