JJEES

JJEES (2026) 17 (2): 139-154
ISSN 1995-6681

Jordan Journal of Earth and Environmental Sciences

Exploring Vulnerability of Coastal Livelihoods to Climate Change in Dacope Upazila, Khulna, Bangladesh: A Multidimensional Assessment Using Indices and Analytical Approaches

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Received on 5 June 2025; Accepted on 7 October 2025

Abstract

Life, livelihood, nature, and the onset of extreme climate change continue to pose challenges for the coastal residents of Dacope Upazila in Khulna district, Bangladesh, almost daily. As Dacope is one of the key areas affected by climate change, it is highly vulnerable to these changes. Recognizing the hardships faced by the community and the need for targeted support, this study evaluates the impacts of climate change on various livelihood assets using the Livelihood Vulnerability Index (LVI), LVI-IPCC, and Livelihood Effect Index (LEI) methods. Data were collected through a semi-structured household questionnaire survey covering nine unions within Dacope Upazila, with a sample of 400 households. Secondary data was obtained from the NASA Power website. Results show that Sutarkhali Union is the most vulnerable, with an LVI score of 0.584. Both the LVI-IPCC and LEI approaches ranked Sutarkhali as the most vulnerable. This study provides insight into living conditions and the factors that make the livelihoods of Dacope Upazila's residents vulnerable to climate change. Consequently, it offers valuable information for policymakers and development practitioners to design effective interventions for building resilience in coastal communities.

Keywords: *Climate Change; Vulnerability; Livelihood; LVI; LVI-IPCC; LEI*

1. Introduction

Climate change is a major global environmental challenge of the 21st century. Man-made greenhouse gas emissions, primarily from fossil fuel combustion and land-use changes, have led to higher global temperatures, rising sea levels, and extreme weather phenomena (IPCC, 2021). The Intergovernmental Panel on Climate Change (IPCC) warns that unmitigated changes could lead to devastating impacts for ecosystems, human health, and economies worldwide. Coastal regions around the world are experiencing significant challenges due to climate change, which has exacerbated environmental vulnerabilities and intensified socio-economic risks for dependent populations (IPCC, 2014). The southwest coastal region of Bangladesh is particularly vulnerable to climate-induced hazards, including cyclones, saline intrusion, and rising sea levels, all of which threaten the livelihoods of local communities (Islam & Hasan, 2016). The region's unique geographical position exposes it to both regular monsoon flooding and increasingly frequent natural disasters, making it a hotspot for climate vulnerability and livelihood insecurity (Hossain, 2024; Rahman & Rahman, 2022; Alam et al., 2017).

In Dacope Upazila, located in Khulna District, these challenges are especially severe. This area heavily relies on agriculture, fisheries, and forest resources for livelihood, all of which are highly sensitive to environmental changes (Ahmed et al., 2019). Recent studies have highlighted that communities in Dacope face multidimensional risks, including reduced agricultural productivity, fishery losses, and declining access to potable water due to salinity intrusion, all of which contribute to an increasingly precarious livelihood situation (Kabir et al., 2024). Vulnerability in this area is further intensified by socio-economic factors, such as limited access to markets, low adaptive capacity, and inadequate infrastructural resilience, which together exacerbate the impacts of environmental hazards on local livelihoods (Ali, 2019).

Although significant research by Haque et al. (2014), Alam et al. (2017), and Hossain et al. (2024) has addressed climate vulnerability in coastal Bangladesh, there is a lack of comprehensive analysis specifically focusing on livelihood vulnerability in Dacope Upazila. A targeted assessment is essential to understand the local aspects of vulnerability and identify specific factors that undermine livelihood sustainability. While studies have looked at coastal vulnerability using general indicators (e.g., agriculture, fisheries, or infrastructure damage) (Huq et al., 2015; Alam & Rabbani, 2015), the use of indices like the LVI and LEI to capture the multi-dimensional nature of livelihood vulnerability remains rare in Bangladesh's coastal zones. The LVI, which considers factors such as income, food security, resource access, and institutional support (Hann et al., 2009), has been applied in countries like Indonesia (Riantini et al., 2024) and India (Islam et al., 2024), but its use in Dacope Upazila—where diverse livelihoods are affected by both slow and rapid climate events—is limited. Additionally,

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while the LEI, which evaluates the direct and indirect effects of climate change on livelihoods (Scoones, 2009), has been used in some parts of Bangladesh (Ali, 2018), its specific application in the South-West coastal region and comparison with the LVI are largely unexplored.

Additionally, although there have been studies examining individual livelihood vulnerabilities to climate change in the coastal belt of Bangladesh, such as those by Rahman et al. (2020) and Sarker et al. (2019), most of these studies focus on sectoral impacts-agriculture or fisheries without offering an integrated view of how climate impacts interact across sectors. The combination of LVI and LEI could provide a more comprehensive understanding of how vulnerability manifests across various dimensions of livelihoods, including economic dependency on climate-sensitive sectors, social capital, adaptive capacity, and institutional responsiveness.

This study aims to evaluate the sensitivity of a portion of Bangladesh's coastal areas to the effects of climate change on the way people live there. The Livelihood Vulnerability Index (LVI), developed by Hahn et al. (2009), is applied in this research. This index derives its primary data from housing units and utilizes certain variables. As a result, it can measure not only the extent to which households are vulnerable to natural disasters and climatic variability, but also their capacity for adaptation and sensitivity to climate change. Additionally, the computation of this index is more straightforward than that of other indices because it utilizes primary data from residences (Akram et al., 2025). The study also examines livelihood vulnerability using the LVI-IPCC approach and attempts to identify the effects of climate change on various community capitals using the Livelihood Effect Index (LEI). Through this approach, the study aims to provide policymakers and development practitioners with valuable insights to design effective interventions that build resilience in coastal communities. The study is important in various dimensions, including focused action strategies, priority-driven policy development, and the fulfillment of the goals set by the IPCC. It supports the scientific community by delivering consistent insights on climate change, while also striving to alleviate the challenges faced by the most at-risk populations.

2. Materials and Methods

2.1 Study Area Profile

These areas are essentially vulnerable to climate change impacts and natural disasters that seriously affect the livelihood of the people living there (Swarnokar et al., 2025b). Vulnerability is increased by a lack of resources and infrastructure, and by economic dependence on climate-sensitive sectors (Islam et al., 2014). Dacope (Figure 1), an upazila amidst nine upazilas of Khulna district, is essentially a coastal area; hence, it is vulnerable to climate change. This situation underlines the challenges faced by the local population. More precisely, Dacope is situated between 22°24' and 22°40' north latitudes and between 89°24' and 89°35' east longitudes. It is bounded by Batiaghata Upazila to the north, Batiaghata and Rampal Upazilas to the east, the Sundarbans to the south, and Paikgachha Upazila to the west. It has an area of 991.98 sq. km., which is divided into 9 unions; the total number of households in this Upazila is 42186 (BBS, 2022).

The selection of Dacope Upazila as a case study area will be guided by its unique geographical location and proximity to a UNESCO World Heritage Site, which adds to its cultural and environmental significance. This area is considered highly vulnerable to the impacts of global warming (Swarnokar et al., 2025b); hence, it will be an important case for studying climate-related challenges. Second, the socioeconomic conditions in the Dacope Upazila provide such privileged ground for research; it is obvious that many of those factors will be strong variables when accounting for the resilience, adaptation capability, and development needs of that region.

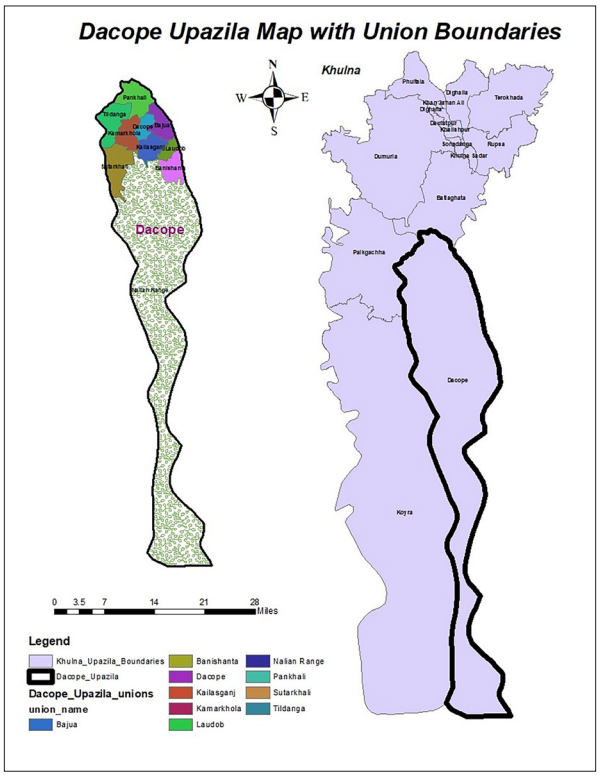

Figure 1. Map of Dacope Upazila.
Source: Hasan et al., 2025

2.2 Data Source, Sample Size, and Method of the Study

2.2.1 Data Sources

In the research study, primary data were collected through an intensive, semi-structured questionnaire survey at the household level, and approximately 400 data points were obtained from 9 unions of the Dacope Upazila, along with data sourced from the NASA Power website (maximum temperature, minimum temperature, and precipitation). The primary data were collected randomly to obtain a representative sample.

2.2.2 Sample Size for the Household Survey

According to BBS (2022), the number of households in the Dacope Upazila is 42186. Since the population size is known, the Yamane formula is suitable for determining sample size. Researchers widely utilise the Yamane formula (Kayes et al., 2025; Sultana & Hasan, 2024; Kayes et al., 2025h). The mathematical expression of the formula:

$$n = \frac{N}{1 - Ne^2} \quad (1)$$

(Yamane,1967)

In this equation, n denotes the required sample size, N is the total number of households in the study area, and e is the margin of error. For this study, taking a margin of error of 5% with a 95% confidence level, the sample was:

$$n = \frac{42186}{1 + 42186 \times (0.05)^2} = 397$$

So, the sample size was 397 for the household survey.

2.2.3 Method of vulnerability analysis

In 2009, Hahn et al. developed a framework that better represented community-level vulnerability by incorporating multiple components. This was immediately adopted by researchers the world over and remains one of the most popular among these researchers in related climate change research because of its structured approach, for example, Chowdhury et al. (2024), Phuong et al. (2022), and so many. The LVI became an instant hit, especially with many more aspiring researchers in this field, due to its composite structure. This enabled nuanced analysis across communities and regions in light of their vulnerabilities (Sullivan & Meigh, 2005). Therefore, this method is adopted in this study. Based on the conceptualization and literature review, 46 sub-components across 10 major components are included in this study. Where some major and sub-components are adopted from different research, and some are developed for this study. The ten major components are Socio-demographic profile (SDP), Livelihood strategies (LS), Social network (SN), Food security (FS), Water scarcity (WS), Income security (IS), Land (L), Physical facilities (PF), Health security (HS), and Natural disaster and climate variability (ND & CV). The data for sub-components are in different units and either have a positive or negative relationship with vulnerability. For that reason, we need to standardize the values of sub-components. There are two equations for the standardization, equation 2 is for positive sub-components and equation 3 for the negative sub-components:

$$Index\ X_{si} = \frac{X_{si} - MIN\ X_{sc}}{MAX\ X_{sc} - MIN\ X_{sc}} \quad (2)$$ *(Hahn et al.,2009)*

$$Index\ X_i = \frac{MAX\ X_{sc} - X_{si}}{MAX\ X_{sc} - MIN\ X_{sc}} \quad (3)$$ *(Adu et al.,2018;Hahn et al.,2009)*

In these two equations, Index Xsi is the standardized value of the sub-indicators, which ranges from 0 to 1; Xsi is the actual value of the sub-indicators; MAXsc is the maximum possible value for the sub-indicators; and MINsc is the minimum possible value for the sub-indicators. For example, for subcomponents taken as percentages, the maximum and minimum possible are 100 and 0, respectively.

Each of these major components consisted of several sub-components and was averaged using Equation 4. The consolidated value thus determined allowed comparison in vulnerability between the major components.

$$M_{cv} = \frac{\sum_{i=1}^{n} Index\ Xsi}{n} \quad (4)$$ *(Adu et al.,2018)*

In the equation 4, Mcv stands for the index value of major component (SDP, LS, SN, FS, WS, IS, L, PF, HS and ND & CV), "$\sum_{i=1}^{n} Index\ Xsi$" is the summation of the sub-indicators standardized value obtained by the equation 2 or 3. "n" stands for the number of sub-components under the respective major components after calculating the index value for each major component the overall LVI has been calculated by the equation 5.

$$LVI_d = \frac{W_{SDP}SDP_d + W_{LS}LS_d + W_{SN}SN_d + W_{FS}FS_d + W_{WS}WS_d + W_{IS}IS_d + W_LL_d + W_{PF}PF_d + W_{HS}HS_d + W_{ND\&CV}ND\&CV_d}{W_{SDP} + W_{LS} + W_{SN} + W_{FS} + W_{WS} + W_{IS} + W_L + W_{PF} + W_{HS} + W_{ND\&CV}} \quad (5)$$

(Hahn et al.,2009)

In this equation, LVI_d refers to the vulnerability index for study area d (Dacope), while "W ($_{SDP, LS, SN, FS, WS, IS, L, PF, HS, ND\&CV}$)" refers to the number of sub-components for relevant major components. SDP_d, LS_d, SN_d, FS_d, WS_d, IS_d, L_d, PF_d, HS_d, ND & CV_d represent the index value for each major component obtained from equation 4. For instance, the value of W_{SDP} is 6. The value from equation five is explained by the sequence of lower to higher value, from least vulnerable to most vulnerable.

2.2.4 LVI–IPCC: Based on IPCC Framework

The Intergovernmental Panel on Climate Change defines vulnerability as the susceptibility of a system to and inability of a system to cope with adverse effects of climate change, which includes the characteristics of the exposure in concerned areas and their sensitivity concerning the degree of impacts and adaptive capacity or the ability to adjust or manage impacts (IPCC, 2014). The highest magnitude of vulnerability arises from high exposure and sensitivity and from low adaptive capacity (IPCC, 2014).

Adaptive capacity contains the SDP, LS, and SN. Sensitivity contains FS, WS, IS, L, PF, and HS. And at last, exposure contains only one major component: natural disasters and climate variability. Equation (6) is the formula for calculating adaptive capacity, sensitivity, and exposure according to the IPCC framework, which is utilized in this study.

$$CF_d = \frac{\sum_{i=1}^{n} W_{cvi}\ M_{id}}{\sum_{i=1}^{n} W_{cvi}} \quad (6)$$ *(Hahn et al.,2009)*

In this equation, CF_d is the adaptive capacity, sensitivity, and exposure, W_{cvi} is the number of variables for each major component, Mid is the index value obtained by equation 4. $\sum_{i=1}^{n} W_{cvi}$ is the total sub-components under adaptive capacity, sensitivity, and exposure. After that the overall LVI – IPCC is calculated by equation 7:

$$LVI - IPCC = (Expo. - AC) * Sen. \quad (7)$$

Here, "Expo." is the exposure index, "AC" stands for the adaptive capacity index, and "Sen." means the sensitivity index. On the other hand, there exists a record by (Sultana & Hasan, 2024) that IPCC-VI uses the scale ranging from -1 to +1 where -1 stands as the least susceptible position, in other words when the adaptive capacity is more than the exposure, 0 for the moderately vulnerable and 1 stands for the severely vulnerable when the exposure would be much higher than the adaptive capacity.

2.2.5 Livelihood Effect Index (LEI)

The Livelihood Effect Index (LEI) is a composite indicator designed to assess the impacts of external factors. It captures various dimensions of livelihood security, including income, access to resources, employment, and quality of life (Scoones, 1998; Ellis, 2000). Likewise, LVI – IPCC, LEI are categorized in Human capital, Natural capital, Social capital, Financial capital and Physical capital.

The normalized values by equations 2 and 3, the capital values are obtained by equation 6 mentioned before. The LEI calculated by Equation 8:

$$LEI = \frac{\sum_{i=1}^{n} \text{capital value}}{\sum_{i=1}^{n} W_{sc}} \quad (8)$$

In this equation, LEI is the livelihood effect index and $\sum_{i=1}^{n} W_{sc}$ is the number of total sub-indicators. Figure 2 represents the methodological flowchart that followed during this research. The research started with the conceptualization of the topic climate change and vulnerability. Then, with proper literature review and standard survey tools, this study collects the required data from secondary sources and at the household level. The findings are validated with proper discussion.

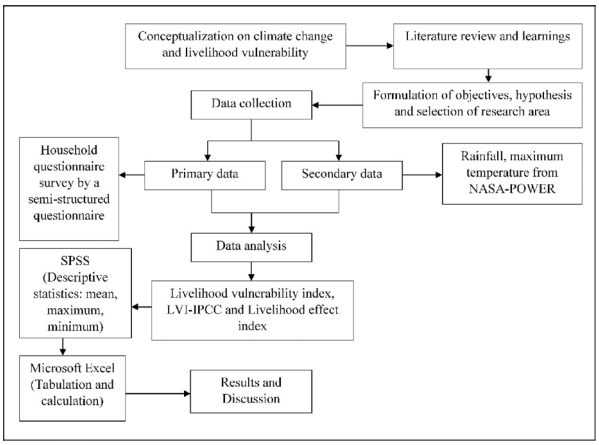

Figure 2. Methodological flowchart of the research

3. Results

3.1 Comparison of major Components of LVI among unions

According to the previous studies of Hahn et al. (2009; Nguyen & Leisz, 2021; Tewari et al., 2014; Hoang et al., 2020; Rahman, 2014; Piya et al., 2012; Thorpe et al., 2007; Toufique et al., 2013; Shah et al., 2013; Koirala et al., 2015). A total of 46 sub-components are selected under ten major components for calculating LVI.

3.1.1 Socio-demographic Profile (SDP):

Vulnerability is judged from aspects of the major and sub-components, as depicted in Table 1, across the nine unions. The highest values are an indication of more vulnerabilities, whereas lower values indicate less vulnerability. As indicated in Table 1, Sutarkhali is the most vulnerable area concerning the socio-demographic profile, with an LVI high value of 0.56. In contrast, Tildanga has the lowest vulnerability, with an LVI of 0.30. The second position for each is held by Bajua and Banishanta, with an LVI of 0.45, followed by Laudobe with an LVI of 0.44.

Sutarkhali has the highest values for four of the six sub-components: dependency ratio (0.43), presence of disabled members in the household (0.14), primary education level of the household head (0.59), and households with at least one female member lacking functional education (0.76). On the other hand, Tildanga has the lowest values in three sub-components: dependency ratio (0.14), households with girl children (0.26), and single-headed households (0.62).

Dacope, the Upazila town, and the surrounding areas exhibit average to low vulnerability, as indicated by moderate to low LVI values. These areas benefit from better employment opportunities, education, and communication infrastructure, resulting in lower levels of vulnerability.

3.1.2 Livelihood Strategies (LS):

Coming to the LS, Sutarkhali comes out to be the most vulnerable area, having an LVI value of 0.73. The unions of Dacope and Bajua have values quite near to the previous one, that is, 0.71 and 0.70, respectively. On the other hand, Tildanga shows the lowest vulnerability in livelihood strategies, with an LVI of 0.58.

The Livelihood Strategies component consists of four sub-components; three of them indicate a negative relationship with vulnerability. Therefore, in the case of higher values of these sub-indicators, it will reflect lower vulnerability. Thus, the lesser the value, the more vulnerable. Nevertheless, a higher general value of LVI signals greater vulnerability. In one such case, a household has a member working outside the area, providing a regular source of income and reducing its vulnerability.

The union with the lowest LVI is Laudobe, at 0.40, indicating it is the most vulnerable in livelihood diversification. The burden of loans is positively related to vulnerability; this means that a higher loan burden increases households' vulnerability . In this respect, Sutarkhali has the highest value, 0.81, making it the most vulnerable in terms of loan burdens, as nearly every household is indebted there (Table 1).

Agricultural livelihood diversification and non-agricultural livelihood diversification also reduce vulnerability. The lowest value, 0.71, belongs to Laudobe, which is the most vulnerable area, while Banishanta, Pankhali, and Dacope have the highest values at 0.81, which indicate that vulnerability is relatively low. It is because agricultural activities are less dominant in these areas, contributing to higher indices in non-agricultural livelihoods.

3.1.3 Social Network (SN):

The SN component is one of the primary determinants for vulnerability, comprising four sub-components, all of which are negatively associated with the vulnerability phenomenon. In this respect, Laudobe Union emerges as the most vulnerable, with an LVI value of 0.63, the highest for the areas, which indicates that, in terms of social networks, the vulnerability is marked. By contrast, Dacope Union has the lowest value, 0.50, indicating the least vulnerable area in this regard. Beyond that, LVI values for Koilashganj, Tildanga, Pankhali, and Sutarkhali are 0.62, 0.57, 0.56, and 0.55, respectively, indicating medium-to-high vulnerability.

Support from the neighbors, NGOs, and the government reduces vulnerability; hence, the relation is negative with this sub-component. As for the ratio of help provided to help received, Sutarkhali Union shows the lowest value of 0.63, indicating the highest vulnerability, while Pankhali Union shows a higher value, indicating a lower vulnerability.

It further reduces vulnerability, as membership in microcredit organizations offers small loans to help a household cope with adverse impacts of natural disasters. Reports show that Sutarkhali and Bajua unions have the highest membership value of 0.86, which indicates low vulnerability. On the other hand, Laudobe Union has reported the least value of 0.55, which reflects higher vulnerability with regard to access to micro-credit support.

Table 1. Major components, variables (sub-components), and average index values of nine Unions and their LVI values.

Sub- Components	Bajua	Banishanta	Laudobe	Pankhali	Dacope	Koilashganj	Kamarkhola	Sutarkhali	Tildanga	Major Component	Bajua	Banishanta	Laudobe	Pankhali	Dacope	Koilashganj	Kamarkhola	Sutarkhali	Tildanga
Avg. Number of Dependent members	0.29	0.29	0.14	0.29	0.14	0.14	0.29	0.43	0.14	Socio-Demographic Profile (SDP)	0.45	0.45	0.44	0.41	0.36	0.37	0.38	0.56	0.30
% of households have disabled persons	0.05	0.02	0.05	0.05	0.03	0.05	0.07	0.14	0.05										
% of households with no Primary Education of the household head	0.48	0.52	0.14	0.37	0.30	0.36	0.28	0.59	0.26										
% HH has a girl child aged 10-15 years	0.33	0.29	0.62	0.40	0.39	0.38	0.48	0.48	0.26										
% of single-headed elderly family	0.99	0.99	1.00	0.79	0.98	0.72	0.65	0.98	0.62										
% of HH having at least one female member with no functional education	0.55	0.59	0.67	0.56	0.32	0.55	0.52	0.76	0.48										
% of HH having at least 1 family member working outside the community	0.90	0.90	0.40	0.81	0.82	0.57	0.63	0.67	0.64	Livelihood Strategies (LS)	0.70	0.68	0.62	0.65	0.71	0.62	0.60	0.73	0.58
% of HH with burden of loan in the last 5 years	0.74	0.72	0.67	0.68	0.59	0.72	0.59	0.81	0.62										
Average agricultural and non-agricultural livelihood diversification	0.78	0.81	0.71	0.81	0.81	0.78	0.78	0.80	0.73										
% of HH changed sowing and cropping schedule	0.38	0.28	0.71	0.32	0.63	0.4	0.41	0.64	0.31										
Help received: Help provided	0.79	0.72	0.77	0.89	0.80	0.82	0.82	0.63	0.84	Social Network (SN)	0.53	0.52	0.63	0.56	0.50	0.62	0.51	0.55	0.57
% of households that did not apply to their local government for assistance in the past 12 months	0.24	0.17	0.36	0.19	0.27	0.19	0.17	0.29	0.4										
% of HH having no membership in Local Committee/ Samiti	0.07	0.36	0.62	0.33	0.07	0.55	0.28	0.24	0.38										
% of HH having no membership in the micro-credit organization	0.86	0.81	0.55	0.70	0.66	0.78	0.61	0.86	0.57										
% of HH having no access to at least a single social network platform	0.71	0.55	0.83	0.70	0.7	0.74	0.67	0.74	0.67										
Avg. no. of months households struggle to find food	0.42	0.42	0.17	0.42	0.67	0.25	0.42	0.50	0.17	Food Security (FS)	0.68	0.69	0.61	0.76	0.84	0.55	0.63	0.71	0.53
Household with primary irrigation source	0.23	0.14	0.72	0.5	0.95	0.07	0.3	0.37	0.31										
% of the HH with no ability to save harvested crops to eat during a different time of year	0.87	0.96	0.59	0.92	0.65	0.54	0.69	0.79	0.53										
% of HH having no ability to save seeds to grow the next year	1	0.96	0.72	0.96	0.95	0.89	0.83	0.95	0.72										
% of HH having no access to free seeds and fertilizer	0.87	0.96	0.86	1	1	1	0.9	0.95	0.91										
% of HH having no easy access of safe drinking water	1.00	1.00	0.57	0.98	0.96	1.00	1.00	0.98	0.53	Water Scarcity (WS)	0.42	0.39	0.38	0.53	0.44	0.52	0.49	0.39	0.35
Avg. distance to source of natural water	0.05	0.10	0.05	0.10	0.05	0.10	0.20	0.10	0.10										
% of HH experienced scarcity of water	0.60	0.36	0.83	0.88	0.66	0.86	0.65	0.43	0.71										
Avg. money spent by the households to get water	0.04	0.09	0.08	0.16	0.09	0.10	0.13	0.06	0.05										

Continuing from Table 1. Major components, variables (sub-components), and average index values of nine Unions and their LVI values.

Sub- Components	Bajua	Banishanta	Laudobe	Pankhali	Dacope	Koilashganj	Kamarkhola	Sutarkhali	Tildanga	Major Component	Bajua	Banishanta	Laudobe	Pankhali	Dacope	Koilashganj	Kamarkhola	Sutarkhali	Tildanga
% of HH members have loss of income	0.95	1	0.62	0.86	0.98	0.71	0.74	1	0.71	Income Security (IS)	0.46	0.61	0.36	0.51	0.53	0.43	0.53	0.62	0.36
% of HH having income lower than 12000 taka per month	0.41	0.62	0.45	0.35	0.55	0.41	0.72	0.57	0.33										
% of HH loss Income loss for Robbery	0.02	0.21	0	0.33	0.07	0.17	0.13	0.29	0.05										
% of landless HH	0.38	0.33	0.38	0.28	0.36	0.36	0.3	0.5	0.26	Land (L)	0.48	0.53	0.47	0.50	0.51	0.53	0.54	0.57	0.55
% HHs reporting land degradation by climate -related extremes during past 20 years	0.91	1	0.6	0.84	0.93	0.93	0.94	1	0.88										
% of HHs with small land (0.1–0.5 ha)	0.14	0.26	0.43	0.37	0.25	0.29	0.37	0.21	0.52										
% of HH having no Solar energy as a source of electricity	0.19	0.21	0.45	0.33	0.25	0.33	0.37	0.29	0.31	Physical Facilities (PF)	0.24	0.23	0.24	0.19	0.16	0.25	0.20	0.36	0.19
Avg. time to reach nearest primary school	0.32	0.28	0.08	0.03	0.02	0.21	0.04	0.61	0.06										
Avg. time to reach nearest vehicle station	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19										
% of HH having at least one member getting illness due to disaster	0.79	0.98	0.17	0.37	0.05	0.31	0.57	1.00	0.29	Health Services (HS)	0.40	0.48	0.15	0.31	0.26	0.28	0.41	0.55	0.29
Avg. Number of chronically ill persons	0.60	0.98	0.33	0.42	0.36	0.50	0.54	1.00	0.57										
Avg. time needed to reach nearest health facility	0.31	0.31	0.12	0.20	0.52	0.32	0.45	0.22	0.27										
Avg. cost of reaching health facility	0.14	0.12	0.03	0.08	0.16	0.09	0.10	0.10	0.06										
% HH did not immunize their children	0.02	0.00	0.05	0.02	0.09	0.00	0.02	0.02	0.05										
% HH did not receive training on health facilities	0.55	0.50	0.17	0.79	0.39	0.45	0.80	0.95	0.50										
Avg. no. of natural disasters during the last 10 years	0.38	0.48	0.41	0.66	0.66	0.55	0.66	0.86	0.41	Natural Disaster and Climate Variability (ND & CV)	0.61	0.62	0.36	0.58	0.38	0.45	0.54	0.68	0.44
% HH that did not receive a warning about the pending natural disasters	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00										
% of HH reported damaged or Loss of fish in crops, golphata, honey etc.	1.00	1.00	0.53	0.86	0.21	0.76	0.74	1.00	0.53										
% HH reported livestock damaged	1.00	1.00	0.38	0.84	0.82	0.76	0.78	1.00	0.74										
% of HH reported damaged or Loss of fish in ponds/gher	1.00	1.00	0.31	0.84	0.07	0.19	0.72	1	0.55										
Mean standard deviation (MSD) of average maximum temperature by month	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49										
Mean standard deviation (MSD) of average precipitation by month	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38	0.38										
LVI	0.509	0.529	0.422	0.507	0.463	0.456	0.487	0.584	0.417										

Source: Authors' calculation, 2026

3.1.4 Food Security (FS):

The fifth key component is food security, which consists of five sub-components that all show a positive relation to vulnerability; the higher the values, the greater the vulnerability. Based on the overall LVI, Dacope was identified as the most vulnerable, with an LVI score of 0.84, followed by Pankhali (0.76) and Sutarkhali (0.71) (Table 1). Tildanga thus has the lowest vulnerability to food security with an LVI value of 0.53.

Field observations show that most unions, excepting a few, are plagued by food security, and Dacope is the worst in terms of acute food scarcity, striving for food roughly 6 to 8 months of the year. The LVI for food scarcity is highest in Dacope, at 0.67, making it the most vulnerable to food scarcity. Sutarkhali, though the second most vulnerable area, has a value of 0.50, where households again have better access to natural resources than the average. Correspondingly, the bottom position is held by Laudobe and Tildanga, each with a value of 0.17, which means food struggle prevails in these areas for a few months of the year.

Savings from crops and access to free fertilizers will reduce food insecurity, lower costs, and improve food safety, thereby reducing household vulnerability. More than 80%, according to Table 1, in all unions either do not receive free fertilizers or cannot save crops for next year, and hence are more vulnerable.

3.1.5 Water Scarcity (WS):

In the coastal area, the crisis of water is enormous. Among them, Pankhali has been found to be the most vulnerable, with an index value of 0.53 (Table 1). Koilashganj is the second-most vulnerable area, with an index of 0.52 (Table 1). On the contrary, Laudobe has been recorded as the least vulnerable area since its water scarcity index is 0.38 (Table 1).

In these seven areas, 90–100% of households lack easy access to safe drinking water. Rainwater collected in plastic tanks and pond water treated with chemicals were the main sources. Though there are sources of water, they are way from the households, between 1 and 5 kilometers, and hence not reachable. Because of this, several households buy water either from the supply line or in bottled form. Above all, the residents of Pankhali bear the highest cost in securing water for consumption. This indicates that these areas are suffering from severe water scarcity, and this calls for a sustainable solution to enable them to access safe water.

3.1.6 Income Security (IS):

Due to climate change, the main sources of income have been hugely destroyed. Besides losses due to climate, robbery, especially in the Dacope area and the Sundarban region of Khulna District, is another concern that adds to economic insecurity. It therefore increases vulnerability because income instability is directly linked to greater vulnerability. Of the three sub-contributors of vulnerability, Sutarkhali bears the highest vulnerability regarding income security with an index value of 0.62, while Banisanta Union follows closely with an index value of 0.61 (Table 1). On the other hand, Laudobe and Tildanga, being in the heart of the upazila, were found to be the least vulnerable with an index value of 0.36 (Table 1). Sutarkhali and Banisanta are the most vulnerable sites, located very near the Sundarban forest and the Bay of Bengal. Because of their geography, they are particularly prone to various types of disasters.

In the studied areas, all households in the most vulnerable location report the rate of income loss due to natural disasters, while more than 90% of households face this problem in other areas. High dependence on natural resources for livelihoods has been coupled with increased natural disasters, which in turn have had a direct and significant impact on household income, further raising vulnerability. On average, more than half of households in the study area had incomes below 12,000 BDT, placing them below the extreme poverty line.

This is further compounded by robbery, which has also contributed to income loss and increased vulnerability in these communities. Of late, the incidence of robbery has decreased and is currently faced by less than 50% of households. In part, this decrease is attributed to livelihood adjustments, whereby many households have moved out of high-risk activities, such as fishing in the Sundarban region, and have concentrated on mainland fishing only. This has brought down their vulnerability to robbery, though the economic challenges remain.

3.1.7 Land (L):

In this case, the vulnerability for the major component of land has been measured using three selected sub-components. The results clearly indicate that Sutarkhali is the most vulnerable area, with an index value of 0.57, and Laudobe is the least vulnerable, with an index value of 0.47 (Table 1).

On average, Sutarkhali Union is characterized by a landlessness rate of 50%. Landlessness puts high-level stress on mental health, increases feelings of insecurity, and lowers coping ability with regard to disaster impacts; thus, it increases overall vulnerability. Over the last 20 years, land degradation has been observed across all study areas, contributing to increased migration. This type of migration, driven by land loss, further adds to the vulnerability of affected households.

In this case, as found in the field survey, a large number of respondents reported that land degradation has been worsening over time, which clearly indicates that land loss remains an ongoing challenge and impacts livelihoods and resilience in these communities.

3.1.8 Physical Facilities (PF):

Share of houses with solar energy, time to reach nearest vehicle station, and time to reach nearest primary school are physical facility subcomponents. These sub-components show that Sutarkhali is the most vulnerable of the nine unions, with an index value of 0.36, and Dacope Union is the least vulnerable, with 0.16 (Table 1). Two of the three energy subcomponents are positively associated with vulnerability, whereas energy access is negatively associated.

Pyra Power Plant near Dacope Upazila provides grid electricity to residents. Solar panels are too expensive for

many homeowners to install. The most vulnerable households for solar panel installation are Bajua, Banishanta, and Sutarkhali (Table 1). Laudobe has the lowest vulnerability at 0.43 (Table 1). The average travel time to the nearest vehicle station is 2 hours and 17 minutes to the nearest primary school. These two subcomponents increased vulnerability.

3.1.9 Health Services (HS)

Six sub-components of the second-to-last main health services component include household health status, distance to health facilities, and healthcare prices. Given these considerations, Sutarkhali Union is the most vulnerable with an index value of 0.55, whereas Laudobe Union is the least vulnerable, with an index value of 0.15 (Table 1).

100% of Sutarkhali families reported at least one person unwell due to disaster or chronic illness. Just 17% of Laudobe residents report this. At least one family member is unwell in 98% of Sutarkhali homes, increasing vulnerability. Because it takes 30–40 minutes to reach the nearest hospital, this lack of access is worse. Poor households are further hampered by healthcare transport fees of 50–100 BDT per person.

Fortunately, nearly 50% of households have immunized their children to decrease health risks. Most homes have not received a single day of health care instruction. In very vulnerable Sutarkhali, 95% of households had no primary health care training. However, certain areas received training, indicating resource and health access and utilization disparity between unions in the research area.

3.1.10 Natural Disaster and Climate Variability (ND & CV):

The final main component, Natural Disaster and Climate Variability, has seven subcomponents. As climatic or atmospheric influences, these sub-components directly affect vulnerability.

Table 1 shows that Sutarkhali Union has the highest natural-disaster and climatic-variability risk index, at 0.68 out of 1. Bajua and Banishanta rank next, with index values of 0.61 and 0.62, respectively. At 0.36, Laudobe has a low vulnerability index. These sites are more susceptible due to climate and natural factors.

Table 1 shows that the Sutarkhali Union averages 26 natural disasters per year. Most unions have over 20 natural disasters per year. According to Table 2, Sutarkhali has a standardised index value of 0.86, while Bajua has 0.38, based on local perceptions. The good news is that, in most cases, the government or NGOs warned people.

It harms fish, animals, crops, golpata, honey, and other resources. Table 1 shows Bajua, Banishanta, and Sutarkhali, which have damage values close to 1, signifying severe disasters.

Mean maximum temperature and mean precipitation had uniform standard deviations of 0.49 and 0.38 in all unions.

3.2 Outcomes of correlation

The correlation matrix of the major components of LVI across the unions of Dacope Upazila is shown in Figure 3.

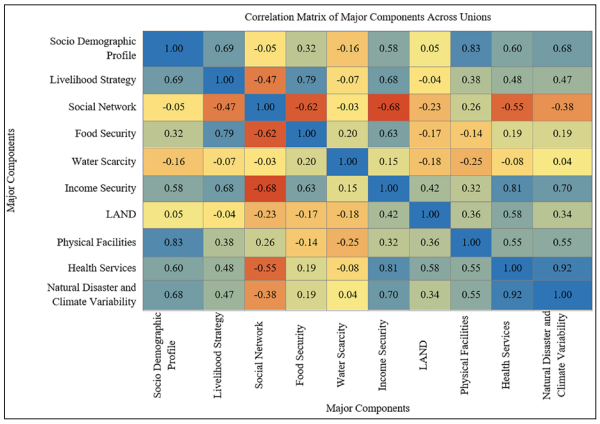

Figure 3. Correlation matrix of major components across unions.
Source: Authors' calculation, 2024

3.2.1 Strong Positive Correlations:

Physical Facilities (PF) and Socio Demographic Profile (SDP) show a strong positive correlation, suggesting that regions with better physical facilities tend to also have higher socio-demographic resilience (Figure 3).

Health Services (HS) and Natural Disaster and Climate Variability (ND & CV) are highly correlated (0.92), indicating that health services are closely linked to vulnerabilities from natural disasters and climate change. Food Security (FS) and Livelihood Strategies (LS) (0.79) also show a strong correlation, suggesting that food security is closely related to livelihood strategies.

3.2.2 Moderate Correlations:

Income Security (IS) and Health Services (HS) (0.81) have a moderate positive correlation, indicating a link between income stability and access to health services (Figure 3). Socio-demographic profile (SDP) and Livelihood Strategies (LS) (0.69) show a moderate correlation, meaning that better livelihood strategies can help improve socio-demographic factors.

3.2.3 Negative Correlations:

Social Networks (SN) and Livelihood Strategies (LS) (-0.47) have a negative correlation, suggesting that stronger social networks might not always align with certain livelihood strategies (Figure 3). Social Networks (SN) and Health Services (HS) (-0.55) also show a negative correlation, suggesting that stronger social networks may not always be associated with better health services.

3.3 Overall LVI in Dacope Upzila:

Among the nine analyzed unions, Sutarkhali is seen as the most vulnerable area to climate change from the total LVI represented in Table 2 with the highest index value of 0.584, followed by Banishanta with an index value of 0.529 and Bajua with a value of 0.509. The subsequent sequence of vulnerabilities includes Pankhali with an LVI of 0.507, followed by Kamarkhola with 0.487, Dacope with 0.463, and Koilashganj with 0.456. In contrast, Tildanga is the least vulnerable, with the smallest index value of 0.417, while Laudobe is the second least vulnerable, with an index value of 0.422. A livelihood vulnerability map is prepared showing the overall LVI score of all the unions of Dacope Upazila and is represented in Figure 4.

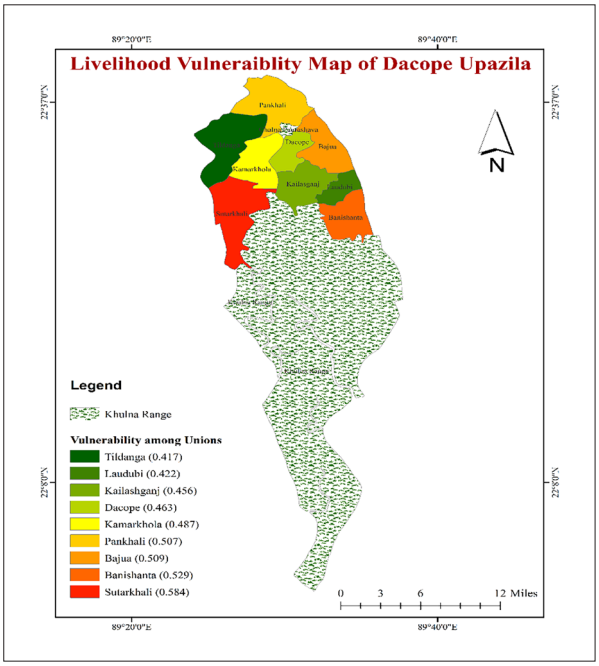

Figure 4. Union-wise livelihood vulnerability map of Dacope upazila

Table 2 shows the ranking of nine representative unions of Dacope Upazila according to their relative ranking of major components of LVI and overall Livelihood vulnerability to climate change. The ranking is based on values derived from the Livelihood Vulnerability Index (LVI), which shows the magnitude of vulnerability a community has to the consequences of climate change. The following is an assessment of the degree of vulnerability of the unions. A score ranging from one to nine has been used, with one representing the least vulnerable and nine the most vulnerable. The Table depicts Sutarkhali as the most vulnerable union in Dacope Upazila across seven major components: socio-demographic profile, livelihood strategies, income security, land resources, physical facilities, health services, and vulnerability to natural disasters and climatic variability. In contrast, Laudobe is the most vulnerable in the case of social networks, Dacope in food security, and Pankhali due to water scarcity.

3.4 LVI-IPCC

Under the LVI-IPCC framework, major components are categorized into three groups: adaptive capacity, sensitivity, and exposure. The socio-demographic profile, livelihood strategies, and social networks—the capacity of a community to adapt to changing conditions—make up the factors which, in turn, comprise adaptive capacity. The second category, sensitivity, consists of food security, water scarcity, income security, land availability, physical infrastructure, and health services. These aspects bring out a community's susceptibility to the impacts of climate change. The third one, exposure, has its key component in only one: natural disasters and climate variability, which estimates a community's degree of exposure to climate-related hazards. By applying the LVI-IPCC formula, these three groups are combined to produce the LVI-IPCC score, ranking areas from most vulnerable to least vulnerable. Results are shown in Table 3:

Table 2. Ranking of vulnerable area for each major component.

Unions	Major Components & Overall LVI										
	Socio-Demographic Profile	Livelihood Strategies	Social Network	Food Security	Water Scarcity	Income Security	Land	Physical Facilities	Health Services	Natural Disaster & Climatic Variability	Overall LVI
Bajua	8	7	4	5	5	4	2	6	6	7	7
Banishanta	7	6	3	6	4	8	5	5	8	8	8
Laudobe	6	3	9	3	2	2	1	7	1	1	2
Pankhali	5	5	6	8	9	5	3	3	5	6	6
Dacope	2	8	1	9	6	6	4	1	2	2	4
Koilashganj	3	4	8	2	8	3	6	8	3	4	3
Kamarkhola	4	2	2	4	7	7	7	4	7	5	5
Sutarkhali	9	9	5	7	3	9	9	9	9	9	9
Tildanga	1	1	7	1	1	1	8	2	4	3	1

Source: Authors' calculation, 2026

Compared with the LVI results in Table 1, the findings in Table 3 indicate that the ranks of the study areas by vulnerability have shifted. Despite an LVI rating of 0.046, Sutarkali remains the most vulnerable area in the region. With an index value of 0.044, Banishanta comes in as the second most vulnerable region after the region already mentioned. The LVI-IPCC value for Bajua is 0.029, which places it in third place. The fourth point is that Pankhali and Kamarkhola, both of which have the identical index value of 0.026, are the most vulnerable sections. With an exceptionally low LVI-IPCC rating of -0.069, Laudobe is the region with the least vulnerability.

Adaptive capacity, sensitivity, and exposure are the three primary categories described in the vulnerability triangle diagram shown in Figure 5. This diagram illustrates the diversity of scores observed across all study areas.

Table 3. LVI value calculated by IPCC definition (-1 least vulnerable) to (+1 most vulnerable).

Major components	Study area									IPCC contributing factors	Study area								
	Bajua	Banishanta	Laudobe	Pankhali	Dacope	Koilashganj	Kamarkhola	Sutarkhali	Tildanga		Bajua	Banishanta	Laudobe	Pankhali	Dacope	Koilashganj	Kamarkhola	Sutarkhali	Tildanga
SDP	0.45	0.45	0.44	0.41	0.36	0.37	0.38	0.56	0.30	Adaptive capacity	0.54	0.53	0.55	0.53	0.50	0.52	0.48	0.60	0.47
LS	0.70	0.68	0.62	0.65	0.71	0.62	0.60	0.73	0.58										
SN	0.53	0.52	0.63	0.56	0.50	0.62	0.51	0.55	0.57										
FS	0.68	0.69	0.61	0.76	0.84	0.55	0.63	0.71	0.53	Sensitivity	0.46	0.50	0.36	0.47	0.46	0.42	0.48	0.54	0.38
WS	0.42	0.39	0.38	0.53	0.44	0.52	0.49	0.39	0.35										
IS	0.46	0.61	0.36	0.51	0.53	0.43	0.53	0.62	0.36										
LAND	0.48	0.53	0.47	0.50	0.51	0.53	0.54	0.57	0.55										
PF	0.24	0.23	0.24	0.19	0.16	0.25	0.20	0.36	0.19										
HS	0.40	0.48	0.15	0.31	0.26	0.28	0.41	0.55	0.29										
NS & CV	0.61	0.62	0.36	0.58	0.38	0.45	0.54	0.69	0.44	Exposure	0.61	0.62	0.36	0.58	0.38	0.45	0.54	0.69	0.44
LVI-IPCC score											0.029	0.044	-0.069	0.026	-0.059	-0.029	0.026	0.046	-0.008

Source: Authors' calculation, 2026

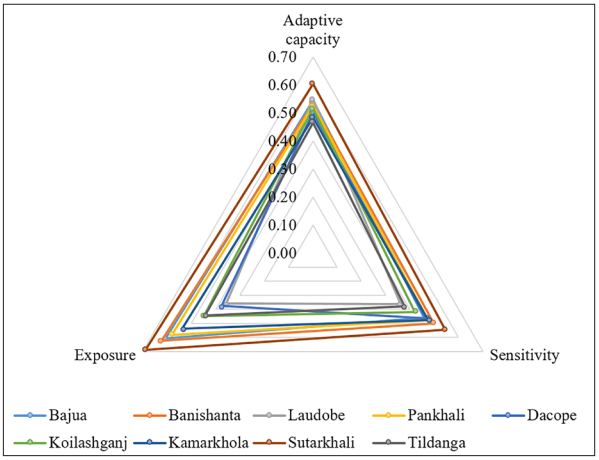

Figure 5. The vulnerability triangle of the components of the Livelihood Vulnerability Index - IPCC (LVI-IPCC) for Dacope Upazila

The comparative degree of vulnerability in the study areas presents sharp dissimilarities from the definition, presented by the IPCC, by its contributing factors, adaptive capacity, sensitivity, and exposure. After scoring, adaptive capacity is highest for Sutarkhali (0.60) and lowest for Tildanga (0.47), indicating stronger socio-demographic resilience, livelihood strategies, and social networks in Sutarkhali. Laudobe also has a relatively higher adaptive capacity, which is 0.55, hence indicating a better potential to cope with changing conditions than areas, like Kamarkhola, standing at 0.48. Sensitivity analysis has given Sutarkhali a value of 0.54; hence, it is the most sensitive area. This implies that the area is most at risk for health, food security, and access to water. It is closely followed by Banishanta at 0.50 and Kamarkhola at 0.48, whereas Laudobe has the lowest sensitivity, with a score of 0.36, making it the least susceptible to these various factors. Sutarkhali is again the most exposed to natural hazards and climate variability, with an exposure score of 0.69, placing it at higher risk due to potential climate impacts. On the other hand, Laudobe is the least exposed in relation to climate-related hazards, with a score of 0.36. Banishanta and Bajua are among the most exposed villages, having scores of 0.62 and 0.61, respectively. Whereas relatively lower exposure can be observed in the villages of Tildanga and Dacope, with scores of 0.44 and 0.38, respectively.

3.5 Differences in mean LVI and LVI-IPCC among unions

Table 4 shows the result from a one-way ANOVA test to compare the difference in mean value among the ten major components of the livelihood vulnerability index.

Table 4. Comparison of mean value of major components of LVI in Dacope.

Variable	Significance (levene statistics)	Sum of square	df	Mean square	F	Significance (P value)
Socio Demographic Profile	0.80	0.279	8	0.035	0.41	0.911
Livelihood Strategies	0.98	0.092	8	0.012	0.34	0.944
Social Network	0.984	0.078	8	0.01	0.13	0.997
Food Security	0.961	0.401	8	0.05	0.55	0.812
Water Scarcity	0.96	0.135	8	0.017	0.09	0.999
Income Security	0.998	0.221	8	0.028	0.21	0.986
Land	0.997	0.027	8	0.003	0.03	1
Physical Facilities	0.865	0.086	8	0.011	0.55	0.807
Health Services	0.256	0.542	8	0.068	0.76	0.638
Natural Disaster & Climate Variability	0.457	0.799	8	1	1.05	0.412

Source: Authors' calculation, 2026

Because the p-value is greater than 0.05, there are no discernible differences in the socio-demographic profiles of the nine unions. As a result, all unions are equally susceptible to socioeconomic factors. For the other major components, the P-values are as follows: livelihood strategies have a value of 0.944, social networks have a value of 0.997, food security has a value of 0.812, water scarcity has a value of 0.999, income security has a value of 0.986, land has a value of 1.000, physical facilities have a value of 0.807, health services have a value of 0.638, and natural disaster and climate variability has a value of 0.412. All of these values are greater than 0.05. The conclusion that can be drawn from this is that there is no statistically significant difference among the unions in these components, suggesting that the unions are equally vulnerable across all dimensions.

It is important to note that Table 5 presents the results of a t-test conducted on a single sample to compare the mean values of adaptive capacity, sensitivity, and exposure. The following is the hypothesis that is tested:

Null hypothesis (H_0): There is no significant difference in the mean value of adaptive capacity, sensitivity, and exposure.

Alternative hypothesis (H_A): There is a significant difference in the mean value of adaptive capacity, sensitivity, and exposure.

The p-values of all components are 0, less than 0.05. This therefore means rejecting the null hypothesis and proves that adaptive capacity, sensitivity, and exposure vary significantly among the nine unions.

Table 5. Comparison of the mean value of adaptive capacity, sensitivity and exposure

One-Sample Te One-Sample Test st						
Test Value = 0						
Value	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Adaptive capacity	38.813	8	0.000	0.525	0.493	0.556
Sensitivity	23.472	8	0.000	0.453	0.409	0.498
Exposure	13.429	8	0.000	0.519	0.4298	0.6080

Source: Authors' calculation, 2024

3.6 Livelihood Effect Index (LEI):

The results from the calculation table of LEI shows that the overall LEI score ranges from 0.552, which makes Sutarkhali the most vulnerable area, up to 0.370, which makes Tildanga the least vulnerable one. Other areas, except Laudobe, are moderately vulnerable with close scores: Bajua 0.456, Banishanta 0.491, Pankhali 0.454, Dacope and Koilashganj 0.420, and Kamarkhola 0.445.

Table 6 shows the detailed Livelihood Effect Index values for the study area, indicating human capital as the highest contributing factor with three major components. It shows that Sutarkhali is the most vulnerable of the nine, with a capital value of 0.646, while Laudobe is the least, with a capital value of 0.415. About 55% of the households do not have easy access to health facilities. This area lacks large hospitals, and local markets typically house smaller health facilities far from residential areas, making them accessible to only 48% of households. The time and cost to reach the health facilities are also high compared to the areas with the least vulnerability. This percentage is found in areas located in the center of Dacope Upazila, which are closer to growth centers. In terms of livelihood strategies, the majority of these areas rely heavily on nature-based livelihoods, which are highly vulnerable to environmental conditions.

The second influencing factor comprises three major components: land, water, and natural disasters and climatic variability. Based on natural capital values, Sutarkhali again demonstrates higher vulnerability with a score of 0.579. Conversely, Laudobe remains the least vulnerable area, with the lowest score of 0.389. The scores for the other areas are quite close, as the geographical and economic conditions across Dacope are largely similar. In terms of land ownership, more than or nearly 50% of households do not own land. Additionally, 69% of households in Sutarkhali

Union are at risk from natural disasters and environmental changes.

The fourth capital in LEI is social capital, which is derived from two major components: socio-demographic profile and social networks. According to the table 6, Sutarkhali has the highest vulnerability in terms of social capital with an index score of 0.555, whereas Tildanga has the lowest vulnerability with an index score of 0.423. While Sutarkhali is the most vulnerable area in terms of socio-demographic factors, with a vulnerability score of 56%, Laudobe tops the list for social networks, with a vulnerability score of 63%.

Table 6. Livelihood effect of five capitals in Dacope.

Capital	Major Components	Bajua	Banishanta	Laudobe	Pankhali	Dacope	Koilashganj	Kamarkhola	Sutarkhali	Tildanga
Human	Health	0.40	0.48	0.15	0.31	0.26	0.28	0.41	0.55	0.29
	Livelihood Strategies	0.70	0.68	0.62	0.65	0.71	0.62	0.60	0.73	0.58
	Food	0.68	0.69	0.61	0.76	0.84	0.55	0.63	0.71	0.53
Human Capital Score		**0.564**	**0.598**	**0.415**	**0.544**	**0.564**	**0.449**	**0.529**	**0.646**	**0.438**
Natural	Land	0.48	0.53	0.47	0.50	0.51	0.53	0.54	0.57	0.55
	Water	0.42	0.39	0.38	0.53	0.44	0.52	0.49	0.39	0.35
	Natural Disasters and Climate Variability	0.61	0.62	0.36	0.58	0.38	0.45	0.54	0.69	0.44
Natural Capital Score		**0.528**	**0.535**	**0.389**	**0.549**	**0.425**	**0.487**	**0.526**	**0.579**	**0.438**
Social	Socio-Demographic Profile	0.45	0.45	0.44	0.41	0.36	0.37	0.38	0.56	0.30
	Social Networks	0.53	0.52	0.63	0.56	0.50	0.62	0.51	0.55	0.57
Social Capital Score		**0.486**	**0.482**	**0.526**	**0.478**	**0.424**	**0.484**	**0.439**	**0.555**	**0.423**
Financial	Income	0.46	0.61	0.36	0.51	0.53	0.43	0.53	0.62	0.36
Financial Capital Score		**0.46**	**0.61**	**0.36**	**0.51**	**0.53**	**0.43**	**0.53**	**0.62**	**0.36**
Physical	Physical Facilities	0.24	0.23	0.24	0.19	0.16	0.25	0.20	0.36	0.19
Physical Capital Score		**0.24**	**0.23**	**0.24**	**0.19**	**0.16**	**0.25**	**0.20**	**0.36**	**0.19**
Livelihood Effect Index (LEI)		**0.456**	**0.491**	**0.386**	**0.454**	**0.420**	**0.420**	**0.445**	**0.552**	**0.370**

Source: Authors' calculation, 2024

In conclusion, the two variables that contribute to vulnerability are financial capital and physical capital. With a score of 0.62 for physical capital and 0.36 for financial capital, Sutarkhali is the most vulnerable area and ranks as the most vulnerable neighbourhood overall. The level of income fluctuation in Sutarkhali is rather high; revenue losses are common due to thefts and natural calamities. When it comes to financial capital, Laudobe and Tildanga have a score of 0.36, indicating they are somewhat vulnerable. Dacope remains the area with the lowest vulnerability, with a physical capital score of 0.16. Figure 6 presents a comparison of the Livelihood Effect Index scores of various unions in Dacope Upazila. The following spider diagram summarizes all capital scores.

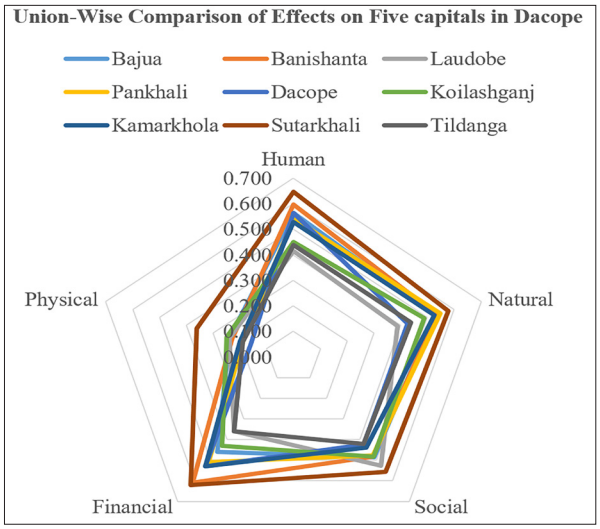

Figure 6. Comparison of the livelihood effect index in nine unions of Dacope

4. Discussion

The findings showed that areas remote from major rivers and forests are more vulnerable than other areas. These findings align with those of Sultana & Hasan (2023), Kayes et al. (2025), and Akram et al. (2025). Their identified vulnerable areas are also close to the sea, river, and forest. The findings of our study indicate that significant indicators, including food security, education, water scarcity, income insecurity, access to health services, exposure to natural disasters, and climate variability, are critical factors contributing to heightened vulnerability. According to Jui (2021), educational institutions in the coastal regions of Bangladesh encounter numerous obstacles stemming from recurrent natural disasters, the effects of climate change, and socio-economic vulnerabilities. This report also supports our findings.

The findings of this study strongly highlight that livelihood vulnerability is a multidimensional concept. Therefore, the local government and local NGOs alone cannot improve the community's livelihoods in Dacope Upazila. Effective collaboration among multiple government agencies and international NGOs, along with local governments and NGOs, can ensure the community's resilience, adaptive capacity, and sustainable mitigation strategies. Considering this importance, an action plan is provided in Figure 7, which includes the policy for specific wings of the government and NGOs. Where policy sections are symbolized as Slot1-4, which is discussed below in Figure 7.

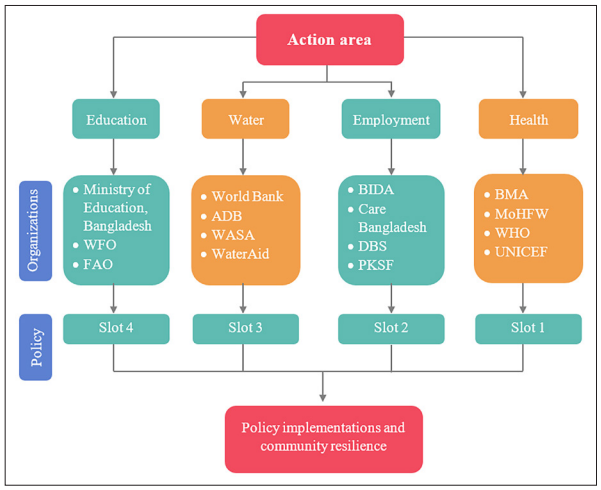

Figure 7. Action plan for climate resilience.

Slot-1: The World Health Organization (WHO), UNICEF, the Ministry of Health and Family Welfare (MoHFW), and the Bangladesh Medical Association (BMA) will work together to make sure the suggested policies are carried out. It is suggested that medical students be required to complete an internship in a seaside area after completing their final year of study. While the other organizations will provide financial, management, and coordination support, the BMA will be in charge of regulating this process.

Slot-2: The Bangladesh Investment Development Authority (BIDA), Care Bangladesh, Daridra Bimochon Shangstha (DBS), and Palli Karma-Sahayak Foundation (PKSF) are set to work together to enhance employment opportunities and diversify livelihoods in coastal regions. BIDA will spearhead the establishment of industries in these regions, while DBS will streamline access to loans. Care Bangladesh is committed to upholding transparency and accountability in the functions of both BIDA and DBS. Furthermore, PKSF will offer training and assistance for the overseas export of manpower.

Slot-3: The World Bank, Asian Development Bank (ADB), WASA, and WaterAid are joining forces to guarantee the availability of clean and sufficient water for the community. The project will receive funding from ADB and the World Bank, with WASA taking the lead in water purification efforts and ensuring access to clean water in vulnerable areas. WaterAid will assist WASA in implementing the project, maintaining transparency and accountability at every stage of the process.

Slot-4: The Ministry of Education in Bangladesh, along with the World Food Organization and the Food and Agriculture Organization, will work together to guarantee that everyone has access to fundamental education. The Ministry of Education plans to integrate disaster preparedness and response education into the school curriculum. The WFO and FAO will facilitate the implementation of current policies to ensure food provision for children in educational institutions. Furthermore, there will be ongoing workshops focused on disaster preparedness and essential actions at the community level throughout the year.

5. Conclusion

To assess how vulnerable different populations are to the consequences of climate change, this study used the LVI, LVI-IPCC, and LEI techniques. Every tactic provides an in-depth analysis of the factors that make people's ability to survive in a particular area so unstable. The goal in developing the LVI and LVI-IPCC calculation algorithms was to make them accessible to a wide audience in a variety of settings. More information can be found by using vulnerability spider and triangle diagrams to compare two or more research zones. Notable shortcomings of our methodology include the following: the subjective nature of sub-component selection; the inherently bidirectional nature of the sub-components' relationship to vulnerability; the masking of extreme values through the use of index calculation methods; and the possibility of selection bias as a result of the exclusion of vacant homes from the sample. What follows is a more in-depth discussion of each of these difficulties. To better understand how exposure, adaptability, and sensitivity evolve with the implementation of adaptation mechanisms, this study could be repeated in the same region at different intervals. To get a more accurate assessment of social ties in future research, it may be necessary to enhance the Social Networks and Natural Capacity subcomponents. It is also possible to assess the vulnerability of neighbourhoods using the LVI method. One useful instrument for city planners is the Livelihood Vulnerability Index (LVI). By doing so, they may determine which industries are most at risk from the impacts of climate change on local residents' livelihoods and work to mitigate those impacts. Furthermore, this study will provide a valuable resource for understanding the health,

socioeconomic, and demographic factors that influence climate sensitivity on a local or regional scale. Everyone from parliamentarians to development organizations and public health experts can use this tool to their advantage.

Knowledge Contribution:

This study presents the Livelihood Effect Index, a metric that has not been examined in prior investigations. Furthermore, the study presents a detailed action plan, specifying policies, institutions, and responsibilities to aid policymakers and government officials in decision-making, which can be used in other coastal areas of Bangladesh as well. This study addresses a significant gap left by previous investigations by providing a well-defined action plan for effective implementation.

Limitations of the study:

Historical rainfall and temperature data from the Bangladesh Meteorological Department are sparse, and most are unavailable or not readily accessible.

Further areas of research:

Future studies may focus on implementing the action plan, particularly on estimating the costs associated with each project, as significant capital is required for effective implementation. Furthermore, working alongside international organizations requires careful consideration and demands a high level of transparency. Future investigations could examine how the government will collaborate with international partners on these initiatives and identify which policies might affect national interests.

Declaration of Conflicting Interests:

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Authorship contribution statement:

- Md. Kamrul Hasan: Conceptualization, investigation, data curation, methodology, software, and writing-original draft.
- Md. Mizanur Rahman: Resources, supervision, writing, review, and editing, and validation.
- Abu Nayem Md. Kayes: Formal analysis, writing-original draft, data presentation, software, and methodology.

Declaration of Conflicting Interests:

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics Statement:

Ethics approval was obtained from the Ethics Committee of the Department of Urban and Regional Planning, Pabna University of Science and Technology (Bangladesh). In addition, the participants provided their informed consent to participate in this study.

Acknowledgements:

We would like to express our heartfelt gratitude to all the individuals who generously shared their valuable insights, experiences, and data that were integral to the success of this research. We are also profoundly grateful to the University Grants Commission (UGC) for its financial assistance in funding this research.

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