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Article

Exploring Flood-Induced Livelihood Vulnerabilities in Bangladesh: Insights from Teota, Manikganj and the Bangladesh Delta Plan 2100

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ABSTRACT

Climate change is largely to blame for the increasing frequency of natural disasters in Bangladesh, a country that has long been vulnerable to such events. Continuing the trend, flood shave become a very common phenomenon in this country, which takes place almost every year. This natural hazard affects millions of people and makes the community more vulnerable, especially in terms of livelihood. To address this situation, the government of Bangladesh has initiated several long-term plans. 'Bangladesh Delta Plan (BDP) - 2100' is one of them. As such, this research primarily aims to assess the livelihood vulnerability due to the flood of the community in Teota, Manikganj. Later, the study explores the credibility of the strategies mentioned in the BDP to mitigate flood vulnerability. To access the livelihood flood vulnerability, the study applied the livelihood vulnerability index (LVI) and IPCC-LVI approaches and to examine the adaptive measures outlined in the BDP-2100, the study employed content analysis. The results show that the Teota community is highly vulnerable to floods for their livelihood, both in LVI (0.6 out of 1) and IPCC-LVI (positive) approaches. Among the five livelihood capitals, physical (0.8) and human (0.7) capitals are identified as the most vulnerable, while financial (0.6) and natural (0.5) capitals fall in the middle range. Social capital shows the least vulnerability, with a score of 0.2. This intensifies the exposure (0.6 out of 1) and sensitivity (0.6) and weakens the adaptive capacity (0.5) of Teota community. BDP cannot fully mitigate the vulnerability as it does not address all the infirmities, i.e., BDP does not address social vulnerability. Overall, the successful implementation of BDP could increase the resilience of communities in Teota Union, leading to a considerable reduction in flood vulnerability, however, analyzing the BDP strategies in a quantitative approach could be more effective. Moreover, other long-term strategic plans of Bangladesh, such as 'My Village My Town', and 'Smart Bangladesh', that deal with flood vulnerability should address the issues that are missed in BDP-2100.

KEYWORDS

Flood-induced livelihood; community; adaptive capacity; livelihood capitals; Bangladesh delta plan (BDP) - 2100.

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1. Introduction

Table 1. Impacts of flood in Bangladesh (adopted from Bagchi et al. (2020))

Year	Affected People	Deaths	Economic Loss (USD)
2017	9,536,905	299	3.45 billion
2016	3,20,000	42	225 million
2015	2,00,000	19	
2007	13,771,380	1110	
2004	36,000,000		2.2 billion
1998	14,000,050	1050	430 million
1995	12,656,006		
1993	11,469,537		
1988	45,000,000	2379	2.13 billion
1987	29,700,000	2055	727.5 million
1984	30,000,000	1200	

Bangladesh is one of the world's most disaster-prone countries (Morgan &McINTIRE, 1959) due to its location in the largest delta in the world, the delta formed by the confluence of the Ganges, Brahmaputra, and Meghna rivers (Graveline&Germain, 2022)it has evolved extensively both etymologically and conceptually in time and across scientific disciplines. The concept has been (re, where floods happen most often (Ali, Mahjabin, and Hosoda 2012). Bangladesh mainly faces flash floods, rain-fed floods, river's flood and flood due to cyclone (Akhtar Hossain 2003) caused primarily by urbanization and climate change but also by extreme weather events, soil erosion, and cyclones, storms, and tidal surges (Hadihardaja, Kuntoro, and Farid 2013). Bangladesh has a very long history of being affected by flood, where Table 1 represents, a small scenario, the chronological flood events and their impact from 1984 to 2017. Effects of flood lead to declining agricultural production (Banerjee 2010), loss of income (Banerjee 2007; Haque and Jahan 2015), and eventually decline in environmental conditions (Boudaghpour, Bagheri, and Bagheri 2015). Besides health and education of the flood affected community also remains under threat (Rahman 2014). Some of the most productive farmland in the country, are floodplains and submerged for three to four months out of the year (Shalant 2018). Natural disasters like this is making the poor community 2.5 times more vulnerable than the wealthier one (Younus and Harvey 2014)but the economic consequences of failure effects of autonomous crop adaptation on marginal farmers are large. The failure effects are defined as total input costs plus the small profit (otherwise. In sum, flood affects housing and communication; water, sanitation and health; livestock and agriculture; and education and these components aggregated together are livelihood (Rahman 2014), especially 50% of these damages is done to agriculture and another 40% to infrastructure (Delta Plan 2100 2018).

To cope with these flood adversities and other economic challenges, govt. of Bangladesh has introduced the 'Bangladesh Delta Plan - 2100 (BDP). The BDP is a long-term plan that integrates water, land use, ecosystem, and climate change technologies and economics to achieve positive development outcomes. Long-term water and food security, in addition to economic growth and environmental sustainability, are priorities for BDP. The BDP also aims to strengthen resilience against climate change and natural disasters through the implementation of comprehensive strategies and policies(Delta Plan 2100 2018).

Several studies have assessed flood vulnerability using different methodologies for example,(Mavhura, Manyena, and Collins 2017) developed a multivariate approach to evaluate the vul-

nerability of societies to flood hazards. While the use of an indicator-based evaluation methodology has been widespread in multiple studies(Balica et al. 2013; Cutter et al. 2009; Pelling 1997; Rayhan 2010; Zevenbergen et al. 2008), these approaches tend to focus primarily on exposure and sensitivity, often overlooking factors like adaptive capacity or socio-economic vulnerabilities. Several studies have assessed the vulnerability of households to floods by combining attributes related to exposure, sensitivity, and adaptive capacity (Balica et al. 2013; Cutter et al. 2009; Pelling 1997; Rayhan 2010; Zevenbergen et al. 2008), but these methods are sometimes limited in capturing the full spectrum of vulnerabilities, especially those related to social and economic resilience. Furthermore, (Koks et al. 2015) and others conducted significant studies examining risk, hazard, exposure, susceptibility, capacity, and mitigation strategies. However, these frameworks often fail to consider the dynamic, interrelated nature of these factors in real-world contexts. Similarly, the use of spatial vulnerability and inundation mapping (Karmakar et al. 2010) offers useful insights, but it does not always incorporate critical local-level social vulnerabilities. While national-level flood vulnerability assessments (Abdullah et al. 2019; Khan et al. 2015; Roy and Blaschke 2015) provide valuable data, they can miss the nuances of local vulnerability conditions, such as access to resources and governance structures. In contrast, Livelihood Vulnerability Index (LVI) and IPCC-LVI are two different ways to measure flood vulnerability. LVI measure the community exposure to natural disasters and climate variability, socioeconomic status, health, and food and water resources to determine their sensitivity to future disasters (Asaduzzaman 2015)most of the adverse effects of climate change occur in the form of extreme weather \nevents, such as cyclone, flood, drought, salinity ingress, river bank erosion and tidal surge, leading to large scale damage to crops, employment, livelihoods and the national well-being. Although it is generally stated that women are relatively more vulnerable \ nthan men in the context of climate change, few studies have been done to closely examine this statement, especially in Bangladesh. The present study, therefore, investigates the structure of women's livelihoods, livelihood vulnerabilities and coping capacity in the context of climate variability and change in a disaster vulnerable coastal area (Shyamnagar upazila of the Satkhira district and IPCC-LVI indicates exposure means being vulnerable to community threats, and adaptive capacity means being able to handle adversity (Chambers 1989). Our study is employing LVI because it provides a structured framework for assessing how vulnerable people's livelihoods are to climate change, supporting development organizations in formulating policies related to vulnerability (Balica et al., 2009). Specifically, Hahn, Riederer, and Foster (2009) developed the LVI to measure the vulnerability of livelihoods based on various environmental, socio-economic, and institutional factors. Unlike national-level flood damage assessments, which focus primarily on physical infrastructure, the LVI integrates a broader set of indicators, including socio-economic variables, to provide a more comprehensive vulnerability assessment.

While substantial research has been conducted on flood vulnerability in Bangladesh, much of it has focused primarily on physical impacts, overlooking the socio-economic and adaptive dimensions of vulnerability. For instance, studies often find health/wash, food/water access, weak infrastructure and finance limits as main issues, with higher vulnerability where adaptive capacity is low (Al Mamun et al. 2023; Hoq, Raha, and Hossain 2021; Sarker 2019)the livelihood system of a community is a key element of the social system which may frequently be disrupted by the ecological, financial, natural and human-made vulnerability. Therefore, the purpose of this study is to clarify the concept of vulnerability and resilience in the perspective of livelihoods in a climate vulnerable context. It also addresses the methodological gaps through translation of theory from existing literature. This study argues that vulnerability and livelihood resilience are inversely related. It recommends some indicators and pillars for a better understanding of the vulnerability and livelihood resilience drawing from assorted literature through analysing the concept from various dimensions. The study will be helpful in understanding the livelihood dynamics and its assessment in the perspective of vulnerability and resilience.","container-title":"Applied Ecology and Environmental Research","DOI":"10.15666/aeer/1706_1276912785","ISSN":"1589-1623, 1785-0037","issue":"6","-journalAbbreviation":"Appl. Ecol. Env. Res.","language":"en","note":"publisher: ALOKI Ltd","-source":"Crossref","title":"VULNERABILITY AND LIVELIHOOD RESILIENCE IN THE FACE OF NATURAL DISASTER: A CRITICAL CONCEPTUAL REVIEW","title-short":"VULNERABILITY AND LIVELIHOOD RESILIENCE IN THE FACE OF NATURAL DISASTER","URL":"http://aloki.

hu/pdf/1706_1276912785.pdf","volume":"17","author":[{"family":"Sarker","given":"M N I"}],"accessed":{"date-parts":[["2025",9,1]]},"issued":{"date-parts":[["2019"]]}}],"schema":"https://github.com/citation-style-language/schema/raw/master/csl-citation.json"} . Several studies analyzed the correlation between land use patterns, flood risks, and poverty rates in Bangladesh's coastal communities (Abdullah et al., 2019; Khan et al., 2015; Roy &Blaschke, 2015). Adnan et al. (2020) investigated the connection between land use patterns, flood hazards, and poverty among Bangladesh's coastal population. Mondal et al. (2020), focused on the examination of flood risk, specifically by assessing the susceptibility of families and communities residing on riverine islands in northern Bangladesh. This study fills this gap by applying the Livelihood Vulnerability Index (LVI) and IPCC-LVI frameworks, which offer a more comprehensive assessment by incorporating factors like exposure, sensitivity, and adaptive capacity. By focusing on Teota Union, a flood-prone area in Manikganj, this research aims to evaluate the vulnerability of the local community to flood hazards and to assess the effectiveness of the Bangladesh Delta Plan (BDP) - 2100 in reducing flood vulnerability. The findings aim to provide policy-relevant insights for improving flood risk management strategies and enhancing climate resilience at the local level, thereby contributing to the broader discourse on sustainable development and climate adaptation in Bangladesh.

2. Livelihood Vulnerability

A livelihood is considered sustainable if it can withstand and recover from challenges, preserving or improving resources without depleting natural ones(Ellis, Kutengule, and Nyasulu 2003). Livelihoods are supported by five capitals: human, natural, financial, physical, and social(Bebbington 1999; Scoones 1998). The Sustainable Livelihood Framework (SLF), introduced by Chambers & Conway (1992), assesses these capitals to determine vulnerability. Additionally, the IPCC-LVI framework(IPCC 2007) examines how exposure, sensitivity, and adaptive capacity contribute to vulnerability.

2.1. Livelihood Vulnerability Index (LVI)

Natural adversities and climatic inconsistencies make a community exposed, and their possessed resources determine their sensitivity for the future calamities. Adaptivity, on the other hand, depends on their socio-economic condition. And all these are weighed by various factors in LVI (Asaduzzaman 2015)most of the adverse effects of climate change occur in the form of extreme weather \nevents, such as cyclone, flood, drought, salinity ingress, river bank erosion and tidal surge, leading to large scale damage to crops, employment, livelihoods and the national well-being. Although it is generally stated that women are relatively more vulnerable \nthan men in the context of climate change, few studies have been done to closely examine this statement, especially in Bangladesh. The present study, therefore, investigates the structure of women's livelihoods, livelihood vulnerabilities and coping capacity in the context of climate variability and change in a disaster vulnerable coastal area (Shyamnagar upazila of the Satkhira district.The UNDP uses a method called the human development index to define a community's quality of life based on a number of indicators expressed as a composite index; LVI modifies this index by incorporating new factors from the SLA. This approach includes external factors, named hazard exposure, and social and political risks. Prediction ability, resistance and recovering ability, named as internal factors, are also considered by SLA along with other related indicators(Bohle 2001). Rahman (2014) studied the vulnerability of flood affected people by assessing in total fifteen components (see Table 2). Ten of these were taken from the original composite index and combined with exposure, adaptive capacity, and sensitivity to form the three vulnerability factors. But M. B. Hahn et al. (2009) broke down those fifteen factors into the five capitals of livelihood (i.e., human, natural, financial, social, and physical) and evaluated them to determine the LVI of people in extreme flood conditions. However, both of the authors emphasized the importance of primary household data than secondary data that often fails to represent the actual scenario. These two methods are incorporated into one and used in this study to offer a broader context on vulnerability.

2.1.1. Livelihood Asset Pentagon

The pentagon of livelihood assets is the heart of SLF within the vulnerability context. The pentagon represents the effect on vulnerability of the five capitals of livelihood. The intersecting point of the five lines at the center means no access to livelihood capitals, where the boundary line shows full access (see Figure 1). By this, a whole pentagon means adequate access to livelihood resources and a stuffed one presents the counterpart (Asaduzzaman 2015)most of the adverse effects of climate change occur in the form of extreme weather \nevents, such as cyclone, flood, drought, salinity ingress, river bank erosion and tidal surge, leading to large scale damage to crops, employment, livelihoods and the national well-being. Although it is generally stated that women are relatively more vulnerable \nthan men in the context of climate change, few studies have been done to closely examine this statement, especially in Bangladesh. The present study, therefore, investigates the structure of women's livelihoods, livelihood vulnerabilities and coping capacity in the context of climate variability and change in a disaster vulnerable coastal area (Shyamnagar upazila of the Satkhira district.

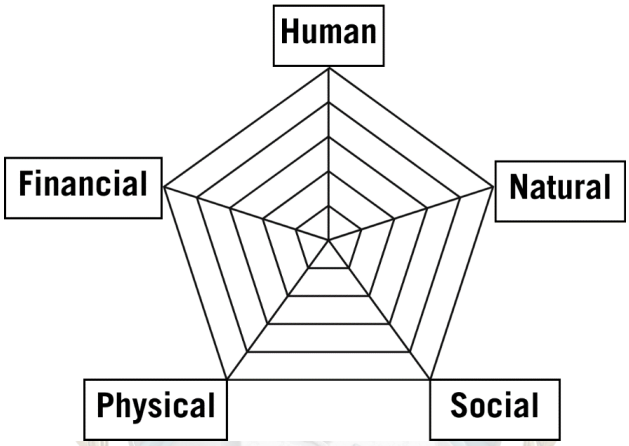


Figure1: The pentagon of livelihood assets

2.1.2. Components of livelihood capitals

The fifteen components from Rahman (2014) can be categorized into five livelihood capitals introduced by Hahn et al. (2009) to measure the vulnerability of livelihood of flood affected people. The categorization is shown in Table 2. All major components are sub-divided into several sub-components, in total 41, formed based on availability of data from household survey.

Table 2. An adapted version of M. B. Hahn et al. (2009)'s classification of major components and subcomponents according to five livelihood capitals

Livelihood Capital	Major Component	Sub-component (Percentage of Household)

Human	Health	Health damage due to flood;
		No access to medical facilities;
		Family planning facilities are inaccessible or limited in availability.
		Inadequate sanitation facilities.
	Knowledge & Skills	Household members that just passed primary school; and
		Having any training to cope with flood.
	Livelihood Strategies	Having no regular income;
		Primarily depending on agriculture for income;
		Households without non-farm activities affected by flood;
		Jobless during flood season; and
		Fishing during flood season.
Natural	Land	No cultivable land;
		No land ownership; and
		Households with small farm (0.1-0.5 ha).
	Water	No source of clean water;
		Relying on water from a nearby pond or river for household chores; and
		Time spent fetching water on average.
	Natural Assets	Having no trees; and
		Avoid growing the third crop.
	Climate Change and Natural Disasters	The ten-year average number of severe floods;
		flood-related fatalities/injuries reported over the past decade; and
		That do not receive flood warning.
Financial	Annual Income	Who are in deficit; and
		Inverse of income index.
	Asset ownership	Those who do not own a boat and nets for fishing;
		Those who do not own livestock;
		Absence of poultry ownership.
	Finance	Insufficient availability of financial services or access to financial institutions; and
		Having to repay money to a specific lender.
Social	Socio-Demographic Profile	Average family size;
		Percentage of female heads; and
		Dependency ratio.
	Social Networking	Receiving helps due to flood; and
		Do not have been member to any organizations.
Physical	Housing	Without a solid (pucca) house; and
		With house affected by flood (partially to totally submerged).
	Household Asset	Not being able to get flood updates via radio or TV; and
		Having no asset to sell during deficit.
	Communication & Electricity	Without sufficient transportation and road infrastructure; and
		Devoid of electrical infrastructure.

2.2. IPCC-LVI

Adaptive capacity is the ability to deal with adversity, and exposure means that a community is not resilient to any threat(Chambers 1989).When defining vulnerability, Adger(2006) andBirkmann et al. (2006)took the same tack. The most useful definition was introduced by IPCC in 2007. They explained it as the functioning between exposure, sensitivity and adaptive capacity.

$V = f(E, S, A)$	Here,
	V = Vulnerability
	E = Exposure
	S = Sensitivity
	A = Adaptive Capacity

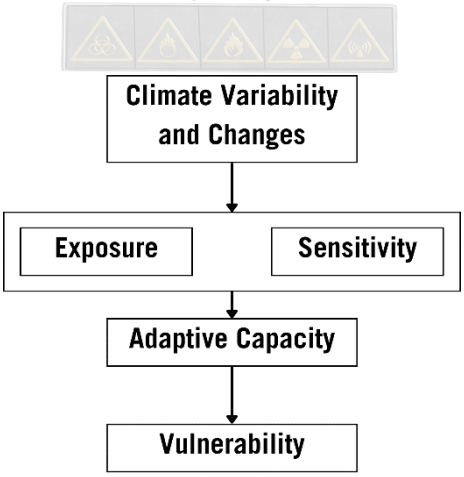
2.2.1. Exposure

Exposure, as defined by Hewitt (1997), is the extent to which a community or ecosystem is in contact with specific hazards. The U.S. Department of Water Resources (2013) further refined this definition by focusing on persons, resources, and areas that are affected by these hazards. According to the IPCC (2007), exposure refers to "the presence of people, livelihoods, species or ecosystems, environmental services, and resources in places and settings that could be adversely affected" by climate-related hazards. It is also defined as the degree, duration, and range of a system (e.g., a community) being in contact with hazards Rahman (2014) based on Adger (2006). In climate studies, exposure is considered one of the key modules of vulnerability(Adger 2006; IPCC 2007).

2.2.2. Sensitivity

Sensitivity refers to the extent to which a system is affected by climate change, either positively or negatively. This influence can be direct, such as when changes in temperature affect crop production, or indirect, such as the damage caused by more frequent flooding due to rising sea levels(IPCC 2007).

2.2.3. Adaptive Capacity



Adaptive capacity refers to a community's ability to adjust to adverse conditions, thereby reducing its vulnerability to climate change. As defined by Brooks (2003), adaptability involves the "capacity of an organism to undergo physiological, behavioral, and/or morphological changes in response to current and/or projected changes in the climate". The IPCC (2007)defines adaptive capacity as "the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage

of opportunities, or to cope with the consequences". This concept is crucial in determining how a system can successfully manage and respond to climatic variation and extreme events, thus reducing its vulnerability.

A community or system's vulnerability to the effects of climate change is illustrated in Figure 2. The vulnerability of an organism is, however, also influenced by its capacity for adaptation.

The IPCC initiated the IPCC-LVI method as an extension of the work begun by M. B. Hahn et al. (2009). Exposure, sensitivity, and adaptive capacity are the three primary factors held in account by this method. Incorporating these three components results in a variation from the initial LVI. In accordance with the methodology described previously, S. U. Rahman (2014)assessed the three vulnerability factors that comprised the fifteen components he identified (Table 3).

Table 3. Categorization of major components into IPCC factors to vulnerability

IPCC Factors	Major Components
Exposer	Change and Natural Disasters
Adaptive Capacity	Socio-Demographic Profile
	Social Network
	Livelihood Strategies
	Finance
	Knowledge and Skills
Sensitivity	Health
	Land
	Water
	Natural Assets
	Housing
	Household Assets
	Communication and Electricity
	Annual Income

2.3. Conceptual Diagram

The present study employed the LVI framework to examine the myriad elements and sub-elemental groups that contribute to livelihoods. A comprehensive set of fifteen primary elements and forty subsidiary elements was discerned, all of which were classified under the five capitals of livelihoods: financial, human, natural, social, and physical. The aforementioned elements encompass food, water, health services, socio-demographic profile, and livelihood mechanisms. These components are reinforced by social networking, climate variability, and disasters. Utilizing the selected setting-specific LVI approach, the particular circumstances that contribute to livelihood vulnerability will be investigated. Figure 3 illustrates how the sub components of vulnerability influence both LVI and IPCC-LVI.

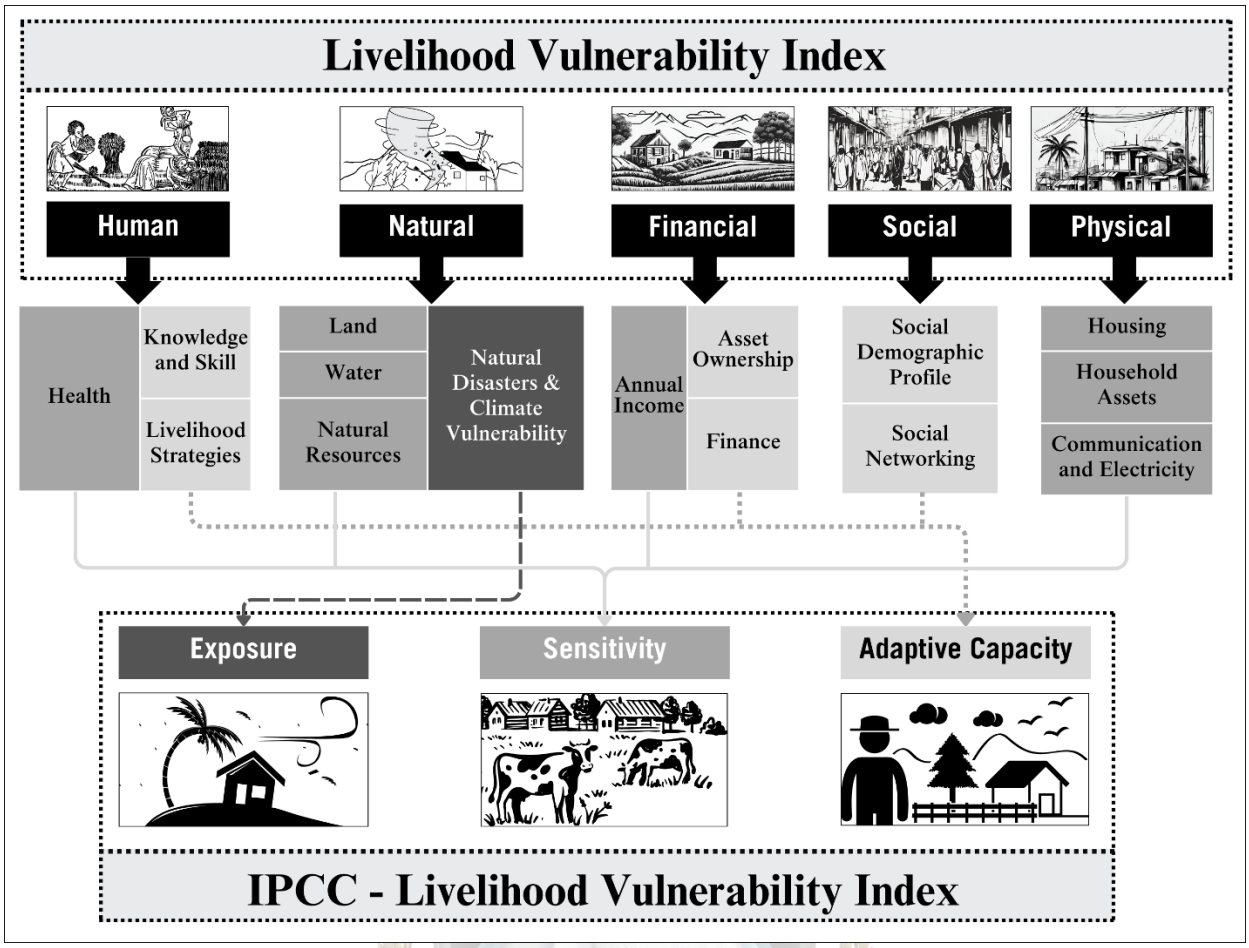


Figure 3. Conceptual Framework

2.4. Bangladesh Delta Plan – 2100

The Bangladesh government has aimed to achieve long term food and water security across the country by the year 2100. BDP has mainly focused on four livelihood capitals: human, natural, financial and physical. It suggests some strategies prior to individual levels for *human capital*. For health, BDP has strategies to ensure rural health service, hospitals and flood proof infrastructures, e.g., all weather road, elevated houses etc. (BDP 6.3.4). Providing adequate, equitable, safe and sustainable sanitation system (BDP 5.3.2); improved and integrated drainage and sanitation at acceptable level (BDP 6.3.6, 6.8.3, 6.9.2, 6.10.2); and involving non-governmental organizations, private sectors and strengthening local participation for sanitation. Proper training must be provided to local level to ensure resilience (BDP 6.3.4). Livelihood strategies include appropriate crop and asset insurance (BDP 6.3.6); promotion of climate smart agricultural and farming mechanism, protecting crops from flood and providing incentives for modernization (BDP 6.9.2, 6.9.3); and reducing agriculture dependence by creating new formal employment (BDP 5.4.1). Basically, these strategies are intended for the development of human capital of livelihood.

To develop the *natural capital* of livelihood BDP has strategies to rehabilitate land (the process of restoring land to its natural state (Adam Hayes 2022)) (BDP 7.7). BDP suggests lands under the govt should be distributed to the poor (BDP 7.6.2); and dredging waterbodies (BDP 6.9.2) and sustainable, equitable and adequate access to affordable quality drinking water (BDP 5.3.2, 6.9.2) for land and water components. Besides, innovative flood-resilient cropping system is encouraged (BDP 6.3.4) and developing small forecasting, early warning, preparedness and action goals (BDP 6.3.6) to build resilience against climate variability.

Financial capital or other monetary components are a big factor in achieving any goal. For this BDP will subsidize and enhance the purchasing power of the commons (BDP 6.9.3, 8.4.4); enhance social safety net and financial services (BDP 6.3.4); and implement zoning based financial and legal instruments.

The *physical capital* or the infrastructure related strategies occupy a major portion of the BDP. BDP suggested to ensure flood resilient elevated housing (BDP 6.3.4, 6.10.2) and also to develop forecasting system (as discussed earlier). In case of communication infrastructure e.g., road networks, they should be flood resilient (BDP 6.3.4), flood passage should be incorporated with their design, and river-road-rail transportation must be integrated (BDP 6.9.2). For power supply, BDP instructed to produce solar energy and prioritize rapid power supply restoration (BDP 6.9.2, 6.9.3)

3. Methods and Materials

3.1. Study Area

The Teota Union of ShibalayaUpazila in Manikganj, Bangladesh, is a low-lying region along the Jamuna River, which served as the study area for this research. According to the Union Land Office of Teota Union (2017), 35 mouzas in the area are susceptible to flooding, with annual floods severely affecting the local population.

Figure 4: Study Area Map

This region, located between 23°48′45″N and 23°55′30″N latitude and 89°41′30″E and 89°48′0″E longitude (Figure 4), is characterized by its proximity to the riverbank and high vulnerability to climate hazards. The Jamuna River, one of Bangladesh's major rivers, poses challenges to the community, including the depletion of agricultural land, crops, and other livelihood assets, especially during flood events. Flooding and riverbank erosion are frequent occurrences, negatively impacting the communities living near the river (Sarker and Rahman 2018)approximately one million people are affected by river bank erosion. River bank erosion not only compels people to migrate or leave their place of origin, but also destroys their belongings. This research is conducted to analyze the river bank erosion scenario of Teota Union in Shibalaya Upazila of Manikgonj District located on the left bank of Jamuna River and also to analyze migration patterns. Teota union is the most vulnerable for river bank erosion due to char formation, shifting channels, and erosion. The amount of eroded and accreted areas of the study area in different periods from 1988 to 2014 has been computed from the satellite images of different years using GIS. During 1988-2014, the maximum bank erosion was occurred during 1988-1990 and 2606.22 acres of land was eroded during that period and the minimum amount of land (995.12 acres.

The study area was chosen based on its vulnerability to these natural risks(Islam and Tingsanchali 2024).. The participants were selected using a random sampling method. This research focuses on the riverbank areas, where residents are particularly exposed to frequent flooding and erosion (Sarker and Rahman 2018) approximately one million people are affected by river bank erosion. River bank erosion not only compels people to migrate or leave their place of origin, but also destroys their belongings. This research is conducted to analyze the river bank erosion scenario of Teota Union in Shibalaya Upazila of Manikgonj District located on the left bank of Jamuna River and also to analyze migration patterns. Teota union is the most vulnerable for river bank erosion due to char formation, shifting channels, and erosion. The amount of eroded and accreted areas of the study area in different periods from 1988 to 2014 has been computed from the satellite images of different years using GIS. During 1988-2014, the maximum bank erosion was occurred during 1988-1990 and 2606.22 acres of land was eroded during that period and the minimum amount of land (995.12 acres.

3.2. Data Contributors

A total of 100 households were selected using the simple random sampling method from a total of 7,492 households in the study area. The sample size was calculated using Yamane's formula (1967), with a confidence level of 95% and a precision of 10%. After selecting the households, surveys

were conducted through structured interviews with household heads to collect data on key livelihood variables. The collected data were then analyzed using both quantitative (LVI and IPCC-LVI calculations) and qualitative (content analysis) methods, as detailed in Section 3.4.

According to YAMANE (1967), the sample size calculation process-
Total population =33,622
Number of households = 7492
n =Size of the sample
N =Number of total households =7492,
Precision (e) =10%,
Confidence Level = 95%,
Proportion of Variability, P =0.5
So,
$n = 7492/\{1+7492\ (0.1)^2\}$
=98.68
=100 (approximately)

With N = 7,492 households, 5% precision at 95% confidence would require ≈380 observations; our n = 100 therefore targets ≈10% precision. We reflect this by reporting 95% confidence intervals for key proportions and by framing the results as descriptive diagnostics for a single union. For context, LVI/LVI-IPCC studies report varied n tailored to their geographies/designs: 262 households in Bangladesh chars (Al Mamun et al. 2023); 284 in Ethiopia (Weldegebriel and Amphune 2017); 217 in Nepal (Pathak et al. 2020); 182 (25%) along Nepal's southern Bagmati (Shreevastav et al. 2021); 337 in India (Mitra and Kumar Mandal 2022); 398 and 200 in Pakistan's Bait and Mianwali (Ahmad and Afzal 2022; Akram et al. 2025)flood disasters are the most recurrent hazards that cause Bait households' livelihood to be more vulnerable. Hence, this research work has focused to investigate livelihood vulnerability of flood-prone Bait households in southern Punjab of Pakistan. This study used multistage sampling technique for collection of the cross-sectional data of 398 flood disasters vulnerable Bait household's respondents from three high-risk flood-prone districts Muzaffargarh, Rajanpur, and Rahim Yar Khan. Face-to-face interview procedure and welldeveloped pre-tested questionnaire were used for data collection in this research work. This study applied vulnerability framework of LVI-IPCC and LVI in the direction of comparing the level of vulnerabilities in preferred three Bait district households. Empirical estimates of LVI major components and framework of IPCC vulnerability have indicated Bait households of Muzaffargarh more vulnerable owing to higher exposure and sensitivity and lower adaptive capacity than other districts. In contrast to other districts, Muzaffargarh households have investigated more vulnerable to flood disasters more particularly in LVI sub-components such as health (0.460; 120 in Vietnam's Mekong(Nguyen-Phuoc et al. 2018); and 402 in Malaysia (Nor Diana et al. 2019).

3.3. Variables

The LVI is calculated using data collected through household surveys, which include variables such as health, knowledge & skills, livelihood strategies, land, water, natural resources, annual income, asset ownership, and other socio-demographic factors. These variables were selected based on their relevance to measuring the five capitals of livelihood (human, natural, financial, social, and physical) (See Table 2 and Table 3).

3.4. Analysis Methods

This study utilized a mixed-methods analysis approach, including both the quantitative and qualitative methods. The quantitative section involved the calculation of LVI and IPCC-LVI using a methodology developed by M. Hahn, (2008). On the other hand, the qualitative component employed content analysis to examine the adap*tive* measures outlined in BDP-2100, which aims to

provide a comprehensive and sustainable feature to the management of land resources and water resources of Bangladesh. The ensuing discussion is constructed on the hypothetical assumption, where all indications of vulnerability have a value of zero, which was already addressed in a different section under several policy strategies (Table 12) of the delta plan. The study investigates the vulnerability situation under this policy strategy and its implications at the local level in Bangladesh, with a focus on how these implications can contribute to the reduction of flood vulnerability (Figure7). However, several approaches, such as multivariate statistical models, which primarily explore correlations among variables. Nevertheless, the LVI and IPCC-LVI approaches supports aggregation and normalization of diverse indicators. Similarly, while GIS-based models are powerful for spatial visualization, our primary aim was to quantitatively assess and compare livelihood vulnerability rather than to produce spatial view.

3.4.1. 3.4.1 Calculation of LVI

LVI has been developed using balance weighted average approach (Hahn 2008), each sub-component makes an equal contribution to the overall index. As individual sub-component was measured on a different scale, each must initially be standardized as an index.

The standardized index for individual sub-components was determined through,

……. *Equation-1*

here,

S_v is the value of a sub-component;

The minimum and maximum values are denoted by S_{min} and S_{max}, respectively;

After standardizing individual sub-component value, major component value was calculated by,

…….. *Equation-2*

here,

the value of the major component is denoted by Mc;

Index sci are indicators of indexed subcomponents;

M_c is the major component;

The number of sub-components is n;

Value for fifteen major components were used to get the values of livelihood assets including Human, Natural, Financial, Social and Physical Capital by,

…….… *Equation-3*

here,

Cv is the value of capital;

Weight of the major component is W_{mi};

Indexed value of the major component is Mci;

The values for the livelihood capitals, the weighted average value of the LVI is obtained by,

……. Equation-4

here,

LVI_w is the value of the LVI;

C_{vi} and ${}^{w}C_i$ represent the index value of individual capital as well as their particular weight.

The LVI is scaled from 0 to 1, where 0 represents minimal vulnerability and 1 represents maximal vulnerability. Vulnerability levels are classified into three categories: low vulnerability (0 to 0.25), high vulnerability (0.25 to 0.5), and very high vulnerability (above 0.5). While a medium vulnerability category could be included, we have grouped values between 0.25 and 0.5 under high vulnerability to simplify the classification and reflect the degree of vulnerability more effectively. Future studies may consider adding a medium category if the distribution of vulnerability scores justifies it.

3.4.2. Calculation the value of IPCC-LVI

The IPCC-LVI measures exposure to the natural disasters and climate change. Sensitivity is measured by various factors including health, land, water, natural resources, housing, household assets, communication, electricity, and annual income. Livelihood strategies, socio-demographic profile, asset ownership, social network, finance, and knowledge and skills are covered by adaptive capacity.

Using weighted averages of normalized variables, an index for exposure, sensitivity, and adaptive capacity was created through,

…….. Equation-5

here,

A defined contributing factor of IPCC is CF_w;

Mi are the major components;

^wM_i is the weight to find individual major component;

The number of major components is n;

Combining the calculated values of exposure, sensitivity, and adaptive capacity to derive vulnerability index by,

…… Equation-6

here,

IPCC-LVI is the vulnerability index;

Exposure Index (EI), Adaptive Capacity Index (ACI)and Sensitivity Index (SI) are the scores of exposures, adaptive capacity and sensitivity respectively.

The LVI-IPCC scale measures vulnerability, with values ranging from -1 (indicating the least vulnerable) to +1 (indicating the most vulnerable), where negative value indicate slow vulnerability and positive value indicates high vulnerability (Asaduzzaman 2015)most of the adverse effects of climate change occur in the form of extreme weather \nevents, such as cyclone, flood, drought, salinity ingress, river bank erosion and tidal surge, leading to large scale damage to crops, employment, livelihoods and the national well-being. Although it is generally stated that women are relatively more vulnerable \nthan men in the context of climate change, few studies have been done to closely examine this statement, especially in Bangladesh. The present study, therefore, investigates the structure of women's livelihoods, livelihood vulnerabilities and coping capacity in the context of climate variability and change in a disaster vulnerable coastal area (Shyamnagar upazila of the Satkhira district.

4. Livelihood Vulnerability to flood impacts

The vulnerability of flood affected people was measured by LVI and IPCC-LVI index.

4.1. The Livelihood Vulnerability Index

The LVI utilized in this study was developed using five livelihood capitals, namely human, natural, financial, social, and physical.

Table 4. Vulnerability index of human capital

Major Component	Subcomponent	Unit	Observed value	Max value	Min value	Index value
Health	HHs who experienced health damage.	%	54	100	0	.54
	HHs have no access to medical facilities.	%	51	100	0	0.51
	HHs have limited or no access to family planning facilities.	%	87	100	0	0.87
	HHs have inadequate sanitation facilities.	%	72	100	0	0.72
	Value					0.66
Knowledge and skills	HHs head just passed primary school.	%	73	100	0	0.73
	HHs who do not have any training to cope with flood.	%	100	100	0	1
	Value					0.865
Livelihood strategies	HHs who have no regular income.	%	72	100	0	0.72
	HHs dependent on agriculture as major income source.	%	89	100	0	0.89
	HHs without non-farm activities.	%	75	100	0	0.75
	Jobless HHs during flood season.	%	69	100	0	0.69
	HHs does fishing during flood season.	%	36	100	0	0.36
	Value					0.682
Vulnerability index of human capital						0.707

Human capital is very highly vulnerable according to The LVI utilized in this study was developed using five livelihood capitals, namely human, natural, financial, social, and physical.

(Table 4). With that all the major components of human capital, health, knowledge and skills, livelihood strategies are also highly vulnerable and values are 0.66, 0.865 and 0.682 respectively.

Table 5. Vulnerability index of natural capital

Major Component	**Subcomponent**	**Unit**	**Observed value**	**Max value**	**Min value**	**Index value**
Land	HHs have no access to cultivable land.	%	62	100	0	.62
	HHs have no access to land ownership.	%	48	100	0	0.48
	HHs with small farm (0.1-0.5 hector).	%	19	100	0	0.19
	Value					0.43

Water	HHs not have access to safe drinking water.	%	9	100	0	0.09
	HHs use pond or river water for household work.	%	94	100	0	0.94
	Average time to fetch water.	minute	13.06	30	2	0.395
	Value					0.475
Natural resources	HHs who not have any trees.	%	42	100	0	0.42
	HHs not cultivate 3rd crop.	%	71	100	0	0.71
	Value					0.56
Natural disasters and Climate variability	Number of severe floods in the past 10 years.	count	6	7	4	0.67
	HHs reporting death/injury due to floods in past 10 years.	%	60	100	0	0.6
	HHs do not receive flood warning.	%	81	100	0	0.81
	Value					0.69
Vulnerability index of natural capital						0.537

From Table 5 natural capital is very highly vulnerable. But land and water aren't very highly vulnerable, on the contrary natural resources and natural disasters and climate variability are very highly vulnerable with values of 0.56 and 0.69.

Table 6. Vulnerability index of financial capital

Major Component	Subcomponent	Unit	Observed value	Max value	Min value	Index value
Annual income	HHs are in deficit.	%	82	100	0	0.82
	Inverse of income index.	BDT	.881 (.1354*)	1	0	0.881
	Value					0.85
Asset ownership	HHs without fishing boat and net ownership.	%	59	100	0	.59
	HHs without livestock ownership.	%	82	100	0	0.82
	HHs without poultry ownership.	%	62	100	0	0.62
	Value					0.677
Finance	HHs without adequate access to financial services or financial institution.	%	94	100	0	0.94
	HHs have debt to pay back to individual lender.	%	37	100	0	0.37
	HHs with no income within flood season.	%	38	100	0	0.38
	Value					0.5
Vulnerability index of financial capital						0.678

Financial capital vulnerability index is also very high. And the value of major components of financial capital including annual income, asset ownership is very highly vulnerable with values 0.85 and 0.667 respectively. Besides finance is highly vulnerable representing the value of 0.5 (Table 6).

Table 7. Vulnerability index of social capital

Major Component	Subcomponent	Unit	Observed value	Max value	Min value	Index value
Socio-demographic profile	Average family size of HHs.	Number	5.2	12	2	0.32
	Female headed HHs.	%	5	100	0	0.05
	Dependency ratio.	Ratio	1.06	4	0	0.266
	Value					0. 212
Social networking	HHs receiving helps due to flood	%	32	100	0	0.32
	HHs not have been member to any organizations.	%	91	100	0	0.91
	Value					0.615
Vulnerability index of social capital						0.373

Social capital vulnerability index is in high vulnerability section which is 0.373, where socio-demographic profile is situated in low vulnerability section with a value of 0.373 and social networking is situated in very highly vulnerable section (See Table 7).

Table 8. Vulnerability index of physical capital

Major Component	Subcomponent	Unit	Observed value	Max value	Min value	Index value
Housing	HHs without a solid (pucca) house.	%	88	100	0	0.88
	HHs with house affected by flood (partially to totally submerged)	%	82	100	0	0.82
	Value					0.85
Household asset	HHs has no access the flood related information.	%	69	100	0	0.69
	HHs have no asset to sell during deficit.	%	94	100	0	0.94
	Value					0.815
Communication & electricity	HHs without adequate road and transport facilities.	%	86	100	0	0.86
	HHs without electricity facilities.	%	79	100	0	0.79
	Value					0.825
Vulnerability index of physical capital						0.83

Condition of physical capital is very highly vulnerable with a value of 0.83. The major components of physical capital include housing, household asset and communication & electricity are in very high vulnerability contain the values 0.85, 0.815, 0.83 respectively (See Table 8).

Table 9. Livelihood Vulnerability Index (LVI)

Capital	Number of components	Vulnerability index by capital	Livelihood vulnerability index
Human capital	3	0.707	0.6246
Natural capital	4	0.537	
Financial capital	3	0.678	
Social capital	2	0.373	
Physical capital	3	0.831	

The LVI was determined by assigning weights to the vulnerability scores of the five livelihood capitals, which ranged from 0 to 1. The resulting LVI value was 0.6246 (Table 9) which indicated the livelihood vulnerability of that area is highly vulnerable.

4.2. IPCC-LVI

Table 10. IPCC-LVI Value

Factors	Major component	Value
Exposure	Natural disaster and climate variability	0.69
EI		0.69
Adaptive capacity	Socio-demographic profile	0.212
	Social network	0.615
	Livelihood strategies	0.682
	Asset ownership	0.677
	Finance	0.561
	Knowledge and skills	0.865
ACI		0.5959
Sensitivity	Health	0.66
	Land	0.43
	Water	0.475
	Natural resources	0.56
	Housing	0.85
	Household asset	0.815
	Communication and electricity	0.825
	Annual income	0.85
SI		0.6578
IPCC-LVI		0.0619

Table 10 designates that people were very highly exposed to the effects of flood, with a value of 0.69, and the adaptive capacity is lower than exposure, with a value of 0.5959. The livelihood was also very sensitive with a value of 0.6578. The IPCC-LVI score was documented at 0.0619, which designates a 'high level' of vulnerability to flood as it is a positive value (See Table 10).

5. Results and Discussion

Assessing the livelihood vulnerability of households in the Teota Union due to flooding was the primary objective of this study.

At first glance from the figure 4, results show high vulnerability in both LVI and IPCC-LVI approach. . In the case of LVI, the Physical and human capital were found to be most vulnerable to flood. This is mostly due to a lack of factors like knowledge and training of the community members and proper infrastructure in the area. A study conducted by Muganyizi et al. (2021) in south-western Tanzania similarly identified these factors as the primary contributors to the region's high rate of livelihood vulnerability. Besides, the financial and natural capitals also worsen the scenario by contributing in flood vulnerability of the community. The main influencers of this adversity are natural disasters, climate change, lack of asset ownership and income. Hoq et al. (2021) studied the

flood vulnerability of char land people in Bangladesh and also found that the livelihood vulnerability of that community is alsotriggered by these factors. In China, the human, material, financial, and social capitalhas a considerable negative effect on the vulnerability, particularly for rural households(Zhang et al. 2025). The comparison between Bangladesh, Nepal, and Tanzania is made based on the shared challenges of flood vulnerability and climate change impacts. While these countries differ geographically, they all face significant flood risks due to their reliance on river systems for agriculture and livelihoods. Bangladesh, Nepal and Tanzania, has large portions of its population living in flood-prone areas with limited infrastructure. The demographic and socio-economic characteristics shape the vulnerability, where of farming households, income, education, and age stand out as primary determinants (Raza and Hatab 2025). Among the five, the first *natural capital* was assessed under the LVI approach, which showed a very high vulnerability in Teota, also supported by Didar-Ul Islam et al. (2015) and Hoq et al. (2021) in the Bangladesh context.. ARM Towfiqul Islam & Md. Yousuf Mia (2019), Didar-Ul Islam et al. (2015) and Hoq et al. 2021)regarding Bangladesh and Muganyizi et al. (2021) in south-western Tanzanian revealed that no access to early warning system is the main reason behind this high rate, as so by this study. While Hoq et al. (2021) found that the Bangladesh government's water management strategies have been effective at the national level, our study focuses on a smaller spatial unit—Teota Union, Manikganj. This local-level focus reveals that the effectiveness of these strategies can vary depending on the specific geographic and socio-economic context. In Teota Union, the lack of access to adequate water facilities and infrastructure exacerbates the vulnerability of the community to flood risks, which might not be as apparent at the national scale where broader interventions are more visible. Inadequate access to water facilities makes the community much more vulnerable. However, this study revealed that having no access to land ownership possess a significant rate of vulnerability which also effects the rate of tree ownership and cultivation causing vulnerability to natural resources. These three components (land, water and natural resources) cause relatively lower rate of sensitivity, also reported by Hoq et al. (2021), yet significant, than the other components, like housing, household asset and communication & electricity of physical capital, the second among the five.

Teota is also very highly vulnerable to the *physical capital* under the LVI approach. This mainly results from having no solid housing, being directly affected by flood, lack of assets and poor infrastructure, as revealed by this study and supported by (Rahman 2014). The health vulnerability values at Teota is 0.66 and which shows the moderately vulnerability like other Asian county like India (Kaur, 2020). However, vulnerability to these three components of physical capital causes in highest index of sensitivity among the others in the IPCC-LVI approach. ARM Towfiqul Islam & Md. Yousuf Mia (2019), Didar-Ul Islam et al. (2015) and Hoq et al. (2021) also found the same. Annual income causes the most and health causes a significant sensitivity for the community as it also possesses a high vulnerability to flood under the financial and human capital respectively.

The component annual income, under the *financial capital*, has the highest vulnerability to flood in Teota and so causing a high sensitivity towards natural disasters like flood. Al Mamun et al. (2023) and Sarker et al. (2019)its riverine-island (char also found the same in their study on char land of Bangladesh. Asset ownership and finance also makes a significant rate of vulnerability under the financial capital along with the former component in LVI. Our study revealed that, mainly lack of livestock and no access to financial services and institutions worsen the scenario, as supported by Panthi et al. (2016). Rahman (2014) supported that, debts to individual lenders is a major factor for vulnerability along with the previous two. Moreover, under the IPCC-LVI approach, lack of asset ownership and financial adversities cause high vulnerability to adaptive capacity for the community, as supported by ARM Towfiqul Islam & Md. Yousuf Mia (2019). However, this adaptive capacity is mostly affected by the knowledge and skills, a major component of human capital, of the community members, as revealed by our result.

The *human capital*, assessed under LVI approach, is very highly vulnerable to flood, as revealed by our study. Like its three other major components, health, an extremely useful measure of susceptibility to livelihood vulnerability, as stated by Alam (2017) has a significant effect on vulnerability of Teota. This vulnerability is mostly due to lack of medical, family planning and sanitation facilities within the community, as found in our study and also supported by many authors (Hoq et al. 2021; Ntali and Lyimo 2022; Tasnuva et al. 2023; Kaur, 2020). And this ultimately results in higher rate of

sensitivity in the IPCC-LVI approach, indicating high vulnerability to flood. Besides, our study reported that, livelihood strategies, a component, of the community make the scenario worse (Hoq et al. 2021) as most the community members have no regular income and they are mostly dependent on agriculture as well as having no other income source other than farm-based activities. Didar-Ul Islam et al. (2015) and Kayes et al., 2025 also found the same. Moreover, Didar-Ul Islam et al. (2015) argued that, lack of knowledge and skill, another component, due to illiteracy and zero training impacts vulnerability of the community most, which is also supported by our study findings as it has the highest index of vulnerability among all. This knowledge and skill component, on the other side, makes up the most for vulnerability index of adaptive capacity in IPCC-LVI approach and livelihood strategies also makes up a significant one, as found by this study for Teota. Adaptability is, however, also affected by factors such as a person's socio-demographic profile and social network.

Under the LVI approach, only the *social capital* has low vulnerability due to flood in Teota. Among the two components, socio-demographic profile is the strongest one in the place of research, as it has the lowest rate of vulnerability. Similar findings were also revealed by (Didar-Ul Islam et al. 2015; Hoq et al. 2021; Muganyizi et al. 2021; Ntali and Lyimo 2022; Rahman 2014; Tasnuva et al. 2023; Ogunleye, and Arohunsoro, 2024. However, social networking in Teota possesses high rate of flood vulnerability mainly due lack of organizational involvement, such as farmers' or political organizations, as found by this study and supported by (Hoq et al. 2021). Agrawal (2008) and Mearns & Norton (2010)such as the connection of prosperity, growth, equity, and sustainable development. This volume seeks to establish an agenda for research and action built on an enhanced understanding of the relationship between climate change and the key social dimensions of vulnerability, social justice, and equity. The volume is organized as follows. This introductory chapter first sets the scene by framing climate change as an issue of social justice at multiple levels, and by highlighting equity and vulnerability as the central organizing themes of an agenda on the social dimensions of climate change. Chapter two leads off with a review of existing theories and frameworks for understanding vulnerability, drawing out implications for pro-poor climate policy. Understanding the multilayered causal structure of vulnerability then can assist in identifying entry points for pro-poor climate policy at multiple levels. Building on such analytical approaches, chapters three and four, respectively, consider the implications of climate change for armed conflict and for migration. Those chapters are followed by a discussion of two of the most important social cleavages that characterize distinct forms of vulnerability to climate change and climate action: gender (chapter five stated that, enhancement of adaptive capacity and reduction of vulnerability can be done by involving in a good social structure.

Figure 6. IPCC-LVI Triangle at Teota Union

See Figure 6 for a summary of the ways in which natural disasters and climate change have made residents of Teota. Union's housing stock and their ability to protect themselves from floodwaters vulnerable. Because of limited education, employment opportunities, and access to healthcare and financial resources, the community as a whole has a low adaptive capacity.

Table 11. Comparing vulnerability and BDP Strategies for them

Livelihood Capital	Major Component	Sub-component (Percentage of Household)	BDP Check
Human	Health	Health damage due to flood;	
		No access to medical facilities;	
		Family planning facilities are inaccessible or limited in availability.	×
		Inadequate sanitation facilities.	
	Knowledge & Skills	Household members that just passed primary school; and	×
		Having any training to cope with flood.	
	Livelihood Strategies	Having no regular income;	
		Primarily depending on agriculture for income;	
		Households without non-farm activities affected by flood;	×
		Jobless during flood season; and	
		Fishing during flood season.	×
Natural	Land	No cultivable land;	
		No land ownership; and	
		Households with small farm (0.1-0.5 ha).	×
	Water	No source of clean water;	
		Relying on water from a nearby pond or river for household chores; and	
		Time spent fetching water on average.	×
	Natural Asstes	Having no trees; and	×
		Avoid growing the third crop.	
	Climate Change and Natural Disasters	The ten-year average number of severe floods;	×
		flood-related fatalities/injuries reported over the past decade; and	×
		That do not receive flood warning.	
Financial	Annual Income	Who are in deficit; and	
		Inverse of income index.	×
	Asset ownership	Those who do not own a boat and nets for fishing;	×
		Those who do not own livestock;	×
		Absence of poultry ownership.	×
	Finance	Insufficient availability of financial services or access to financial institutions; and	
		Having to repay money to a specific lender.	
		No income within Flood Season	×
Social	Socio-Demographic Profile	Average family size;	×
		Percentage of female heads; and	×
		Dependency ratio.	×
	Social Networking	Receiving helps due to flood; and	×
		Do not have been member to any organizations.	×

Physical	Housing	Without a solid (pucca) house; and	
		With house affected by flood (partially to totally submerged).	
	Household Asset	Not being able to get flood updates via radio or TV; and	
		Having no asset to sell during deficit.	×
	Communication & Electricity	Without sufficient transportation and road infrastructure; and	
		Devoid of electrical infrastructure.	

Studying the adaptive measures of BDP-2100 to reduce flood vulnerability was the second aim of this research. At a glance, BDP covers almost all the capitals of livelihood except the social one. However, BDP will contribute only a little for financial capital, as only three of the adverse situations for flood vulnerability are addressed by BDP among seven, where physical, human, and natural capitals will benefit most, since most of their adversities will be minimized by BDP (see Table 11).

The livelihood strategies that make up a large part of human capital have a substantial effect on flood vulnerability, highlighting the importance of *human capital* in this context (as found by this study and Azam et al., 2021; Hahn, 2008; Hoq et al., 2021; Kamruzzaman& Shaw, 2018). BDP promises to take necessary step to ensure job and regular income of people; and to lessen the dependency on agriculture and the chances of becoming jobless during flood. Addressing these issues might reduce the vulnerability of the Teota union. Islam et al. (2013), and Sujakhu et al. (2019) also found that households who are strong in these scenarios, especially in income, are less vulnerable than others. Besides, BDP also aims to strengthen the health sectors, an additional significant metric for assessing livelihood vulnerability (Alam 2017; Hoq et al. 2021), by building necessary health infrastructure, like hospitals and clinics, and providing required health services to the community level. BDP will also train the households to cope with flood, which enriches their knowledge and skill. Nevertheless, BDP is not obligated to strengthen critical sectors such as primary education and family planning, which may have long-term adverse effects on the community's livelihood vulnerability.

Teota is particularly vulnerable in the area of *natural capital*. The most significant impacts come from natural disasters and climatic variability (found by this study and MPHA (2012)). As the second goal of BDP is obtaining environmental sustainability, it formulates several strategies, like early flood warning system; enriching natural resources, to fight back these negative effects. Moreover, BDP seeks to guarantee that all citizens have access to safe and sufficient water, and the ownership or access to land for cultivation or other purposes. These strategies of BDP are meant to lessen the adversities of natural capital in livelihood vulnerability.

However, in terms of *financial capital*, BDP contributes only a little, is a sense that it is not bothered about asset ownership of the community members, even though this indicator is making Teota highly vulnerable (also found by Kamruzzaman& Shaw (2018)). This may make the community more vulnerable to flood. But, BDP does address the need for financial services to the root level and helping the households who are in deficit. These strategies will somewhat solve the vulnerability situation of financial capital of livelihood vulnerability.

BDP promises highest development in *physical* components between others. Having the right infrastructure in place can lessen the impact of floods on people's daily lives (Hoq et al. 2021). Teota is highly vulnerable to housing. CAN (2017) reported the same in Bangladesh. Not only that, household assets and communication is another significant contributor of livelihood vulnerability in our study area. Islam et al. (2013); Kamruzzaman& Shaw (2018) and Jevtić et al. (2025) found the same in their studies. However, with the implementation of BDP strategies household will gain much more stability in all of these components of physical capital.

Social networking is a major issue for flood vulnerability. The social networks involvement can enrich the adaptive capacity of communities (Agrawal 2008; Smit and Wandel 2006). This study revealed that, Teota is highly vulnerable in social networking. Hoq et al. (2021), studying on haor areas, also found the same. Moreover, his results also indicated that the communities are highly vulnerable to their demographic profile, but surprisingly Teota possesses low vulnerability in this case.

However, this doesn't mean that, leaving this sector behind will have no harmful effect. BDP, in this case, fails to address any of these adversities which might result in chaotic situation in the future.

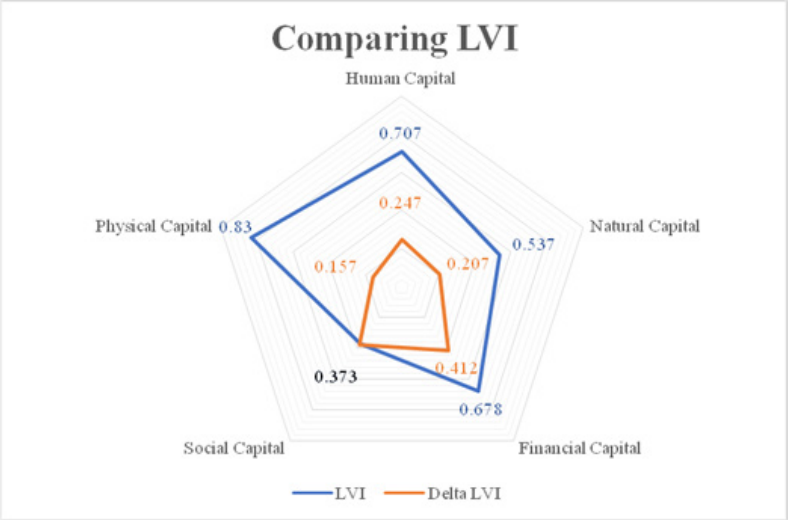


Figure 7. Comparing LVI after BDP

In short, BDP tries to cover all the negative indicators for flood vulnerability except some few. If the goals of BDP are achieved then the scenario of flood vulnerability in Bangladesh, also in Teota, will massively change. Communities will likely to become less vulnerable compared to present. A hypothetical livelihood asset pentagon, after BDP is achieved, is compared with the present one in Figure 7. The comparison clearly indicates to the possible success of BDP to reduce flood vulnerability.

Limitations

The study is cross-sectional, so it does not show how recovery changes over time. Exposure is measured at the community level, not at household level. Future studies should add more detailed in vulnerability component of BDP and in community level. The validation is only internal and is based on BDP; external checks could be done with projected model and some statistical model. Finally, LVI designs depend on context and are often adapted. Future research could compare different dimensions of vulnerability to connect vulnerability classes with impacts and compare LVI and LVI-IPCC results to choose better tools for exposure- or capacity-focused interventions (Islam and Ghosh 2024; Pathak et al. 2020; Sarker et al. 2019; Yang et al. 2021)sensitivity and adaptation. Livelihood vulnerability assessment (LVA.

6. Conclusion

The Teota union is vulnerable to flooding because of its proximity to the Padma River and its low-lying terrain. This research paper assesses the livelihood vulnerability of households in Teota Union, focussing on flood-related challenges. The study used the LVI and the IPCC-LVI approach, considering five livelihood capitals. The findings revealed that Teota Union faces high vulnerability in both LVI and IPCC-LVI, with physical (0.93) and human capitals (0.707) being particularly vulnerable to floods. Lack of knowledge and skills to cope with flood (table 4), , lack of household asset ownership, and lower level of annual income were identified as key influencers contributing to vulnerability. The study also explored adaptive measures, focusing on the BDP-2100, which addresses various livelihood capitals. Subcomponents of each capital have also been defined for BDP in this research paper along with a hypothetical explanation of how these subcomponents can lessen the vulnerability presented in this study. The research suggests that successful implementation of BDP could increase the resilience of communities in Teota Union, leading to a considerable reduction in flood vulnerability. In short, Teota's vulnerability is mainly in physical and human constraints, with financial buffers also tight. BDP-2100 addresses many of these but leaves social capital/collective action. The index-to-policy

crosswalk offers a ready checklist for local action: early warning & information; basic health & sanitation; resilient housing/roads; livelihood diversification and reliable finance access; and network-building (women's groups, producer associations) to strengthen adaptive capacity. However, to compare the potential success of BDP, this study did not use any quantitative method to measure the vulnerability of the capitals. The main limitations of this study is, in the BDP, all the covered sectors were valued as zero hypothetically in terms of vulnerability. This is because, BDP is a set of strategies and it does not contain specific plan, which constrains us from measuring the expected vulnerability of each capital. Like BDP, some other plans are also formulated to shape the future of the country which will directly impact the livelihood of people. One is, 'My Village, My Town', which aims to reduce livelihood vulnerability in the villages by providing all the civic amenities to the local level (Saifuddin Saif 2021). Another is 'Smart Bangladesh Vision 2041' and this aims to ensure use of technology in every possible sector which might result in the reduction of livelihood vulnerability of the communities (Smart Bangladesh Vision 2041 – a2i n.d.). Further studies are required to identify the effectiveness of various plan, by the govt of Bangladesh, to reduce Livelihood vulnerability.

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