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Livelihood vulnerability and adaptation strategies of coastal areas in the face of climate change in Bangladesh: A literature review

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Abstract

Bangladesh is one of the world's most vulnerable countries to climate change because of its flat and low-lying topography. The country's coastal areas are most susceptible to river erosion, flooding, tropical cyclones, salinity intrusion, and tidal surges. Natural and human-induced hazards and disasters have a ripple effect on the ecosystem, resulting in the loss of human lives, property, and the valuable resources needed for human subsistence. The review summarizes the current literature, highlighting the vulnerability index, local-level adaptation strategies, and future research work. The reviewed literature has reported common hazards like tropical cyclones and tidal waves that can cause tidal floods and riverbank erosion, all of which have a high-to-medium impact on the structure of homes, income, wealth, and employment. Agriculture is the most vulnerable sector in the coastal areas. Aquaculture, shrimp, open-water fish collection, and infrastructure are all vulnerable to disasters in coastal areas. The widely used vulnerability indexes are Livelihood Vulnerability Index (LVI), Coastal Vulnerability Index (CVI) and principal components (PCs) reported in the literature. The local level adaptation strategy is to build the house on high land using bamboo and wood. The pond/gher bound ponds by the net to protect fish from the overflow water, put soil on the gher dike, and sell fish as soon as possible. Diseases of shrimp viruses and white fishes use calcium carbonate, fertilizer, and potash alum as preventative measures. The farmer converted their agricultural land into gher for fish/shrimp cultivation. The community stored/harvested rainwater in a plastic pot or soil pot. The study results will help the government with landscape planning and a disaster-prevention plan at the local level.

1. Introduction

Green House Gases (GHGs) emissions from uncontrolled human activity have resulted in global warming, which has led to climate change (CC) [1-3]. Changing climatic variables, such as rainfall, temperature, water and soil salinity, cyclones, tidal surge, drought, and sea level, have long been considered to impact the global environment and society at numerous scales, including the oceans [3-5]. By 2100, 170 million people from 22 low-lying coastal nations would be at risk of being stranded

by rising sea levels, according to the Fourth Evaluation Report (AE4) of the Intergovernmental Panel on Climate Change (IPCC) [7]. Other isolated habitats will also be subjected to new climate pressures [6, 7]. Climate change (CC) occurs at an ever-increasing pace [8]. Meanwhile, CC contains evidence of high temperatures, irregular rain, heat and cold waves, tidal floods, droughts, salt, and tropical cyclones affecting the natural ecology, agriculture, and livelihoods directly and indirectly [9, 10]. Crop productivity will suffer significantly due to global warming-induced climate change (CC). This means that 12 percent of the world's population will be hungry, and 700 million people will be malnourished as a result [11]. FAO (2008) stated that CC will threaten food security on 25 percent of the world's farmland [12, 13].

Bangladesh's southwest coastline region is the country's most disaster-prone and most at risk from climate change brought on by human-caused global warming [14-16]. With a total length of 710 kilometres and more than 35 million populations, Bangladesh's coastal areas are spread throughout 20 districts and 140 Upazilas [17, 18]. Upazilas in the coastal districts of Bangladesh's 20 districts range from 1.2 to nearly 4.5 meters above sea level. Natural and man-made disasters have a direct or indirect impact on these districts. According to WARPO (2006) and Uddin et al. (2019), the coastline area is about 47,201 km2 and comes inside the tropical zone between 21°23′′N and 89°9′′E. Summer lasts from March to May, followed by the monsoon season from June to September, and winter from November to February in a subtropical environment. As the principal source of income, agriculture is responsible for a large portion of land utilization [17, 19]. In Bangladesh, the Chittagong and Khulna city, home to nearly 20,000 people per square kilometre, are two of the most densely populated coastal cities (Fig. 1). On the other hand, the coastal areas are home to some of the world's most distinctive and diversified ecosystems, including the Sundarbans Reserve Forests (SRF), the world's longest beaches, coral reefs, and sand dunes [20-23]. Ecosystems and people's livelihoods in coastal regions are already under significant threats from climate change and variability [24-26]. Another important source of income and employment in the coastal area is shrimp farming in gher land, agricultural (crop) production, and natural resource exploitation [25]. The coastal region is home to the vast majority of the world's poor. There were 62.46 percent farmers, 3.84 percent on-farm laborers, 0.81 percent industry, 12.20 percent commerce, and 10.35 percent service as the principal sources of revenue [22]. According to Table 1, drinking water sources included tube wells (90.11%), tap water (0.40%), pond water (7.53%), and others (1.86%) [15]. The coastal region's climatic scenario predicts an annual maximum and lowest temperature of 25.3°C and 12.2°C, respectively. It rains on average about 2377 millimetres a year, and the humidity level is at 80.9 percent on average. Storm frequency has increased by half (2008-2011), while river erosion has increased by 100% [25, 27]. As a result, it's critical to look at how climate change may influence the livelihoods of those who are most vulnerable [28-31]. The findings of this review include measuring livelihood vulnerability, the impact of climate change on livelihoods, and the development of local-level adaption methods.

2. Methodology

2.1 Research design

A systematic literature review of information was conducted, covering relevant research over the last seven years. Recent data was collected from participants in the ongoing debate over the potential of climate change, livelihood vulnerability, local-level adaptation strategies, and coastal disaster resilience. This study focuses on local-level adaptation strategies aimed at livelihood climate resiliency.

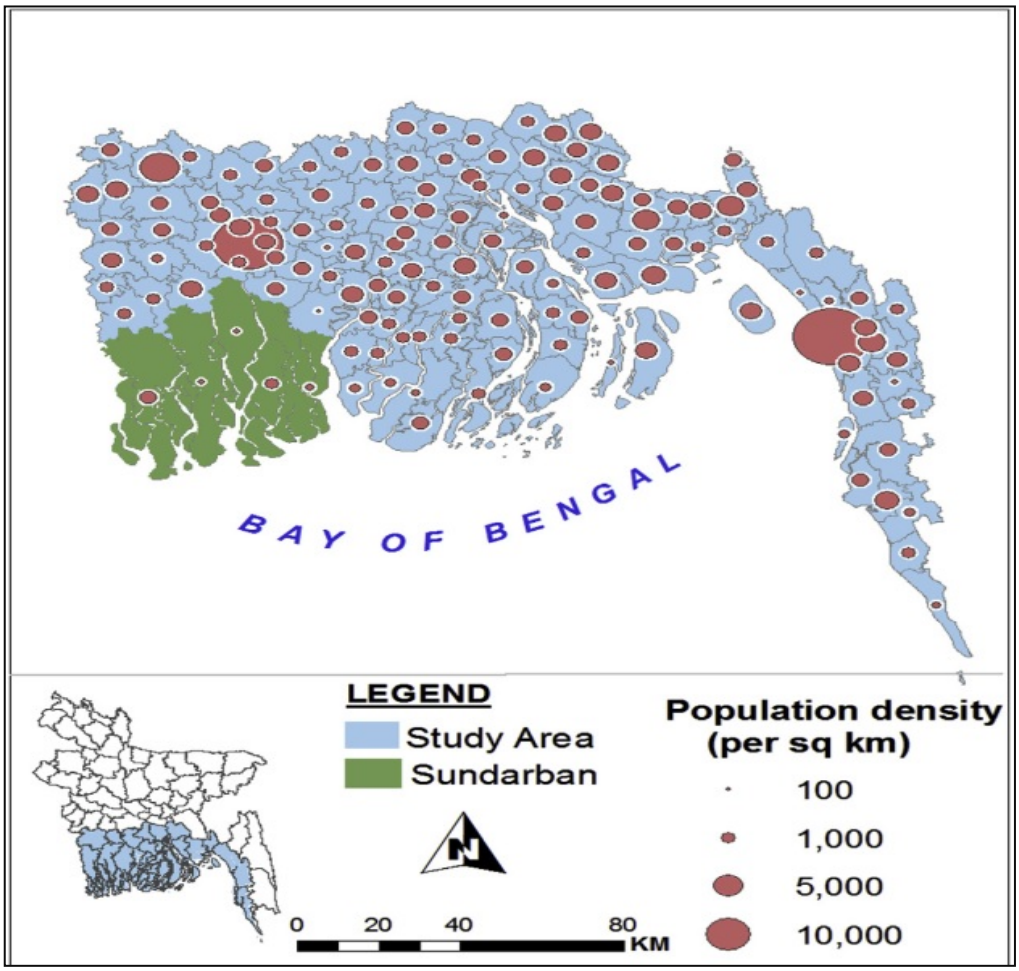

Figure 1: The coastal areas of Bangladesh with population density [17].

2.2 Search Strategy

A scan of the literature is required as the first step in identifying and establishing new paradigms in developing fields of inquiry. As a result, the most recent relevant research was combed via various reliable sources, including Scopus, the Web of Science, and Springer. These include "climate change," "vulnerability," "livelihood," "resiliency," "adaptation demand," and "coastal area," among others. As of 2020, there are no formal restrictions on the number of published articles found through keywords. Only published scientific papers in the English language were evaluated for this systematic review investigation.

2.3 Inclusion and exclusion criteria

The desk review was guided by criteria such as (a) Is the study focus on disaster resilience reflected in the desk review criteria? (b) Does the study quantify the amount of local-level adaptation techniques in the study? In addition, do you have access to the study whole text? Specific exclusion criteria, such as publications in languages other than English, duplication, and repetitive subjects, have also been followed.

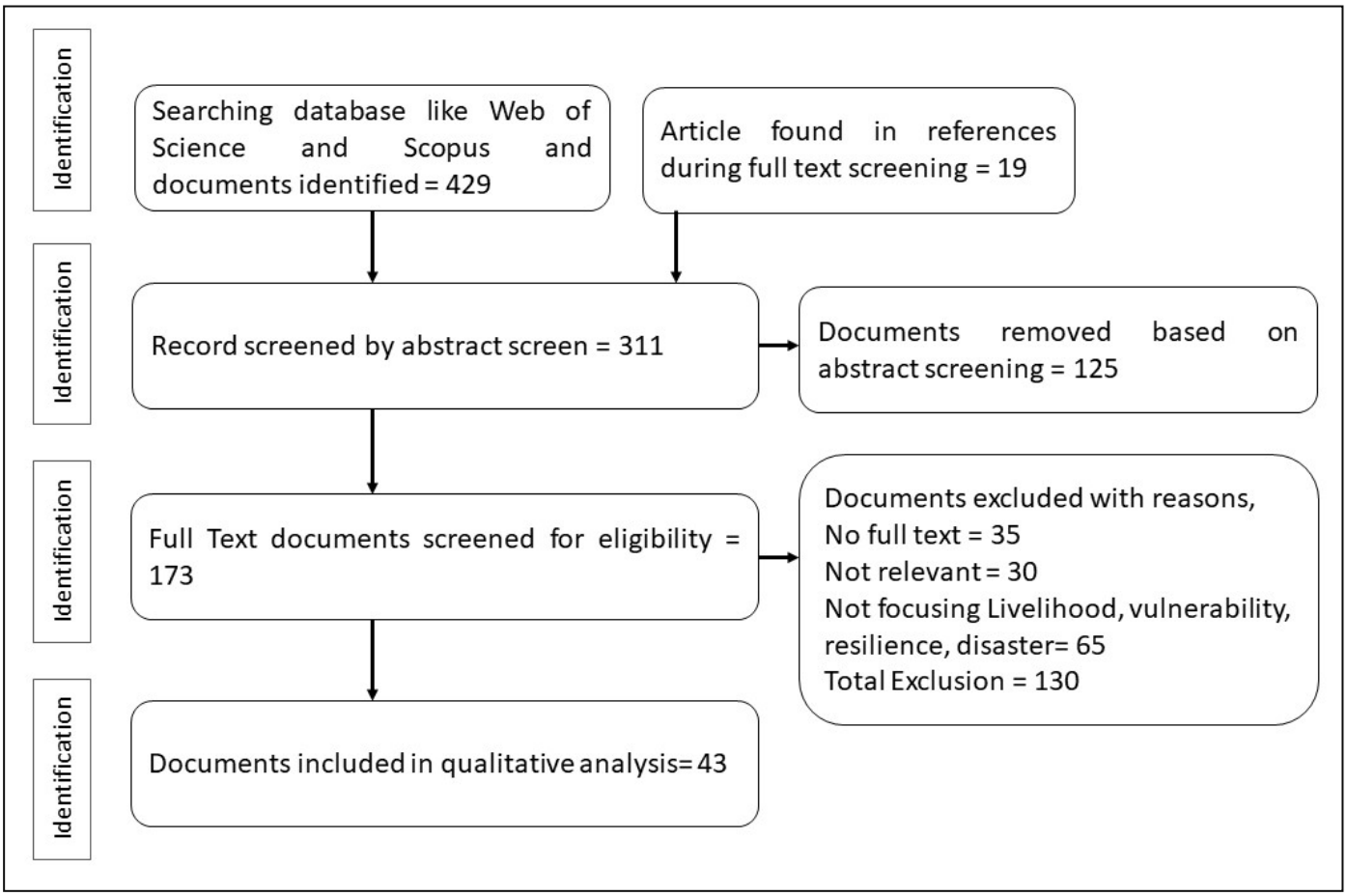

Figure 2: Documents selection by PRISMA guidelines

3. Results

3.1 Systematic review results

Methods for conducting a systematic literature review were based on PRISMA recommendations [32]. It was initially necessary to gather 429 papers and an additional 19 from the bibliographies of those documents. 173 articles were found after the abstract screening. As a result, 130 publications were removed, including those that did not match the full text criteria or were repetitive. Forty-three documents, including journal articles, book chapters, and working papers, were analyzed in-depth to conclude [33], Fig. 2.

3.2 Analytical Results.

3.2.1 Livelihood vulnerability

The findings of this study are based on the analysis of the 11 most relevant texts. Crab farming, shrimp culture, agriculture, and infrastructure are the main livelihood sector which is most vulnerable due to climate induces natural disaster and hazards [34-36, 15]. The livelihoods vulnerability are presented in Table 2.

3.2.2 Livelihoods vulnerability measurement index

A majority of the researchers suggested three indexes of livelihood vulnerability measurement. The highly cited index is LVI, CVI, and PC [37-39, 17]. The primary focused areas and applied documents are presented in Table 3.

3.2.3 Existing local-level adaptation strategies

Relevant documents analysis reveals that local-level adaptation strategies are the key challenges to livelihoods vulnerability [14-16]. The most frequently mentioned of these are summarized and presented in Table 4.

4. Discussion

Based on the examined literature, this section provides a detailed explanation of the livelihoods vulnerability, measurement index, and local-level adaptation strategies.

4.1 Overview of climate impact on the livelihood

Due to its deltaic topography, Bangladesh is extremely prone to CC, and many notable academics have studied susceptibility to CC in the past [40-41]. More than half of the negative consequences of climate change (CC) on Bangladesh are caused by sea-level rise and other natural disasters such as cyclones; storm surges; floods; waterlogging, drought; saline intrusion; riverbank erosion; and tidal surges [42-43]. The impacts on livelihood due to CC depend on the nature and severity of the physical effects relating to agriculture, water availability and quality, disaster-proneness, the hospitability of the physical environment due to rising temperature, and changing water regimes to pathogenic activity and coastal inundation. CC impacts on livelihood thus become a challenge of development under the most adversarial changes in dynamics of nature. If cyclones and storm surges increase in frequency and intensity, the potential losses to life and livelihood would be most severe [44].

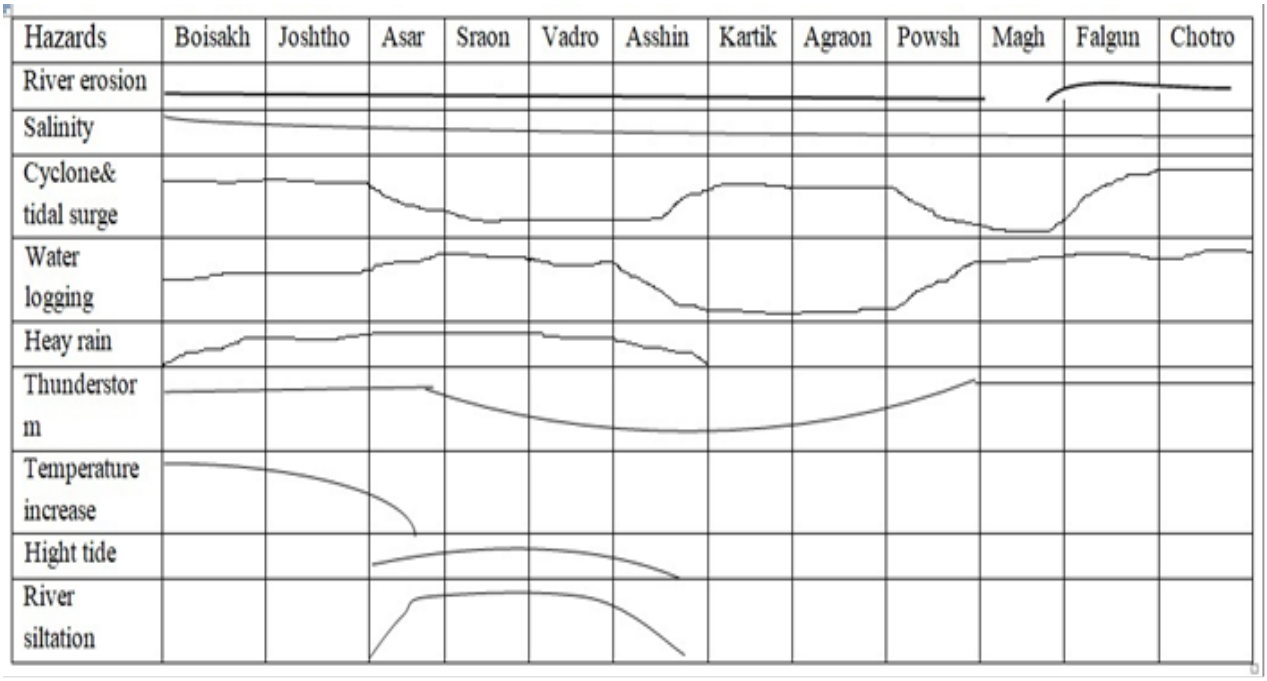

Figure 3: Seasonal hazards Calander Sources: [14, 15, 19]

The following tables show the seasonality of hazards and livelihood patterns in Bangladesh's coastal areas (Table 2 and 3). River erosion and salinity problems happen throughout the year, although storm surges and cyclones are more prevalent in the months of Boishak, Joshtho, Agraon, Chotro, and Kartik. There is a lot of waterlogging in Asar, Vadro, and Sraon, while heavy rain has also been reported from Boishakh to Asshin. In contrast, frequent thunderstorms have been reported from Boishakh to Asar, and Magh to Chotro, while high temperatures have been reported from Boishakh to Asar. In the months of Asar to Asshin, researchers have discovered particularly high tides and river siltation. Animal husbandry (duck, hen, cow, and goats), forest resource exploitation, and van and rickshaw puller are the main sources of income for coastal residents. Throughout the year, small businesses have found. In addition, the vegetables, shrimp, fish, crab, and golpata extraction have been seen as seasonal trends. When considering the possible implications of climate change on people's livelihoods, it is evident that the poorest members of each community are the most susceptible. Women, children, the older people are the most vulnerable in even the most impoverished communities. Therefore, it is assumed that the most vulnerable populations in the country and each susceptible region would bear the adverse effects of climate change [45].

Table 1: Livelihoods patterns in the coastal areas

Livelihoods sector	Boisakh	Joshtho	Asar	Sraon	Vadro	Asshin	Kartik	Agraon	Powsh	Magh	Falgun	Chotro
Vegetable cultivation			✓	✓	✓	✓	✓	✓	✓	✓		
Shrimp cultivation	✓						✓	✓	✓	✓	✓	✓
Fish cultivation			✓	✓	✓	✓						
Crab cultivation						✓	✓	✓	✓			
Animal rearing (duck, hen, cow, and goats)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Daylabor	✓						✓	✓	✓	✓	✓	✓
Forest resource extraction	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Van & rickshaw puller	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Small business	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Golpata extraction									✓	✓	✓	

Sources: [14, 15, 19]

4.2 Livelihood vulnerability ranking

Intergovernmental Panel on Climate Change (IPCC) report working group II's (2007) definition of vulnerability is "a consequence of the nature, size and pace of climate fluctuation to which a system

is exposed, the sensitivity, and its adaptive capability" [6]. "Vulnerability" is a mathematical concept that describes the relationship between an individual exposure, sensitivity, and ability to adapt [46].

V (Vulnerability) = F (exposure, sensitivity, adaptive capacity)

Agriculture is the most vulnerable sector to climate change in coastal areas, based on the table 1. Meanwhile, aquaculture is the second-largest entity at risk, and infrastructure is the third-most susceptible. Crab, shrimp, and fish culture from open water are placed fourth and fifth, respectively. The exploitation of forest resources due to various natural hazards and disasters is another vulnerability.

Table 2: Livelihood vulnerability assessment based on spatial and social context

Vulnerable sector	Risk created hazards								Total Score
	River erosion	Salinity	Cyclone & Tidal surges	siltation	Waterlogging	Heavy rain	thunderstorm	Temperature rise	
Fish cultivation	3	3	2	2	1	1	0	2	14 (2nd)
Forest resources extraction	0	1	3	1	0	0	1	1	7 (6th)
Fish collection from open water	0	1	3	2	0	2	0	1	9 (4th)
Crab cultivation	0	0	3	0	2	2	0	1	8 (5th)
Shrimp collection	0	1	3	2	0	2	0	1	9 (4th)
Agriculture	2	3	2	1	3	2	0	2	15 (1st)
Infrastructure	3	2	3	0	1	1	1	2	13(3rd)
Total	8	11	19	8	7	10	2	10	

Sources: [14, 15, 19]

4.3 Approach to measure livelihood vulnerability

According to the IPCC, vulnerability is a function of exposure, sensitivity, and the ability to adapt to environmental change [6]. Livelihood Vulnerability Index (LVI), established by Hahn, Riederer, and Foster (2009), assesses vulnerability [37]. The LVI employs a variety of variables to gauge a community's vulnerability to natural disasters and climatic variability, as well as the social and economic aspects that influence a household's ability to adapt and the present state of the community's health, food, and water resources. The index is constructed using primary data from household surveys, which sets it apart from earlier approaches. There are various advantages to the method Hahn et al. (2009) adopted over previous attempts [37]. Principally, the index is based on data gathered through surveys of households. Using secondary data might have its drawbacks. A methodology for combining and aggregating indicators at the regional level is provided as a secondary benefit of the report. It is not dependent on climate models and neglects the complexity of local livelihoods [34]. The CVI is one of the most often used and straightforward approaches [47]. One of the most important aspects of quantifying climate change and climatic variability impacts on livelihoods is the development of several indicators. Swain (2011) developed a composite index by combining the indexing and vulnerability profile methods [48]. Gbetibouo and Ringer developed an aggregate vulnerability index (2009), used to determine the farming sector's level of susceptibility to climate change and variability

[39]. Multiple factors are selected and combined to represent the degree to which an individual is vulnerable.

Table 3: Vulnerability measurement index

Name of Index	Focus area	Reference
Livelihood Vulnerability Index (LVI)	The LVI uses multiple indicators to assess exposure to natural disasters and climate variability, social and economic characteristics of households that affect their adaptive capacity, and current health, food, and water resource characteristics that determine their sensitivity to climate change impacts.	[37]
Coastal Vulnerability Index (CVI)	The Coastal Vulnerability Index (CVI) is one of the most commonly used and simple methods to assess coastal vulnerability to sea-level rise, particularly due to erosion and/or inundation.	[38]
principal components (PCs)	Population dynamics in the coastal region of Bangladesh with the complex agroecological system have been investigated.	[17]
aggregate vulnerability index	determining the level of vulnerability of the farming sector to climate change and variability	[39]

4.4 Local Adaptation strategies

Although Bangladesh contributes very little to global climate change, it is predicted to suffer considerably due to climate change in the next decades. To achieve adaptation, vulnerability assessments from various disciplines must be merged. The country's coastal area may benefit from some of the ideas outlined below [16, 49]. Aquaculture is the primary source of income for most coastal residents [16]. Tropical cycles, storm surges, increased salinity, drought, increasing warmth, and heavy rain affect aquaculture [14, 15]. People bound their fish ponds by the net to protect fish resources from water overflow. In addition, they made high pond dike by soil and sometimes sold fish as soon as possible to recover the loss [25]. Calcium carbonate, fertilizer, and potash alum are used to prevent shrimp virus and whitefish infections when the pond/gher has dried up. Sometimes the tidewater cause flows from it [14, 15]. Due to rising salinity, tropical cyclones, tidal surges, and waterlogging, the soil fertility of the agricultural land has declined [16]. The majority of the farmer converted their agricultural land into gher for fish and shrimp culture. The organic fertilizer is also used to produce vegetables in pots and plastic bottles in their garden and yard [14, 15]. Most people lack safe drinking water because of salinity intrusion. The tube-well and deep well water are unfit for human consumption because of excessive salt levels in the surface and groundwater [15]. As part of their local adaptation techniques, they used plastic pots or soil pots to collect rainwater. They have to collect safe water for cooking and household purposes from distant sources, which consume their time for baby care. People construct large ponds to store safe water for consumption during the summer [50, 51]. During disaster emergencies, people move to a secure location due to damage to their houses, shelters, and infrastructure. They build the temporary shelter on dams and embankments. Some people make their homes or shelter on elevated land with bamboo and wood. Sometimes, the affected people have to stay in the open sky [14,15]. The Sundori and Keora trees have succumbed (agamora) disease due to increasing salt in coastal water and soil. Trees absorb silt from soil and water via their roots during high tide, which impacts their respiration and growth. Due to increased salinity in soil and water, the framer has to face difficulties cultivating vegetables at their yards and gardens [49, 15, 16]. Prolonged

drinking salty water may pose potential threats to human health, especially women and wild animals. Previous studies find that women have prolonged drinking of saltwater to face pregnancy problems [49, 16]. The available previous literature has reported that people used dead trees as fuelwood during a disaster emergency. They plant various trees in their yards, along the roadside, and in other open areas [50].

Table 4: Local-level adaptation strategies

Livelihoods sectors	Climate hazards	Adaptation strategies	References
Fisheries sector	Tropical cycle, storm surges, salinity intrusion, drought, increase temperature, heavy rain.	Pond/gher is bounded by the net, putting soil on the gher dike and selling fish as soon as possible. Diseases of shrimp virus and white fishes, as preventive measures, use calcium carbonate, fertilizer, and potash alum.	[14-16, 35]
Agriculture and yard garden	Salinity intrusion, tropical cyclones, tidal surges, and waterlogging	converting the agricultural land into gher for fish/shrimp cultivation. cultivate vegetables in high land in their home yard; sometimes, the organic fertilizer is used to grow vegetables in pot/plastic bottles	[14-16, 35]
Drinking water	Salinity intrusion, cyclone, and tidal surge increase temperature.	They stored/harvested rainwater in a plastic pot or soil pot. Collect safe drinking water from long-distance sources for drinking and cooking purposes. In summer, safe drinking water is stored in a large pond for consumption.	[16, 49]
Home and Infrastructure	River erosion, Salinity intrusion, cyclone and tidal surge	People moved to another safe place. Build temporary shelters on dams and embankments. Some people use bamboo and wood to make their houses on up/high land. Some people also live in the open sky	[14-16, 35]
Forest resources and Biodiversity	Salinity intrusion, cyclone, and tidal surge increase temperature: flood and high tide.	People use it as fuelwood for dead trees. People are plant trees on their home yeard, roadsides, and open places.	[14-16, 35]

Conclusion

The coastal areas of Banladesh have a high population density, particularly in Khulna and Chittagong, where more than 20,000 people live per square kilometre. The livelihoods of these highly populated cities are impacted by various natural and man-made disasters. Agriculture is the principal source of economic activity in the coastal zone, and it takes up a significant amount of land. Salt intrusion and shrimp farming are eroding the agricultural sector's dominance. Climate change, as well as natural catastrophes, have put resource-based livelihoods at risk. In coastal locations, agriculture is the most susceptible sector. Meanwhile, aquaculture is the second-largest industry at risk, and infrastructure is the third-most susceptible. It is the fourth most vulnerable sector. According to the literature, the most commonly used vulnerability indices are LVI, CVI, and PCs. Building embankments out of bamboo and wood to raise their homes to higher ground is a local adaption need. They make high dike by soil due to high tides or flash floods or sell fish quickly to recover the loss.

Use calcium carbonate, fertilizer, and potash alum to prevent shrimp virus and whitefish diseases. Agricultural land is repurposed for the production of fish and shrimp. They used a plastic or earth container to collect rainwater. The findings of the literature study will assist local authorities and the government in developing a local-level landscape plan and disaster mitigation.

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