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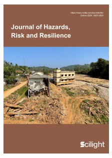

Article

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Measuring Natural Hazards Resilience of Coastal Community in Kalapara Upazila, Patuakhali, Bangladesh

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Abstract: The coastal region of Bangladesh is highly vulnerable to multiple climate-induced hazards, including cyclones, storm surges, tidal flooding, and salinity intrusion, which significantly threaten local livelihoods and ecosystems. Assessing community resilience in these hazard-prone areas is therefore essential for effective disaster risk reduction (DRR) planning. This study aimed to identify the major natural hazards affecting coastal communities and to assess community hazard resilience using the Climate Disaster Resilience Index (CDRI) framework. The study was conducted in Latachapli Union under Kalapara Upazila of Patuakhali District, Bangladesh. Primary data were collected from 120 randomly selected households through semi-structured questionnaires and also 5 Focus Group Discussion (FGD) were conducted on October–November 2025. The CDRI framework evaluates resilience across five dimensions-physical, social, economic, institutional, and natural-where indicator variables are aggregated into parameters, parameters into dimensions, and finally into an overall resilience index ranging from 1 (very low resilience) to 5 (very high resilience). The results show that the overall community resilience score is 2.26, indicating a moderate level of resilience according to the CDRI classification scale. Among the five dimensions, the natural dimension recorded the highest score (2.41), while the physical and economic dimensions had the lowest scores (2.16 each). The social and institutional resilience scores were 2.31 and 2.26, respectively. Despite the moderate overall resilience score, the community faces substantial structural and socio-economic vulnerabilities, including fragile housing conditions, limited financial capacity, and inadequate access to basic services. The findings highlight the need for targeted interventions focusing on resilient infrastructure, livelihood diversification, improved disaster governance, and community-based adaptation strategies. These insights can support policymakers, development practitioners, and disaster management agencies in designing effective programs to enhance coastal resilience and sustainable development in Bangladesh.

Keywords: coastal community; disaster resilience measurement; Climate Disaster Resilience Index (CDRI); disaster risk reduction

1. Introduction

Bangladesh is widely recognized as one of the most disaster-prone countries in the world due to its geographical and geological setting and its high exposure to climate-induced hazards [1–3]. Although the entire country is vulnerable to climate-related risks, the coastal belt is particularly exposed [4,5]. Communities in these areas are highly dependent on natural resources, which are severely affected by recurring climate-induced disasters, increasing the risk of displacement and climate migration [6,7]. Coastal hazards include both rapid-onset events such as cyclones and storm surges, and slow-onset processes such as sea-level rise, coastal subsidence, and degradation of ecosystem services [8,9].

The coastal region of Bangladesh comprises 19 districts, covering about 32% of the country's total area and hosting more than 35 million people [10]. This region is highly exposed to climate-induced hazards [11–14]. It is broadly divided into three zones: south-western, south-central, and south-eastern [15]. Among these, the south-western and south-central zones are particularly vulnerable. Hydro-meteorological hazards such as tropical cyclones, storm surges, salinity intrusion, and tidal flooding frequently disrupt livelihoods in these fragile environments [16–19]. The region's vulnerability is further intensified by its unique geomorphology, including low elevation, funnel-shaped coastline, river dynamics, heavy monsoon rainfall, sediment flow, and shallow coastal waters [20]. Patuakhali District, located in the south-central coastal zone, is among the most severely affected areas, with a long history of cyclone impacts [17,21–23].

Kalapara Upazila in Patuakhali District is highly exposed to natural hazards due to its proximity to the Bay of Bengal. Climate change has further intensified this vulnerability [19]. The upazila is located in a low-lying area surrounded by the Andharmanik, Nilganj, and Dhankhali rivers, making it highly prone to flooding and storm surges [24]. Residents frequently experience climate-induced disasters and have reported increasing sea-level rise during tidal events compared to the past [25]. High poverty levels further exacerbate vulnerability, as many households lack the resources to prepare for and recover from disasters such as cyclones, storm surges, and coastal flooding. In addition, slow-onset hazards such as salinity intrusion continue to worsen livelihood insecurity. Financial losses from recurrent disasters place a significant burden on households, many of whom have limited coping capacity [26–28]. Livelihoods are further affected as income-generating activities and productive assets are frequently disrupted. In rural areas, where poverty is widespread and access to services is limited, vulnerability is particularly high. A significant proportion of households depend on a single income source, further increasing exposure to risk [19,29]. Socio-economic conditions such as rapid population growth, poverty, limited resources, low adaptive capacity, and strong dependence on natural resources collectively increase sensitivity to climate hazards [19,30,31].

The concept of resilience has emerged as a key framework for understanding and improving disaster risk management. Post-disaster recovery is often interpreted through the lens of resilience, where resilient communities experience lower losses, recover more quickly, and maintain essential functions through adaptation and resistance [32]. Such communities are better able to absorb shocks and manage stress through behavioral, social, and institutional mechanisms [33]. As a result, measuring community resilience has become an important step in reducing disaster risk and improving preparedness.

Despite increasing attention to resilience, there is still limited consensus on how it should be defined, operationalized, and measured. Existing literature offers few standardized methodological approaches for quantifying resilience or comparing it across communities. Key challenges remain in identifying core determinants and translating them into measurable indicators. Against this background, this study conducts a case study of a coastal community in Bangladesh to assess disaster resilience across multiple dimensions, including social, economic, institutional, infrastructural, health, and environmental aspects.

Objectives of the Study

The main objective of this study was to assess the level of community disaster resilience in Latachapli Union of Kalapara Upazila, located in the south-central coastal region of Bangladesh. The specific objectives of the study were:

(a) To identify the major natural hazards affecting the community in the study area.
(b) To assess the level of community hazard resilience using the Climate Disaster Resilience Index (CDRI) across physical, social, economic, institutional, and natural dimensions.
(c) To identify potential Disaster Risk Reduction (DRR) strategies for strengthening community resilience.

2. Methodology

2.1. Study Area

The study was conducted in Latachapli Union under Kalapara Upazila of Patuakhali District (Figure 1), located in the south-central coastal region of Bangladesh. The area lies between 21°48′00″ and 21°52′30″ north latitude and 90°06′00″ and 90°12′00″ east longitude. Latachapli Union covers a total area of 15,544 acres and comprises approximately 5872 households [34]. It is bordered by the Bay of Bengal to the south, Amtali Upazila to the north, Taltoli Upazila to the west, and the Rabnabad Channel and Galachipa Upazila to the east.

The total population of the union is 25,925, of which 13,327 are male and 12,598 are female, with a literacy rate of 53.5%. The population density is approximately 412 persons per square kilometer. The main livelihood activities include agriculture, fishing, commerce, services, and wage labor [34].

Patuakhali District was selected for this study as it represents a highly hazard-prone coastal region of Bangladesh, frequently affected by cyclones, storm surges, tidal flooding, and salinity intrusion [19]. Within this district, Latachapli Union in Kalapara Upazila was purposively selected due to its direct exposure to the Bay of Bengal and its history of recurrent climate-induced disasters. This makes the area an appropriate case for examining community-level disaster resilience in a coastal hazard context. However, the study was designed as an in-depth case study; therefore, the findings should be interpreted as representative of the selected study area only and not generalized to all coastal regions of Bangladesh.

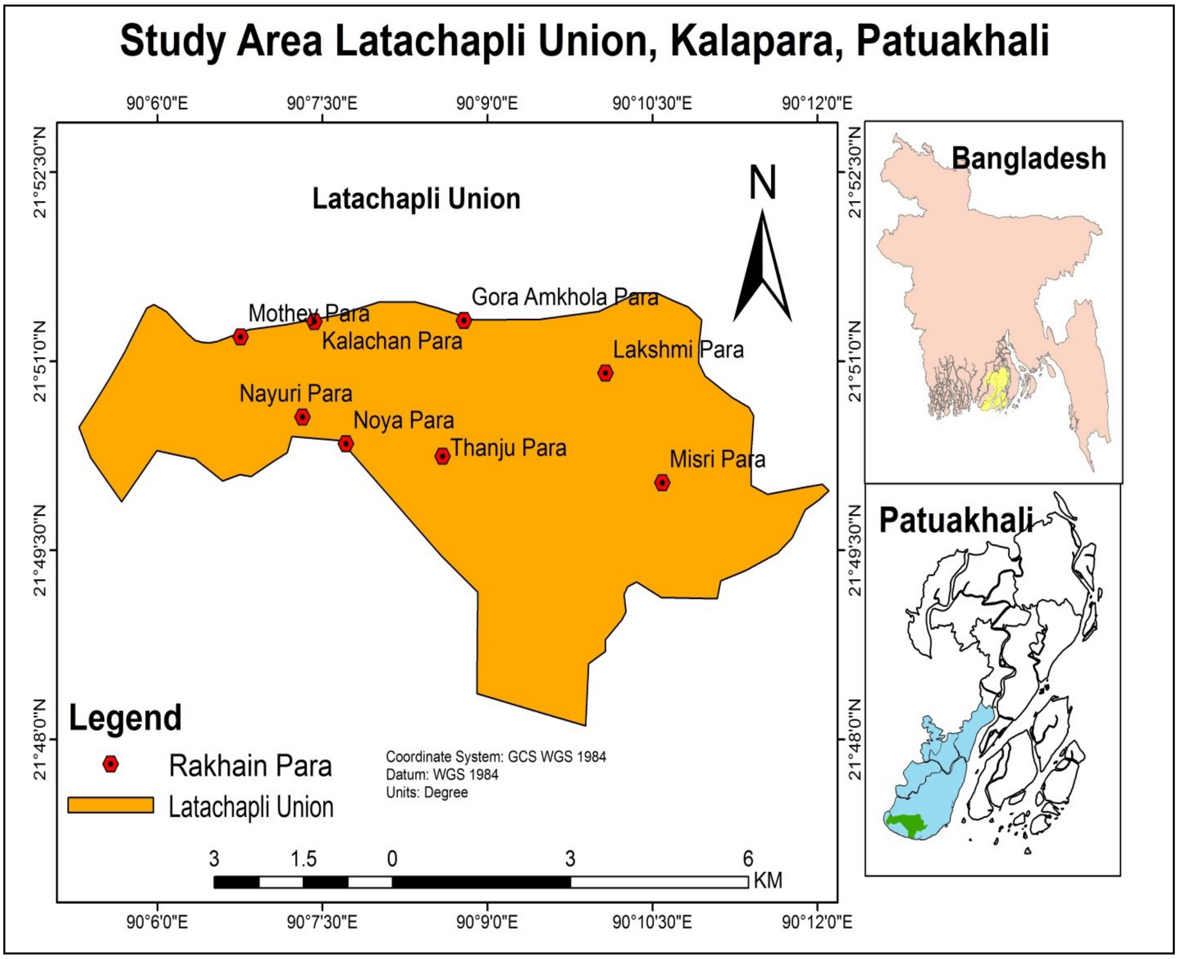

Figure 1. Location of the Study area (Latachapli Union at Kalapara, Patuakhali, Bangladesh).

2.2. Sampling Procedure and Sample Size

The study was conducted in Latachapli Union of Kalapara Upazila under Patuakhali District. A multi-stage sampling approach was employed. In the first stage, Kalapara Upazila was purposively selected from the eight upazilas of Patuakhali District due to its high exposure to coastal hazards. In the second stage, Latachapli Union was selected as the specific study area. At the final stage, households were selected using a simple random sampling technique.

The total number of households in Latachapli Union is 5872, which constituted the target population (N). The required sample size was determined using a standard sample size formula for proportions [35], assuming a 95% confidence level and a 9% margin of error. The sample size was calculated as follows:

$$\text{Sample Size, } n_0 = \frac{z^2 \times p \times q}{e^2} \quad (1)$$

where $Z = 1.96$ for a 95% confidence level, $e = 0.09$ is the margin of error, and $p = 0.5$, $q = 1 - p = 0.5$. In this study, $p = 0.5$ was assumed to represent maximum variability in the population in the absence of prior information, which yields the most conservative (largest) sample size.

$$n_0 = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.09)^2} = 118.57$$

Since the population is finite, the sample size was adjusted using the finite population correction:

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} \quad (2)$$

$$n = \frac{118.57}{1 + \frac{(118.57 - 1)}{5872}} = 116.23$$

Thus, the minimum required sample size was approximately 116 households. For practical and conservative purposes, the sample size was rounded up to 120 households.

Although a 5% margin of error is commonly used in household surveys, a 9% margin of error was considered acceptable in this study due to time, financial, and logistical constraints associated with conducting field surveys in remote coastal areas. Given the exploratory and case-study nature of the research, this level of precision was deemed sufficient to capture community-level resilience patterns.

2.3. Research Method

Assessing community resilience was challenging due to the interconnected and evolving relationships among people, society, and the environment. Although many disaster resilience frameworks existed, most highlighted similar drivers that reduced vulnerability and strengthened resilience. This study aimed to evaluate community-level disaster resilience using a multidimensional approach. It developed a method that integrated environmental, social, economic, institutional, physical, and community dimensions. Community resilience was assessed using the Climate Disaster Resilience Index (CDRI).

2.3.1. Climate Disaster Resilience Index

Climate Disaster Resilience Index (CDRI) is a planning tool developed by the Climate and Disaster Resilience Initiative of Kyoto University. CDRI measures climate disaster resilience by considering five dimensions [36]. They are physical, social, economic, institutional and natural. Each dimension has five parameters and each parameter in turn has five variables (Table 1).

Table 1. Content of Climate Disaster Resilience Index, adopted and modified from Joerin and Shaw [36].

Dimension	Key Components
Physical Systems	Power supply access; Safe water availability; Sanitation facilities; Road connectivity and transport access; Housing conditions and land planning
Social Conditions	Demographic characteristics; Health status; Education and awareness levels; Social networks and cohesion; Community readiness for disasters
Economic Capacity	Income stability; Household resources and assets; Access to finance and savings; Employment opportunities; Public financial support and subsidies
Institutional Capacity	Integration of DRR and CCA into planning; Effectiveness of crisis management systems; Information sharing and knowledge systems; Coordination among agencies and stakeholders during disasters; Governance quality
Natural Environment	Severity of hazards; Frequency of hazard events; Natural land use patterns; Environmental regulations and policies; Ecosystem benefits and services

2.3.2. Computation of Climate Disaster Resilience Index (CDRI)

The Climate Disaster Resilience Index (CDRI) was computed following the framework proposed by Joerin and Shaw (2011) [36]. The CDRI questionnaire comprises 125 variables, organized into five dimensions: physical, social, economic, institutional, and natural. Each dimension consists of five parameters, and each parameter includes five variables. Each variable was assessed using a five-point Likert scale ranging from 1 (very poor/not available) to 5 (best condition). The parameter scores were calculated using a weighted average approach:

$$\mathrm{CDRI} = \frac{\sum_{i=1}^{n} w_i\, x_i}{\sum_{i=1}^{n} w_i} \quad (3)$$

where x_i represents the score assigned to each variable and w_i denotes the corresponding weight reflecting its relative importance.

In this study, the processes of scoring and weighting were conducted separately to ensure clarity and consistency. Household respondents were responsible only for assigning scores (x_i) to each variable based on their perception of current conditions.

Weights (w_i) were assigned through Focus Group Discussions (FGDs) conducted after the household survey. During these FGDs, participants were asked to assess the relative importance of variables within each parameter using a five-point scale ranging from 1 (least important) to 5 (most important). The discussions were facilitated using a structured guide, and participants engaged in collective deliberation to reach agreement on the importance of each variable. A consensus-based weighting scheme was developed for each parameter by reconciling differing views through discussion until general agreement was achieved among participants. The final agreed weights were then averaged where necessary and compiled into a single weighting framework.

Following the calculation of parameter scores, dimension scores were obtained by averaging the five parameters within each dimension using equal weighting. The overall CDRI score for Latachapli Union was then calculated as the arithmetic mean of the five-dimension scores. The index ranges from 1 to 5, where higher values indicate greater resilience to climate-related hazards. For interpretation, the index values were categorized as follows: 1.0–2.0 = poor resilience, 2.1–3.0 = moderate resilience, 3.1–4.0 = good resilience, and 4.1–5.0 = very high resilience.

To ensure data quality and reliability, several measures were adopted. The questionnaire was pre-tested with 10 respondents to assess clarity and appropriateness of the indicators. Trained enumerators conducted face-to-face interviews and provided standardized explanations of the Likert scale to minimize variation in respondents' understanding. Potential biases inherent in perception-based data, including recall bias and social desirability bias, were considered during data collection. To enhance the robustness of findings, quantitative results were triangulated with qualitative insights from FGDs, which supported the interpretation of resilience conditions and identification of locally relevant disaster risk reduction strategies.

Although formal statistical tests of internal consistency (e.g., Cronbach's alpha) were not performed, methodological rigor was maintained through pretesting, enumerator training, and standardized data collection procedures. Nevertheless, given the perception-based nature of the assessment, some degree of subjectivity and response variability remains, which is acknowledged as a limitation of the study.

2.4. Method of Data Collection

This study employed a mixed-methods approach, integrating both quantitative and qualitative data collection techniques. Quantitative data were collected through face-to-face household interviews using a semi-structured questionnaire. The study was conducted in Kalapara Upazila of Patuakhali District, which was purposively selected due to its high exposure to coastal hazards, including cyclones, storm surges, and salinity intrusion. Within this Upazila, Latachapli Union was selected as the specific case study area for assessing community disaster resilience. Accordingly, the findings are context-specific and should be interpreted as representative of the selected study area rather than generalized to other regions.

A simple random sampling technique was applied to select households for the survey. A complete household list (N = 5872), obtained from the Latachapli Union Parishad office, served as the sampling frame. Each household was assigned a unique identification number, and 120 households were selected using a computer-generated random number procedure (e.g., MS Excel RAND function) without replacement. In cases where selected households were unavailable after two revisit attempts or declined to participate, replacement households were drawn using the same randomization procedure from the remaining sampling frame. A total of 18 households were replaced (11 due to unavailability and 7 due to refusal), resulting in 120 completed interviews. The overall nonresponse rate was approximately 15%. No systematic pattern of nonresponse was observed, although the possibility of minor nonresponse bias cannot be entirely excluded.

To complement the household survey, five Focus Group Discussions (FGDs) were conducted to generate qualitative insights and facilitate triangulation. Each FGD comprised 8–10 participants, including both men and women from diverse occupational and social groups such as farmers, fishermen, local leaders, and general community members. Participants were purposively selected to ensure representation of varied perspectives. A structured discussion guide was used to explore key themes, including disaster experiences, preparedness practices, infrastructure conditions, livelihood challenges, and potential disaster risk reduction (DRR) strategies.

In addition, secondary data were collected from academic literature, reports, and relevant online sources to support and contextualize the empirical findings.

2.5. Data Processing and Analysis Methods

Data processing and analysis were conducted systematically following the completion of field data collection. The quantitative data obtained from household surveys were checked for completeness and consistency, followed by editing, coding, and tabulation. Data entry and analysis were performed using Microsoft Excel 2010. Descriptive statistical techniques, including frequencies, percentages, and summary measures, were applied to analyze the data and present key findings related to community disaster resilience.

Qualitative data collected through Focus Group Discussions (FGDs) were analyzed using a thematic analysis approach. The discussions were reviewed and organized to identify recurring patterns and key themes, such as hazard perception, preparedness behavior, infrastructure constraints, and livelihood impacts. These themes were systematically categorized and interpreted to provide deeper insights into community experiences and perspectives.

The qualitative findings were used to complement and triangulate quantitative results, thereby enhancing the validity and interpretability of the study. In particular, the FGD insights helped explain patterns observed in the community hazard resilience indicators and supported the identification of context-specific disaster risk reduction strategies.

2.6. Limitations of the Study

Despite providing useful insights into community disaster resilience in a coastal setting, this study has several limitations. First, part of the assessment is based on respondents' perceptions, which may be influenced by personal experiences and may not fully reflect objective conditions. Second, the study is cross-sectional and captures resilience at a single point in time, without accounting for temporal changes or long-term effects of interventions.

Third, the study was conducted in Latachapli Union, which was purposively selected due to its high exposure to coastal hazards. Therefore, the findings are context-specific and should not be generalized to all coastal regions of Bangladesh. In addition, the CDRI involves indicator selection and weighting, and different weighting approaches could affect the final resilience scores.

Finally, some indicators in the natural dimension may reflect exposure or environmental conditions rather than adaptive capacity alone; therefore, results from this dimension should be interpreted with caution.

3. Results

3.1. Major Natural Disasters Impacting the Community

The study identified the major natural hazards affecting the community based on respondents' perceptions of frequency and intensity of occurrence. Both indicators were measured using a five-point Likert scale, and a composite hazard score was derived by multiplying mean frequency and intensity values (Frequency × Intensity). This provided a relative ranking of hazards in the study area.

The results (Table 2) show that coastal communities are exposed to multiple climate-related hazards, including cyclones, storm surges, salinity intrusion, tidal flooding, riverbank erosion, extreme rainfall, drought, thunderstorms, and nor'westers. Among these, salinity intrusion ranked highest, followed by tidal flooding and cyclone/storm surge events, indicating strong exposure to both slow-onset and rapid-onset hazards.

FGD findings further confirmed that salinity intrusion and tidal flooding are currently perceived as the most severe and persistent hazards in the area.

Seasonal patterns of hazard occurrence were also observed. Cyclones and storm surges are most intense during April–June and September–November, while salinity intrusion persists throughout most of the year. Tidal flooding commonly occurs during June–September, riverbank erosion increases from April–September, and drought conditions are more prominent during January–March and November–December. Nor'westers and thunderstorms mainly occur from March to August.

Table 2. The major natural hazards on the community.

Name of the Hazards	Frequency	Intensity	Frequency × Intensity	Rank
Cyclone	3	4	12	3
Storm surge	4	3	12	3
Nor'wester	1	4	4	7
Tornado	1	5	5	6
Salinity intrusion	5	5	25	1
Riverbank erosion	2	5	10	4
Thunderstorm	2	5	10	4
Tidal flooding	5	3	15	2
Extreme rainfall	3	3	9	5
Drought	3	4	12	3

Overall, the results indicate that both slow-onset hazards (e.g., salinity intrusion) and rapid-onset events (e.g., cyclones, storm surges, and flooding) jointly shape livelihood vulnerability in the study area. Salinity intrusion reduces freshwater availability and agricultural productivity, while rapid-onset disasters cause sudden losses of life, housing, infrastructure, crops, and income-generating assets. Together, these hazards significantly constrain livelihoods and reduce household coping capacity in the coastal community.

3.2. Community Resilience

3.2.1. Physical Resilience

Physical resilience in the study area was assessed based on five indicators: electricity supply, access to drinking water, sanitation facilities, road accessibility, and housing and land use. Overall, the findings indicate that the physical dimension of resilience is relatively low, reflecting underdeveloped infrastructure and limited basic service provision in Latachapli Union.

Electricity access was found to be particularly weak, with a mean score of 1.67 on the CDRI scale, indicating very low service reliability. Access to safe drinking water showed a comparatively better condition but remained moderate, with a score of 2.23, as many households depend on distant or shared water sources. Sanitation conditions were also poor, scoring 1.80, reflecting inadequate sanitation facilities and limited awareness regarding proper toilet use and maintenance (Figure 2).

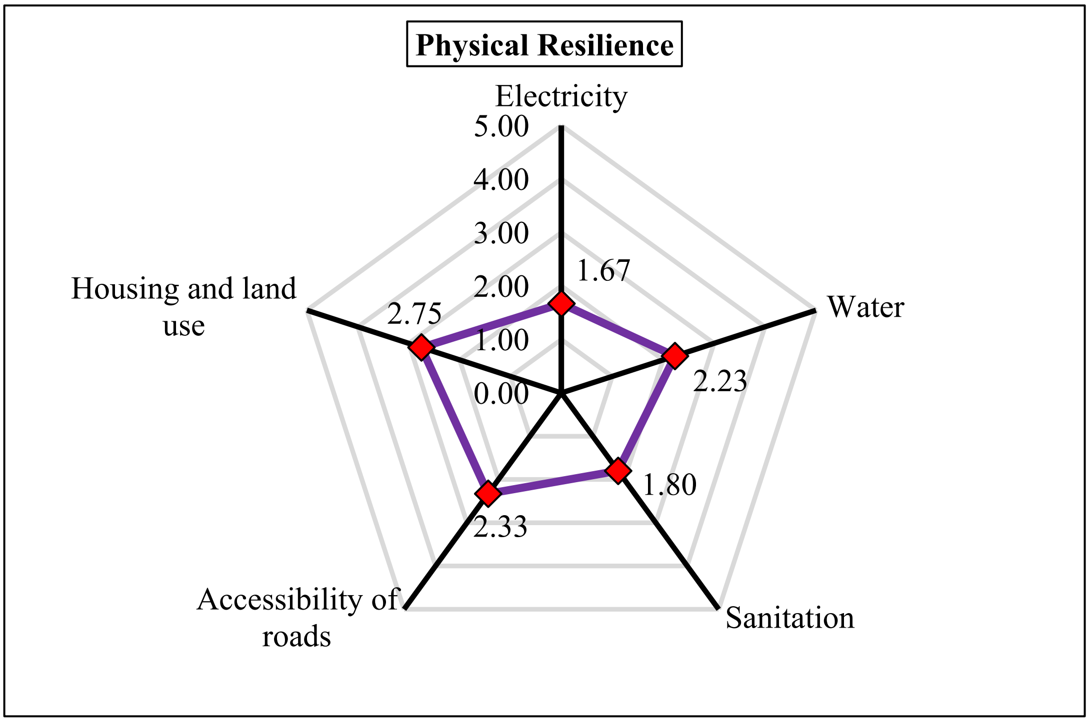

Figure 2. Physical resilience.

Road accessibility was assessed as moderately low, with a score of 2.33. The majority of roads in the area are katcha (earthen roads), which become severely disrupted during adverse weather and disaster events, limiting mobility and emergency response. Housing and land use received a relatively higher score of 2.75. Most households are katcha or semi-pucca structures constructed using temporary or semi-permanent materials such as bamboo, mud, and tin. In addition, limited awareness of the Bangladesh National Building Code contributes to structural vulnerability (Figure 2).

Overall, the composite score for physical resilience was 2.16, indicating a medium but fragile level of resilience within the CDRI framework (Figure 2). The results suggest that while some basic infrastructure exists, its quality and reliability remain insufficient to support effective disaster preparedness and response.

3.2.2. Social Resilience

Social resilience in Latachapli Union was assessed using five parameters: population, health, education and awareness, social capital, and community preparedness. The overall social resilience score was 2.31, indicating a moderate level of resilience with notable internal variation across indicators. Among the parameters, education and awareness recorded the lowest score (1.67), reflecting low literacy levels and limited disaster awareness (Figure 3). Health services also remained weak, indicating insufficient primary healthcare support. The population-related indicator scored 2.20, reflecting moderate conditions influenced by high population concentration and limited participation in organized emergency activities.

In contrast, social capital scored 2.60, suggesting the presence of community networks and support from NGOs, CBOs, and religious groups, though these are largely reactive rather than preventive. The highest score was observed in community preparedness (3.40), indicating relatively better awareness of immediate response actions, although gaps remain in evacuation planning, shelter management, and coordinated response mechanisms (Figure 2).

Overall, the findings indicate that social resilience is moderate but uneven, with relatively stronger community response capacity but weaker underlying conditions such as education, health, and preparedness systems.

The CDRI framework does not explicitly capture the differential resilience of vulnerable groups (e.g., children, older persons, and persons with disabilities), which may lead to an overestimation of actual resilience in practice. In addition, qualitative findings suggest that repeated exposure to disasters has contributed to risk normalization and partial fatalistic attitudes, which reduce the effectiveness of preparedness behavior despite awareness of warnings. Strengthening inclusive disaster education and behavior-focused preparedness programs is therefore essential for improving social resilience in the study area.

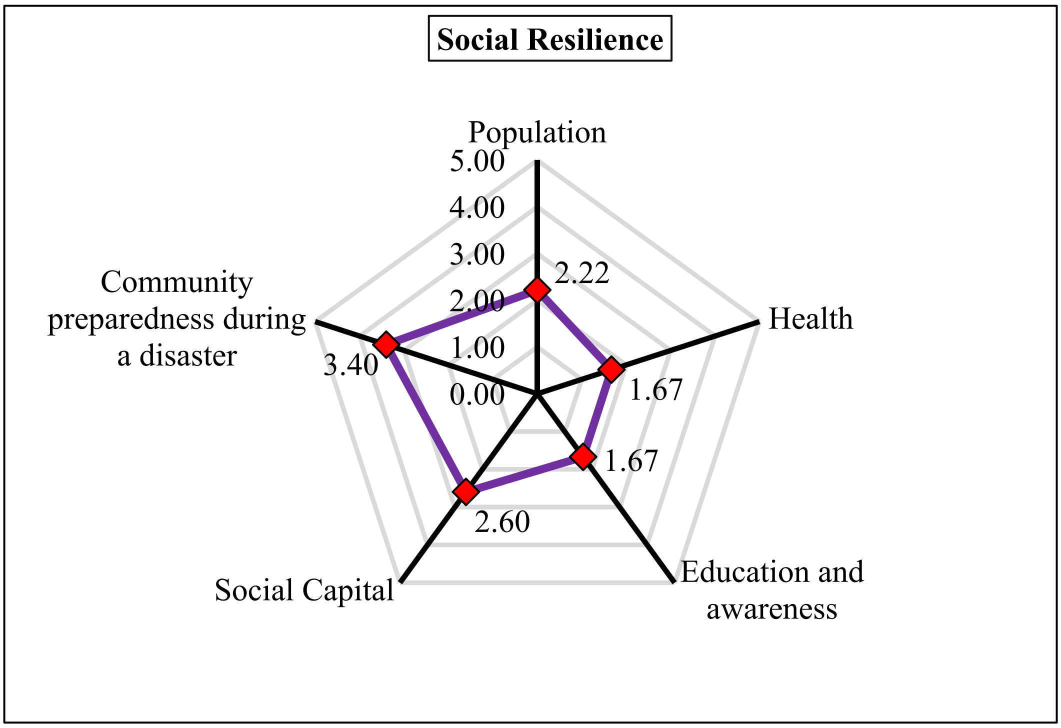

Figure 3. Social resilience.

3.2.3. Economic Resilience

Economic resilience in Latachapli Union was assessed using five parameters: income level, employment, household assets, financial savings, and budget and subsidy support. The overall economic resilience score was 2.16, indicating a moderate level of resilience within the CDRI framework. Among the indicators, income showed a relatively higher score (3.13), suggesting that a portion of households maintain stable earnings, largely from agriculture, fishing, and wage labor. Household assets scored 2.93, reflecting a moderate level of material ownership. Employment scored 2.75, indicating seasonal and informal livelihood patterns typical of coastal communities (Figure 4). In contrast, financial savings and access to budget/subsidy support recorded the lowest score (1.00), highlighting a critical weakness in formal financial resilience. Field findings indicate that although Union Parishad promotes Union Disaster Management Committees (UDMCs), there is no dedicated local budget for disaster risk reduction activities. Financial support from the Union Parishad is largely project-based and concentrated on infrastructure development rather than household-level resilience support. In addition, access to disaster-related credit facilities, savings mechanisms, and post-disaster recovery subsidies are extremely limited. As a result, households rely primarily on informal coping strategies, which reduces their capacity to recover from shocks despite relatively moderate income and asset levels (Figure 4).

Overall, the findings suggest that while income and asset ownership provide a basic economic foundation, weak financial systems and lack of institutionalized disaster support significantly constrain economic resilience. The composite score of 2.16 reflects a medium but fragile economic resilience structure in the study area (Figure 4).

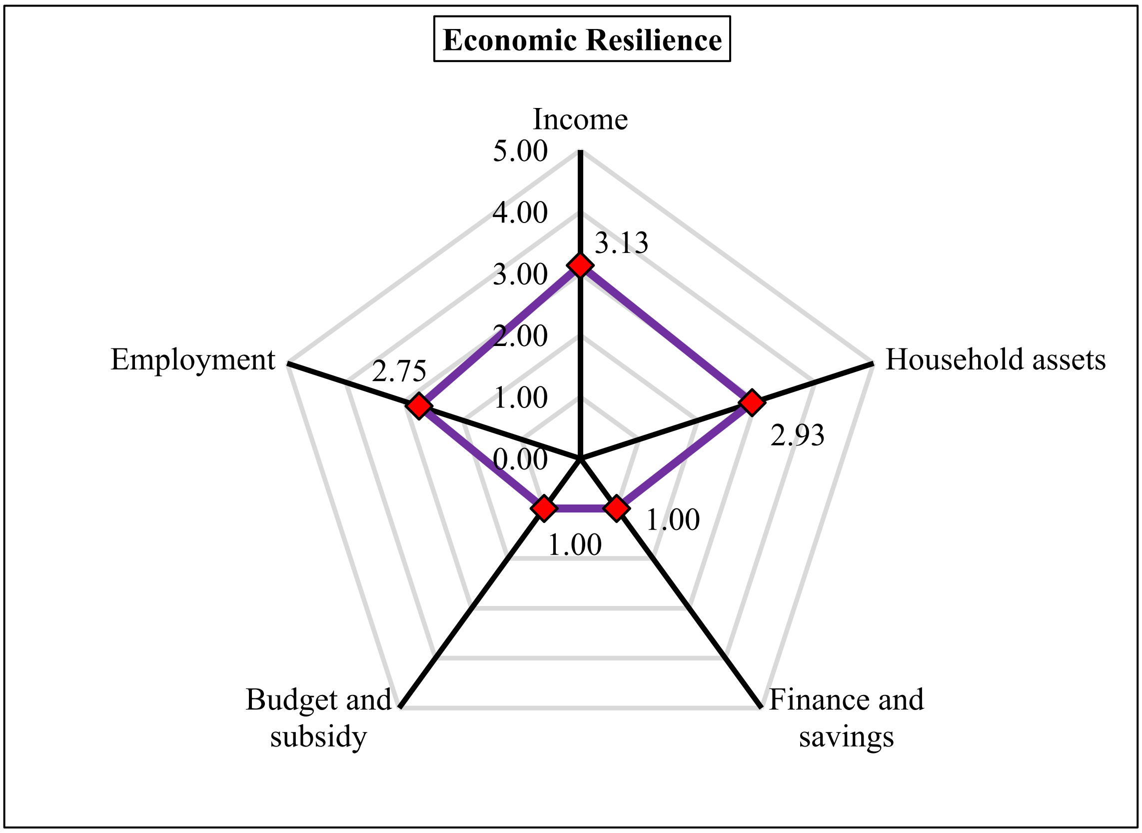

Figure 4. Economic resilience.

3.2.4. Institutional Resilience

Latachapli Union has a medium level of institutional resilience with a CDRI score of 2.26 (Figure 5). Among the parameters of this dimension, knowledge dissemination and management scored relatively higher (3.00), while mainstreaming of Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) scored 2.50 (Figure 5). Institutional resilience in this study was assessed through five parameters: mainstreaming of DRR and CCA, effectiveness of the crisis management framework, knowledge dissemination and management, institutional collaboration with other organizations and stakeholders during disasters, and good governance.

The findings suggest that while some institutional mechanisms for disaster management exist in Latachapli Union, their effectiveness remains limited. Community respondents reported that disaster training programs, disaster drills, and institutional collaboration with NGOs and private organizations are not conducted regularly.

Although a small number of NGOs operate in the union and have initiated some disaster risk reduction activities, these programs do not reach all community members due to limited coverage and various local challenges. Among the parameters, institutional collaboration with other organizations and stakeholders scored 2.20, while good governance scored 2.11 (Figure 5), indicating moderate institutional capacity in disaster management. The effectiveness of the crisis management framework received the lowest score (1.50) among the five parameters. This low score reflects limited interaction between community members and local government institutions and insufficient implementation of disaster management activities at the community level.

Overall, the institutional resilience score suggests that although some structures for disaster risk reduction exist in Latachapli Union, their implementation and outreach remains limited, which reduces the community's capacity to effectively prepare for and respond to disasters.

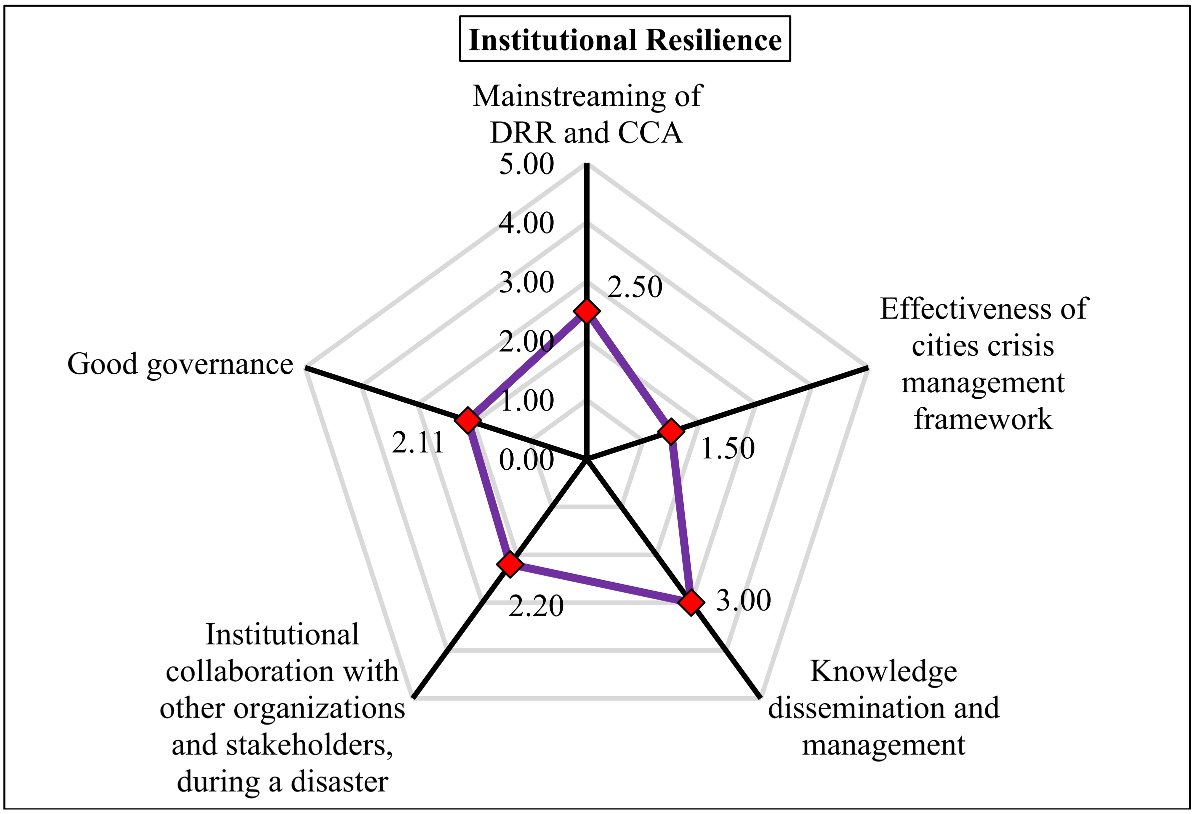

Figure 5. Institutional resilience.

3.2.5. Natural Resilience

Institutional resilience in Latachapli Union was assessed using five parameters: mainstreaming of Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA), crisis management framework effectiveness, knowledge dissemination and management, institutional collaboration, and good governance. The overall institutional resilience score was 2.26, indicating a moderate level of resilience.

Among the indicators, knowledge dissemination and management scored the highest (3.00), followed by mainstreaming of DRR and CCA (2.50), suggesting that basic awareness-building activities and policy integration exist to some extent. However, these efforts remain limited in scope and coverage (Figure 6).

In contrast, institutional collaboration scored 2.20, and good governance scored 2.11, reflecting moderate but weak institutional coordination and limited accountability mechanisms at the local level (Figure 6). The crisis management framework received the lowest score (1.50), indicating weak operational capacity during emergencies and limited interaction between community members and local government institutions. Field findings further show that although some NGOs operate in the area and implement disaster risk reduction activities, these initiatives are irregular and do not reach all households. Disaster training, drills, and coordinated preparedness programs are also limited, reducing the overall effectiveness of institutional arrangements.

Overall, the results indicate that while institutional structures for disaster management exist in Latachapli Union, their implementation, coordination, and outreach remain weak. This limits the effectiveness of disaster preparedness and response mechanisms, resulting in a moderate but underperforming institutional resilience system.

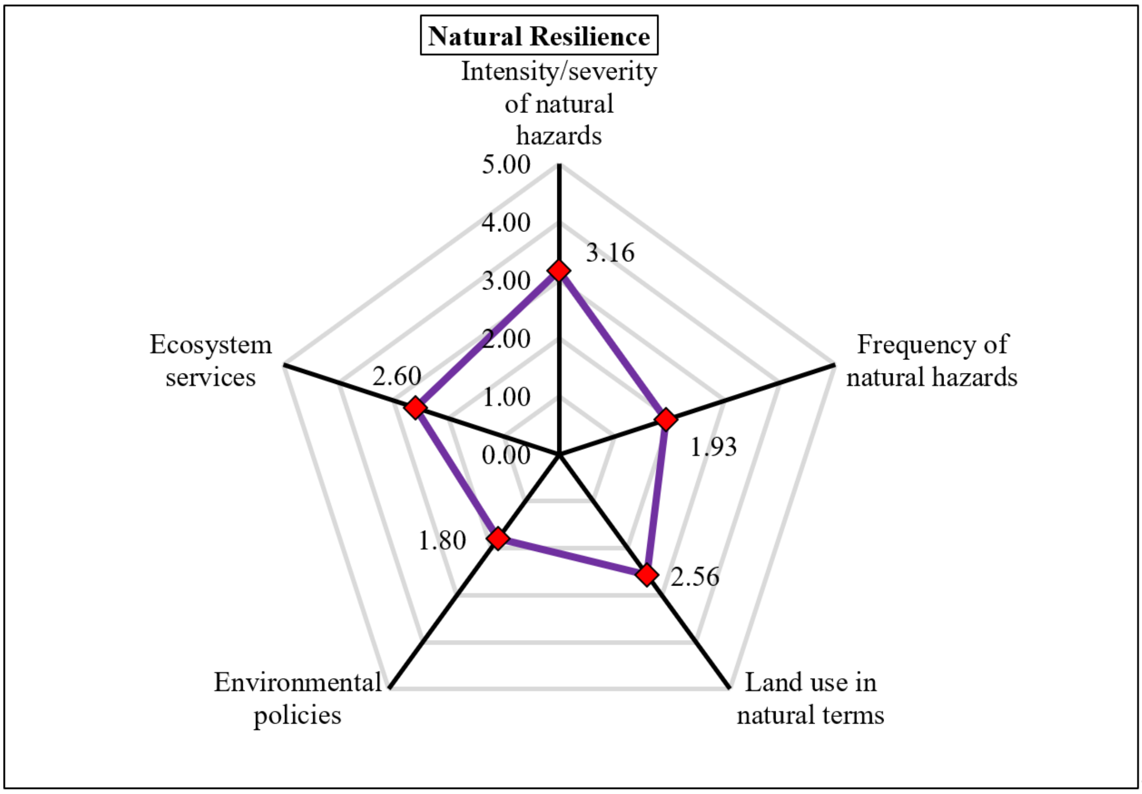

Figure 6. Natural resilience.

3.2.6. Overall Community Resilience

The overall Climate Disaster Resilience Index (CDRI) of Latachapli Union was 2.26, indicating a moderate level of community resilience. Among the five dimensions, natural resilience showed the highest score (2.41), while physical and economic resilience were the lowest, highlighting key structural and livelihood-related constraints in the study area (Figure 7).

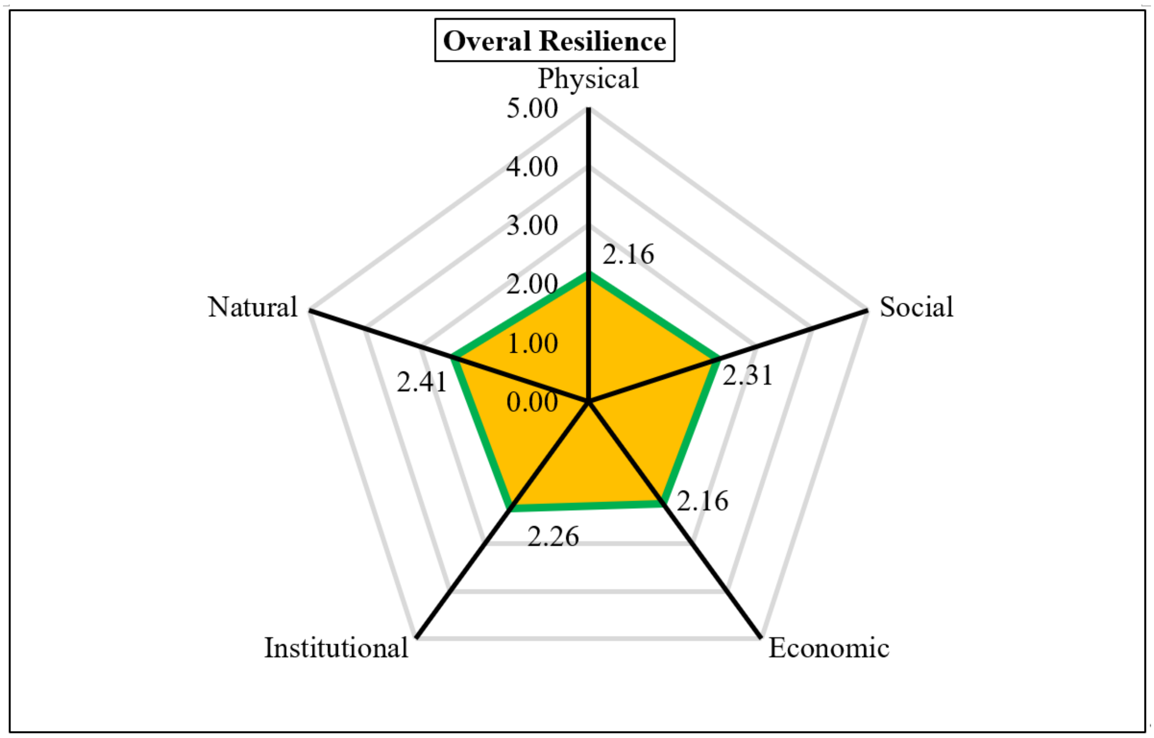

Figure 7. Overall community resilience.

Across all indicators, the highest resilience was observed in community preparedness during disasters, income levels, knowledge dissemination and management, and household asset ownership. These factors reflect relatively stronger awareness and basic coping capacity within the community.

In contrast, the lowest levels of resilience were found in DRR-related budget and subsidy support, financial savings systems, effectiveness of crisis management frameworks, health services, education and awareness, electricity supply, and sanitation facilities. These weaknesses highlight critical gaps in institutional support, basic infrastructure, and human development components of resilience.

Overall, while certain coping capacities exist at the community level, the low performance of key structural and institutional indicators limits overall resilience, keeping the CDRI value within a moderate range.

3.3. Strategies for Strengthening Community Resilience

The proposed disaster risk reduction (DRR) strategies are directly informed by the lowest-performing indicators identified in the CDRI assessment. Priority areas include improving sanitation facilities and access to safe drinking water, which respond to low sanitation scores (1.80), and expanding rural electrification to address limited electricity access (1.67). Similarly, strengthening primary healthcare services and community awareness programs is essential to address low health and education indicators (1.67). Financial resilience can be enhanced through microcredit access, savings schemes, and emergency funds, targeting critical gaps in financial savings and budget support (both 1.00). In addition, strengthening local disaster management institutions and conducting regular community-based drills are necessary to improve the weak crisis management framework (1.50).

During Focus Group Discussions (FGDs) and stakeholder consultations, respondents emphasized improvements in emergency road access, primary healthcare, disaster awareness, community participation, household preparedness, and the establishment of local emergency response teams. These priorities reflect both perceived needs and structural gaps in existing resilience systems.

A key infrastructure-related concern identified was the malfunctioning of sluice gates, which play a critical role in regulating saline and freshwater exchange for agriculture and fisheries. Participants reported that ineffective sluice gate management has increased salinity intrusion during the dry season and reduced flood control capacity during the monsoon, negatively affecting agricultural productivity. Regular maintenance and rehabilitation of sluice gates are therefore essential for improving both livelihood security and environmental resilience.

Similarly, the maintenance and strengthening of embankments emerged as a high priority. FGDs highlighted that embankment breaches have historically led to significant losses of life and property. Timely repair and sustainable maintenance of these structures are therefore critical for reducing disaster impacts in the coastal zone.

Water scarcity during the dry and winter seasons was also identified as a major challenge. Participants noted that limited freshwater availability restricts crop diversification and homestead gardening, reducing household income opportunities. The promotion of rainwater harvesting systems and small-scale water storage ponds was suggested as a practical adaptation strategy to improve water security and support Rabi crop production.

Gaps in early warning dissemination and disaster preparedness were also evident. Although warning messages are received, many community members lack access to modern communication technologies and adequate knowledge of appropriate response actions. FGDs revealed that most residents have not received formal disaster preparedness training. Expanding community-based training programs and improving access to communication technologies are therefore essential to strengthen preparedness and reduce disaster losses.

Access to cyclone shelters is further constrained by poor road connectivity, particularly in remote areas where transportation routes are damaged or inadequate. Improving road infrastructure linking settlements to shelters is critical to ensuring timely evacuation during emergencies. Similarly, limited access to healthcare facilities due to poor transportation networks further increases vulnerability during disaster events.

In addition, delays and inefficiencies in warning dissemination were identified as a major constraint, particularly among fishing communities with limited access to radios or mobile-based alerts. Strengthening multi-channel early warning systems and ensuring last-mile communication is therefore essential for effective risk reduction. Though some study in Japan suggest high-frequency ocean radar system for accurate early warning [37,38].

Economic resilience can be strengthened through improved access to affordable credit and productive investment opportunities. Currently, most loans are used for consumption or housing reconstruction rather than income-generating activities. Providing low-interest credit and promoting livelihood diversification can enhance adaptive capacity. FGDs and Union Parishad consultations also highlighted the importance of post-disaster cash assistance, which can support recovery and enable households to rebuild livelihoods more effectively.

Finally, in line with the Sendai Framework for Disaster Risk Reduction, strengthening community-based preparedness, inclusive disaster governance, and participatory early warning systems is essential for long-term resilience. Accordingly, the strategies presented in Table 3 integrate infrastructural, institutional, social, and economic interventions aimed at enhancing overall disaster resilience in Latachapli Union.

Table 3. Potential disaster risk reduction strategies.

SL. No.	Area of Risk	Potential Initiative
01	Physical	▫ Construction and maintenance of existing embankments ▫ Installation of blocks on embankment slopes ▫ Construction and proper maintenance of sluice gates ▫ Construction and maintenance of cyclone shelters ▫ Ensuring quicker and better access to cyclone shelters ▫ Excavation of new ponds for rainwater storage ▫ Raising pond embankments ▫ Raising the plinth level of houses and promoting disaster-resilient housing ▫ Improvement of communication roads
02	Social	▫ Public awareness campaigns through films, video shows, and publicity programs ▫ Raising awareness among community members on disaster impacts and preparedness benefits ▫ Awareness programs for children on natural disaster risks ▫ Training on first aid, search and rescue, and leadership ▫ Use of drama, folk songs, and public rallies for awareness generation ▫ Warning dissemination through loudspeakers, megaphones, and sirens ▫ Participatory disaster planning involving women, elderly, children, and persons with disabilities ▫ Community-based disaster preparedness workshops ▫ Training on household emergency planning ▫ Awareness campaigns using local cultural tools such as folk drama, storytelling, and community meetings
03	Economic	▫ Storage of dry food items (rice, onion, garlic, puffed rice, molasses, etc.), fuel, candles, matches, ropes, and medicines at household level ▫ Preparation of portable mud stoves for use during floods and storm surges ▫ Collection and safe storage of firewood ▫ Storage of fodder for livestock ▫ Preparation and preservation of dry fish ▫ Development of alternative livelihood options ▫ Sector-based skill training programs for self-employment development
04	Institutional	▫ Development of an effective and widely accessible early warning system ▫ Rapid dissemination of warning messages ▫ Provision of disaster preparedness training for community members ▫ Promotion of rainwater harvesting practices ▫ Provision of low-interest loans for poor households ▫ Cash incentives for post-disaster rehabilitation ▫ Mainstreaming Disaster Risk Reduction into Union Parishad development planning to strengthen resilience ▫ Establishment of community-level disaster risk reduction systems, including early warning, drills, and accountable response mechanisms ▫ Community monitoring of embankments and local infrastructure ▫ Strengthening collaboration among local government, NGOs, and community-based organizations ▫ Implementation of school-based disaster education programs
05	Natural	▫ Afforestation activities ▫ Introduction of salt-tolerant crop varieties ▫ Promotion of homestead gardening

4. Discussion

Assessing community resilience is essential for strengthening disaster risk reduction and building disaster-resilient communities. In this study, the Climate Disaster Resilience Index (CDRI) framework was applied to assess the resilience level of a coastal community in Bangladesh (Figure 8). The results indicate that Latachapli Union has an overall CDRI score of 2.26, which represents a medium level of resilience. Among the five dimensions, the natural dimension scored the highest (2.41), while the physical and economic dimensions recorded the lowest scores (2.16 each). The institutional and social dimensions scored 2.26 and 2.31, respectively.

Although the overall CDRI score of 2.26 falls within the "medium resilience" category, this classification should not be interpreted as indicating satisfactory or adequate resilience. Rather, it reflects a fragile and borderline condition. Several critical parameters including finance and savings (1.00), budget and subsidy (1.00), health (1.67), education and awareness (1.67), electricity (1.67), sanitation (1.80), and crisis management framework (1.50) remain at very low levels (Figure 8).

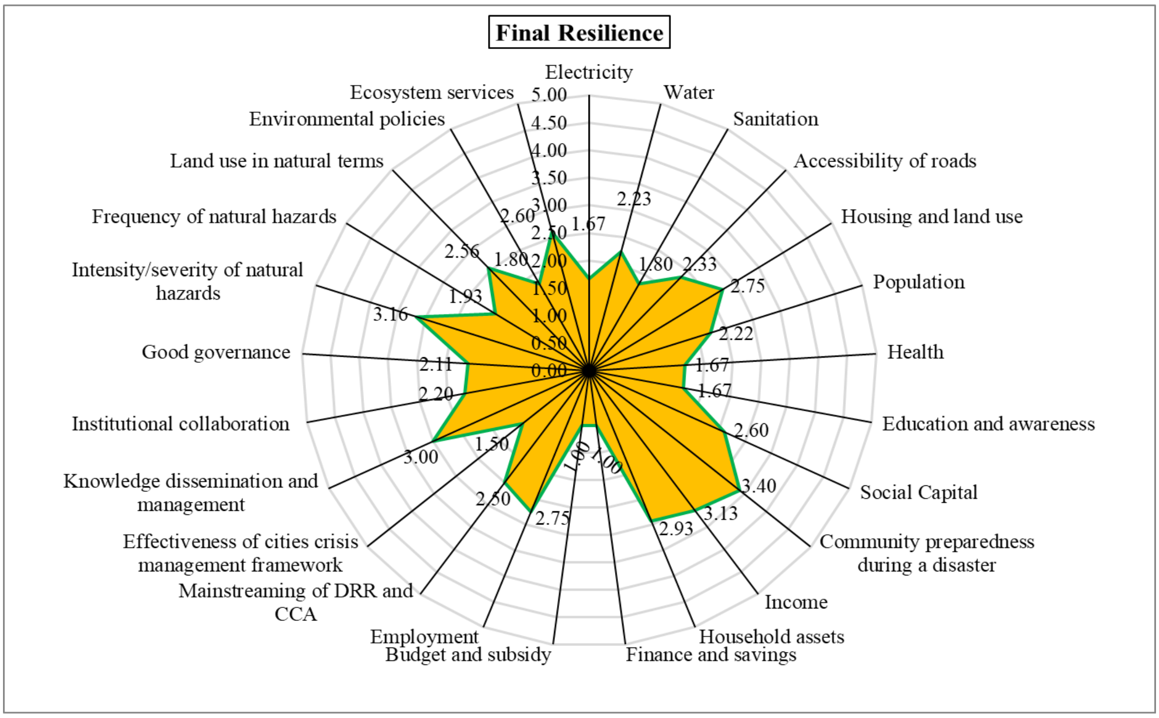

Figure 8. Final resilience.

These deficits highlight significant structural weaknesses that limit the community's capacity to prepare for, respond to, and recover from disasters. Therefore, the overall resilience status should be understood as uneven and constrained by major gaps in essential services, infrastructure, and institutional capacity.

The relatively lower scores in the physical and economic dimensions suggest that infrastructural limitations and livelihood constraints play a significant role in shaping community vulnerability in the study area. In coastal regions such as Latachapli Union, frequent exposure to cyclones, storm surges, tidal flooding, and salinity intrusion affects housing conditions, transportation networks, and access to basic services. In addition, salinity intrusion and climate variability negatively influence agricultural production and freshwater availability, which are critical components of rural livelihoods in the coastal zone. These environmental pressures, combined with limited financial resources and employment opportunities, reduce the capacity of households to invest in disaster preparedness and recovery. The institutional dimension also reflects moderate resilience, indicating that although some disaster management mechanisms exist, their implementation and outreach remain limited. Local governance structures, including the Union Disaster Management Committee (UDMC), play an important role in disaster preparedness and response; however, community respondents reported that disaster training programs, drills, and institutional collaboration with NGOs and other organizations are not conducted regularly. Strengthening coordination between local government institutions, community organizations, and development agencies could therefore enhance institutional capacity for disaster risk reduction.

The findings of this study are generally consistent with previous research applying the CDRI framework in different contexts. For example, a CDRI-based study conducted in Bangabandhu Colony under Barishal City Corporation reported medium resilience levels across all five dimensions [32]. Similar patterns of moderate resilience were also observed in studies conducted in Bangkok following the 2011 flood [39] and in coastal communities in Indonesia [40] and Korea [41]. Another study assessed the urban disaster resilience of Dhaka North City Corporation (DNCC) using the Urban Disaster Resilience Index (UDRI), where the overall UDRI score reported medium resilience levels across all five dimensions [42]. However, the dimension-specific pattern observed in Latachapli Union highlights the particular influence of coastal environmental stresses, especially salinity intrusion and climate-related hazards, on local livelihoods and infrastructure conditions.

It is important to note that this study was conducted as a case study in a single union purposively selected due to its high exposure to coastal hazards. Therefore, the findings should be interpreted as an in-depth diagnostic assessment of community resilience in Latachapli Union rather than a general representation of all coastal communities in Bangladesh. Nevertheless, the results provide useful insights into how environmental pressures, infrastructure limitations, and institutional capacity interact to influence resilience in hazard-prone coastal settings. These insights can inform targeted disaster risk reduction interventions, such as improving climate-resilient infrastructure, strengthening livelihood diversification, enhancing local disaster governance, and expanding community-based disaster preparedness programs.

5. Conclusions

This study assessed community hazard resilience in Latachapli Union, a highly climate-exposed coastal area in Bangladesh, using the Climate Disaster Resilience Index (CDRI). The findings show that the community has a moderate overall level of resilience, shaped by uneven performance across different dimensions.

The results indicate relatively stronger conditions in natural and social aspects, while physical and economic conditions remain weak. Key vulnerabilities include limited access to basic services, structurally weak housing, low levels of education and awareness, inadequate sanitation, and weak financial preparedness. These factors collectively reduce the community's capacity to effectively prepare for, respond to, and recover from climate-induced disasters.

Although the composite index suggests moderate resilience, field observations highlight persistent household-level vulnerabilities that are not fully captured by aggregated scores. This reflects the complexity of resilience in coastal contexts, where improvements in some areas may mask critical weaknesses in others.

The study identifies several priority areas for intervention, including strengthening coastal infrastructure, improving access to safe water and sanitation, expanding disaster preparedness training, enhancing early warning systems, and improving financial support mechanisms such as credit access and post-disaster assistance. Strengthening institutional coordination and mainstreaming disaster risk reduction into local planning are also essential for long-term resilience building.

The findings provide practical insights for policymakers and development actors to design targeted, context-specific interventions for enhancing disaster resilience in coastal Bangladesh.

Author Contributions

M.F: conceptualization, formal analysis, investigation, methodology, project administration, resources, software, supervision, validation, visualization, writing—review & editing; J.P.: conceptualization, data curation, formal analysis, methodology, resources, software, validation, visualization, writing—original draft, writing—review & editing; M.K.S.: conceptualization, writing—review & editing. All authors have read and agreed to the published version of the manuscript.

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Not applicable. Ethical review and approval were not applicable to this study, as it is based on empirical social science research. The research utilized non-destructive and computer-based analytical methods and did not involve any procedures that posed risks or harm to human participants or animals.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study to publish this paper.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The authors declare no conflict of interest.

Use of AI and AI-Assisted Technologies

During the preparation of this work, the authors used AI-assisted tools, including ChatGPT and Grammarly, during the preparation of this article. These tools were employed exclusively for editorial purposes, such as language polishing, grammatical refinement, and improving clarity and readability. All aspects of research design, data collection and analysis, interpretation, and core arguments are entirely our own work. After using these tools/services, all authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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