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# CYCLONES' EFFECTS ON THE DANGER AND VULNERABILITY OF RESIDENTIAL STRUCTURES IN THE INDIAN SUNDARBANS

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**ABSTRACT**
About one in five people are affected by storms, which are the second most deadly form of natural disaster (Opdyke et al., 2022). Tropical cyclones are thought to have killed around 1.33 million people over the past 20 years (Doocy et al., 2013). 195 of the 637 cyclones that struck the planet between 1940 and 2010 were deemed severe (Weinkle et al., 2012). Climate change is predicted to greatly increase storm intensity and the impact they have on coastal populations (Hoque et al., 2021; IPCC, 2012). As a result, cyclone effects are anticipated to be more complex than they have been in the past (Knutson et al., 2010; Mendelsohn et al., 2012). The Bay of Bengal is the source of the tropical cyclone, which causes severe harm to the nearby coastal areas and a considerable loss of life and property (Sahoo & Bhaskaran, 2016). Cyclones are round storms that form over warm tropical oceans worldwide and are characterised by low air pressure, high wind speeds, and a lot of precipitation. Cyclones are particularly dangerous and severe for coastal locations because of these powerful winds and water (Ali et al. 2020).
**KEYWORD:** Cyclones, Natural, Metrological Department, Speed, Popoulation, Sundarbans

## INTRODUCTION

By measuring the amount of damage a tropical storm does to the landmass when it makes landfall, its strength is determined (Kumar et al., 2021). Air instabilities (such as depressions and atmospheric waves), moisture in the lower troposphere (which results in latent heat release), and low values of vertical wind shear (VWS) between 200 and 850 hPa pressure levels (12.5 m s-1) are some of the atmospheric factors that affect their development and intensification (van Westen et al., 2023). The Indian Meteorological Department (IMD) divides low pressure systems across the Indian area into seven main kinds based on the maximum sustained wind speed and the number of closed isobars related to the system (Table 1.1).Table 1.1: Major Cyclone Types

| Storm type | Pressure drop hPa | Wind Speed Knots (km/hr) |
|---|---|---|
| Low-pressure area (L) | <1.43 | <17(<32) |
| Depression (D) | 1.43- 3.61 | 17-27 (32–50) |
| Deep Depression (DD) | 3.91–5.40 | 28-33 (51–61) |
| Cyclonic storm | 5.73-10.95 | 34-47 (62-88) |
| Severe Cyclonic Storm (SCS) | 11.43-19.69 | 48-63 (89-117) |
| Very Severe Cyclonic Storm (VSCS) | 20.00-49.00 | 64-119 (118-220) |
| Super Cyclonic Storm (SuCS) | ≥50 | ≥120 (≥221) |

**Source: Indian Meteorological Department (IMD)**

### Storm Surge

When strong atmospheric disturbances cause seawater to rise and fall abnormally, the result is a devastating natural phenomena known as a storm surge. Typhoons, extratropical cyclones, and other extremely damaging weather systems are frequently associated with these disturbances (S. Zhang et al., 2022). One of the most destructive natural hazards in coastal areas with low terrain is storm surges, which are known to cause a large number of fatalities as well as severe damage to assets and infrastructure (A. H. M. R. Sarker et al., 2020). Significant environmental deterioration, climate change, and population growth are predicted to significantly enhance the risk of its recurrence over the next decades (A. Ghosh & Mukhopadhyay, 2017; Sahana & Sajjad, 2019). The hazards to human health, safety, and livelihoods in coastal regions have increased dramatically due to the continuous rise in sea levels and the ensuing occurrence of various dangerous events such cyclones, storm surge floods, and land subsidence (Sahin & Mohamed, 2014). Storm surges have affected around 2.6 million people globally since the turn of the 19th century (Nicholls, 2002). It is important to note that the sea level is rising by 2 mm year in the northern Indian Ocean and by 4 mm annually in the northeastern Bay of Bengal (Unnikrishnan & Shankar, 2007). According to current projections, the rate of sea level rise is expected to reach 0.26 to 0.98 meters by the year 2100 (Bittermann et al., 2013). In addition, high intensity winds have caused storm surges to increase in height (Nicholls et al., 2008).

## Literature Review

Many academic studies have been conducted on coastal catastrophes, including susceptibility and risk from storms and cyclones.

### Cyclone vulnerability

**Hussain, M. S. et al. (2019)** analysed the historical cyclonic hazards and prepared a vulnerability and risk map in their study entitled *"Application of GIS for Cyclone Vulnerability analysis of Bangladesh"*. They used Getis-Ord Gi* spatial statistics for the hotspot analysis to explore pattern of spatial significance of areas among their neighbors. Gi* discovered that some areas are significant risk prone to being spatially influenced by their neighbours.
**Rahman, M. S. et al. (2018)** assessed the nature, intensity, trends, risk hazard, vulnerability and consequences of cyclone and tidal surge disaster in their study *"Exploring Socio-economic Vulnerability of Disadvantaged People in Bangladesh: the Context of Cyclone and Tidal Surge"*. They concluded that the most vulnerable groups to frequent disasters and hazards include persons from all socioeconomic groups, particularly marginalised groups including poor women, girls, children, the elderly, the disabled, and the destitute.

**Hossain, M. N. (2015)** examined the human vulnerability to tropical and storm surges based on physical and socioeconomic factors of vulnerability at household level in his study entitled *"Analysis of human vulnerability to cyclones and storm surges based on influencing physical and socioeconomic factors: Evidences from coastal Bangladesh"*. The findings show that socioeconomic and physical aspects of human vulnerability play an important role in determining how vulnerable a household is to disasters induced by cyclones and storm surges. A household's susceptibility to danger is caused by its inherent vulnerability. The study suggested that reducing vulnerability is the first step in effective and successful catastrophe management.

## Goals

1. To examine the physical susceptibility of the residences to cyclonic threats.
2. To assess the vulnerability of the residences to cyclonic threats
3. To assess the physical susceptibility of the residences to storm surges
4. To assess the physical vulnerability of the residences to storm surges

5. To Propose Management Strategies

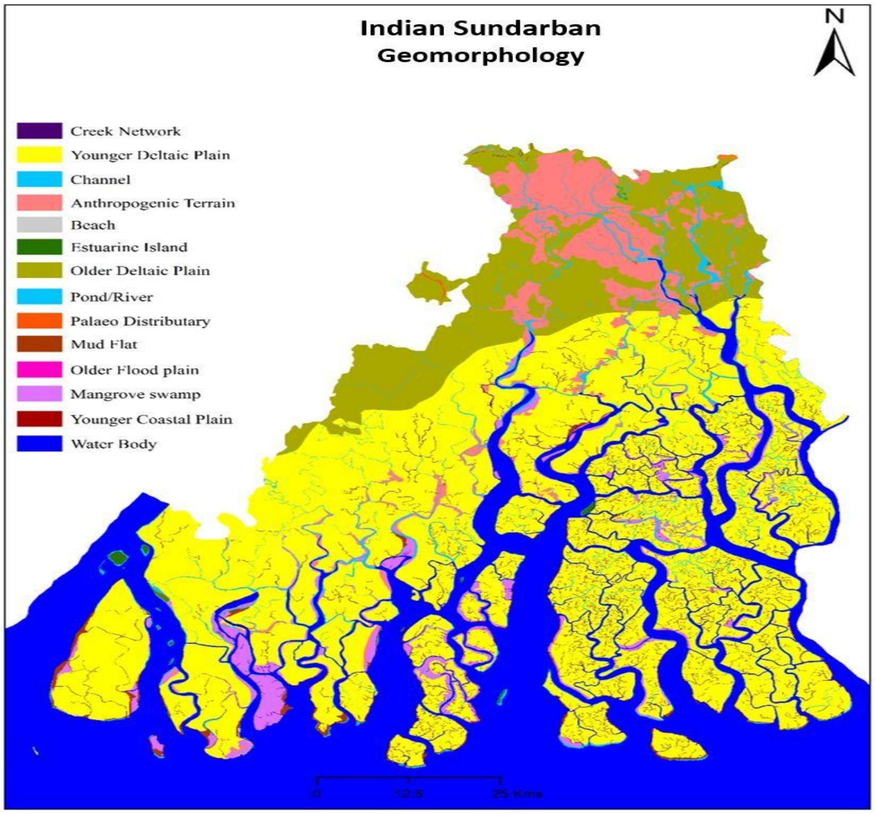


**Fig.-Indian Sundarban: Gemorphology**

**Geomorphology**

The study area encompasses diverse landforms, including creeks, mud flats, salt flats, both younger and older deltaic plains, older flood plains, mangrove swamps, river channels, beaches, and mangrove tracts. The northern section of the researchThe study area encompasses diverse landforms, including creeks, mud flats, salt flats, both younger and older deltaic plains, older flood plains, mangrove swamps, river channels, beaches, and mangrove tracts. The northern section of the research region is mostly characterized by coastal and alluvial plains. The coastal plain, composed of Holocene unconsolidated sediments, exhibits a reasonably autonomous geomorphic character that is minimally affected by particular lithological attributes. This area exemplifies continuous sedimentary processes and land formation activity. The majority of the southern islands are covered by extensive mangrove forests, a characteristic hallmark of the area. These mangrove areas provide a distinctive perspective on ecosystem adaptability to fluctuating and salty conditions. In the southern region of the study area, the topography undergoes a significant transformation. This region is characterized by sandy beaches, sandbars, mudflats, and salt flats. This geomorphic variety illustrates the interaction between sediment deposition and erosional processes, highlighting the landscape's dynamic character.

**Conclusions:**

The Indian Sundarbans is an area characterized by the dynamic interaction between human settlement and the natural environment. This research has methodically analyzed the impact of cyclones and storm surges on residential structures. The Indian Sundarbans are perpetually endangered by storm surge floods, cyclones, saline intrusion, rising sea levels, land subsidence, waterlogging, and coastal erosion. The study primarily indicates that cyclones and storm surges significantly affect land usage and residential structures at a geographical scale. The subsequent overarching findings derived from this analysis are as follows: The research analyzed the effects of five significant cyclones that transpired

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from 2001 to 2021 in the SBR area on the Land Use and Land Cover (LULC) patterns. Four machine learning approaches were employed for this purpose. During the pre-cyclone and post-cyclone stages. Following the evaluation of all four machine learning algorithms, the Radial Basis Function method was chosen for comprehensive investigation. The method was originally utilized to assess the effects of five specific cyclones: Sidr (2007), Aila (2009), Bulbul (2019), Amphan (2020), and Yaas (2021), on land use and land cover changes.

Cyclone Sidr, with a formidable wind speed of 135 mph, resulted in a significant reduction of agricultural land and an expansion of waterlogged regions. Cyclone Aila (2009), with wind speeds reaching 120 km/h, resulted in a considerable decline of thick forest, a notable expansion of waterlogged regions, and a loss in communities. Conversely, Cyclone Bulbul (2019), which had a wind speed of 145 km/h, resulted in a substantial rise in water bodies. The effect intensified significantly with storm Amphan (2020), a super storm featuring an astonishing wind speed of 260 km/h. This cyclone caused a significant reduction in thick forest coverage and a considerable expansion of marsh regions. Finally, Cyclone Yaas (2021), featuring a wind speed of 140 km/h, was distinguished by its storm surge effects, leading to considerable expansions of waterlogged and marsh regions. Following Cyclone Yaas, the vicinity saw considerable flooding, requiring the evacuation of local inhabitants from their residences due to the inundation produced by the storm surge.

The region, due to its geographical position and adverse economic conditions, is susceptible to cyclones and associated risks. The susceptibility and peril associated with residences and the environment is concerning. The AHP analysis indicated that a greater percentage of structures in Namkhana (43.33 percent) and Sagar (46.67 percent) exhibit significant vulnerability, while those in Canning I (46.67 percent) and Jaynagar I (46.67 percent) have the least vulnerability. Higher elevation locations are susceptible to cyclonic dangers. Conversely, areas with greater river density have heightened risks of storm surges, erosion, and water-related hazards, hence amplifying housing vulnerability. Regions exhibiting elevated road density typically correlate with development and enhanced infrastructure, resulting in reduced vulnerability.

The correlation results highlight the importance of income in understanding and mitigating housing risk. This correlation is linked to greater access to resources and services, which may result in superior housing quality, stronger emergency response capabilities, and increased catastrophe resilience. These elements jointly reduce susceptibility. After evaluating cyclone susceptibility, a hazard map was developed using critical indicators such as wind speed, atmospheric pressure, proximity to the shore, cyclone trajectory, Land Use and Land Cover (LULC), and Normalized Difference Vegetation Index (NDVI). The results indicate that the wind pressure and wind velocity of a cyclone diminish with increasing distance from the shore. Consequently, locations near the beach are more susceptible to dangers, as cyclones directly impact coastal towns. The risk index was developed by multiplying vulnerability and hazard. The risk assessment, including vulnerability and hazard evaluations, has produced essential insights into the risk picture for cyclonic occurrences in the Sundarbans. Notably, regions like Sagar, Namkhana, and Gosaba are identified as high-risk locations, necessitating prompt, focused actions to improve structural resilience and community readiness.

The AHP highlights the varying effects of cyclones and storm surges on residential buildings, stressing the necessity for customized resilience methods. The AHP allocates more importance to roofing materials in relation to cyclones, highlighting their essential function in reducing cyclone-associated hazards. Roofs, immediately subjected to intense winds and debris during cyclones, are crucial for preserving structural integrity and ensuring occupant safety. In contrast, regarding storm surges, the AHP attributes increased significance to flooring materials. The Sagar block is more susceptible to cyclones due to its specific topographical characteristics. Namkhana and Patharpratima demonstrate increased susceptibility to storm surges, chiefly because to their reduced elevation. The physical susceptibility of residences to cyclones and storm surges is a significant issue that necessitates comprehensive and interdisciplinary strategies.

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