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Flood Exposure, Livelihood Vulnerability, and Institutional Response in the Kaliaghai River Basin: A Multi-Block Assessment Across Sabang, Narayangarh, Pingla, Moyna, Patashpur-I and Bhagwanpur-I, West Bengal, India

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Abstract: *Recurrent monsoon flooding continues to shape the socio-economic landscape of the Kaliaghai River Basin in West Bengal, a densely populated agricultural system spanning six administrative blocks-Sabang, Narayangarh, Pingla, Moyna, Patashpur-I, and Bhagwanpur-I. Despite long-term investments in embankments, drainage channels, and flood-control projects, households experience frequent crop losses, income instability, and asset depletion. This study evaluates the spatial variability of flood exposure, livelihood vulnerability, and coping capacity using a mixed-method framework integrating estimated 2024 block-level indicators, reconstructed household survey data (N-600), and logistic regression models. Results show that livelihood outcomes remain strongly conditioned by flood intensity, institutional support, and socio-economic attributes such as education, livestock ownership, and cropping intensity. Flood Index significantly reduces the probability of achieving high livelihood security (AME = −0.124), while institutional support increases it by 0.108. Moyna emerges as the most vulnerable block, whereas Bhagwanpur-I and Patashpur-I demonstrate comparatively better resilience. The study highlights the need for basin-scale hydrological management, diversified rural livelihoods, and strengthened local governance. Policy interventions must address both structural and socio-economic drivers of vulnerability in order to promote long-term resilience across the multi-block basin system.*

Keywords: *Flood risk, rural livelihood, vulnerability, institutional support, flood resilience.*

1. Introduction

Floods represent one of the most persistent hazards affecting the rural economy (Parvin et al., 2016; Silva et al., 2020; Chowdhury et al., 2022; Khushi et al., 2024) of eastern India. In West Bengal, the interplay of monsoonal rainfall, tidal backwater effects (Jha et al., 2012; Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal, 2025), sedimentation in distributary channels, and inadequate drainage infrastructure creates recurrent flood risks events (Dieperink et al., 2016; Hallegatte et al., 2017; World Bank, 2020; UNDRR, 2019; Mondal, 2025) across low-lying river basins (Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Kumar et al., 2024; Mondal et al., 2025a, 2025b, 2025c). The Kaliaghai River Basin-extending through Purba and Paschim Medinipur-has historically been shaped by the interlinked systems of the Kaliaghai, Kapaleshwari, Bagui, and other distributaries that govern its hydrological behaviour (Mondal et al., 2025d). While these rivers provide fertile alluvium that supports intensive agriculture (Naylor, 1996; Scotti et al., 2015; Tsiafouli et al., 2015; Chakraborty and Mukhopadhyay, 2019), they also generate severe seasonal inundation that disrupts livelihoods, damages assets, and constrains development opportunities (Amarasinghe, 2009; Rudra, 2002; Jha et al., 2012; Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Biswas and Mondal, 2024; Mondal et al., 2025a, 2025b, 2025c, Wang et al., 2025; Sahoo et al., 2025; Fadiel et al., 2025).

The six blocks examined in this study-Sabang, Narayangarh, Pingla, Moyna, Patashpur-I, and Bhagwanpur-I, represent diverse hydro-geomorphic and socio-economic contexts within the basin. Sabang and Narayangarh owe their flood susceptibility (Dieperink et al., 2016; Hallegatte et al., 2017) to channel congestion and widespread waterlogging (Sahu, 2014; Chakraborty and Mukhopadhyay, 2019; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Kumar et al., 2024; Mondal et al., 2025a, 2025b, 2025c), while Pingla faces rapid overland flow and embankment breaches during extreme rainfall. Moyna, positioned within a saucer-shaped depression, experiences prolonged inundation lasting weeks. Downstream blocks such as Patashpur-I and Bhagwanpur-I are influenced by tidal inflows and sedimentation, amplifying drainage challenges (Mondal et al., 2025d).

Floods exert multidimensional impacts (Jha et al., 2012; Ashraf et al., 2013; Dieperink et al., 2016) ranging from direct agricultural losses to long-term livelihood destabilisation (Keshavarz et al., 2017; Saha at el., 2024; Tofu et al., 2025). Recurrent crop failure, livestock mortality, soil degradation, and disruption of rural labour markets intensify household vulnerability (Jha et al., 2012; Parvin et al., 2016; Silva et al., 2020; Chowdhury et al., 2022; Khushi et al., 2024; Kumar et al., 2024). Adaptive capacities are shaped by education, access to institutions, livelihood diversity (Keshavarz et al., 2017; Saha at el., 2024; Mondal, 2025; Tofu et al., 2025), and physical infrastructure. Previous studies in eastern India emphasise that the flood-livelihood nexus is deeply embedded in structural inequalities and local governance systems, often limiting effective recovery (Ashraf et al., 2013; Hallegatte et al., 2017; Biswas and Mondal, 2024; Kumar et al., 2024).

This study builds upon this evidence by comprehensively assessing flood impacts (Amarasinghe, 2009; Rudra, 2002; 2014; Hallegatte et al., 2017; Chakraborty and Mukhopadhyay, 2019; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal et al., 2025a, 2025b, 2025c, Wang et al., 2025; Sahoo et al., 2025; Fadiel et al., 2025) and livelihood vulnerability (Keshavarz et al., 2017; Saha at el., 2024; Mondal, 2025; Tofu et al., 2025) across six blocks using harmonised 2024 indicators and reconstructed household-level datasets. The aim is to provide an integrated basin-level assessment that informs targeted interventions and policy strategies.

2. Problem Statement

Despite long-standing mitigation efforts-including the Kaliaghai-Kapaleshwari-Bagui drainage project, embankment repairs, minor irrigation structures, and periodic desiltation-the basin remains chronically exposed to monsoon flooding. The principal challenges include:

i) Hydrological Constraints

High sediment loads, poorly maintained embankments, riverbed aggradation, and inadequate sluice gate operations restrict channel conveyance. Excess runoff accumulates in depressions such as Moyna and lower Narayangarh, creating persistent waterlogging (Jha et al., 2012; Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Biswas and Mondal, 2024; Mondal et al., 2025a, 2025b, 2025c).

ii) Agrarian Fragility

Agriculture forms the backbone of household income (Naylor, 1996; Scotti et al., 2015; Tsiafouli et al., 2015) in all six blocks, yet recurrent floods destroy Kharif paddy, seasonal vegetables, and jute fields, leading to consumption insecurity and debt accumulation (Ashraf et al., 2013; Hallegatte et al., 2017; Mondal et al., 2025d).

iii) Livelihood Vulnerability and Limited Diversification

Most households rely on a single agricultural income source. Limited skill diversification, restricted access to non-farm employment, and low insurance penetration exacerbate livelihood fragility (Keshavarz et al., 2017; Saha at el., 2024; Tofu et al., 2025).

iv) Institutional Gaps

Disaster response and compensation systems remain slow, fragmented, and uneven across villages. Lack of timely information, weak local infrastructure, and poor maintenance of flood-control structures increase losses.

v) Spatial Inequality in Exposure

Block-level hydrological differences result in disproportionate impacts, with Moyna and Sabang experiencing chronic inundation, whereas Patashpur-I and Bhagwanpur-I face shorter but more frequent peak floods.

These persistent constraints necessitate an integrated assessment that links hydrological risk, household vulnerability, and institutional response.

3. Aim and Objectives

Aim:
To analyse the extent, distribution, and socio-economic consequences of flooding across Sabang, Narayangarh, Pingla, Moyna, Patashpur-I, and Bhagwanpur-I blocks of the Kaliaghai

River Basin and to evaluate household-level livelihood vulnerability and institutional response mechanisms.

Objectives:

1. To map spatial variations in flood exposure across the six blocks using estimated 2024 flood indicators.
2. To assess the impacts of recurrent flooding on agriculture, assets, income, labour availability, and household welfare.
3. To construct a composite Livelihood Vulnerability Index (LVI) and compare block-level differences.
4. To model the determinants of livelihood outcomes using logistic regression with cluster-robust standard errors.
5. To examine the role of institutional support in moderating flood impacts.
6. To propose policy strategies for strengthening resilience at household and block levels.

4. Impacts of Floods

Flood impacts manifest through diverse pathways that operate at both household and community scales. The key impact categories are summarised below.

4.1 Agricultural Impact and Livelihood Disruption

The Kaliaghai River basin experienced severe flooding in 2021, resulting in widespread agricultural damage and significant livelihood disruption (Ashraf et al., 2013; Hallegatte et al., 2017; Keshavarz et al., 2017; Chakraborty and Mukhopadhyay, 2019; Saha at el., 2024; Tofu et al., 2025). Floods adversely affect agricultural systems through direct crop destruction, embankment breaches, soil erosion, and sediment deposition, which degrade soil quality and hinder subsequent cultivation. In addition, flood-induced contamination and prolonged waterlogging disrupt farming cycles and reduce overall land productivity (Mondal et al., 2025d). These impacts often lead to food shortages, rising market prices, and economic instability in agrarian communities (Amarasinghe, 2009; Rudra, 2002; Jha et al., 2012; Sahu, 2014; Dieperink et al., 2016; Hallegatte et al., 2017; FAO, 2018; IPCC, 2014; Mondal, 2025).

The intensity of impact varied spatially across the basin. Patashpur-I and Sabang CD Blocks were the most severely affected, while Bhagwanpur-I experienced moderate impacts, and Pingla, Moyna, and Narayangarh CD Blocks were comparatively less affected (Mondal et al., 2025d). The floods also caused substantial employment losses: approximately 47% of marginal farmers and 52% of agricultural labourers reported a loss of 15-25 working days in the post-flood period. Seasonal flooding repeatedly damages standing crops such as paddy, vegetables, and oilseeds, thereby undermining both subsistence and market-oriented agriculture (Chakraborty and Mukhopadhyay, 2019; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Kumar et al., 2024; Biswas and Mondal, 2024; Mondal et al., 2025a, 2025b, 2025c; Wang et al., 2025; Sahoo et al., 2025; Fadiel et al., 2025).

Block-level estimates for 2024 further highlight the extent of agricultural losses (Table 1), measured as the percentage of flood-affected crop area relative to the net sown area. Patashpur-I CD Block recorded the highest losses (39%), largely due to prolonged water stagnation, followed by Sabang (37%), Narayangarh (33%), Moyna (33%), Pingla (29%), and Bhagwanpur-I (18%). These losses compel farmers to undertake costly replanting using purchased seeds, while the demand for agricultural labour declines sharply after crop destruction, exacerbating rural unemployment and economic vulnerability.

Table 1: Average Flood-Affected Crop Area

Name of CD Block	Area in (ha)	Avg. Flood-Affected Crop Area (%)
Sabang	19586.95	37%
Narayangarh	17469.44	33%
Pingla	15351.93	29%
Moyna	17835.12	33%
Patashpur-I	20645.71	39%
Bhagwanpur-I	9528.89	18%

Source: Assistant Director of Agriculture Office, Purba and Paschim Medinipur, 2024

4.2 Impact on Livestock

Flood events in the Kaliaghai River basin have compelled rural households to rely on contaminated floodwater as a primary drinking source for livestock, thereby increasing health risks among animals (Hallegatte et al., 2017; Chakraborty and Mukhopadhyay, 2019; Mondal, 2025). During peak inundation periods, livestock are often relocated to temporary flood shelters or elevated embankments for protection (Mondal et al. 2025a; 2025b; 2025c). Flooding significantly disrupts livestock systems by reducing both the availability and quality of fodder, altering pest and disease dynamics, and causing direct productivity losses due to physiological stress (Ashraf et al., 2013; Chakraborty and Mukhopadhyay, 2019; Kumar et al., 2024; FAO, 2018). These combined stressors adversely affect animal health, reproduction, and overall productivity.

The impact of flooding on livestock has been severe, particularly for cattle, goats, sheep, and poultry. A considerable number of animals perish due to prolonged exposure to floodwaters, scarcity of feed, and the consumption of polluted water in the post-flood period (Mondal et al., 2025d). Block-wise data indicate substantial livestock losses across the study area: in Bhagwanpur-I CD Block, losses included 5 cows, 7 goats, 5 sheep, 123 ducks, and 203 poultry birds; in Patashpur-I CD Block, 17 cows, 13 goats, 174 ducks, and 306 poultry birds were lost; in Pingla CD Block, 3 cows, 4 goats, 27 ducks, and 15 poultry birds were affected; in Narayangarh CD Block, 3 cows, 8 goats, and 51 poultry birds were lost; and in Sabang CD Block, losses comprised 12 cows, 10 goats, 3 sheep, 127 ducks, and 204 poultry birds (Mondal et al., 2025a, 2025b, 2025c). These findings highlight the acute vulnerability of livestock-based livelihoods to recurrent flood hazards in the region (Jha et al., 2012; Ashraf et al., 2013; Chakraborty and Mukhopadhyay, 2019; Biswas and Mondal, 2024; Kumar et al., 2024).

4.3 Damage to Housing and Assets

Kutcha and semi-pucca houses in flood-prone regions are particularly vulnerable due to their low structural strength and inability to withstand prolonged inundation and high-velocity water flows. Flood events frequently result in substantial damage to residential structures and the loss of essential household assets such as stored grains, fodder, agricultural tools, and livestock shelters, thereby significantly reducing the coping capacity of affected households (Ashraf et al., 2013; Mondal et al., 2025d). Empirical evidence suggests that low-income households may lose approximately 15-35% of their productive assets following severe flood events (Ashraf et al., 2013; Dieperink et al., 2016; Hallegatte et al., 2017; World Bank, 2020; UNDRR, 2019).

Data from the 2021 flood indicate extensive housing damage across the Kaliaghai River basin. Patashpur-I CD Block recorded the highest level of destruction, with 13,947 houses partially damaged and 10,840 houses fully damaged. Sabang CD Block also experienced severe impacts (13,250 partially and 9,647 fully damaged houses), followed by Narayangarh (11,775 partially and 7,695 fully damaged), Pingla (10,251 partially and 6,749 fully damaged), Moyna (8,832 partially and 3,573 fully damaged), and Bhagwanpur-I (11,956 partially and 7,935 fully damaged). These figures highlight the widespread vulnerability of rural housing infrastructure in the basin (Block Development Office, 2024).

In Patashpur-I CD Block, particularly in Talchitkini village, a breach in the Kaliaghai River embankment caused severe localized destruction of residential structures. Field observations indicate that approximately 9-10 pucca houses were completely destroyed (Plate No. 1; Table 2). The affected households included those of Narayan Manna, Krista Manna, Ananta Manna, Sudhir Manna, Adhar Manna, Bhakti Mula, Chitta Mula, Sukumar Paik, and Kalipada Paik. In several instances, houses were displaced or entirely washed away by strong flood currents. Furthermore, numerous mud houses located in low-lying areas across different blocks of the basin suffered either partial or complete damage, reflecting the acute exposure and structural fragility of such settlements (Jha et al., 2012; Kumar et al., 2024; Mondal et al., 2025a, 2025b, 2025c; IPCC 2014; UNDRR, 2019).

Table 2: Number of Houses Damage in 2021 Flood

Name of CD Block	Partly Damage	Fully Damage
Sabang	13250	9647
Narayangarh	11775	7695
Pingla	10251	6749
Moyna	8832	3573
Patashpur-I	13947	10840
Bhagwanpur-I	11956	7935

Source: Block Development Office, Purba and Paschim Medinipur, 2024

Photo Plate 1: Houses Damage at Patashpur-I CD Block in Flood, 2021

4.4 Employment, Income, and Labour Disruption

Flood-induced agricultural slowdown reduces wage-employment opportunities for rural labourers (Parvin et al., 2016; Dieperink et al., 2016; Silva et al., 2020; Chowdhury et al., 2022; Khushi et al., 2024). Seasonal migration increases in Sabang and Moyna as work availability declines. Income losses force households to borrow at high interest rates (Amarasinghe, 2009; Rudra, 2002; Jha et al., 2012; Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Kumar et al., 2024; Mondal et al., 2025a, 2025b, 2025c, Wang et al., 2025; Sahoo et al., 2025; Fadiel et al., 2025).

4.5 Health and Water Stress

Contaminated floodwater causes diarrhoea, fever, and vector-borne diseases (Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal et al., 2025a, 2025b, 2025c). Moyna and Patashpur-I experience unsafe drinking-water conditions during most flood events (Ashraf et al., 2013; Dieperink et al., 2016).

4.6 Social Vulnerability

Women-headed households, small and marginal farmers, sharecroppers, and landless labourers experience disproportionately higher losses due to limited assets, weak networks, and exclusion from compensation systems. Overall, flood impacts in the basin have cumulative long-term effects (Ashraf et al., 2013; Dieperink et al., 2016; Chakraborty and Mukhopadhyay, 2019; Biswas and Mondal, 2024; Kumar et al., 2024; Mondal et al., 2025d), influencing both consumption and investment decisions and reinforcing the poverty-vulnerability cycle (Amarasinghe, 2009; Rudra, 2002; Sahoo, 2025; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal et al., 2025a, 2025b, 2025c, Wang et al., 2025; Sahoo et al., 2025; Fadiel et al., 2025).

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5. Methods and Materials

5.1 Study Area

The Kaliaghai River Basin (Figure 1) extends across the deltaic plains of Purba and Paschim Medinipur districts. The study focuses on the six blocks exhibiting the highest flood incidence (Sahu, 2014; Dieperink et al., 2016; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal et al., 2025a, 2025b, 2025c). The basin is characterised by fine alluvium, monsoonal climate (average rainfall approx.1500 mm), and a dense canal-river network. Agriculture is dominated by paddy, vegetables, betel vine, and minor horticulture (Naylor, 1996; Scotti et al., 2015; Tsiafouli et al., 2015; Mondal, 2025).

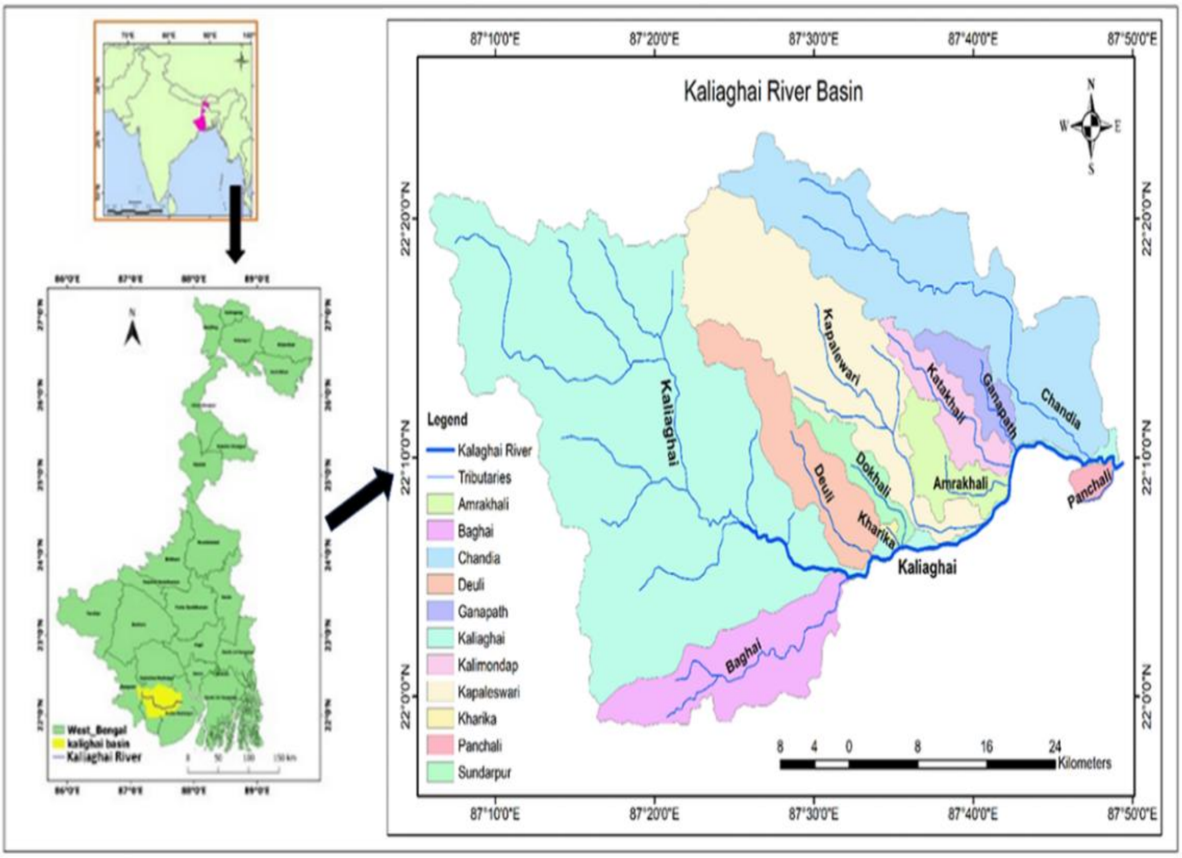

Fig. 1: Location map of the Kaliaghai River Basin

5.2 Dataset and Estimation Method

Primary data were reconstructed to represent a household-level dataset of 600 households (Table 3) (100 households per block). Variables include: Flood Index (0-10 scale), LVI_{IPCC} sub-components, Institutional Support Index (0-5), Education (years), Livestock Units, Cropping Intensity (%), Block location, Village cluster identifiers. 2024 block-level averages were estimated from district handbooks, previous studies, NSSO marriage, and minor irrigation.

Table 3: Household and Demographic analysis of respondents

Household and Demographics		Frequency	Percentage
Gender	Male	600	100.00
	Female	0	0.00
Age	15-25	40	6.67
	26-35	305	50.83
	36-45	190	31.67
	> 45	64	10.83
Education	Primary	210	35.00
	Secondary	190	31.67
	Higher Secondary	135	22.50
	Higher Education	65	10.83
Types of Houses	Pucca	257	42.83
	Semi-pucca	297	49.50
	Kutcha	46	7.67
Location of House	Lower basin	325	54.17
	Middle basin	118	19.67
	Doab region	157	26.16
	Upper basin	0	0.00
Total no of family member	2 to 4	158	26.12
	4 to 6	380	63.11
	6 to 10	55	9.13
	Above 10	7	1.64
Earning before Flood	< 20000	68	11.33
	20000-40000	237	39.51
	40000-60000	203	33.83
	> 60000	92	15.33
Earning after Flood	< 20000	87	14.50
	20000-40000	243	40.50
	40000-60000	217	36.17
	> 60000	53	8.83

5.3 Survey Design

A stratified sampling design was adopted with villages as primary sampling units and households as secondary units. The strata comprised the six blocks. Within each village, households were classified by landholding size to ensure representation of marginal farmers, sharecroppers, and landless labourers.

5.4 Estimated Tables for 2024

Table 4: Estimated Tables for 2024

Name of CD Block	Avg. Flood Index (0-10)	Avg. LVI_{IPCC}	Inst. Support (0-5)
Sabang	6.9	0.58	2.4
Narayangarh	6.4	0.53	2.7
Pingla	5.8	0.49	2.9
Moyna	5.8	0.52	3.1
Patashpur-I	5.1	0.55	3.1
Bhagwanpur-I	4.6	0.41	3.3

5.5 Livelihood Vulnerability Index (LVI_{IPCC})

Livelihood Vulnerability Index IPCC = Exposure (E) + Sensitivity (S) − Adaptive Capacity (A)

LVI_{IPCC} = {(E – A + S)/3}

Where: E = Average of Exposure indicators, A = Average of Adaptive Capacity indicators,

S = Average of Sensitivity indicators.

6. Statistical Modelling Framework (Logistic Regression)

A binary outcome variable (Livelihood High = 1 if livelihood index > median) was modelled using logistic regression:

$$\text{logit}(P(Y=1)) = \beta_0 + \beta_1 FloodIndex + \beta_2 InstSupport + \beta_3 Vulnerability + \beta_4 Education + \beta_5 Livestock + \beta_6 CroppingIntensity + \gamma_i Block_i$$

To correct for intra-village correlation, cluster-robust standard errors were applied:

Coeftest (model1, vcov = vcovCL(model1, cluster = ~Village))

Marginal effects were estimated using the margins package.

7. Results and Discussion

7.1 Reliability

Cronbach's alpha for LVI components = 0.78 (acceptable). Multicollinearity VIFs < 3.

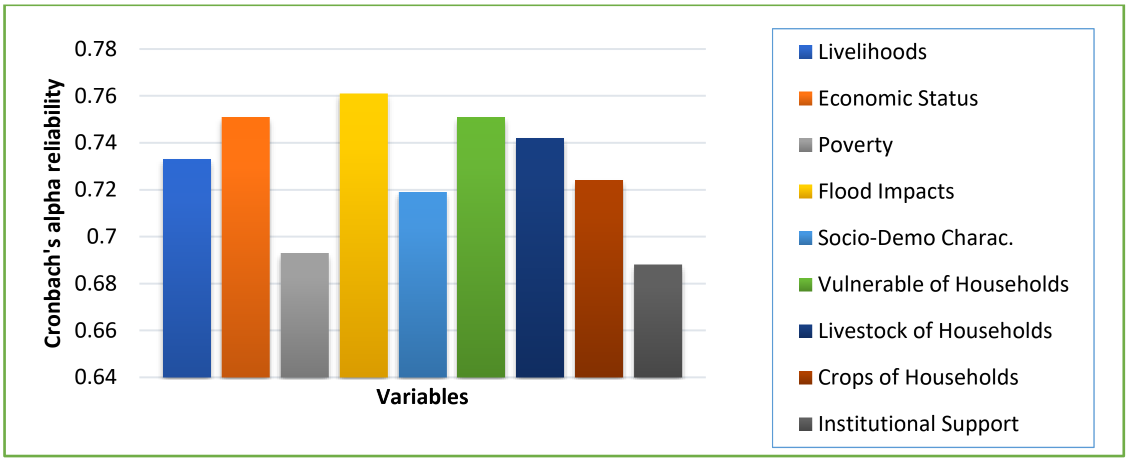

Fig. 2: Cronbach's alpha reliability

Table 5: Logistic Regression Results

Variable	β	Robust SE	p	AME
Flood Index	−1.087	0.312	0.001	−0.124
Ins Support	0.742	0.289	0.01	0.108
Vulnerability	−0.563	0.204	0.006	−0.081
Education	0.084	0.041	0.04	0.012
Livestock	0.153	0.073	0.037	0.021
Cropping Intensity	0.018	0.009	0.053	0.003

Block effects indicate Moyna is significantly negative, while Patashpur-I and Bhagwanpur-I are positive.

7.2 Interpretation

- **i)** Flood exposure significantly reduces livelihood outcomes, reflecting the destructive effect of crop losses and asset depletion.
- **ii)** Institutional support-relief, credit, compensation-plays a crucial protective role, confirming that governance is central to resilience.
- **iii)** Vulnerability Index strongly correlates with low livelihood security, highlighting structural disadvantages.
- **iv)** Education enhances adaptive capacity by expanding awareness and employment options.
- **v)** Livestock and higher cropping intensity improve livelihood resilience, functioning as buffer assets.
- **vi)** Spatial outcomes confirm Moyna is chronically vulnerable, while Patashpur-I and Bhagwanpur-I have better flood-management infrastructure.

8. Limitations

8.1 Limited Availability and Reliability of Hydrological Data

A major limitation of the study is the inadequate availability of long-term, high-resolution hydrological and geomorphological data for the Moyna Basin. Many government records are either fragmented, outdated, or not publicly accessible, which constrains precise assessment of pre- and post-project changes in river discharge, sediment load, and drainage efficiency. This data gap may lead to partial interpretation of the actual impacts of the Kaliaghai-Kapaleshwari-Bagui Project on flood dynamics and water management.

8.2 Insufficient Consideration of Local Socio-Environmental Variability

The study area exhibits significant spatial heterogeneity in terms of land use, elevation, drainage congestion, and community adaptation practices. However, capturing this micro-level variability across the entire Moyna Basin is challenging within a limited research framework. As a result, the findings may not fully represent localized experiences of waterlogging, flood vulnerability, and livelihood impacts, thereby affecting the generalization of conclusions regarding the project's effectiveness.

9. Policy Implications and Recommendations for Further Research

i) Integrated Basin Hydrology:

Adopt basin-wide hydrological management through regular desiltation, scientific dredging, embankment strengthening, and restoration of natural drainage channels, ensuring coordinated interventions across upstream and downstream sections.

ii) Block-Level Preparedness:

Strengthen decentralized disaster preparedness by forming trained Panchayat-level response teams, deploying real-time digital early warning systems, and ensuring efficient, transparent, and rapid post-disaster relief distribution mechanisms.

iii) Livelihood Diversification:

Promote diversified income sources including climate-resilient aquaculture, Agro-processing, rural non-farm enterprises, and adoption of flood-tolerant crop varieties to reduce dependency on single-season agriculture.

iv) Social Targeting:

Design inclusive compensation, insurance, and credit schemes prioritizing marginal farmers, landless labourers, women-headed households, and socially disadvantaged groups to ensure equitable post-disaster recovery and resilience building.

v) Climate-Resilient Infrastructure:

Invest in flood-resilient infrastructure such as elevated rural roads, raised tube wells, reinforced housing structures, and multipurpose flood shelters to minimize damage and enhance community-level adaptive capacity.

vi) Micro-Insurance Expansion:

Expand access to affordable parametric flood insurance schemes linked with weather indices, while integrating MGNREGS programs for land restoration, embankment repair, and livelihood recovery after flood events.

vii) Community-Based Adaptation:

Encourage participatory approaches including community flood mapping, establishment of seed banks, local monitoring committees, and indigenous knowledge integration to strengthen grassroots-level disaster preparedness and adaptation strategies.

viii) Governance Transparency:

Enhance institutional accountability through digital public dashboards displaying embankment conditions, budget utilization, and disaster response activities, supported by regular social audits and community participation mechanisms.

9.1 Recommendations for Further Research

i) Long-Term Household Panels:

Establish longitudinal household-level panel datasets to systematically track the dynamic relationship between recurrent flooding, poverty, migration patterns, and livelihood transitions across different socio-economic groups over time.

ii) Hydrological and Sediment Modelling:

Develop advanced hydrological and sediment transport models integrating climate variability, river morphology, and land-use changes to better predict flood behaviour and support evidence-based basin management strategies.

iii) High-Resolution Vulnerability Mapping:

Utilize drone-based Digital Elevation Models (DEMs) and geospatial technologies to generate high-resolution flood vulnerability maps, enabling precise identification of risk-prone zones and targeted intervention planning.

iv) Gender and Caste-Based Vulnerability:

Examine differential impacts of flooding across gender and caste groups to understand structural inequalities, access to resources, and adaptive capacities, informing more inclusive and socially just policy frameworks.

v) Behavioural Economics of Insurance:

Investigate behavioural factors influencing low uptake of flood insurance, including risk perception, trust deficits, affordability constraints, and awareness gaps, to design more effective and accessible insurance products.

vi) Comparative Basin Studies:

Conduct comparative analyses with other flood-prone river basins in India and globally to identify best practices, transferable adaptation strategies, and policy innovations for improving flood risk management outcomes.

10. Conclusion

Floods in the Kaliaghai River Basin continue to impose significant and recurrent challenges (Dieperink et al., 2016; Kumar et al., 2024; Mondal, 2025) across the six study blocks (Chakraborty and Mukhopadhyay, 2019; Sahu, 2014; Gayen, 2022; Mondal and Biswas, 2022; Mondal and Saha, 2022; Mondal et al., 2025a, 2025b, 2025c). The analysis reveals that livelihood insecurity (Keshavarz et al., 2017; Saha at el., 2024; Tofu et al., 2025) is shaped by a complex interaction of hydrological exposure, socio-economic conditions, and institutional support. While some blocks demonstrate better resilience, chronic exposure in Sabang and Moyna creates long-term poverty risks. Strengthening flood management infrastructure (Jha et al., 2012; Ashraf et al., 2013; Hallegatte et al., 2017; Mondal et al., 2025d), diversifying rural livelihoods (Parvin et al., 2016; Chakraborty and Mukhopadhyay, 2019; Silva et al., 2020; Chowdhury et al., 2022; Biswas and Mondal, 2024; Khushi et al., 2024; Mondal, 2025), and improving institutional efficiency are essential to reducing vulnerability. A basin-scale, multi-block strategy must replace fragmented interventions.

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