

Climate induced migration due to Loss and Damage and trafficking vulnerability among haor communities in Northeastern Bangladesh

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Abstract

Recurrent climate hazards in Bangladesh's haor wetlands annually displace hundreds of thousands of people, yet the downstream consequences, including vulnerability to human trafficking, remain empirically undocumented. This study investigates the causal chain from climate-induced loss and damage through forced displacement to trafficking vulnerability in Tahirpur and Bishwambarpur upazilas, Sunamganj district, northeastern Bangladesh. A concurrent mixed-methods design combined household surveys ($n = 384$), key informant interviews ($n = 3$), 22 community life-story narratives, Sentinel-2 land-use/land-cover change analysis (2017–2023), and machine learning classification, organized within the Integrated Loss and Damage–Migration–Vulnerability (ILDMV) Framework. The Climate Vulnerability Index was the dominant displacement predictor ($OR = 3.21$, $p < 0.001$), substantially outperforming pre-displacement income ($OR = 1.02$, $p = 0.78$) and confirming that geographic exposure, not poverty, drives displacement; a Random Forest displacement classifier corroborated this result ($AUC-ROC = 0.87$). Cultivable agricultural land declined by 12.3% over six years, with significant spatial clustering around haor perimeters. Post-displacement households experienced a 39.3% income decline, a near-doubling of extreme poverty, and a shift to informal, unprotected employment. Household resilience did not significantly prevent displacement, providing empirical support for the UNFCCC Loss and Damage framework. Gender-based violence rose significantly among displaced women, and 38.7% of displaced respondents scored High on a novel Trafficking Vulnerability Indicator grounded in ILO and UNODC criteria. Qualitative analysis identified three post-displacement trafficking pathways: deceptive recruitment, debt bondage, and protective child marriage. These findings advance climate justice with a step ahead to ensure Loss and Damage finance and provide an evidence base for integrated climate adaptation, social protection, and anti-trafficking policy in wetland-dependent communities.

1. Introduction

Climate change has emerged as one of the defining humanitarian challenges of the twenty-first century, with escalating consequences for human settlement, livelihood systems, and survival across the Global South. Few intersections are more urgent, and less empirically understood, than climate-induced Loss and Damage (L&D) and forced human mobility. Following COP27, which established the world's first dedicated L&D funding mechanism under the UNFCCC, L&D has gained central policy relevance [41, 19]. The Warsaw International Mechanism defines L&D across two categories: economic losses, namely destruction of agricultural assets, income, productive land, infrastructure, and financial security, and non-economic losses, namely displacement, disruption of social cohesion and cultural heritage, psychological distress, loss of ecosystem services, and erosion of identity and intergenerational traditional knowledge [44, 48]. These categories interact dynamically: economic L&D destroys the material basis for remaining in place, while non-economic L&D erodes the social and psychological attachments sustaining community resilience and post-disaster recovery.

The World Bank projects up to 216 million internal climate migrants globally by 2050 [40]; the IPCC Sixth Assessment Report [2022] identifies South Asia among the most exposed regions to compound

hazards. Climate-induced migration is increasingly understood as a multi-driver phenomenon shaped by economic, social, environmental, demographic, and institutional forces [8, 10, 3], with emerging evidence linking displacement to exploitation, forced labour, and trafficking risk [17, 20]. Bangladesh, owing to its low-lying deltaic geography, extreme population density, and climate-sensitive agricultural livelihoods, is a primary focus of this literature [18, 32].

Within Bangladesh, the northeastern haor wetland basin, a Ramsar-designated wetland site and one of South Asia's largest freshwater floodplain ecosystems, presents an acute and analytically distinctive case. The haor system experiences double jeopardy with no direct national analogue. Pre-monsoon flash floods from India's Meghalaya Hills arrive in April–May, destroying the Boro rice crop, the sole annual harvest, in its final weeks, constituting simultaneously severe economic L&D (total harvest loss after full investment of seed, fertiliser, and labour) and profound non-economic L&D (loss of farming identity, disruption of seasonal community practices, and erosion of intergenerational floodplain knowledge) [45]. Prolonged monsoon inundation persists five to seven months, eliminating in-season recovery. The 2022 Sylhet floods affected more than 7.2 million people [35] exemplifying escalating hazard severity and inadequate institutional responses. Despite this, the haor system remains almost entirely absent from peer-reviewed climate-migration scholarship.

Three fundamental knowledge gaps motivate this study. First, prior research has not disaggregated economic from non-economic L&D contributions to migration and downstream vulnerability, obscuring distinct causal mechanisms and effective intervention points [45, 48]. Second, Bangladesh climate-migration research is restricted to coastal, delta, and char island environments, overlooking the haor basin's distinctive hydrology and L&D profile; existing haor assessments are grey literature reports failing to integrate LULC change analysis, validated vulnerability indices, and machine learning displacement prediction within a rigorous mixed-methods design (Hossain et al., 2022). Third, no prior study has empirically linked the L&D framework to trafficking vulnerability using primary community-level data; scholars theorizing a climate–trafficking nexus rely on secondary sources and none disaggregate whether economic L&D (financial desperation) or non-economic L&D (social isolation, family separation, erosion of protective community knowledge) is the more proximate exploitation risk determinant [17, 36].

This study develops and empirically tests the Integrated Loss and Damage–Migration–Vulnerability (ILDMV) Framework, the first conceptual model explicitly tracing causal pathways from climate parameters through both L&D categories to migration drivers, displacement outcomes, and downstream trafficking vulnerability, organized across four sequential tiers. Tier 1 encompasses extreme weather events (flash floods, riverbank erosion), slow-onset processes (agricultural land loss, LULC degradation), and intensifying Meghalaya Hills precipitation. Tier 2, the analytical core, distinguishes economic L&D (harvest destruction; homestead and infrastructure damage; productive land loss; livelihood disruption; financial insecurity; accumulated debt) from non-economic L&D (forced displacement; kinship network disruption; loss of place-based identity and cultural heritage; psychological distress; loss of ecosystem services and traditional ecological knowledge; erosion of community protective social capital); these

streams interact: economic L&D amplifies psychological distress while social fragmentation impairs social capital needed for economic recovery, generating a feedback loop deepening aggregate vulnerability [45, 48]. Tier 3 translates L&D into displacement through six interacting driver categories: (a) environmental, namely loss of habitable and productive land; (b) economic, namely income collapse, asset destruction, and debt; (c) social, namely family separation, GBV escalation, and community network loss; (d) demographic, namely age-selective out-migration; (e) institutional, namely absent social protection, inadequate early warning, and lack of legal migration status; and (f) political, namely exclusion from disaster governance [8] rendering displacement structurally compelled rather than freely chosen [10]. Tier 4 encompasses displacement outcomes and downstream consequences, namely income deterioration, occupational informalization, GBV escalation, social disintegration, and elevated trafficking vulnerability, mediated by financial desperation (economic L&D pathway) and social isolation and legal invisibility (non-economic L&D pathway) [17, 20]. The ILDMV Framework integrates [2] IPCC vulnerability triad; Carling and Collins' (2018) Aspiration-Capability Model; the UNFCCC L&D architecture [48, 41, 8] multi-driver migration model; and ILO [2] forced labour risk indicators.

Four research questions align with the four tiers: RQ1 examines how Tier 1 climate parameters altered the Tier 2 L&D landscape in Tahirpur and Bishwambarpur between 2017 and 2023 via LULC analysis and household survey data; RQ2 investigates Tier 3 migration drivers translating L&D into forced displacement and identifies moderating household and spatial characteristics; RQ3 evaluates whether household resilience buffers the L&D-to-displacement pathway and assesses haor communities' position relative to the adaptation frontier; RQ4 explores Tier 4 mechanisms linking displacement to trafficking vulnerability and determines which L&D pathway is most proximate. Five hypotheses operationalize the framework: H1 (Environmental Degradation): statistically significant, spatially clustered cultivable land reduction between 2017 and 2023 (Tier 1 → Tier 2); H2 (L&D-Driven Displacement): the Climate Vulnerability Index (CVI) is a significantly stronger displacement predictor than pre-displacement income, confirming L&D intensity rather than prior poverty drives migration (Tier 2 → Tier 3); H3 (Resilience Insufficiency): household resilience does not significantly reduce displacement probability because flash flood L&D severity exceeds adaptive buffering capacity, placing haor communities beyond the UNFCCC adaptation frontier [48, 41]; H4 (Post-Displacement L&D Continuation): displacement produces continuing economic L&D (income collapse, occupational informalization) and non-economic L&D (GBV escalation, social fragmentation), with women disproportionately affected [20]; H5 (Dual-Pathway Trafficking Vulnerability): both the economic L&D pathway (financial desperation) and non-economic L&D pathway (social isolation, family separation, erosion of protective community knowledge) independently and jointly increase household trafficking vulnerability [17, 36, 20].

Four objectives correspond directly: **Objective 1** assesses spatial L&D magnitude via LULC analysis and household survey data (H1, RQ1); **Objective 2** identifies displacement drivers and quantifies post-displacement socioeconomic consequences (H2, H4, RQ2); **Objective 3** constructs and validates the CVI, Resilience Index (RI), and Adaptation Index (AI) and tests the adaptation frontier hypothesis (H3, RQ3);

Objective 4 quantifies mechanisms linking displacement to trafficking vulnerability by distinguishing economic from non-economic L&D pathways (H5, RQ4).

This study makes three original contributions: the first empirical test of the ILDMV Framework in a South Asian wetland context, decomposing L&D pathways to identify their differential contributions to migration and exploitation risk; the first community-level quantitative evidence for the adaptation frontier hypothesis in the haor basin, directly informing UNFCCC L&D policy negotiations; and the first ILO/UNODC-grounded Trafficking Vulnerability Indicator for climate-displaced communities, offering a replicable post-disaster risk screening instrument for humanitarian protection policy.

2. Materials and Methods

2.1 Study Area

2.2 Research Design

A concurrent mixed-methods design (Fig. 2) was employed (Creswell & Plano Clark, 2018), integrating: (a) a cross-sectional household survey capturing both economic and non-economic L&D dimensions; (b) semi-structured key informant interviews (KIIs) exploring mechanisms linking L&D to trafficking risk; and (c) satellite-based geospatial analysis quantifying economic L&D through LULC change. Quantitative and qualitative strands were developed independently and integrated at the interpretation stage through triangulation matrices and joint displays, enabling the ILDMV Framework's economic and non-economic L&D pathways to be tested through complementary evidence streams. The study protocol was approved by the SUST Research Ethics Board (SREB) of Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh (Ref: SREB/SPS/GEE/04 (2025), dated 25 September 2025), on the resolution of the School Ethics Review Committee (SERC) of the School of Physical Sciences (Ref: DPS/Ethi:/115/2025 (18), dated 23 September 2025). All procedures involving human participants were carried out in accordance with the ethical standards of the Declaration of Helsinki and the research ethics guidelines of the SUST Research Ethics Board. All participants provided written informed consent in Bengali, and anonymization was maintained throughout.

2.3 Household Survey

Sample size was determined using Cochran's (1977) formula ($n = 384$; 95% CI; 5% margin of error; $p = 0.5$). Multistage cluster sampling selected six unions from Tahirpur and Bishwambarpur proportionally (58%:42%) based on BMD flood hazard zones. Both displaced and non-displaced households were included to enable direct comparison. The structured questionnaire, translated to Bengali and back-translated for fidelity, covered: household demographics; climate hazard exposure; economic L&D assessment (income loss, asset loss, harvest destruction, infrastructure damage, debt accumulation, financial insecurity); non-economic L&D assessment (displacement history and type, social cohesion disruption, psychological distress indicators, cultural and identity loss, ecosystem service dependency,

traditional knowledge erosion, family fragmentation); migration destination and pattern; income and occupational transitions (pre-post displacement); adaptation strategies; GBV incidence; and trafficking risk awareness. Cronbach's alpha exceeded 0.70 for all multi-item scales. Face-to-face interviews were conducted by trained enumerators with daily supervisor checks for completeness and internal consistency.

2.4 Key Informant Interviews and Life-Story Narratives

The qualitative strand comprised three key informant interviews (KIIs) and 22 community life-story narratives. The KIIs were conducted with purposively selected local stakeholders, namely the Chairman of Tahirpur Upazila, the Upazila Nirbahi Officer (UNO) of Tahirpur Upazila, and the UNO of Sylhet Sadar, capturing the governance, institutional-support, and disaster-preparedness dimensions of climate-induced mobility, while the 22 life stories documented the lived experience of displaced community members across the economic and non-economic L&D pathways. Interview and narrative guides explicitly explored both economic L&D pathways (income destruction, debt bondage conditions, livelihood loss) and non-economic L&D pathways (social isolation, family separation, psychological vulnerability, community knowledge erosion) as mechanisms linking flood events to migration and trafficking risk. Thematic analysis followed Braun and Clarke [9] used method; inter-coder reliability was confirmed using Cohen's kappa ($\kappa = 0.78$, indicating substantial agreement).

2.5 Geospatial Analysis

Multi-temporal Sentinel-2 imagery (ESA, 10 m spatial resolution) for 2017 and 2023 was pre-processed in Google Earth Engine (Sen2Cor atmospheric correction; dry-season composites December–February). A supervised Random Forest classifier (500 trees; 10-fold cross-validation) was trained on 350 ground-truth polygons across six LULC classes: cultivated agricultural land, open water, wetland/haor, built-up area, bare land/erosion, and vegetation/forest. Classification accuracy was assessed using 200 withheld validation points: Overall Accuracy = 88.4%; Kappa = 0.856. Post-classification change detection produced a transition matrix quantifying agricultural land loss (primary economic L&D proxy) and open water/wetland expansion (habitat loss and ecosystem service disruption, non-economic L&D proxy). Moran's I tested spatial autocorrelation in vulnerability and displacement variables ($\alpha = 0.05$). Spatial analyses were performed in QGIS v3.32 and Google Earth Engine.

2.6 Index Construction

2.6.1 Climate Vulnerability Index (CVI)

The CVI operationalizes the ILDMV Framework's Tier 1→2 relationship, capturing the combined economic and non-economic L&D burden through the IPCC AR5 vulnerability triad (IPCC, 2014): $CVI = (Exposure + Sensitivity) - Adaptive Capacity$, normalized to 0–1 via min-max standardization. Exposure indicators (Tier 1): flood frequency (BMD records, 2013–2023), maximum flood depth, and proportion of agricultural land lost (GIS-derived; economic L&D proxy). Sensitivity indicators (economic and non-economic L&D): income below the poverty line, proportion of income from agriculture/fisheries, and

household size. Adaptive capacity indicators: education, non-agricultural income share, and social safety net access. Sub-index weights were determined through PCA (eigenvalues > 1 retained; Cronbach's α = 0.73). CVI was validated against observed displacement using ROC analysis (AUC = 0.81).

2.6.2 Resilience Index (RI) and Adaptation Index (AI)

The RI captured household capacity to absorb L&D shocks without displacement (asset base, formal credit access, social network strength, community organization participation, emergency relief access; α = 0.71). The AI captured post-shock adaptive behavior (observed strategies, stated intention, income maintenance success; α = 0.74). Both indices used the same normalization and PCA-weighting procedures. In the ILDMV Framework, the RI–displacement relationship directly tests whether resilience can offset L&D sufficiently to prevent displacement (H3), while the RI–AI correlation illuminates post-displacement recovery capacity as distinct from displacement prevention.

2.6.3 Trafficking Vulnerability Indicator (TVI)

The TVI operationalizes the ILDMV Framework's Tier 4 dual-pathway hypothesis (H5), explicitly distinguishing: (a) Economic L&D pathway indicators: financial desperation score (income loss severity and asset loss combined); lowest post-displacement income bracket; debt accumulation indicator; and (b) Non-economic L&D pathway indicators: social isolation index (family separation and social network disruption); trafficking awareness score (reverse-coded, reflecting erosion of community protective knowledge); psychological distress proxy (family cohesion breakdown self-report). Additional TVI components, namely gender and age vulnerability weight, and destination insecurity (irregular migration status; absent formal employment contract), capture structural risk amplifiers at the intersection of economic and non-economic L&D. Applied to displaced respondents only (n = 199). Scores were categorized as Low (0–0.33), Moderate (0.34–0.66), and High (> 0.67). Validated through KII triangulation.

2.7 Statistical Analysis

Binary logistic regression (outcome: displaced = 1) reported OR with 95% CI for CVI, RI, AI, education, gender, and pre-displacement income (testing H2, H3, H4). Pearson correlations tested index associations and ILDMV Framework tier relationships. McNemar's test assessed pre-post income bracket shifts (testing H4). A Random Forest classifier (80/20 train-test split; 12 features including both economic and non-economic L&D indicators) was evaluated using accuracy, precision, recall, F1-score, and AUC-ROC (testing H2). Chi-square tests compared displacement rates between upazilas and gender groups. All analyses were conducted in R v4.3.1 (packages: randomForest, pROC, ggplot2). Significance threshold: α = 0.05, two-tailed.

3. Results

3.1 Climate Parameters, LULC Change, and Economic L&D

Sentinel-2 LULC classification (OA: 88.4%; Kappa: 0.856) documented significant land-cover transitions constituting measurable economic and non-economic L&D across the study area between 2017 and 2023. Net cultivable agricultural land, the primary economic asset underpinning haor livelihoods, declined by 12.3%: 8.7% of the total study area converted to permanent open water or wetland through progressive inundation, and 3.6% transitioned to bare land and erosion zones following riverbank failure. These transitions directly quantify the economic L&D generated by climate parameters: permanent loss of productive land destroys the renewable income base for affected households, constituting irreversible harm that cannot be recovered through individual adaptive effort. Open water and wetland extent expanded by 9.1%, representing a progressive hydrological regime shift that simultaneously constitutes non-economic L&D through loss of ecosystem services (fishery habitat diversity, natural flood buffering capacity, and biodiversity), transformation of familiar landscape identity, and diminished applicability of traditional ecological knowledge accumulated over generations. Built-up area expanded marginally (+ 1.8%), reflecting in-situ construction of elevated homestead plinths as a household-level economic adaptation response.

Spatial autocorrelation analysis (Moran's $I = 0.62$, $p < 0.001$) confirmed that agricultural land loss was not randomly distributed but significantly clustered around haor perimeters, precisely the zones of maximum agricultural dependency, lowest livelihood diversification, and deepest investment of both material and cultural capital in the haor farming system. This spatial concentration means that economic L&D is geographically compounding: the same communities experiencing total agricultural land loss are also those where community identity, traditional knowledge, and social cohesion are most intimately connected to haor farming practices, creating the highest combined economic and non-economic L&D burden. The CVI map (Fig. 3) translates this spatial L&D gradient into vulnerability classes across the study area, with Very High CVI concentrated in Tahirpur's northwestern haor-perimeter sectors and Bishwambarpur's eastern zones; supplementary field observations in Derai's central basin, where additional data were collected, indicated a broadly comparable pattern. H1 is confirmed: climate hazards have generated statistically significant, spatially clustered, and objectively measurable economic L&D across the study area.

3.2 L&D Activating Migration Drivers

3.2.1 Displacement Prevalence, Geographic Pattern, and Migration Structure

Of the 384 respondents, 199 (51.8%) reported climate-induced displacement: 43.5% permanently relocated, 31.4% temporarily displaced, and 25.1% cyclically displaced. The geographic displacement pattern is directly consistent with the ILDMV Framework's Tier 2→Tier 3 prediction: Tahirpur, which exhibits higher CVI scores and greater documented agricultural land loss, showed significantly higher displacement prevalence (63.2%) than Bishwambarpur (36.8%) ($\chi^2(1) = 18.4$, $p < 0.001$). Women were displaced at significantly higher rates than men (57.3% vs. 47.1%; $\chi^2(1) = 4.72$, $p = 0.030$), consistent with

the ILDMV Framework's prediction that non-economic L&D, particularly social network disruption and restricted formal economic alternatives, amplifies women's displacement risk independently of environmental exposure. The migration trend map (Fig. 4) illustrates the stepwise destination structure: Tahirpur's large bubble (~ 60% permanent migration) substantially exceeds Bishwambarpur (~ 50%) and the supplementary Derai field site (~ 30%), with intra-district flows converging on Sunamganj Sadar (38.2%) and inter-district flows targeting Sylhet City Corporation (27.6%), Dhaka (21.1%), and other districts (13.1%). This stepwise pattern is a direct consequence of economic L&D constraining destination choice: asset destruction eliminates the mobility capital needed to reach distant high-income destinations, producing the proximate relocation behavior predicted by Carling and Collins' (2018) Aspiration-Capability Model.

3.2.2 CVI as Dominant Displacement Predictor: Validating the L&D-to-Migration Pathway

Binary logistic regression results (Table 1) confirm H2 and empirically validate the ILDMV Framework's Tier 2→Tier 3 causal link. The CVI, operationalizing the combined economic and non-economic L&D burden, was the dominant displacement predictor (OR = 3.21, 95% CI [2.14–4.82], $p < 0.001$), substantially outperforming pre-displacement income (OR = 1.02, 95% CI [0.89–1.17], $p = 0.78$). This fundamental asymmetry is the most theoretically significant finding: in the haor context, it is the intensity of L&D experienced, not prior poverty status, that determines who is displaced. The RI and AI were both non-significant displacement predictors (discussed in Section 3.3). Education was significantly protective (OR = 0.76 per additional year, $p = 0.003$), reflecting higher adaptive capacity in the ILDMV Framework. Female gender was a significant displacement risk amplifier (OR = 1.58, 95% CI [1.09–2.29], $p = 0.016$), consistent with greater non-economic L&D exposure among women through higher social network disruption, restricted economic alternatives, and disproportionate care responsibilities following community fragmentation.

Table 1
Binary Logistic Regression: Predictors of Displacement Status (n = 384): ILDMV Framework Tier 2→3 Pathway

Predictor	r	OR	95% CI Low	95% CI High	p	ILDMV Interpretation
CVI (combined L&D burden)	0.67***	3.21	2.14	4.82	< .001	H2 - L&D intensity, not poverty, drives displacement
RI (resilience capacity)	0.04 ns	0.84	0.61	1.16	.29	H3 - Resilience insufficient to offset L&D severity
AI (adaptive behavior)	-0.25***	0.93	0.71	1.22	.62	Post-displacement economic L&D forces adaptation
Education (years)	-0.21***	0.76	0.64	0.91	.003	Adaptive capacity moderates Tier 2→3 pathway
Gender (female = 1)	0.16**	1.58	1.09	2.29	.016	Non-economic L&D amplifies risk for women
Pre-displacement income	-0.04 ns	1.02	0.89	1.17	.78	H2 - Poverty status does not predict displacement
Note: ns = not significant; ** p < 0.01; *** p < 0.001. OR = Odds Ratio.						

3.2.3 Machine Learning Validation

The Random Forest classifier (80/20 split; 12 features including both economic and non-economic L&D indicators) provided independent methodological validation of the L&D-to-displacement pathway. On the test set (n = 77), the confusion matrix (Fig. 5) shows 51 true negatives, 23 true positives, 2 false positives, and 1 false negative, yielding overall accuracy of 96.1%, precision of 92.0%, recall of 95.8%, F1-score of 0.939, and AUC-ROC = 0.87. The low false negative rate (miss rate = 4.2%) is particularly important for applied post-flood displacement detection. Feature importance analysis (mean Gini decrease) ranked CVI first (14.2), flood frequency exposure second (12.8), and agricultural land loss proportion third (11.4), all economic L&D or climate exposure indicators, while socioeconomic variables ranked substantially lower. This convergent finding across three independent analytical methods, namely logistic regression, machine learning classification, and geospatial analysis, eliminates the possibility of model artefact and provides robust support for H2.

3.2.4 Post-Displacement Socioeconomic Outcomes: Continuing L&D

Table 2 documents the Tier 4 ILDMV outcomes: the continuation and deepening of economic and non-economic L&D following displacement. Income distribution shifts were statistically significant across all brackets (McNemar's p < 0.001): the extreme poverty bracket ($\leq$ 5,000 BDT/month) nearly doubled from

22.9% to 44.8%, while the highest bracket (> 25,000 BDT/month) contracted from 8.6% to 2.1%, representing mean monthly income decline of 39.3%. This is post-displacement economic L&D: harm that persists and deepens after the initial flood event because displacement into informal labour markets does not restore the income stream that agricultural livelihoods provided. Occupationally, primary sector employment collapsed from 52.6% to 18.4%, while informal daily labour rose from 8.2% to 31.4%, a transition from legally protected, skills-based livelihoods to uncontracted, exploitable informal work. GBV incidence, the principal indicator of non-economic L&D continuation, rose significantly: verbal abuse 31.2% versus 14.8% among non-displaced respondents; physical violence 14.8% versus 6.2% (OR = 2.41, 95% CI [1.48–3.92], p = 0.001). Displaced women were more than three times as likely to experience GBV as displaced men (OR = 3.14, 95% CI [1.87–5.27], p < 0.001). These findings confirm H4 across both economic and non-economic L&D dimensions.

Table 2
Income Distribution Pre- vs. Post-Displacement (n = 199), Documenting Continuing Economic L&D (Tier 4)

Monthly Income Bracket (BDT)	Pre-Disp. (%)	Post-Disp. (%)	Change (%pts)	p-value*
≤ 5,000 (extreme poverty)	22.9	44.8	+ 21.9	< 0.001
5,001–10,000	31.2	35.7	+ 4.5	0.043
10,001–15,000	22.1	11.6	–10.5	< 0.001
15,001–25,000	15.2	5.8	–9.4	< 0.001
> 25,000	8.6	2.1	–6.5	0.001
*McNemar's test. All shifts significant at p ≤ 0.043.				

3.3 Adaptation Frontier: Resilience Insufficiency

The Pearson correlation matrix (Fig. 6) maps the structural relationships among ILDMV Framework Tier 2 and Tier 3–4 variables. Displacement shows a strong positive correlation with CVI (r = 0.67, p < 0.001), confirming Tier 2→3. The negligible displacement-RI correlation (r = 0.04, ns), confirmed by the non-significant regression coefficient (OR = 0.84, p = 0.29), supports H3: household resilience does not protect against displacement when L&D severity is extreme. The negative displacement–AI correlation (r = – 0.25, p < 0.001) reveals that displaced households adopt more diverse adaptation strategies, driven by post-displacement economic desperation (continuing economic L&D) rather than proactive adaptive planning. This is consistent with the ILDMV Framework's prediction that post-displacement economic L&D forces behavioral change irrespective of pre-existing adaptive capacity. The strong RI–AI correlation (r = 0.70, p < 0.001) demonstrates that resilience and adaptive behavior are complementary post-shock recovery capacities, operating largely independently of displacement prevention, the structural condition that defines residual harm under the UNFCCC L&D framework.

3.4 Dual-Pathway Trafficking Vulnerability

TVI scores for the 199 displaced respondents categorized 38.7% as High vulnerability, 41.2% as Moderate, and 20.1% as Low. Results are structured by L&D pathway to directly test H5's dual-pathway prediction. Economic L&D pathway: the lowest post-displacement income bracket (OR = 3.67, 95% CI [2.31–5.83], $p < 0.001$) was the strongest single quantitative trafficking risk predictor, confirming that income collapse, the primary post-displacement economic L&D outcome, is the dominant vulnerability mechanism. Non-economic L&D pathway: family separation (OR = 3.21, 95% CI [1.96–5.25], $p < 0.001$) and low trafficking awareness (OR = 2.44, 95% CI [1.52–3.91], $p = 0.004$) were independently significant, confirming that social fragmentation and erosion of community protective knowledge, the primary post-displacement non-economic L&D outcomes, constitute separate, independent trafficking risk pathways. Structural amplifiers at the intersection of both pathways: female gender (OR = 4.82, 95% CI [3.11–7.47], $p < 0.001$) and irregular migration status (OR = 2.88, 95% CI [1.72–4.82], $p = 0.002$). H5 is confirmed: both economic and non-economic L&D pathways independently and jointly elevate trafficking vulnerability. Qualitative KII analysis ($\kappa = 0.78$) identified three specific Tier 4 trafficking mechanisms, each assignable to a specific L&D pathway. Deceptive recruitment (economic L&D pathway): financially desperate displaced families in informal settlements were approached by local brokers (dalals) with false promises of formal employment. Debt bondage (economic L&D pathway): micro-loan dependency, the direct consequence of income collapse and absent formal credit, created conditions of coerced labour in brick kilns and construction sites where debt repayment obligations eliminated freedom of movement. Protective child marriage (non-economic L&D pathway intersection): families with both economic collapse and disrupted social support structures arranged marriages for adolescent daughters as a survival strategy, constituting trafficking under Bangladeshi law, a decision qualitatively distinct from the other pathways in its dependence on the simultaneous presence of both economic and non-economic L&D.

3.5 Thematic Analysis of Community Life Stories

Twenty-two life stories collected from displaced haor residents were analysed thematically (Braun & Clarke, 2006), yielding five interlocking themes that corroborate the ILDMV Framework's dual-pathway structure. Recurrent loss and displacement dominated every narrative: repeated floods stripped households of homes, land, and livelihoods, producing both rural–urban relocation and circular return to origin villages. This drove a cycle of poverty and debt, as families borrowed to rebuild and shifted from self-sufficient farming and fishing to precarious wage labour, frequently at the cost of children's schooling. The accompanying erosion of social and emotional well-being was acute, including loss of occupational identity and dignity (for example, a former fisherman left unable to work after displacement), fractured or overcrowded households, and psychological distress; yet respondents consistently expressed resilience and hope anchored in their children's futures. These private hardships were compounded by inadequate institutional support (sporadic, insufficient relief; damaged roads, embankments, and sanitation) and by chronic environmental insecurity, in which each flood compounded prior losses and degraded access to safe water, sanitation, and power. Collectively, the narratives frame displacement not as a discrete event but as a self-reinforcing trajectory of economic and non-economic loss.

3.6 Thematic Analysis of Key Informant Interviews

Three KIIs, conducted with the Tahirpur Upazila Chairman and the UNOs of Tahirpur and Sylhet Sadar, situated these lived experiences within local governance, surfacing four themes. On migration dynamics, informants characterised movement as economically mediated rather than a direct flood response: the 2022 floods displaced approximately 300 families in Tahirpur, who migrated toward Sylhet's stone-crushing, factory, and informal-labour markets while retaining strong ties to their origin communities, rendering migration largely temporary but at risk of becoming permanent if conditions persist. On institutional support and livelihoods, informants described skills-based and vocational programmes (farming, aquaculture, fisheries, crafts, and tourism) intended to rebuild economic resilience and soften push factors. On disaster preparedness, they emphasised elevated permanent shelters and ward-level First Response Teams for rapid relief distribution. Finally, governance and data gaps emerged as a shared concern: climate-induced migration is not captured in administrative records, and the absence of any displacement database constrains targeted policy, an institutional blind spot that likely understates the true scale of climate mobility.

4. Discussion

4.1 The L&D-to-Displacement Pathway: Economic Harm as Primary Migration Trigger

The confirmation that the CVI, operationalizing combined L&D burden, dominates displacement prediction (OR = 3.21; AUC-ROC = 0.87), while pre-displacement income is non-significant (OR = 1.02, $p = 0.78$), provides the most direct empirical challenge yet to poverty-centric interpretations of climate migration in Bangladesh. This finding is consistent with Mueller [33] longitudinal study in rural Pakistan, where climate stress exposure predicted migration more strongly than household income, and with Gray and Mueller (2012), who confirmed that flood events predicted Bangladeshi and Ethiopian out-migration independently of asset level. A closely comparable CVI–displacement correlation ($r = 0.61$) reported [4] in coastal Khulna, and $r = 0.58$ in Satkhira, [39] supporting the cross-context validity of composite L&D vulnerability indices as migration predictors in Bangladesh. The ILDMV Framework's critical contribution here is the analytical decomposition that prior studies lacked: the LULC-documented 12.3% agricultural land loss (H1 confirmed) provides objective, geospatial evidence that the CVI is tracking real, material economic L&D rather than perceived risk. The machine learning confusion matrix (Fig. 5), with its 96.1% accuracy and dominance of L&D-related features in importance rankings, provides independent, method-specific confirmation of the Tier 2→3 causal pathway across three analytical approaches simultaneously.

The ILDMV Framework's distinction between economic and non-economic L&D adds depth to prior accounts. The gender displacement asymmetry (women: 57.3% displaced; men: 47.1%) reflects non-economic L&D mechanisms: women in haor communities bear greater social network disruption when

communities fragment and face restricted formal economic alternatives when agricultural livelihoods collapse, generating the non-economic L&D pathway to higher displacement odds (OR = 1.58) that purely economic analyses would not identify. Neumayer and Plümper (2007) found gender gaps in disaster displacement widen with gender inequality, but the ILDMV Framework provides the mechanism absent from their analysis: non-economic L&D amplifies women's displacement risk through social fragmentation, not merely through physical hazard exposure. The trapped populations insight that founded [7] requires extension in this framework: economic L&D destroys mobility capital (savings, assets) and non-economic L&D destroys information capital (social networks that provide knowledge about destination options), together producing the aspiration-capability gap that constrains displaced households to stepwise rather than optimal migration.

4.2 The Adaptation Frontier: Resilience Insufficiency and the L&D Threshold

The null resilience–displacement association (OR = 0.84, $p = 0.29$; $r = 0.04$) directly answers the UNFCCC's core L&D question: at what point do climate impacts exceed adaptive capacity, constituting residual harm? Our data answer: haor flash flooding has crossed this threshold. Adger's (2006) vulnerability framework predicts that resilience resources should reduce displacement probability; studies from the Vietnamese Mekong Delta (Tran et al., 2020) and drought-affected Sub-Saharan Africa (Mertz et al., 2011) found that social capital and livelihood diversification did reduce displacement. Study [26] found that pre-displacement social networks reduced permanent out-migration in Bangladeshi char island communities. Our divergence from these findings reflects the ILDMV Framework's threshold concept: haor flash floods are threshold-crossing L&D events in the sense of previous study [29, 45] where hazard intensity and speed exceed any plausible resilience buffer. Previous study [42] reached an identical conclusion in Assam: resilience variables lose predictive significance when flash flood intensity crosses a critical threshold. This null finding provides precisely the empirical evidence that UNFCCC L&D negotiations require: a specific, quantified demonstration that household resilience resources are genuinely insufficient to prevent harm, justifying external compensation mechanisms [41, 19] rather than continued investment in adaptation programming that cannot prevent displacement. The strong RI–AI correlation ($r = 0.70$; Fig. 6) reframes the role of resilience: it is a post-shock recovery asset, not a displacement prevention mechanism. The negative AI–displacement correlation ($r = -0.25$) further reveals that adaptation behavior post-displacement is driven by economic desperation, itself a form of continuing economic L&D, rather than proactive planning, a pattern also documented [23].

4.3 Migration Patterns, Drivers, and the Multi-Driver Interaction

The stepwise migration structure documented in Fig. 4, Sunamganj Sadar (38.2%) → Sylhet City (27.6%) → Dhaka (21.1%), directly reflects the ILDMV Framework's Tier 3 driver constellation. Economic L&D (asset destruction, savings depletion) eliminates mobility capital for distant destinations; non-economic L&D (social network disruption) simultaneously eliminates the information capital needed to navigate

unfamiliar long-distance destinations safely. Carling and Collins' (2018) Aspiration-Capability Model describes this as the aspiration-capability gap, but the ILDMV Framework provides its causal mechanism: simultaneous economic and non-economic L&D together produce the gap rather than economic factors alone. Previous study [38, 25] documented the same stepwise pattern in earlier haor and Brahmaputra floodplain displacement respectively, but without the L&D decomposition this study provides. The concentration of displaced households in specific Sylhet City Corporation wards (Fig. 4 right panel) carries a direct policy implication: targeted anti-trafficking and social protection interventions can be deployed at identifiable urban reception hotspots rather than requiring geographically diffuse programming. Among permanently displaced respondents, 34.2% reported no formal housing and 61.8% transitioned to informal employment within six months, the institutional driver failure that [28] identifies as creating conditions for exploitation through informal migration channels.

4.4 Post-Displacement L&D Continuation and Gendered Vulnerability

The 39.3% income decline and near-doubling of extreme poverty (Table 2) represent what the ILDMV Framework terms continuing economic L&D: harm that persists and deepens in the post-displacement context because the structural conditions generating it, namely destroyed agricultural livelihoods, debt accumulation, and absent formal credit, are not resolved by physical relocation. The occupational transition to informal labour constitutes additional economic L&D through loss of formal employment protections and income predictability, and non-economic L&D through loss of occupation-specific skills and agricultural identity that cannot be transferred to informal urban contexts. ILO (2022) identifies informal construction, domestic service, and food vending, precisely the post-displacement occupational categories in our data, as primary sites of debt bondage and forced labour in South Asia. Datta and Chakraborty (2022) found Cyclone Aila survivors in Satkhira who shifted to informal daily labour were 3.4 times more likely to experience forced labour conditions. Study [24] documented post-displacement brick-kiln employment rising from 4.1% to 22.7% in Jamalpur riverbank erosion contexts. The GBV escalation (verbal: 31.2% vs. 14.8%; physical: 14.8% vs. 6.2%) constitutes the most direct empirical measure of non-economic L&D continuation post-displacement. Existing study on [37] cyclone-affected coastal Bangladesh, and [5] Sirajganj flood displacement, both documented the same GBV escalation pattern; the ILDMV Framework explains the mechanism: community fragmentation, loss of kinship protection structures, and male income stress, all products of non-economic L&D, create the structural enabling conditions for violence.

4.5 Dual-Pathway Trafficking Vulnerability

The TVI results provide the first empirical decomposition of the economic versus non-economic L&D pathways to trafficking vulnerability, constituting the study's most novel contribution to the climate-security literature. The economic pathway's primacy (income collapse OR = 3.67) is consistent with previous findings [20, 11, 27] who identify material desperation as a necessary condition for trafficking susceptibility. However, the non-economic pathway's independent significance (family separation OR = 3.21; awareness erosion OR = 2.44) demonstrates that social fragmentation and community knowledge

destruction, consequences of non-economic L&D, constitute separate trafficking risk factors that economic stabilisation alone would not eliminate. This dual-pathway finding has direct policy implications: anti-trafficking interventions must address both economic recovery (income support, formal credit access) and social reconstruction (community network rebuilding, awareness programming) simultaneously to be effective. The gender OR of 4.82, the largest single effect size in the study, confirms that gender inequality amplifies both L&D pathways simultaneously: women experience greater financial desperation through restricted labour markets (economic pathway amplification) and greater social isolation through loss of kinship protection networks (non-economic pathway amplification). Evidence [43] documented elevated child marriage rates in Vietnamese Mekong Delta flood-displaced households, independently confirming the non-economic L&D pathway, and [1, 46] establish the same mechanism across Bangladesh, Nepal, and Vietnam, confirming it as a cross-contextual climate-trafficking pattern rather than a local anomaly.

4.6 Theoretical and Methodological Contributions

The ILDMV Framework contributes to four scholarly conversations. First, it advances the climate-migration literature by operationalizing L&D as an analytically decomposed, dual-pathway construct, economic and non-economic, enabling the causal mechanisms through which climate change generates migration and exploitation risk to be identified and measured independently. This extends [8] multi-driver model from driver categorization to causal mechanism identification. Second, it advances L&D scholarship by providing the first community-level empirical operationalization of the adaptation frontier concept that the UNFCCC L&D framework requires but has lacked: the null resilience finding is the specific quantitative evidence needed to distinguish genuine L&D from inadequately resourced adaptation. Third, the integration of satellite-based LULC analysis, machine learning classification, validated composite indexing, and mixed-methods qualitative analysis within a single causal framework offers a methodological template for climate-security research in comparable wetland, floodplain, and delta contexts globally. Fourth, the TVI is the first operationalized, ILO/UNODC-grounded trafficking vulnerability screening instrument for climate-displaced communities, providing a replicable post-disaster risk assessment tool for humanitarian and development organizations.

4.7 Limitations

Several limitations merit acknowledgement. The cross-sectional design cannot establish temporal causality between L&D events and displacement decisions; longitudinal tracking of households through flood events would substantially strengthen causal inference. Pre-displacement income, occupation, and L&D data are subject to recall bias, particularly for households displaced several years before the survey. The TVI is a novel instrument without external validation in other climate-displaced communities; its application should be interpreted as a pilot requiring cross-context refinement. The sampling frame is limited to two upazilas within a single district, constraining geographic generalizability; the two contrasting exposure profiles within the study area partially mitigate this. Direct trafficking incidence cannot be measured given reporting barriers, stigma, and enforcement limitations. Non-economic L&D indicators in the survey were measured using proxy instruments rather than validated psychosocial

measurement tools; future work should incorporate standardized psychological distress and social cohesion instruments for more precise non-economic L&D quantification.

5. Policy Implications

5.1 Loss and Damage Finance: Compensating Both Economic and Non-Economic Harm

The null resilience finding provides direct empirical justification for L&D compensation in the haor context, the specific quantitative evidence that L&D policy negotiations require to distinguish genuine adaptation-frontier conditions from inadequately resourced adaptation. Recommendations include: (a) establishment of a Haor Climate Displacement Fund within the COP27 L&D architecture, providing compensation for irreversible agricultural land loss (economic L&D) and funding community social infrastructure reconstruction (non-economic L&D); (b) investment in early warning systems calibrated to the pre-monsoon flash flood window (April–May), the single event generating the most severe economic L&D in the haor cycle; (c) development of operational non-economic L&D monitoring protocols, namely social cohesion indicators, psychological distress screening, and traditional knowledge documentation frameworks, to support L&D compensation claims under the UNFCCC, which currently lacks operational measurement tools for non-economic losses; and (d) integration of haor community representatives into Bangladesh's National Adaptation Plan processes.

5.2 Migration Governance and Social Protection

The stepwise migration pattern and 34.2% rate of informal destination housing indicate a fundamental migration governance gap. Recommendations include: (a) fast-tracking legal recognition of climate-induced internal displacement, providing IDPs with documentation for access to formal employment, housing, banking, and legal services at destination hotspot wards identified in Fig. 4; (b) extending Bangladesh's social protection schemes (VGD, VGF, EGF) to cover climate-displaced households in informal urban settlements, with priority targeting of female-headed households; and (c) developing Sylhet City Corporation reception infrastructure, namely transitional housing and formal employment matching, for haor-origin displaced households.

5.3 Anti-Trafficking Intervention: Targeting Both L&D Pathways

The ILDMV Framework's dual-pathway structure identifies two distinct and independent intervention targets. For the economic L&D pathway: emergency income support and access to formal credit in the immediate post-flood period to interrupt the financial desperation mechanism before broker recruitment; and enforcement of formal employment contracts for haor-origin workers accessing informal brick-kiln and construction labour at destination. For the non-economic L&D pathway: mandatory anti-trafficking awareness delivered during disaster response phases, before social network fragmentation reduces community protective knowledge; child marriage monitoring in Union Parishad disaster response

protocols triggered by post-flood economic distress indicators; and psychosocial support for displaced community members to address psychological vulnerability to manipulation. Both interventions must operate simultaneously, as the TVI data confirm both pathways independently predict High vulnerability.

5.4 International Dimensions

Bangladesh is a primary sending country for cross-border trafficking flows [47]. Climate displacement enlarges the economically and socially vulnerable migrant pool. Bilateral labour migration agreements should incorporate anti-trafficking due diligence and mandatory pre-departure orientation for haor-origin migrants. The Global Compact for Migration's climate migrant provisions [for objectives 2, 5, and 23] provide the multilateral framework for these measures.

6. Conclusions

This study set out to investigate the causal chain from climate-induced Loss and Damage through forced displacement to human trafficking vulnerability in Bangladesh's haor wetland communities, an empirical nexus previously theorized but never quantitatively tested using primary community-level data. By developing and applying the Integrated Loss and Damage–Migration–Vulnerability (ILD MV) Framework, this study is the first to decompose climate-induced L&D into analytically separable economic and non-economic causal streams and to trace their combined effects across four sequential tiers, namely climate parameters, loss and damage, migration drivers, and downstream vulnerability outcomes, within a unified mixed-methods design. All five hypotheses were supported, yielding a coherent, multi-method body of evidence that advances both the scholarly understanding and the policy governance of climate-induced displacement in wetland-dependent communities.

The findings carry four distinct contributions to knowledge. Theoretically, the ILDMV Framework advances multi-driver migration model [8] from driver categorization to causal mechanism identification, and extends vulnerability framework [2] by operationalizing the adaptation frontier at community level, providing the quantified evidence UNFCCC L&D negotiations require to distinguish genuine adaptation-frontier conditions from inadequately resourced adaptation. The null resilience finding reframes resilience as a post-shock recovery asset rather than a displacement-prevention mechanism, with direct implications for how climate adaptation investment is prioritized in L&D contexts. Methodologically, the integration of validated composite indices, machine learning classification, satellite-based spatial autocorrelation, and a dual-pathway ILO/UNODC-grounded Trafficking Vulnerability Indicator within a single mixed-methods design offers a replicable analytical template for climate-security research in comparable wetland, floodplain, and delta contexts globally. The TVI is a standalone methodological contribution: the first operational forced-labour-grounded vulnerability screening instrument designed for climate-displaced communities. Empirically, the study provides the first quantitative characterization of the haor basin as a climate L&D hotspot of equivalent severity to coastal and char island environments, and the first evidence-based demonstration that human trafficking vulnerability is a systematic, measurable downstream consequence of climate-induced L&D. Practically, the ILDMV Framework's dual-

pathway structure identifies separate intervention targets for economic and non-economic L&D, enabling more precisely targeted anti-trafficking programming than prior conceptual approaches could support.

The policy implications are both specific and urgent. The confirmation that haor flash flooding has crossed the adaptation frontier provides precisely the empirical evidence the COP27 L&D funding mechanism requires to justify dedicated L&D compensation over continued adaptation investment. The TVI dual-pathway structure identifies two independent intervention windows: the economic pathway demands emergency income support and formal credit access before financial desperation creates susceptibility to deceptive recruitment; the non-economic pathway demands anti-trafficking awareness delivery, community network reconstruction, and child marriage monitoring during displacement response. Fast-tracking legal recognition of climate-induced internal displacement, restoring displaced persons' access to formal employment, banking, and legal services, is the highest-impact institutional reform identified, simultaneously addressing both L&D pathways by restoring legal visibility and formal economic access.

Several limitations constrain interpretation and generalizability. The cross-sectional design cannot establish temporal causality, and recall bias may affect pre-displacement data. The TVI requires external validation in other climate-displaced communities before broad application is warranted. The geographic scope is limited to two upazilas, and findings may not generalize to other haor regions or comparable wetland systems. Non-economic L&D was measured using proxy survey items rather than validated psychosocial instruments, and TVI scores represent vulnerability risk profiles rather than confirmed exploitation outcomes.

Future research should prioritize longitudinal cohort follow-up to establish temporal causality and validate the TVI against directly observed outcomes; gender-disaggregated analysis of L&D pathway contributions to women's disproportionate vulnerability; geographic extension across Sunamganj, Netrokona, and Habiganj haor districts; integration of SSP2-4.5 and SSP5-8.5 scenarios with the CVI spatial model; cross-context ILDMV validation in coastal, char island, and drought-affected settings; and development of standardized psychosocial instruments for non-economic L&D measurement.

The haor communities of Sunamganj are an empirically documented harbinger of the systematic conversion of climate-induced Loss and Damage into forced migration and human rights harm. As climate change intensifies under all credible emissions scenarios, this process will affect hundreds of millions in wetland-dependent communities across the Global South. Addressing it demands structural policy transformation: L&D finance compensating the full breadth of economic and non-economic harm, legal recognition of climate migration, targeted social protection, and anti-trafficking enforcement embedded in climate response architecture from the outset.

Declarations

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Author Contributions

Study design, material preparation and conceptualized by Jannatun Nayem.

Fahmida Jaman, and Md Mashrup Hasan performed in data collection and formal analysis.

The first draft of the manuscript was written by Jannatun Nayem and Sumaiya Tasnim.

All authors commented and contributed on draft versions of the manuscript.

The final version of manuscripts was reviewed by Sumaiya Tasnim.

All authors read and approved the final manuscript.

Data Availability

The datasets generated and analyzed during the current study are not publicly available, because of the data sharing restriction imposed by the Shahjalal University of Science and Technology Research Centre and the confidentiality assurances given to participants, but they are available from the corresponding author on reasonable request.

‘Ethics, Consent to Participate, and Consent to Publish declarations:

Ethical Approval

The protocol of this study was approved by the SUST Research Ethics Board (SREB), Shahjalal University of Science and Technology, Sylhet-3114, Bangladesh (Ref: SREB/SPS/GEE/04 (2025), dated 25 September 2025), on the resolution of the School Ethics Review Committee (SERC) of the School of

Physical Sciences (Ref: DPS/Ethi:/115/2025 (18), dated 23 September 2025). All procedures involving human participants were performed in accordance with the ethical standards of the Declaration of Helsinki of 1964 and its later amendments, and with the research ethics guidelines of the SUST Research Ethics Board, which is the body authorized by the University Syndicate to issue research ethics certificates. The approval letter is provided as supplementary material.

Clinical Trial Number: not applicable.

Consent to Publish: Not applicable. The manuscript contains no identifiable images or personal information relating to any individual participant.

Consent from Participants: Informed consent was taken during interview through structured questionnaire. All respondent were asked about their perception consent before taking their responses, and interviews.

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Figures

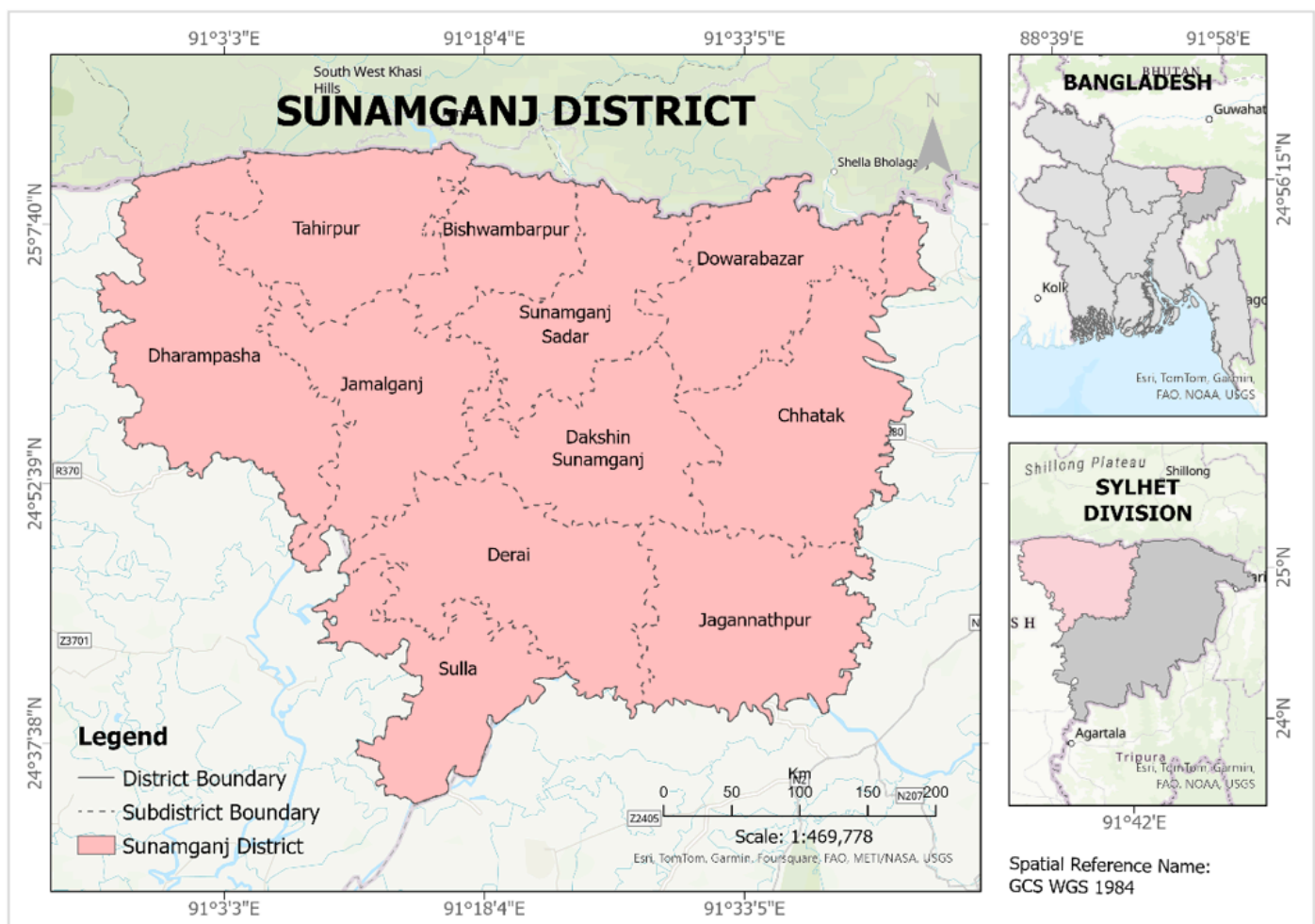


Figure 1

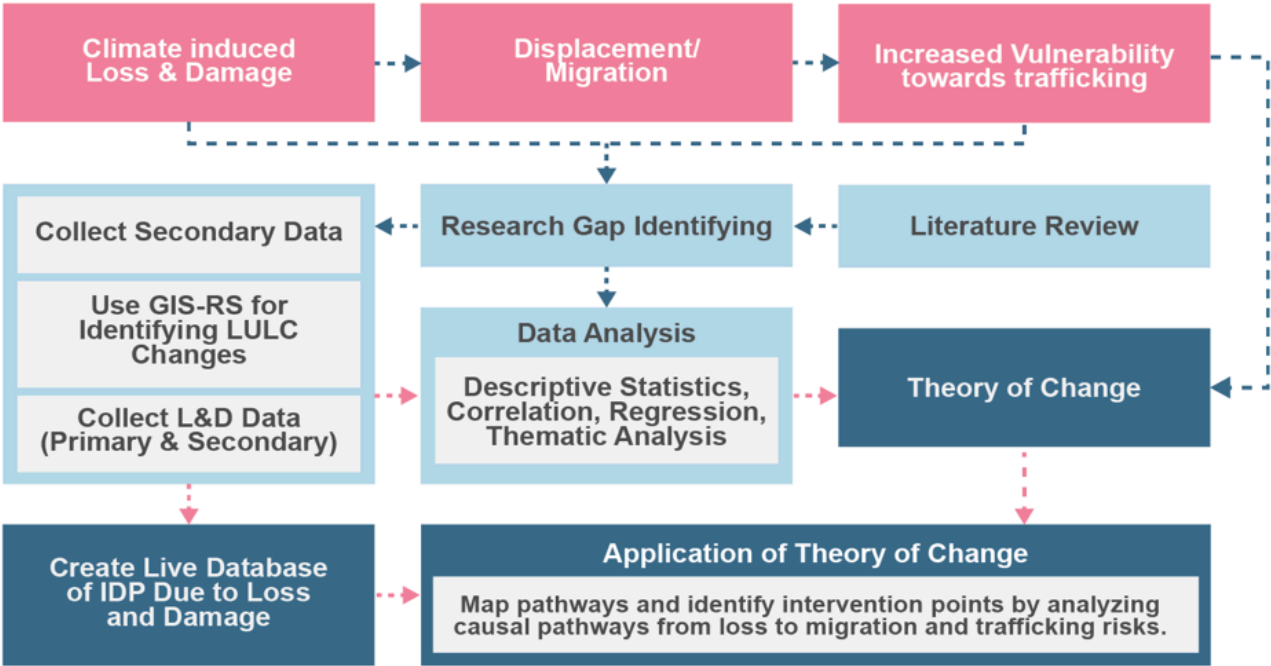


Figure 2

Framework of the Research

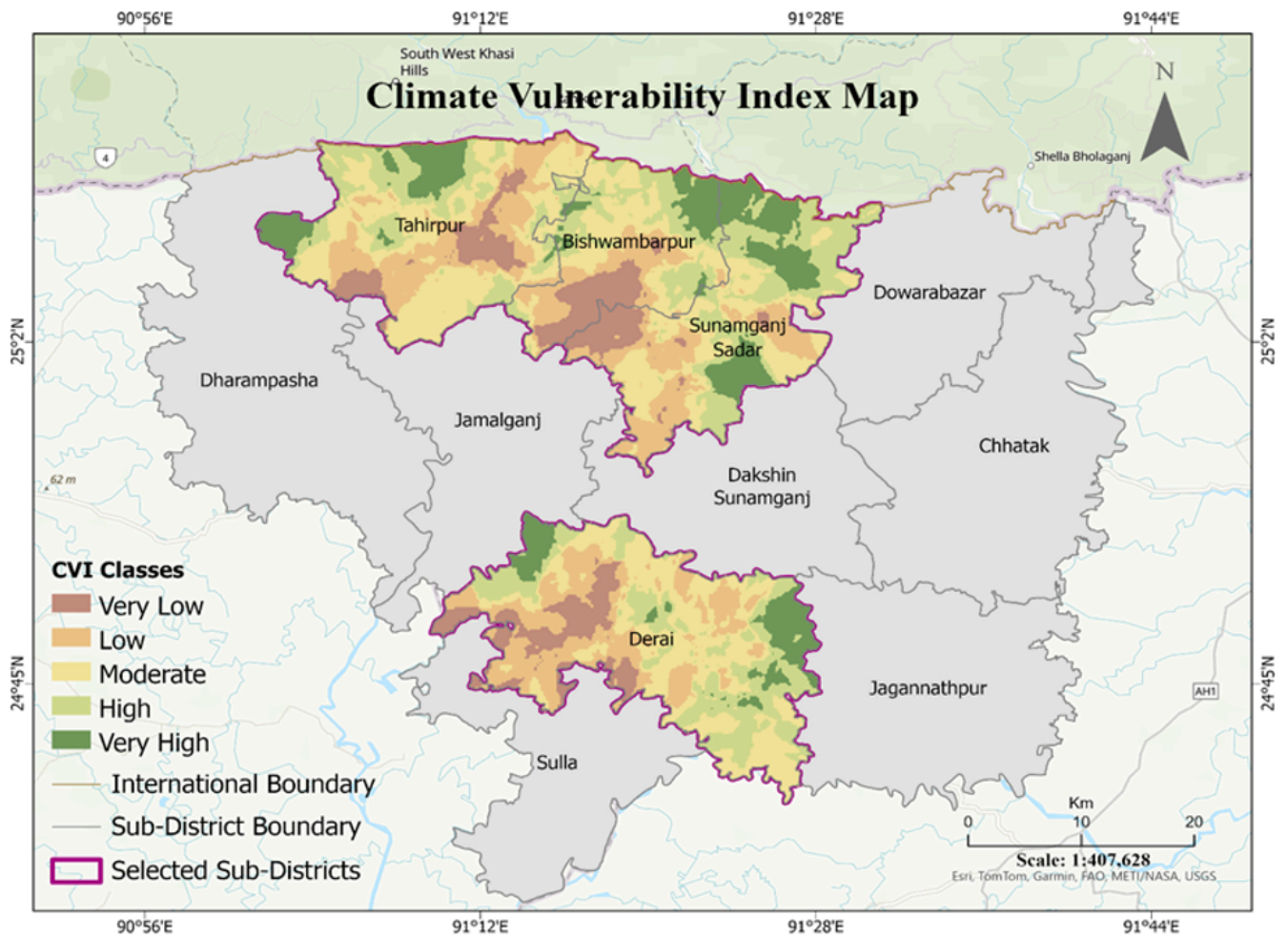


Figure 3

Map of Climate Vulnerability Index (CVI)

MIGRATION TREND MAP

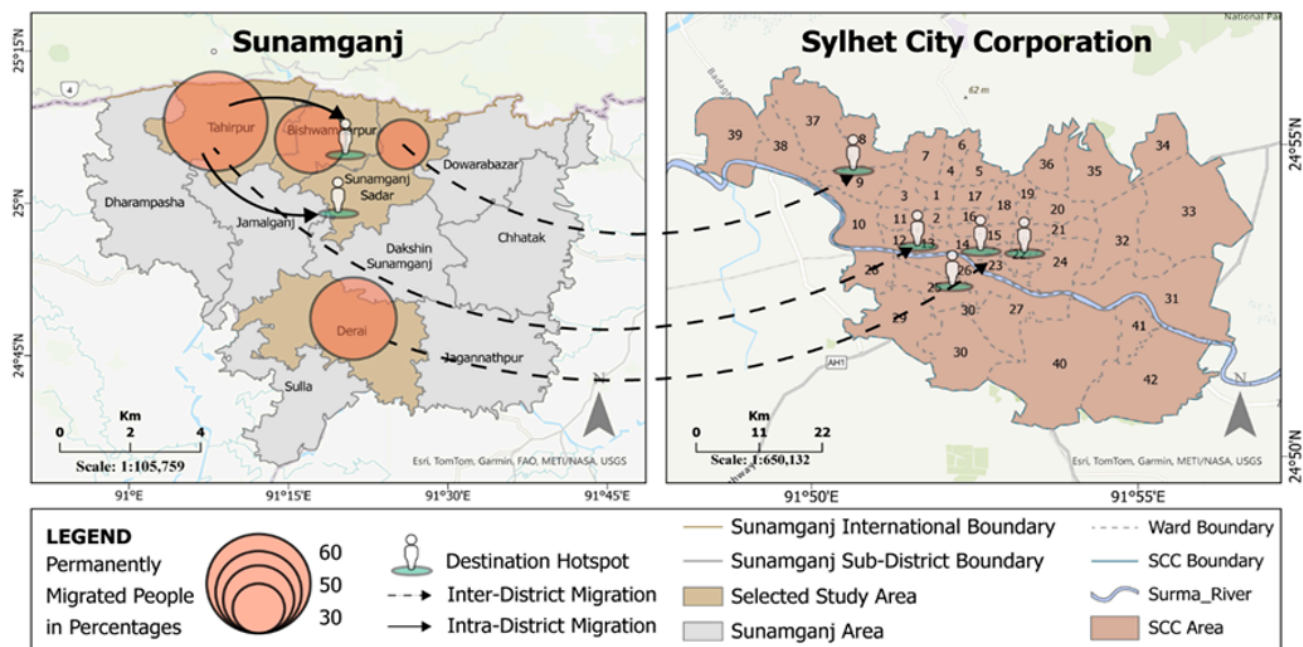


Figure 4

Migration Trend Map

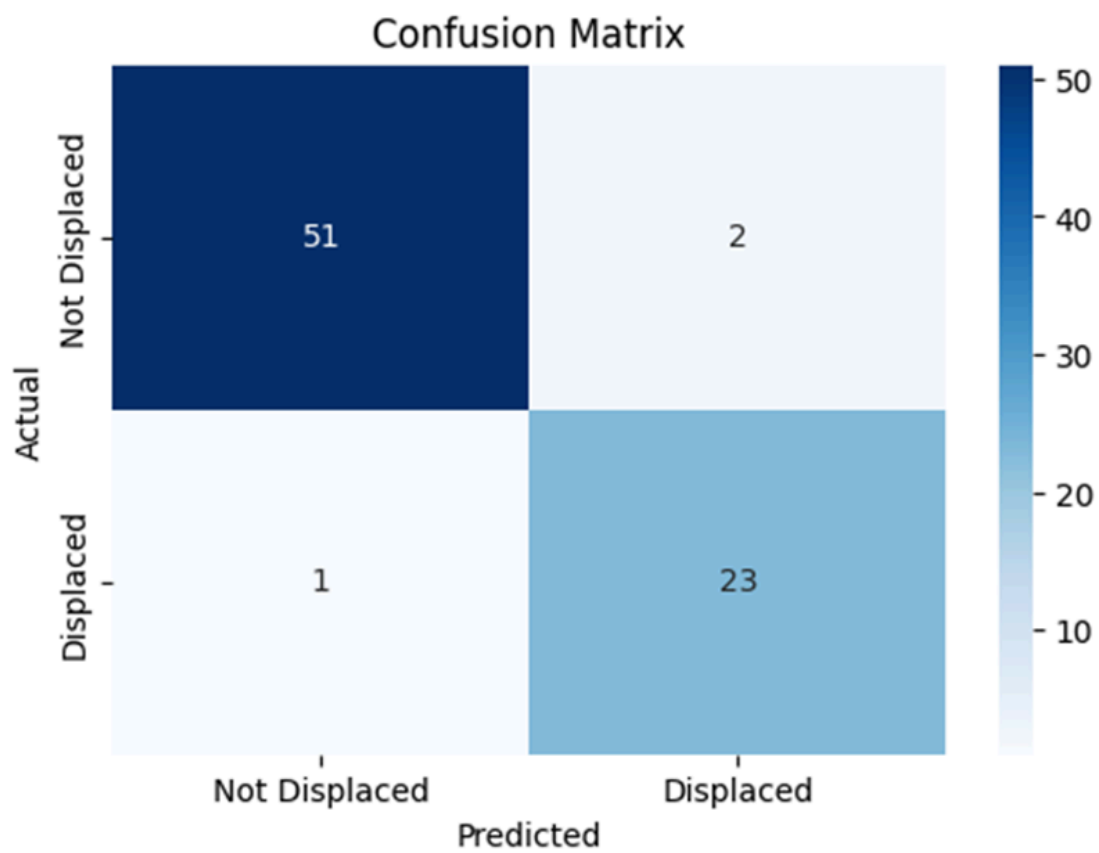


Figure 5

Confusion Matrix for Random Forest Prediction of Displacement Status

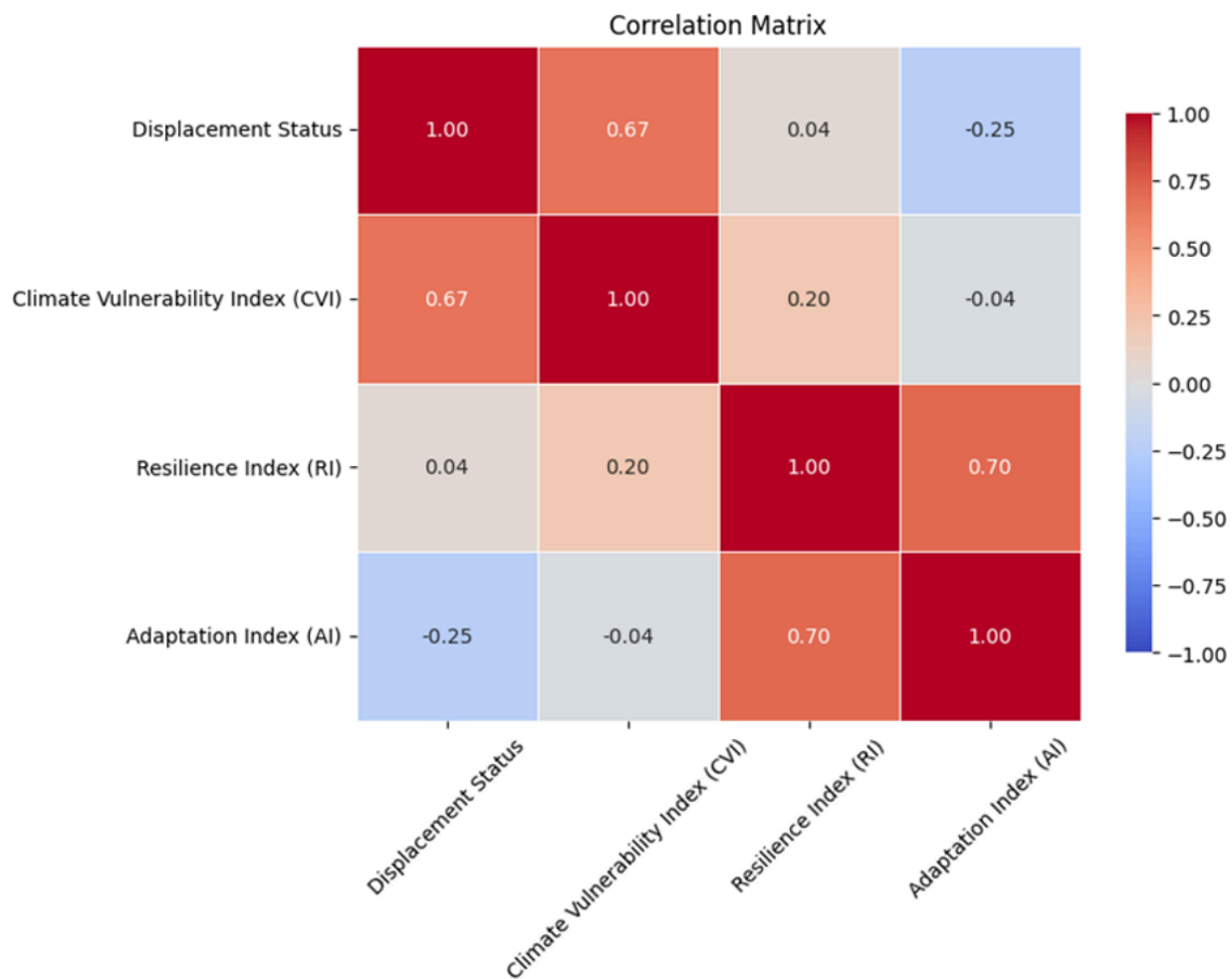


Figure 6

Pearson Correlation Matrix between Displacement Status, Climate Vulnerability Index (CVI), Resilience Index (RI), and Adaptation Index (AI)