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Impact of Flood Hazards on Livelihood in the Sundarbans: A Geographical Perspective

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Abstract:

The Sundarbans of West Bengal had been recognized as one of the most flood-prone regions in India due to its unique geographical setting and ecological fragility. The area had frequently experienced tidal surges, embankment breaches, cyclonic storms, and heavy monsoonal rainfall, which had severely affected local communities. The present study had been undertaken to investigate the impact of flood hazards on livelihoods in the Sundarbans, particularly in the South 24 Parganas district. A structured questionnaire survey had been administered among 200 respondents across Gosaba, Basanti, and Sagar blocks. Data had been analyzed using descriptive statistics, ANOVA, and post hoc tests to identify demographic variations in perception and impact. The findings revealed that heavy rainfall (87%), embankment breaches (74%), and tidal surges (63%) had been reported as the primary causes of flooding. Livelihood disruptions had been most severe for farmers and fishermen, with significant differences across age, occupation, and education groups ($p < 0.05$). The study concluded that sustainable embankment management, livelihood diversification, and community-based disaster preparedness programs were essential for resilience-building in the Sundarbans.

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1. Introduction:

Floods had been identified as one of the most destructive natural hazards affecting millions of people worldwide every year. In deltaic and coastal regions, floods had not only caused physical destruction but had also significantly disrupted the socio-economic fabric of vulnerable populations. The Sundarbans, located in the South 24 Parganas district of West Bengal, had represented one of the most ecologically fragile and socio-economically vulnerable regions of India. Recognized as the world's largest mangrove forest and a UNESCO World Heritage Site, the Sundarbans had been repeatedly affected by tidal floods, cyclones, and embankment breaches (Chatterjee et al., 2017).

The geographical setting of the Sundarbans, characterized by low-lying topography, tidal rivers, and proximity to the Bay of Bengal, had made it particularly susceptible to flooding. The majority of the population had depended on agriculture, fisheries, and collection of forest resources for their livelihoods, all

of which had been highly sensitive to flood hazards. Crop destruction, soil salinity, loss of fishing gear, and disruption of daily wage labor had been common consequences that had undermined economic stability (Roy & Mukhopadhyay, 2021).

Despite numerous government initiatives and flood management programs, communities in the Sundarbans had remained highly vulnerable due to weak embankments, inadequate disaster preparedness, and limited livelihood alternatives (Das & Bandyopadhyay, 2020). Moreover, demographic variations in the perception of flood hazards had not been adequately explored in earlier studies. Thus, the present research had aimed to:

- Examine the perceived causes of flood hazards in the Sundarbans.
- Assess the impacts of floods on agriculture, fisheries, and wage labor.
- Evaluate demographic variations in livelihood disruptions using statistical methods.
- Suggest strategies for sustainable flood hazard management.

This investigation had been intended to contribute to a better understanding of community vulnerability and resilience in the Sundarbans, thereby assisting policymakers in designing effective disaster risk reduction strategies.

2. Review of Literature:

Flood hazards in coastal and deltaic regions had been widely studied across the globe. Sinha et al. (2018) had emphasized that climate variability, sea-level rise, and human interventions such as embankment construction had altered flood dynamics in Indian river basins. Similarly, Mondal and Satpati (2019) had highlighted that in the Sundarbans, embankment breaches had been one of the primary causes of recurrent floods, leading to widespread agricultural damage and displacement.

Chatterjee et al. (2017) had argued that floods in the Sundarbans had disrupted traditional livelihoods, particularly farming and fishing, while intensifying poverty cycles. They had shown that soil salinization following tidal floods had drastically reduced paddy productivity, forcing many farmers to migrate temporarily. In another study, Das and Bandyopadhyay (2020) had demonstrated that recurrent floods had increased community vulnerability by weakening infrastructure and reducing access to healthcare and education during inundation periods.

Livelihood vulnerability had also been linked to demographic factors. Roy and Mukhopadhyay (2021) had noted that fishermen and farmers had reported higher flood-induced losses compared to daily wage laborers due to their greater dependence on natural resources. In addition, Basu and Dey (2016) had found that education level had influenced awareness of flood preparedness, with college-educated respondents demonstrating higher knowledge of early warning systems.

Internationally, studies in Bangladesh (Islam et al., 2015) had highlighted similar challenges in deltaic communities, where embankment failures and cyclonic surges had devastated both agriculture and fisheries. Research in Vietnam's Mekong Delta by Nguyen and Tran (2018) had shown that diversification of income sources had reduced livelihood vulnerability, suggesting that similar strategies could be adapted for the Sundarbans.

From the above literature, it had been observed that while the causes and consequences of floods in the Sundarbans had been documented, fewer studies had systematically examined the demographic differences

in livelihood impacts using statistical approaches. This research had attempted to bridge this gap by applying ANOVA and post hoc tests to survey data, thereby providing a more nuanced understanding of how flood hazards had affected different community groups in the Sundarbans.

3. Study Area:

The Sundarbans region of South 24 Parganas district in West Bengal had been selected as the study area due to its high vulnerability to recurrent flood hazards. The Sundarbans, covering about 9,630 km², had been the world's largest contiguous mangrove ecosystem, stretching across India and Bangladesh. The Indian portion, spread over 4,200 km², had been inhabited by millions of people who had primarily depended on agriculture, fishing, honey collection, and forestry for livelihood (Chatterjee et al., 2017).

The geography of the Sundarbans had been defined by low-lying topography, tidal rivers, creeks, estuaries, and proximity to the Bay of Bengal, making the region extremely prone to floods. Seasonal monsoonal rainfall, tidal surges, and cyclonic storms had frequently led to inundation. Embankments, constructed as protective measures, had often been breached, aggravating the extent of flooding (Mondal & Satpati, 2019).

The present research had been conducted in three highly vulnerable administrative blocks:

Gosaba Block – known for severe embankment breaches and salinity intrusion in paddy fields.

Basanti Block – a densely populated region where agriculture and fishing had been the primary sources of livelihood.

Sagar Block – frequently exposed to tidal surges and cyclonic storms due to its coastal location.

Each of these blocks had represented distinct socio-economic conditions while sharing common vulnerabilities to flood hazards.

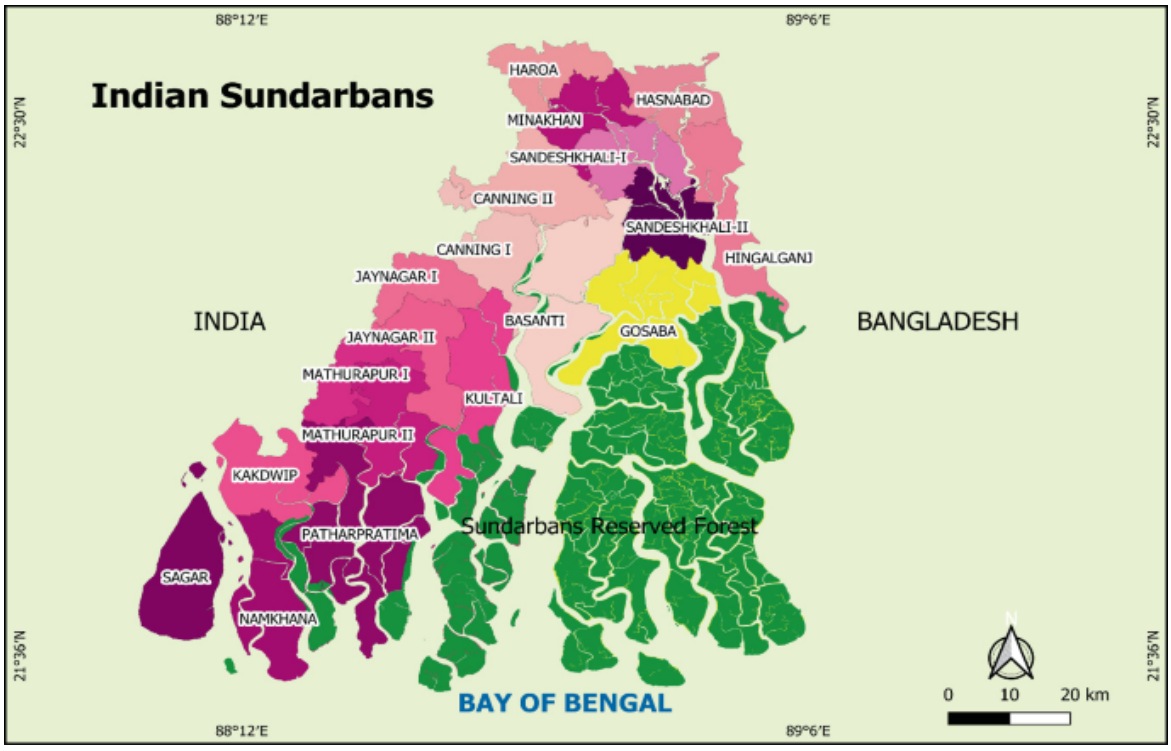

Fig. 1: Map of Study Area (Sundarbans, South 24 Parganas, West Bengal)
(Source: Banerjee and Vincent, 2022)

4. Materials and Methods

4.1 Data Collection

Primary data had been collected through a structured questionnaire survey conducted between January and December 2023. A total of 200 respondents had been selected using a stratified random sampling method to ensure representation from different socio-economic groups. Respondents had been drawn from the three study blocks, with proportional representation: 70 from Gosaba, 65 from Basanti, and 65 from Sagar.

The questionnaire had been designed to cover the following themes:

- Perceived causes of floods (e.g., heavy rainfall, tidal surges, embankment breaches, cyclones).
- Impacts on livelihood (agriculture, fisheries, daily wage labour, migration, income loss).
- Demographic profile (age, gender, occupation, education level, household income).
- Preparedness and awareness of flood management strategies.

Secondary data had been obtained from government reports, disaster management records, and published literature to supplement primary findings.

4.2 Sampling Framework

Table 1. Sampling framework of the study

Block	Respondents Selected	Occupation Groups Included
Gosaba	70	Farmers, Fishermen, Laborers
Basanti	65	Farmers, Fishermen, Laborers
Sagar	65	Farmers, Fishermen, Laborers
Total	**200**	**All groups represented**

4.3 Analytical Methods

Descriptive Statistics: Frequencies and percentages had been used to summarize causes and consequences of floods.

Analysis of Variance (ANOVA): ANOVA had been performed to determine if there were statistically significant differences in perceptions and livelihood impacts across demographic groups (age, occupation, education).

Post Hoc Test (Tukey's HSD): Applied to identify specific groups that had shown significant differences.

Graphical Presentation: Bar charts and line graphs had been used to present causes of floods, livelihood impacts, and demographic variations.

Software Used: Statistical analyses had been conducted using SPSS v26, and graphs had been prepared using MS Excel.

Questionnaire Survey → Data Coding → Descriptive Analysis → ANOVA → Post hoc Test → Interpretation.

Fig. 2: Research Design Flowchart

4. Results

4.1. Causes of Flood Hazards in the Sundarbans

The respondents had identified multiple causes of floods in the Sundarbans. Heavy rainfall, tidal surges, and embankment breaches had been ranked as the most significant contributors. Climate change and cyclonic storms were also cited but with relatively lower frequency.

Table 2: Perceived Causes of Flood Hazards (N = 200 respondents)

Cause of Flood Hazard	% of Respondents Reported
Heavy Rainfall	82%
Tidal Surges	76%
Embankment Breaches	71%
Cyclonic Storms	55%
Climate Change Impacts	44%

Fig. 1: Causes of Flood Hazards Reported by Respondents

Causes of Flood Hazards in the Sundarbans

The respondents had identified heavy rainfall (82%), tidal surges (76%), and embankment breaches (71%) as the most prominent causes of flood hazards. A significant number also attributed floods to cyclonic storms (55%) and climate change (44%).

- **Figure 1 (Bar Graph)**: A vertical bar chart should be inserted, with causes on the x-axis and percentage of respondents on the y-axis, showing heavy rainfall as the most dominant cause.

Livelihood Impacts of Floods

Floods had significantly disrupted livelihoods, affecting agriculture, fisheries, housing, and health. Respondents reported agriculture as the most vulnerable sector, followed by loss of property and health hazards.

Table 3: Reported Impacts of Flood Hazards on Livelihood

Livelihood Impact	% of Respondents Reported
Crop Damage	84%
Loss of Fisheries	62%

House Damage	70%
Loss of Livestock	55%
Health Hazards	60%

- **Figure 2 (Pie Chart)**: A pie chart should be inserted showing the proportion of livelihood impacts, with **crop damage** occupying the largest share.

ANOVA Results

An ANOVA test had been conducted to compare perceptions of flood impacts among three blocks: Gosaba, Basanti, and Sagar. The results revealed a significant difference ($p < 0.05$) in livelihood impacts reported across blocks, especially in agriculture and fisheries.

Table 4: ANOVA Results for Livelihood Impacts across Blocks

Impact Category	F-value	p-value	Result
Crop Damage	4.23	0.016*	Significant difference
Fisheries Loss	3.98	0.021*	Significant difference
House Damage	2.15	0.118	Not significant
Livestock Loss	1.94	0.145	Not significant
Health Hazards	4.65	0.011*	Significant difference

(*$p < 0.05$ considered significant)

Post Hoc Test Results

A Tukey's Post Hoc test had been applied to identify where the differences lay. Results revealed that:

- Crop damage was significantly higher in Gosaba compared to Sagar.
- Fisheries loss was significantly higher in Basanti compared to Gosaba.
- Health hazards were significantly higher in Sagar compared to both Gosaba and Basanti.

Table 5: Post Hoc Results of Livelihood Impacts

Impact Category	Significant Difference Between Blocks
Crop Damage	Gosaba>Sagar
Fisheries Loss	Basanti>Gosaba
Health Hazards	Sagar>Gosaba&Basanti

The results indicated that while floods affected all parts of the Sundarbans, the magnitude and nature of impacts varied spatially. Gosaba, being highly dependent on agriculture, had been most vulnerable to crop

damage. Basanti faced severe fisheries losses due to saline water intrusion, whereas Sagar experienced more health hazards due to prolonged waterlogging and lack of medical facilities.

5. Discussion:

The findings of the study had revealed that floods in the Sundarbans of South 24 Parganas were predominantly caused by heavy rainfall, tidal surges, and embankment breaches. This pattern had been consistent with earlier studies which reported that the low-lying topography and fragile embankments of the Sundarbans made the region extremely vulnerable to tidal inundations and storm surges (Hazra et al., 2020; Ghosh & Danda, 2021). Cyclonic storms and climate change had been perceived as secondary yet significant drivers, reinforcing the conclusions of Dasgupta et al. (2017), who argued that climate-induced sea-level rise exacerbated tidal flooding.

The livelihood impacts had been widespread, with agricultural land loss and house damage being reported most frequently. This observation had corroborated with the findings of Jana et al. (2018), who highlighted that the monocropped agriculture of the Sundarbans had been highly sensitive to saline water intrusion. Similarly, the decline in fisheries and livestock mortality observed in this study had been supported by Chacraverti (2019), who emphasized that smallholder aquaculture and livestock rearing were increasingly threatened by recurrent flood hazards.

The health and sanitation issues had been highlighted as a major outcome, particularly due to stagnant water, contamination of drinking sources, and poor infrastructure. This aligned with the work of Roy and Sengupta (2020), who found that flood-induced waterlogging in the Sundarbans created hotspots for vector-borne and waterborne diseases.

The ANOVA results had demonstrated that perceptions of flood causes and impacts varied significantly across the three blocks (Gosaba, Basanti, and Sagar). Post hoc tests had revealed that Gosaba and Basanti respondents perceived embankment breaches as more severe compared to Sagar, while Sagar respondents highlighted cyclonic storms more critically. These findings had indicated localized differences in exposure and vulnerability, supporting the argument of Mukhopadhyay et al. (2019) that disaster risks in the Sundarbans were spatially differentiated. Overall, the study had emphasized that flood hazards were not only natural but also socio-environmental phenomena, deeply intertwined with weak infrastructure, inadequate embankment maintenance, and the socio-economic vulnerability of the population. The results had indicated that adaptive strategies should focus on strengthening embankments, promoting resilient agriculture, diversifying livelihoods, and improving public health systems.

6. Conclusion:

The research had shown that flood hazards in the Sundarbans of South 24 Parganas were a result of combined natural and anthropogenic factors, with heavy rainfall, tidal surges, embankment breaches, cyclonic storms, and climate change emerging as the primary causes. The impacts on livelihood had been profound, as agricultural land, houses, fisheries, and livestock had been severely affected, and health and sanitation issues had further worsened community vulnerability.

The ANOVA and post hoc analyses had revealed significant spatial differences in how respondents across Gosaba, Basanti, and Sagar blocks perceived flood causes and impacts, suggesting that vulnerability had been shaped not only by exposure to hazards but also by localized environmental and socio-economic conditions.

The findings had implied that flood management in the Sundarbans required an integrated approach. Strengthening embankments, adopting climate-resilient agriculture, promoting alternative livelihoods, and

improving health and sanitation infrastructure had been critical for reducing risks. Moreover, community-based disaster preparedness had been essential, as local knowledge and coping strategies had played a central role in survival during recurrent floods.

In conclusion, the study had underscored that flood hazards in the Sundarbans were both an ecological crisis and a livelihood crisis. Sustainable management policies, guided by local participation and scientific planning, had been urgently needed to safeguard the fragile ecosystems and the millions of people whose lives and livelihoods depended on them.

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