



Preparedness of recovery to the vulnerability of climate change in the coastal areas in Bangladesh

M. Rokonuzzaman¹ , Yuta Hattori²

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Corresponding Author(s):

M. Rokonuzzaman

Department of Agricultural Extension & Rural Development, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh. Email: rokon@bsmrau.edu.bd

Abstract: The purpose of this study is to assess the vulnerability of Bangladesh's coastal areas to natural disasters driven by climate change and to evaluate the effectiveness of current coping mechanisms. The research involved surveying farmers across eight coastal unions, focusing on their socio-economic characteristics, family size, income levels, and the impact of climate change on their livelihoods. The study employed a mixed-methods approach, utilizing face-to-face interviews, in-depth case studies, and focus group discussions to gather both qualitative and quantitative data. The findings indicate that Bangladesh's coastal regions are highly susceptible to climate-related disasters, particularly cyclones and flooding, which exacerbate socio-economic challenges. The study reveals that existing shelters are inadequate for the dense population, a situation further complicated by the COVID-19 pandemic, which increases the vulnerability of affected communities. Coping mechanisms, such as rainwater and groundwater storage and women's involvement in dairy production, have shown some effectiveness in sustaining household income. However, these measures are insufficient to fully mitigate the impacts of climate change. The study concludes that adaptation strategies focusing on accommodation and protection are crucial, given Bangladesh's high population density and limited resources for retreat. The implications of this research suggest that enhancing these adaptation strategies through need-based training and improving infrastructure could significantly bolster the resilience of coastal communities. Furthermore, there is a pressing need for international support to address the broader challenges posed by climate change, particularly in safeguarding the Sundarbans' biodiversity and the livelihoods of millions in coastal areas.

Keywords: Preparedness of recovery; Vulnerability, climate change; Coastal areas; Bangladesh

1. Introduction

Bangladesh is a small deltaic country formed by the mighty Ganges-Brahmaputra-Meghna river system, characterized by a low external elevation. It is a densely populated, poverty-prone country with a 711 km long coastline, featuring an extensive network of rivers (Minar et al., 2013). The entire coastal region covers 47,211 square kilometers, accounting for 32% of the nation's total geographical area. This region is home to approximately 35 million people, residing in 6.85 million households, which makes up over 28% of the country's total population (BBS, 2017). In terms of administrative divisions, 19 out of the 64 districts in the country are located within this coastal belt (Shamsuddoha & Chowdhury, 2007).

Climate change, often referred to as global warming, signifies the rise in the average surface temperature of the Earth. This phenomenon has become a significant concern due to its dramatic impacts, which are being felt across the globe. The combustion of fossil fuels such as coal and oil, which emits various greenhouse gases (primarily carbon dioxide) into the atmosphere, is widely recognized as the primary cause of climate change. Additionally, human activities such as agriculture and deforestation contribute to the emission of these gases, further exacerbating the situation (Gazi, 2019). Even a modest increase in the Earth's temperature due to climate change could have severe consequences for living organisms. One such consequence is the melting of polar ice caps, leading to rising sea levels. Other outcomes include more intense and frequent storms, excessive rainfall causing devastating floods, and wildfires that can destroy environments, homes, and lives, ultimately resulting in fatalities and significant damage (Reyer et al., 2017).

Bangladesh is especially vulnerable to natural disasters because of its geographical position. According to a World Bank report, Bangladesh is among the most affected countries in South Asia due to global warming. A 2°C rise in global average temperatures in the coming decades could have severe implications for the country (World Bank, 2013). This report also revealed that global warming and climate change lead to numerous severe problems, including rising sea levels, increased temperatures resulting in more heatwaves and more intense cyclones, and significant threats to food production, livelihoods, and infrastructure, ultimately slowing down efforts to reduce poverty. The relationship between climate change and agriculture is particularly noteworthy, as agriculture is affected in various ways, such as increased temperature,

¹Department of Agricultural Extension & Rural Development, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Bangladesh

²Department of Preventive Medicine, Nagoya University Graduate School of Medicine, Tsurumai-cho, Japan

heavy rainfall, heatwaves, pest outbreaks, and changes in atmospheric carbon dioxide and ground-level concentrations. These factors contribute to deteriorating the nutritional quality of food and pose a significant threat to food security, particularly for vulnerable groups like the poor and landless (Bank, 1994). Climate change's impact on agricultural production, ecosystem balance, livestock production, and water bodies is already evident and constantly evolving (Figure 2).

The effects of global climate change could become increasingly severe over the next century. Climate change also poses a significant threat to human health and safety. Densely populated, impoverished communities living in river basins and low-lying coastal plains are particularly vulnerable to dangerous natural hazards such as storms, floods, and droughts. A report from the world's leading experts of the IPCC (2014) indicates that the rise in global temperatures during the past century is unlikely to have been caused solely by natural effects; rather, human activities have significantly contributed to global climate change through both temperature changes and the impacts of various human actions on the geographic, seasonal, and vertical patterns of temperature.

Several critical factors make Bangladesh particularly vulnerable to climate change, including its geographical location, high population density, extreme poverty, and dependency on climate-sensitive factors such as agriculture and fisheries (Rahman, 2008). The severe impacts of these factors fall disproportionately on women and girls in Bangladesh. The country's vulnerability is heightened by its geographical features, regional flow patterns, excessive water flow during the monsoon season, and inadequate water flow during the dry season. These impacts significantly affect various socio-economic realities, including population density, poverty, per capita income, inequality, and developmental practices.

The broad impacts of climate variability on Bangladesh are significant, and their consequences are profoundly affecting the country's hydrology (Huq & Ayers, 2008). Bangladesh's regional setting makes it highly vulnerable to extreme climate events, and the rapid pace of climate change is putting immense pressure on the country's water resources and agricultural systems. The effects of climate variability have two major dimensions in Bangladesh: temporal and spatial, both of which have significant consequences (Mishra et al., 2010). The effects of current climate variability include more frequent and intense floods, droughts, and salinity ingress. The country must implement various adaptation measures to mitigate the impact of climate change and variability. In the southwest part of Bangladesh, the impacts of climate variability are particularly concerning, with higher salinity levels, choked-up small rivers, waterlogging, embankment breaches and overtopping, cyclonic storm surges, and riverbank erosion. The Bangladesh Water Development Board has estimated that 1,200 km of riverbank is actively eroding, with over 500 km facing severe erosion problems. Despite some silt deposition, a net area of 8,700 hectares of land is being lost (Maria, 2006). Salinity intrusion into agricultural cropland remains a severe problem in the southwest region of Bangladesh.

Conversely, the upper reaches of the country face fatal drought conditions. Bangladesh experiences a dry period of seven months, from November to May, during which rainfall is low. During this period, about 2.7 million hectares of land in Bangladesh are vulnerable to annual drought. According to the Government of Bangladesh, there is a 10% probability that 41-50% of the country will experience drought in a given year (Rahman, 2008). Ensuring a reliable supply of saline-free water for the southwest region of Bangladesh is a significant challenge for both the population and the ecosystem.

Bangladesh's coastal zone, which covers 47,201 km² or 32% of the country, spans 19 districts. Approximately 35 million people, representing 29% of the population, live in the coastal zone and are directly or indirectly affected by hazards such as coastal floods, tidal surges, salinity intrusion, riverbank erosion, and tropical cyclones (Ahmad, 2019). Climate change is expected to exacerbate these coastal hazards significantly. Bangladesh is one of the countries most likely to suffer from the adverse effects of anthropogenic climate change. A one-meter rise in sea level could submerge 18% of Bangladesh's total land area, potentially displacing around 30 million people living in coastal areas (Minar et al., 2013). Bangladesh is particularly vulnerable to tropical cyclones, with around 718,000 deaths attributed to such events over the past 50 years (Haque et al., 2012). Salinity intrusion is rapidly increasing, already penetrating 100 km inland, further deteriorating the situation (Sobhan, 1994).

The resultant seawater intrusion increases salinity in coastal drinking water, with severe health consequences for the surrounding populations (Daily Star, 2011). About 53% of the coastal areas are affected by salinity. Millions of people in northern Bangladesh are threatened by riverbank erosion and severe droughts (Daily Star, 2011). As most parts of Bangladesh are less than 10 meters above sea level, and about 10% of the population lives below 1 meter in elevation, the country is highly vulnerable to high tides and storm surges. Moreover, the location of the Bay of Bengal contributes to severe cyclonic storms and tidal waves that severely impact the coastline due to the bay's shallow and conical shape (Denissen, 2012). Given these challenges, this research addresses the critical issues faced by Bangladesh.

1.1. Identification Of The Problem

Approximately one-fourth of Bangladesh's population lives in coastal areas, where they struggle to meet basic needs and are highly vulnerable to natural disasters such as cyclones, tidal surges, and saline intrusion. These disasters exacerbate the challenges faced by coastal communities, threatening their livelihoods and making them increasingly susceptible to rising sea levels. It is crucial for these communities to understand how to cope with such disasters, and to develop effective resilience mechanisms.

1.2. Objectives Of The Research

This research aims to:

1. Describe the socio-economic impact of climate change in Bangladesh's coastal areas.
2. Identify the areas most affected by climate change within the coastal belt.
3. Explore the vulnerabilities and coping mechanisms of communities in these regions.
4. Investigate resilience mechanisms and propose suggestions for mitigating the impacts of climate change.

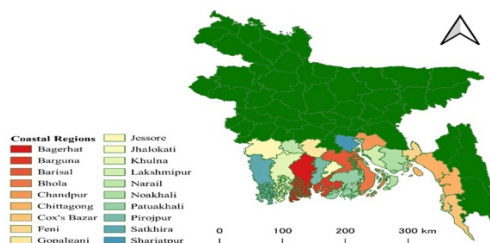


Figure 1: Coastal districts in Bangladesh

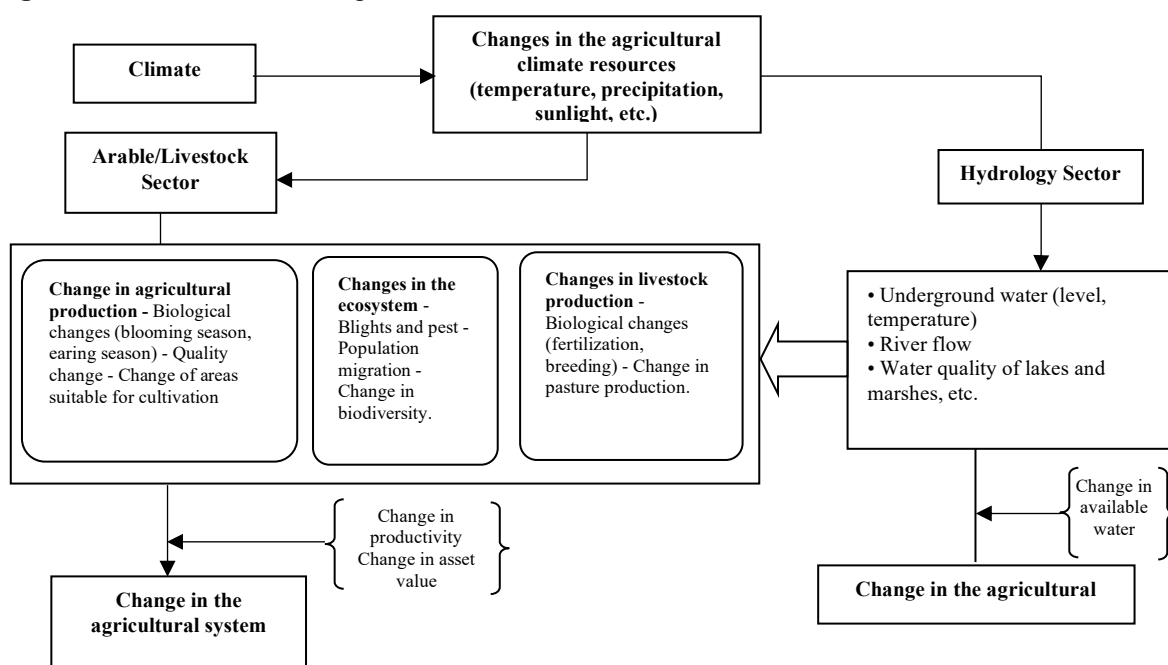


Figure 2: The flow of the climate change impact on the agricultural sector. **Source:** Kim, Chang-Gil and et al. (2009), p.96.

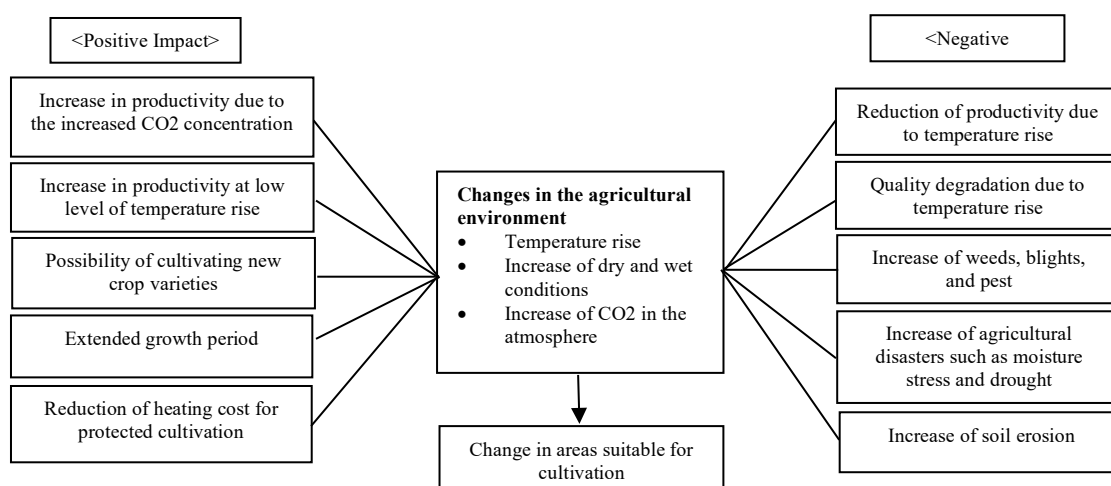


Figure 3: Potential impacts of global warming on the agricultural sector

Source: Kim, Chang-Gil and et al. (2009), p.38.

2. Approaches And Methodologies

Data collection for this study was conducted using a combination of face-to-face interviews, in-depth case studies, and Focus Group Discussions (FGDs). A semi-structured interview schedule was developed and administered to gather empirical data. To obtain in-depth information, consultations with farmers were carried out, utilizing case studies and FGDs. The selection of samples followed a multistage randomization process. The stakeholders involved in the study included local leaders, NGO workers, and government officers, particularly those involved in climate change and disaster management.

Secondary information was gathered from various sources, including recent newspaper articles, journal articles, and books. Both qualitative and quantitative data were collected for the study, which was conducted in three purposively selected districts within the coastal areas of Bangladesh. The chosen districts were Patuakhali and Satkhira, selected deliberately for their relevance to the study (Reyer et al., 2017).

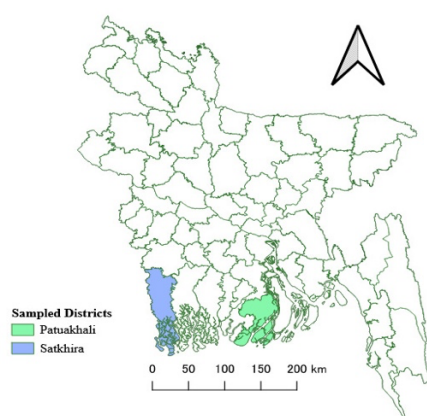


Figure 4: Study area (in districts)

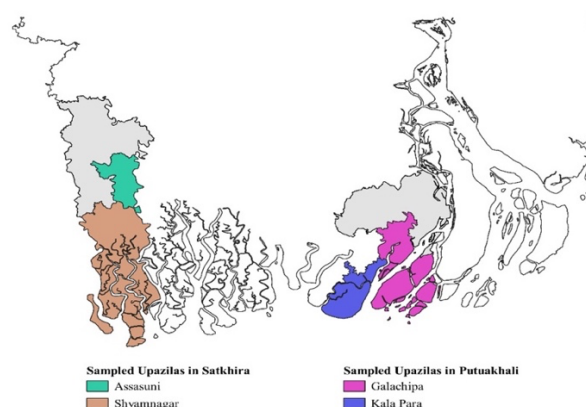


Figure 5: Study area (in Upazila level)

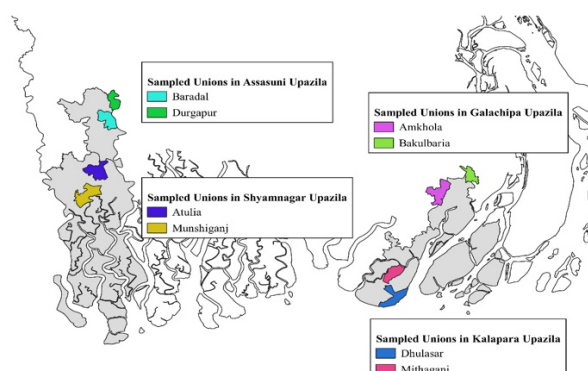


Figure 6: Study area (at union level)

The study population comprised all crop, livestock, and fish farmers in these districts. From each district, two Upazilas were selected, and within each Upazila, two unions were randomly chosen (Table 1). Twenty farmers were then selected from each union through a randomization process. Additionally, two reserve farmers were included from each union to account for any absences in the sample list, resulting in a total sample size of 160 farmers, with an additional 16 in the reserve list (Table 1).

Table 1: List of the Population and Sample

Districts	Upazilas	Name of the Union	Population	Sample	Reserve list
Patuakhali	Kalapara	Dhulasar Union	20199	20	2
		Mithaganj Union	28964	20	2
	Galachipa	Amkhola Union	33132	20	2
		Bakulbari	32827	20	2
Satkhira	Assasuni	Durgapur	21682	20	2
		Baradal	31921	20	2
	Shyamnagar	Atulia	35152	20	2
		Munshiganj	37981	20	2
		Total		160	16

Source: Calculate by author.

In selecting the variables for the study, the researcher carefully considered various personal, economic, social, and psychological factors relevant to the rural community, while also accounting for the availability of time and resources. This process involved reviewing relevant literature and consulting experts in the field. The variables used to describe the socio-economic and psychological characteristics of the people in coastal areas included age, education, family size, farm size, annual income, training experience, cosmopolitans, organizational participation, extension media contact, knowledge of climate change impacts, and coping mechanisms. These variables were measured using appropriate scales, scores, and categorizations.

The extent to which areas in the coastal belt of Bangladesh have been affected by climate change was explored through secondary sources and stakeholder consultations. Other variables examined included vulnerability, resilience mechanisms, and suggestions for mitigating the effects of climate change in these coastal areas.

An interview schedule was meticulously prepared to gather relevant information, aligning with the study's objectives. The schedule included both open and closed-ended questions to obtain comprehensive data regarding the availability of agricultural land. Appropriate scales were developed to compute data into relevant scores. The draft interview schedule was prepared in Bengali and was pre-tested among farmers in the sample area before finalizing it for the main data collection. The pre-test helped identify and correct any faulty questions and statements in the draft schedule. Additionally, case studies and FGDs were conducted to gather qualitative data. The data collection took place from December 17, 2019, to February 16, 2020. The collected data was then analyzed and presented.

3. Results & Discussion

3.1. The Socio-Economic And Psychological Characteristics of The People Of Coastal Areas

To describe the ordinary people's socio-economic and psychological characteristics in coastal areas, the study considered factors such as age, education, family size, farm size, annual income, training experience, cosmopolitanism, organizational participation, extension media contact, knowledge of climate change impacts, and coping mechanism ability. Data in Table 2 indicates that nearly half of the respondents (46.88%) fell into the middle-aged group. More than half (61.25%) of the respondents had a primary level of education. A significant proportion (47.5%) fell into the medium category for family size. A large portion (58.75%) were landless or marginal farmers. A significant proportion (60.63%) of respondents belonged to the very low-income to low-income categories. More than half (51.25%) had a medium level of knowledge regarding climate change impacts, while 28.13% had poor knowledge, and 20.63% had a high level of knowledge on the subject. In terms of coping mechanism ability, 47.5% of respondents had a medium ability, 40% had a poor ability, and 12.5% had a high ability to cope with climate change.

Table 2: Salient socio-demographic features of the respondents (N=160)

Characteristic s	Measurin g units	Range		Category	Respondents (N- 160)		Mea n	Stand ard deviat ion
		Expe cted	Obse rved		Numb er	Percen t		
Age	Year	---	20 to 81	Young (<35)	61	38	44.75	5.45
				Middle-aged (35-50)	75	46.88		
				Old (>50)	24	15		
Education	Years of schooling	---	0 to 16	Illiterate	19	11.88	4.35	1.65
				Primary (1-5 yrs schooling)	98	61.25		
				Secondary (6 to 10 yrs)	38	23.75		
Family Size	Numbers	---	2 to 10	Above secondary (>10)	05	3.13	4.57	1.71
				Small family (2 to 3)	65	40.63		
				Medium family (4 to 6)	76	47.5		
Farm size	Hectares	---	0.07 to 5.0	Large family (>6)	19	11.88	0.38	0.17
				Landless (<0.20 ha.)	38	23.75		
				Marginal farmer (0.20 to 0.40 ha.)	56	35		
		---	0.07 to 5.0	Small farmer (0.40-1.01 ha.)	51	31.88	112.7	7.48
				Medium (1.01-3.03 ha.)	10	6.25		
				Large (>3.04 ha.)	05	3.13		
Annual income	BDT. '000	---	36 to 280	Very low income (<80)	45	28.13	5	
				Low income (80-120)	52	32.5		
				Medium income (121 to 150)	38	23.75		
Knowledge on Climate Change Impact	Score	5 to 25	6 to 23	High income (>150)	25	15.63	12.15	2.20
				Poor knowledge (≤10)	45	28.13		
				Medium knowledge (11 to 20)	82	51.25		
Coping Mechanism Ability	Score	5 to 25	5 to 24	High knowledge (>20)	33	20.63	11.85	2.05
				Poor ability (≤10)	64	40		
				Medium ability (11 to 20)	76	47.5		
				High ability (>20)	20	12.5		

Source: Calculated by the author

3.2. Areas Were Affected Due To Climate Change In The Coastal Belt In Bangladesh.

The coastal zone of Bangladesh covers 20% of the total land area, with 30% of the cultivable land located in this region, primarily in the southwestern areas. This zone comprises diverse ecosystems, including mangrove forests (such as the Sundarbans), coral reefs, beaches, hills, and swamps. Bangladesh offers a range of goods and services to its people through its dynamic natural environments but is frequently affected by storm surges, tropical cyclones, coastal erosion, and rising sea levels, which cause enormous losses in crops, livestock, forestry, and human lives. The Sundarbans, a critical ecosystem, also lose biodiversity due to these disasters.

In recent years, cyclones Sidr (2007) and Aila (2009) have struck Bangladesh, causing significant devastation. Cyclone Sidr, which hit on November 15, 2007, resulted in 3,406 deaths and over 55,000 injuries. Heavy rainfall accompanying the cyclone caused widespread casualties, physical destruction, crop and livestock damage, and flooding across thirty districts in the southwestern coastal areas of Bangladesh. The most severely affected districts were Patuakhali, Barguna, Bagerghat, Satkhira, and Pirojpur. The estimated damage amounted to approximately \$1.7 billion (in 2007 USD). The Government of Bangladesh conducted a rapid preliminary assessment of the damage, revealing a widespread outbreak of waterborne diseases, respiratory tract infections, and other related infections, particularly among children aged five and younger.

Cyclone Aila struck on May 25, 2009, devastating the southern coastline of Bangladesh, particularly the Khulna and Satkhira districts, as well as Pirojpur, Bagerhat, Patuakhali, Barisal, Bhola, Noakhali, Lakshmipur, Feni, Cox's Bazar, and Chittagong. An outbreak of diarrheal disease occurred in the aftermath of the cyclone due to a severe shortage of drinking water and food. Local reports indicated approximately 15 deaths in the Paikgacha, Koyra, and Dacope areas of Khulna district.

Super Cyclone Amphan hit the southern coastal areas of Bangladesh and West Bengal, India, on May 21, 2020, killing 128 people across both countries. Thousands of trees were uprooted, roads were flooded, and electricity was cut off in many areas, causing more than US\$13.6 billion in damage. The Sundarbans once again served as a natural barrier, protecting Bangladesh's landscape. However, the cyclone struck during the peak of the COVID-19 pandemic, making it challenging to evacuate people to shelter centres while maintaining social distancing.

3.3. Exploring The Vulnerability In Coastal Areas In Bangladesh

As a deltaic country, Bangladesh is highly vulnerable to climate change. Several weak socio-economic indicators contribute to this vulnerability, including population density, literacy rate, male-to-female ratio, gender gap in literacy rate, disability percentage, poverty levels, and the availability of cyclone and flood shelters. Additionally, the country's infrastructure, such as irrigation systems, primary schools, freshwater sources, transport facilities, and health centers, is at risk.

Natural indicators of vulnerability include salinity, riverside flooding, storm surges, coastal elevation, rainfall patterns, shoreline erosion, and shoreline accretion. Bangladesh is globally recognized as one of the most climate-vulnerable countries, facing frequent natural disasters that claim many lives. Poor and marginalized households are particularly vulnerable to the adverse impacts of climate change, which damages infrastructure and livelihood assets. The country's sufferings are compounded by these natural disasters, which exacerbate existing issues, especially in the coastal region.

The Ganges-Brahmaputra-Meghna river system frequently causes floods that damage crops, livestock, and infrastructure. Tropical cyclones and storm surges, coupled with high wind speeds, cause severe damage in coastal areas. Over-topping and breaking embankments lead to massive losses of lives and properties in both urban and rural areas. Riverbank erosion results in the loss of homes and agricultural land, while increased sedimentation in riverbeds leads to drainage congestion and water-logging, delaying the cropping season. The melting of Himalayan glaciers causes increased river flows during warmer months, followed by lower river flows and increased saline intrusion as the glaciers shrink or disappear.

In the northern and western regions of Bangladesh, drought conditions arise due to lower and irregular rainfall. In coastal areas, saline water intrusion reduces freshwater availability, damaging the Sundarbans mangrove forest, a UNESCO World Heritage site rich in biodiversity. Drainage congestion within coastal polders adversely affects agriculture, while warmer and more humid weather increases the prevalence of diseases.

Climate change has a significant impact on the environment and natural resource systems, with the livelihoods of people living in coastal areas being the worst affected.

3.4. Finding Out The Resilience Mechanism (How People Cope With Climate Change)

People in the coastal areas of Bangladesh need alternative livelihood activities to cope with climate-induced disasters such as cyclones, floods, and storm surges. Several coping strategies are available to them, but food crises, health, housing, and education for children remain chronic problems. When these issues cannot be resolved, people resort to borrowing money. They also receive loans and microcredit from various agencies and banks, which often become burdensome. Government and NGO relief efforts provide some food aid, but affected people often resort to preparing mats and handicrafts to earn money. While rearing poultry is difficult due to a lack of dry spaces, livestock such as buffalo is raised as a source of income. Additionally, sweetwater fish cultivation provides

an alternative income source. During floods, women help mitigate food crises by storing food, although cooking meals remains challenging due to a lack of fuel, wood, and water.

The loss of topsoil hinders crop farming, as excessive saline water and rising temperatures make cultivation difficult. Some farmers adopt saline-tolerant crops like watermelon and betel leaves to sustain their earnings. Cyclone shelters are often insufficient, and some people fear leaving their homes for shelters, fearing theft of their livestock and belongings.

NGOs, micro-credit institutions, and cooperative organizations provide low-interest loans to help build and supply poultry and livestock. Social safety net programs have been extended to poor and ultra-poor people, and training on climate change adaptation is offered. Pond Sand Filters (PSF) set up by the government to reduce salinity have proven beneficial for local communities.

People have learned to store rainwater and groundwater with the help of government and NGO initiatives, which also support rainwater harvesting for agricultural activities. Women are involved in earth-filling activities, planting vegetables in homesteads and along crop field edges. They also raise poultry and milking cows to earn money for family expenses. Female-headed households are prioritized for land allocation to solve residential issues. Cottage industries provide an alternative source of income for women, with NGOs and GOs offering training and credit to support these activities. Women also prepare dry foods, such as cakes and flattened rice, to address food scarcity during and before calamities. Credit agencies prefer lending to women, as they are more reliable in repaying loans compared to their male counterparts.

However, cyclone shelters are not designed to accommodate social distancing, as was evident during the Amphan cyclone when Bangladesh was under lockdown due to the COVID-19 pandemic. Despite these challenges, it is clear from the study that most people in coastal areas are striving to become more resilient to adapt to climate change.

3.5. Finding Out The Resilience Mechanism (How People Cope With Climate Change)

Stakeholders were consulted through case studies and FGDs to provide suggestions for mitigating the problems caused by climate change. The following recommendations emerged:

Experts suggested that adaptation and mitigation are the two main options for reducing the adverse impacts of climate change in Bangladesh. However, Bangladesh has limited capacity for mitigation due to financial constraints, necessitating global support. Adaptation, a local initiative, can be achieved by involving vulnerable communities. Although Bangladesh does not emit significant greenhouse gases, it suffers the consequences of global emissions.

Three adaptive approaches were identified: accommodation, protection, and retreat. A retreat is not feasible for Bangladesh, given its high population density. However, land reclamation from the sea by constructing polders, as done in the Netherlands, is a viable option. Building embankments to protect communities from saline water intrusion during storm surges was overwhelmingly suggested by residents. Diversifying livelihood activities, providing need-based training, and promoting women's empowerment through education and training are crucial. Reducing polygamy among men, accelerating healthcare facilities, and enhancing social security for the bottom class in coastal areas were also recommended.

Finally, it is essential to explore and implement alternative livelihood activities for the people living in coastal areas. Credit and support should be prioritized for women, as they are more responsible in managing loans. Cyclone shelters need to be improved to ensure social distancing during evacuations, as demonstrated by the Amphan cyclone during the COVID-19 pandemic. Overall, the study emphasizes the importance of resilience and adaptation strategies to help coastal communities cope with the impacts of climate change.

4. Conclusion

People living in extreme weather conditions and those affected by climate change in the coastal areas of Bangladesh face significant challenges in carrying out agricultural activities, which are their primary means of livelihood. The unemployment rate in these coastal regions is much higher than in other parts of the country, and changing climatic conditions often force residents to migrate from their ancestral homes. These communities face numerous issues, including food shortages, inadequate healthcare facilities, and limited utility services. It was found that people adopt indigenous knowledge and coping mechanisms as strategies for alternative livelihoods, such as planting trees, rearing poultry, farming vegetables, harvesting rainwater, and using pond sand filters. Together, the government and NGOs have been supporting coastal communities in building resilience through various adjustment strategies. The government encourages development partners to include local people who need assistance in social safety net programs. Additionally, efforts have been made to provide training for setting up cottage industries and distributing salinity-tolerant seeds. However, these supports are not sufficient to fully address the challenges faced by people living in Bangladesh's coastal areas.

5. Recommendations

Based on the findings and conclusions, it is recommended that efforts be intensified to enhance the capacity of farmers and coastal communities to cope with the adverse effects of climate change on agriculture. This can be

achieved through the provision of proper training, technical support, extension services, and access to relevant information and inputs. Additionally, it is crucial to establish and strengthen physical and social infrastructure, including communication facilities, utility services, healthcare support, and educational opportunities in coastal areas. Moreover, the government and other stakeholders should prioritize the implementation of sustainable agricultural programs that focus on salinity-tolerant crops and practices, ensuring that these initiatives are tailored to the specific needs of Bangladesh's coastal regions.

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