Natural Hazards Research 2 (2022) 84–96

Contents lists available at ScienceDirect

Natural Hazards Research

journal homepage: www.keaipublishing.com/en/journals/natural-hazards-research

Climate change, multi-hazards and society: An empirical study on the coastal community of Indian Sundarban

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ARTICLE INFO

Keywords:
Mitigation
Multi-hazards
Climate change
Risk
Sundarban
Coping

ABSTRACT

Effective mitigation and adaptation methods are critical for addressing multi-hazards in various parts of the world as a result of changing climate occurrences. Basically, coastal areas around the world have been proven to be particularly sensitive and at risk as a result of recent climate change, forcing people to relocate in order to survive. In the previous 2–3 years, cyclones such as *Fani, Bulbul, Amphan,* and *Yass* have wreaked havoc on eastern India's coastal region. The aim of this study is to look into the coastal population of Indian Sundarban's perceptions of hazards and their solutions for dealing with the growing threat of hazards. To measure perceptions of multi-hazard impact, a survey of 850 rural households was conducted in four different geographical regions (i.e. island, coastal, riverine, and inland). Several forms of coping techniques have been discovered, and the results differ from one geographical place to the next, demonstrating the different impact of risks in the studied area. It is obvious from the analysis that, with the exception of island households, other areas use a very limited number of adaptation mechanisms. When it comes to the amount of coping strategies used, it has been discovered that most inhabitants outside of islands use 1–3 techniques (nearly 56%) using food and finance as safeguard, but island dwellers use 4–6 strategies (nearly 78%) in form of asset related issues. Reducing the amount of food consumed, obtaining financing from various organizations, and migrating are some of the primary tactics used in the study region to combat the negative effects of climate change-related multi-hazards.

1. Introduction

Natural hazards are primarily caused by natural hazards and the presence of a vulnerable and exposed population. In most circumstances, vulnerability, whether societal or economic, creates a bridge between risk and tragedy (Ahmad and Ahmed, 2000; Brammer, 2014). There is widespread agreement that there is a dearth of information, understanding, applicable government obligations and adequate resources to deal with the devastation produced by natural hazards (Alam et al., 2017; Becker et al., 2020). Developed countries such as the United States, China and Japan react to hydrometeorological hazards that impact their coastal regions and cities with a sense of helplessness, while spending significant amounts of money to avoid, anticipate and protect susceptible areas from quasi-natural hazards (Ikeuchi et al., 2015; Alam et al., 2017). Analogous scenarios for poor countries, where some aspects of disaster risk reduction (DRR) are unplanned, are intriguing to explore as a corollary (Quesada-Román et al., 2021; Pinos and Quesada-Román, 2021). It is crucial to work out how to change the social and cultural conditions of a country in the case of a crisis, as well as which changes will be socially acceptable (Karim and Mimura, 2008; Mondal and Bandyopadhyay, 2014). This paper will examine these issues using actual examples from the cyclone-ravaged coastline region of India (Indian Sundarban area).

After China and the United States, India is the third most disaster-prone country of the world, with the highest number of all-time natural hazards between 2000 and 2019. In the last 20 years, there have been 6681 climate-related disasters, up from 3656 from 1980 to 1999 (Mondal et al., 2020; Gupta et al., 2019). Despite the fact that climate-related mortality has declined in the twenty-first century as a consequence of technological breakthroughs and enhanced disaster preparedness, the study indicates that the citizens would pay a higher price as a result of rising financial damages and livelihood interruptions (Mondal et al., 2013; Becker et al., 2020). Floods accounted for 44% of all disasters, recorded globally in the last two decades, with India again ranked second after China in terms of floods, with an average of 17 $year^{-1}$ and over 345

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https://doi.org/10.1016/j.nhres.2022.04.002
Received 23 March 2022; Received in revised form 9 April 2022; Accepted 19 April 2022
Available online 22 April 2022

million people affected. Coastal flooding is prevalent in the deltaic Bengal, with river floods, tidal floods, fluvial-tidal floods and storm floods occurring throughout the year (Hoque et al., 2016; Hooijer and Vernimmen, 2021). In the recent past, storm surge floods and tidal floods have wreaked havoc on the Ganga delta. Storm-surge floods caused by cyclones such as *Sidr* in 2007, *Aila* in 2009, *Giri* in 2010, *Phailin* in 2013, *Hudhud* in 2014, *Fani* and *Bulbul* in 2019, *Amphan* in 2020, and most recently *Yaas* in 2021 resulted in a massive loss of livelihoods. The rising trends in sea surface temperature (SST) over the last two decades have made the Bay of Bengal (BoB) basin an ideal breeding environment for these highly destructive cyclonic storms, which have increased fivefold in number (during 1970–2020). Catastrophic cyclones have increased in frequency during the last two to three years, making landfall approximately twice a year. Extreme hydrometeorological events do not occur in isolation; embankment breaching, flooding and saltwater intrusions are all followed by extreme hydrometeorological occurrences (Mondal et al., 2021). Climate-related hazards have made coastal and riverine households particularly vulnerable, contributing to the loss of land, livelihoods and other natural resources, placing them at risk of food insecurity and reducing their ability to alleviate poverty (Gupta et al., 2019; Bricheno et al., 2021; Quesada-Román and Villalobos-Chacón, 2020).

Researchers have found the impact of such hydrometeorological events on migration patterns. Following Cyclone Aila, there is a major outbound exodus from the Sundarban region, which has accelerated in the subsequent two to three years. Using Global LiDAR data (Hooijer and Vernimmen, 2021) shows how tropical areas have grown substantially more vulnerable to Sea Level Rise (SLR). In the coastal areas of India, population growth has averaged 1.10% per year for people settled in less than 1 m height. With such a high population density, the deltaic environment is more sensitive to large-scale land changes such as deforestation, agricultural land converted to aquatic farms and so on. It is anticipated that about 45 million people will be displaced as a result of climatic change in South Asia alone (Panda, 2020; Vernimmen et al., 2020). Deltaic West Bengal has a population of about 28.62 million people, or 25% of the population of the state, with a density of 819 (per km^2), and more than 65% of households are economically disadvantaged (Ali et al., 2014; Bhatia et al., 2019) is considered the most vulnerable to such hydrometeorological extreme events. Despite the fact that it is now possible to predict the speed and the path of cyclones and warn the coastal residents well in advance, the aftermath of such storms continues to injure thousands of people in the deltaic Bengal. Despite recent advancements in disaster preparation and prevention in the coastal portion of West Bengal, India, there is still a shortage of critical infrastructure and governmental capability from the individual to the community level. Nonetheless, there is a lack of appropriate policy implementation, necessitating a comprehensive investigation into how a coastal population in the Bengal delta perceives, reacts to and adjusts to several risks (Gayathri et al., 2016; Danda et al., 2019). This study will look into a variety of topics, including what the victims did before, during and after the storm, how they recovered from the damages and what social and economic changes occurred in the area, among others.

As part of Agenda 21, the United Nations coined the term “multi-hazard” to promote global risk reduction and sustainable development (Pourghasemi et al., 2020; UNDP, 2004). Using a range of statistical and mathematical modelling approaches, multi-hazard research has been conducted systematically throughout the past two decades (Xu et al., 2019). Entropy modelling, fire-area simulation, multi-variate statistical approach (Pourghasemi et al., 2020), logistic regression model (Arabameri et al., 2018), and analytical hierarchical processing (Saalim and Azmir, 2021) have all recently been used for disaster risk assessment and management. Saaty (1977) developed analytical hierarchical processing, a well-known multiple decision-making technique that may be combined with GIS to analyse multi-hazard risk from regional (district) to local (village) viewpoints (Peng et al., 2012). A large dataset can now be used to identify problematic sites using a machine learning approach (Pourghasemi et al., 2020). Multi-hazard risks in deltaic West Bengal are influenced by tropical cyclones, embankment breaching, storm and tidal surge, inundation due to storm-induced rainfall, salinisation, and erosion-accretion. Every year, the Indian Sundarban region faces a disaster as a result of such multi-hazard events. Multiple severe cyclones and their aftermath (other extreme events) have exacerbated the problem in the last decade (Micić Ponjiger et al., 2021).

This research looks at some of the most vulnerable cyclone-affected villages in the southwest coastal regions (Kakdwip Subdivision of South 24 Parganas district) of the Indian Sundarban. It looks at how coastal communities respond to heightened livelihood pressures as a result of cyclone-induced multi-hazards, concentrating on cyclones *Fani* in May 2019, *Bulbul* in November 2019, *Amphan* in May 2020 and *Yaas* in May 2021. It focuses on the real-life experiences, perceptions and reactions of multi-hazards victims in the chosen places. Tropical cyclones (TCs) are intensifying and becoming more common around the world. Not only has TC affected people's lives and livelihoods, but it has also increased the risk of embankment breaching, inundation, salinisation, and coastal erosion. TCs originate in the Bay of Bengal (BoB) basin, and their landfall along the shores of Odisha, West Bengal, and Bangladesh has wreaked havoc in the last 10–15 years. The sensitivity of people living along West Bengal's coast to such hydro-meteorological extreme events, as well as their social and economic weakness, exacerbates the problem. Global warming, rising sea surface temperatures, and rising sea levels have made the area increasingly vulnerable in recent years, and the IPCC-AR-5 and 6 disaster management frameworks have explicitly stated that such occurrences are likely. In the last 10–15 years, the impact of such cyclone-induced multi-hazards has intensified, putting lives and livelihoods at coastal West Bengal in peril. Migration and job losses, as well as a reduction in the number of working days, have clear repercussions.

Sundarban delta (Indian portion) is arranged in extreme southern piece of sea side West Bengal and associated with South and North 24 Parganas district. It covers up across 21°30′ to 22°40′ N degrees and 88°05′ to 89°55′ E longitudes. The mangrove forest has a zone of around 140,000 ha with a tremendous space of an area highlighted on the delta of the streams Ganga, Meghna and Brahmaputra, including streaming mudflats, creeks, and islands (Gopal and Chauhan, 2006). These creeks pass on with them a huge load of sediment and get settled in the delta but recently have faced the fury of climatic change multi-hazards. Such debacle has made basic afflictions foundation, land, animals and households. Because of the effective sea level change, the appraisal area has seen the submergence of a few islands. The evaluation of multi-hazard events and their effect on the monetary situation is thusly of fundamental concern for the security of the tendencies of the ocean side organization (Papathoma-Köhle et al., 2011; Letsie and Grab, 2015). The current examination means to take apart the perception and coping strategies of the households related with delta multi-hazard events in the villages under Kakdwip sub-division of South Parganas region exhaustively. The appraisal district has been segregated into geomorphological and decision-making viewpoint further. Overall cyclonic storms and stream submersion make the region all the more unprotected. The power of these events has been by and large higher during the last three years (2019–2021) and has caused exceptional loss of life and property in the sea shore front squares of South 24 Parganas district. Fifteen villages from four CD blocks have been chosen for a thorough investigation of multi-hazard perceptions and coping mechanisms for dealing with such catastrophic situations.

For this study, two island villages, three coastal villages, five riverine/estuarine villages and five inland villages have been chosen to represent all geomorphological units found in the study area (Fig. 1). This research contributes to a better knowledge of the social dynamics of coastal West Bengal, India, by addressing the three research topics below:

a) What are the perceived impacts of hazards on different asset-capitals (i.e. human, social, financial, physical and natural)?

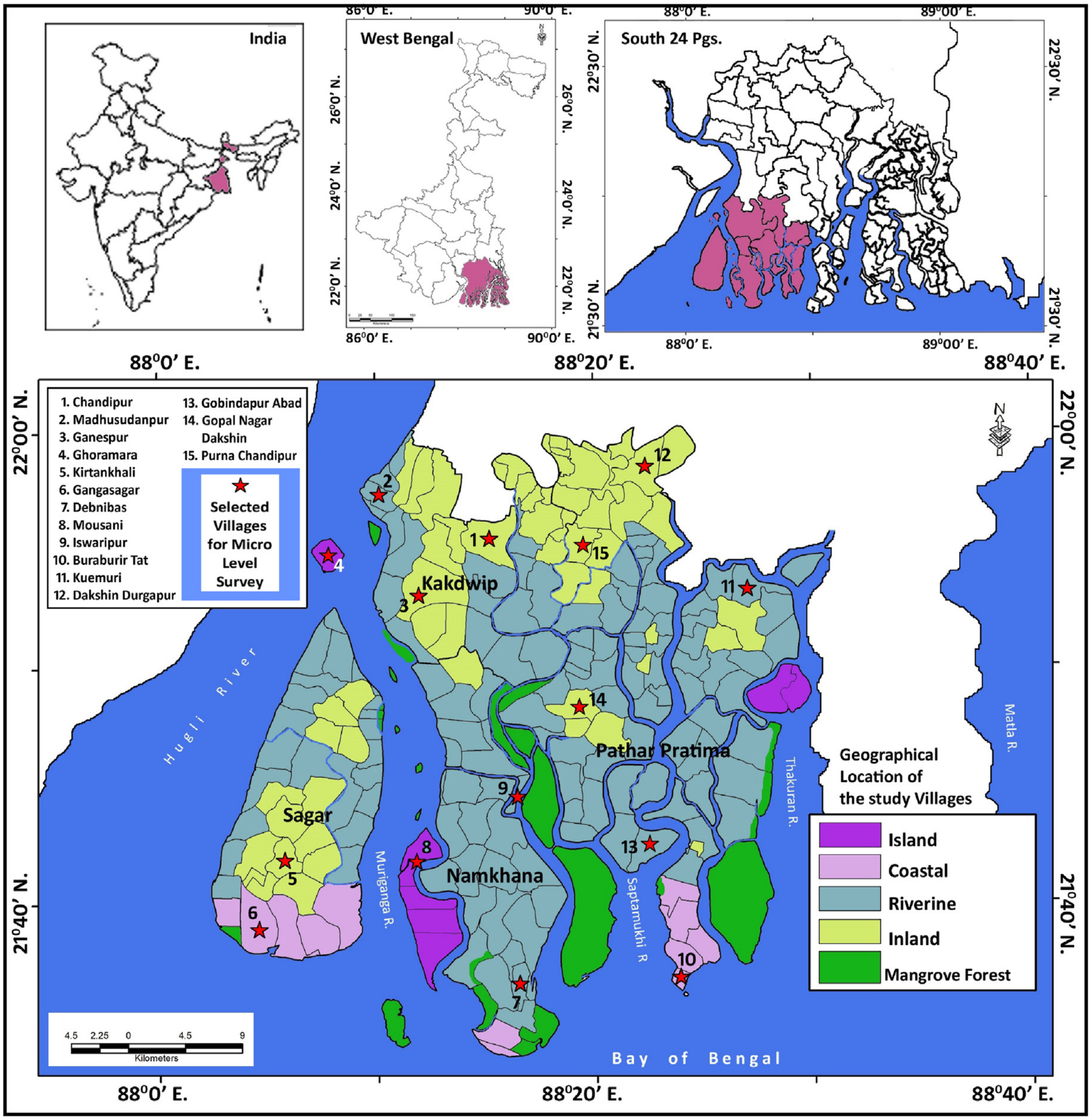

Fig. 1. Location of the study area and selection of villages for micro level study on perceptions and coping strategies to multi-hazards in coastal West Bengal, India.

b) What are the coping strategies that have been adopted by the dwellers of coastal Bengal?

To address the hydrometeorological extreme events, the research is structured as follows: Section 2 provides the premise or foundation of the study; Section 3 explains the study area, data collection technique and data analysis; Section 4 contains the findings and discussion; and Section 5 finishes with a summary and policy suggestions.

1.1. Degree of multi-hazards due to Fani, Bulbul, Amphan and Yaas cyclones

Following the devastation wrought by Cyclone *Aila* in 2009, it has become evident that more frequent cyclones and rising sea levels, both caused by perilous meteorological conditions, would force the Sundarban population to evacuate. Cyclones like *Fani, Bulbul, Amphan* and *Yaas* wreaked havoc on the Sundarban between May 5, 2019, and May 26, 2021, each generating enough damage to justify the fear of impending disaster (Table 1). As a result of producing and fishing-based industry of Sundarban, 'vora kotal' (local word for an increased tide) and 'jhar' (nearby name for a twister) have continuously disrupted the people's lives. Indeed, these two aspects would, in the long run, render the basic monetary model entirely unfit to care for 4.5 million residents of Sundarban, compelling individuals from 75% of families to relocate in search of work.

In a matter of years, the Sundarban might become the most frightening humanitarian calamity of the world since Partition. India has lost 60% of the delta, leaving only 4262 km^2 of Sundarban and 102 islands intertwined in a maze of creeks, rivers and channels. According to the census statistics from 1951, 1.1 million people lived in the Indian part of the Sundarban. In 1984, the Indian portion of the Sundarban, which covers 1330 km^2, was classified as a tiger reserve. The extra islands, which totalled less than 3000 km^2 and were already congested owing to continual relocation, were stuffed with people living in this area. According to the 2011 Indian Census, 4.4 million people lived in a little more than 2000 km^2 of habitable land. The Sundarban would be flooded considerably more quickly than other coastline locations because it is more vulnerable to increasing sea levels than other waterfront areas. In

Table 1
Impact of cyclones on the life and livelihoods in coastal India.

Cyclonic events and Landfall (Place, Time and season)		Impact on life and livelihoods
Cyclone Fani (ESCS)	Cyclonic Storm of Extreme Severity Since the 1999 Odisha cyclone, Fani was the worst tropical cyclone to hit the Indian state of Odisha. On April 26, a tropical depression formed west of Sumatra in the Indian Ocean, giving rise to Fani which quickly became a very severe cyclonic storm, reaching peak strength on May 2 with sustained winds comparable to a category 5 major cyclone in 1 min sustained wind.	Fani has killed 72 persons in India, 64 of them were in Odisha. The storm disrupted electricity and telecommunications in various coastal areas of Odisha, as well as West Bengal to a lesser extent. Odisha's Puri and Khordha districts were the hardest damaged. The Jagannath Temple in Puri was partially damaged, with restoration costs estimated at 51 million rupees (US$738,000). The KIIT University was also damaged to the tune of $300 million (US$4.3 million). The total damage in Odisha was estimated to be 120 billion rupees (US$1.74 billion), primarily due to property damage and humanitarian efforts. Odisha needed $170 billion (US$2.46 billion) to reconstruct its infrastructure after the cyclone. There was also significant environmental damage.
Cyclone Bulbul (VSCS)	Bulbul made landfall near Sagar Island in West Bengal, around 18:30 GMT on November 9, 2019, killing at least two people and weakening back to a Severe Cyclonic Storm, as it interacted with land and released a high storm surge of 2–3 m.	In Odisha, an estimated 200,000 ha (490,000 acres) of crops were damaged. Bulbul made landfall in West Bengal near the Sundarban forest, bringing torrential rain and winds of up to 137 km/h (85 mph) to parts of the state's southern region. Approximately 3.5 million people in West Bengal were directly affected by the cyclone, and 14 people died as a result of storm-related incidents. 517,535 houses and 1,489,924 ha (3,681,680 acres) of crops were damaged or destroyed, resulting in losses of Rs. 238.11 billion (US$3.34 billion).
Cyclone Amphan (SuCS)	Super Cyclonic Storm Amphan bears over North & South 24 Parganas districts and Kolkata on 20 May 2020 barrelling in from the Bay of Bengal with the wind speed of up to 185 km/h with a high storm surge of 3–4 m	The state government estimated that the storm caused at least ₹1.02 trillion (US$13.5 billion) in damage and directly affected 70 percent of the state's population. West Bengal's government reported significant damage to 2.9 million homes and 1.7 million hectares of crops, as well as the grounding of 450,000 electric poles7. More than 15,000 trees were uprooted in the Kolkata Municipal Corporation area alone, while 158,000 acres of mangroves in the Sundarban region were seriously damaged. Heavy rain and strong winds impacted 44.80 lakh people in 89 blocks across Odisha, according to preliminary figures. Amphan wreaked havoc in the districts indicated, killing 123 people and causing about US$ 13 billion in property damage in West Bengal alone.
Cyclone Yaas (VSCS)	Tropical cyclone that made landfall in Odisha and caused severe damage in West Bengal during the last week of May, i.e. 26 May 2021, barrelling in from the Bay of Bengal with wind speeds of up to 140 km/h and a high storm surge of 4–5 m.	Many electrical businesses in West Bengal and Odisha had extra generators and transformers ready in case of a power outage. Low-lying neighbourhoods in East and West Midnapore, as well as Jhargram, were ordered to be evacuated beginning May 24. The cities of Hooghly, Kolkata, and the states of North and South 24 Parganas have been placed on high alert. Due to Yaas, railway and maritime operations were halted, and rescue authorities and medical teams were dispatched to deal with any potential crises. Due to the approaching storm, nearly two million people in Bangladesh's coastal areas have been forced to evacuate. Food and emergency funds were also made available to the evacuees. Yaas claimed the lives of 20 persons in India and Bangladesh. The entire damages in West Bengal, the Indian state most severely damaged by Yaas, were projected to be around 20,000 crores (US$2.76 billion). In Odisha, the storm inflicted an estimated 610 crore (US$83.63 million) in damage.

Source: Developed by the Researcher based on the https://reliefweb.int/report/india/cyclone.

the previous 20 years, four of its islands have sunk, including Lohachara, the first permanently drowned populated island of the world. Ghoramara and other Sundarban islands may face a similar fate in the following days as a result of the triggering and increased catastrophic occurrences.

2. Climatological and environmental characteristics of West Bengal coast

This section explains the foundation of the study, including why it is important to address household perceptions of climatic change and adaptation alternatives. Climatic change adaptation refers to the changes in the human-environment system in response to actual and/or anticipated changes in climatic conditions, with the purpose of avoiding or limiting risks and achieving potential opportunities. Coastal West Bengal is particularly vulnerable to climatic change because of rising temperatures, severe rainfall unpredictability and rain shortages. The climate of the Bengal delta has changed or acted differently in recent years, making it more unpredictable. Climatic change is expected to exacerbate the existing hazards while also introducing new ones in the Bengal delta for people and the environment. The vulnerability of the Bengal delta to multi-hazards is exacerbated by its geographical location, geological setting, near flat terrain with wide floodplains, low river gradients, low-lying estuarine land, significant monsoon rainfall, tidal duration and speed (flood and ebb), effective sea level rise and rising SST throughout the year (Table 2). Such scenarios in coastal Bengal push the people into multidimensional poverty due to loss of livelihoods, forced migration, women's vulnerability and child health.

In the last three years, catastrophic storms have battered the coastal areas of West Bengal, putting people's lives and livelihoods in peril. *Fani, Bulbul, Amphan* and *Yass* clones have shown obvious symptoms of environmental unpredictability between 2019 and 2021 (Fig. 2). When embankment breaching, saline water invasion and prolonged inundation induced by severe storms have a direct influence on standing crops, aquaculture farms, livestock and poultry rearing, the main livelihoods of the region, people become vulnerable. During the pandemic (Covid-19), out-migrated people attempted to return to their native land (following the Aila storm in 2009, a huge migration from the Sundarban area happened), but extreme occurrences in 2020 and 2021 compelled them to migrate once more. Table 3 depicts the specific detrimental impact of multi-hazards on rural livelihoods in the coastal region of West Bengal. As a result, various stakeholders must evaluate studies on household perceptions of climatic change and adaptational actions.

Climate change adaptation refers to the changes in the human-environment system in response to current and/or anticipated changes in climatic conditions, with the goal of reducing or eliminating risks and maximising opportunities (IPCC, 2007; Neelormi et al., 2009). Climatic change has a variety of effects on countries, regions and communities and their adaptational strategies reflect this (Noh et al., 2013; Sikder and Jian, 2014). Adaptive responses are influenced by a variety of factors such as the agro-ecological system, socioeconomics, climatic impact and the enabling environment and competence across geographies (Salauddin and Ashikuzzaman, 2011; Rahman et al., 2018). Two main components of the variation interaction are insight and transformation methods (Tomasz, 2015; Chakrabarty, 2016). People, involved in

Table 2
Seasonality of multi-hazards impact on life and livelihoods in the coastal West Bengal.

Hydro-meteorological Hazards	Months											
	J-F	F-M	M-A	A-M	M-J	J-J	J-A	A-S	S-O	O-N	N-D	D-J
Cyclonic Hazards			Minor	Major	Major					Major	Minor	
Tidal Surge		Minor	Major	Major	Major	Minor	Minor	Minor	Minor	Minor		
Salinity Intrusion	Minor	Major	Major	Major	Minor				Minor	Minor	Minor	Minor
Flood		Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor
Inundation		Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor
Bank erosion		Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor	Minor

Minor Impact (light shading); Major Impact (dark shading)

Source: Developed by the authors

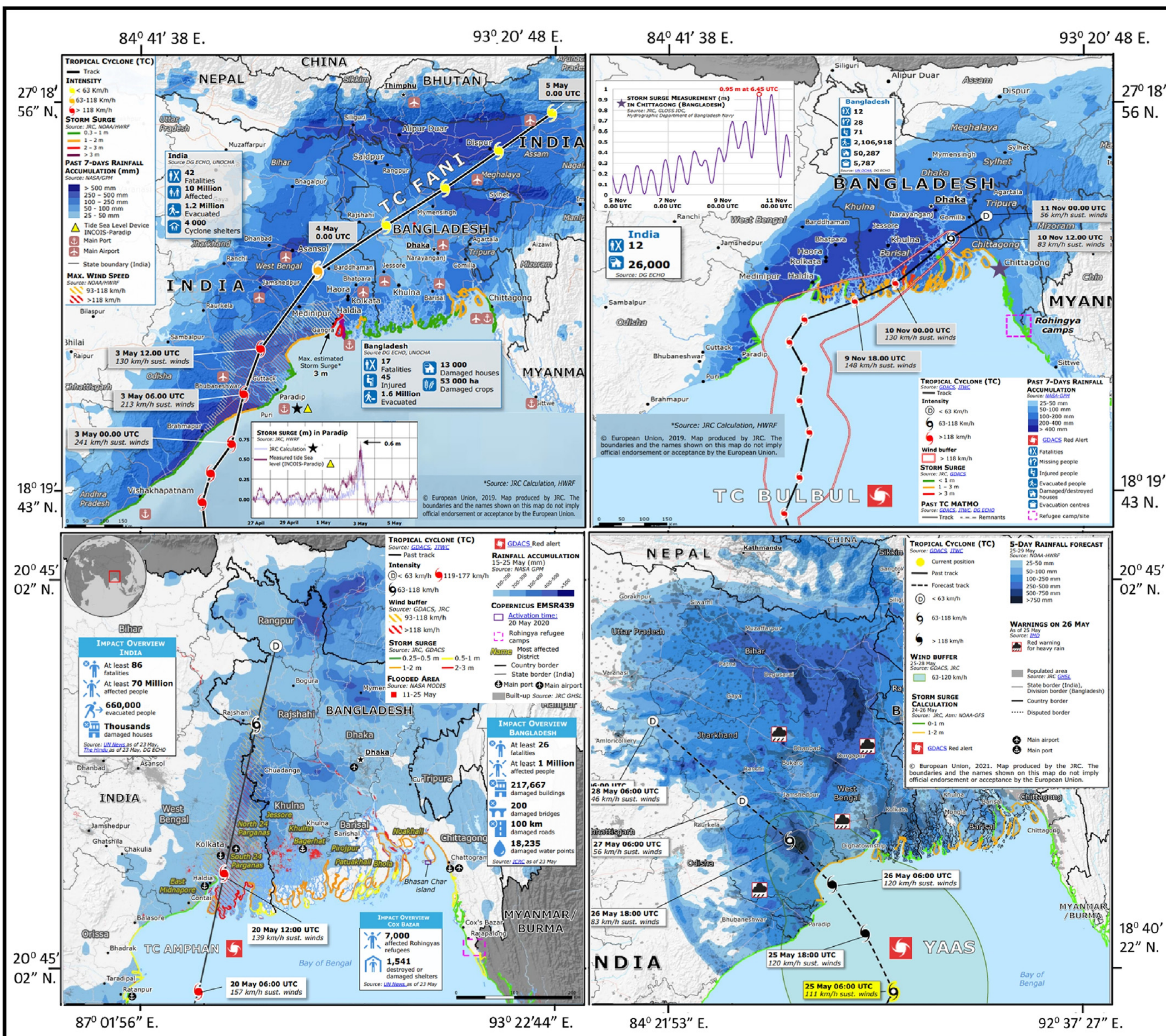

Fig. 2. *Fani, Bulbul, Amphan,* and *Yaas* cyclones, destructive tropical cyclones formed in the BoB basin between 2019 and 2021, with significant storm surge and huge rainfall causing embankment breaches, coastal inundation, and saline water intrusion.

Table 3
Adverse impact on life and livelihoods due to multi-hazards in the coastal West Bengal.

Hazards	Affected Rural Livelihoods	Specific Impacts on Life and Livelihoods
Cyclonic Storms	• Agricultural Labourer • Fishermen	• People injured and died • People unable to go for their livelihood options; no possibility of wage labour
	• Prawn and Crab Collection	• Standing crops damaged
	• Wage Labourer (Farm & Non-Farm activity)	• Fish farms damaged
	• Cattle and Poultry rearing	• Physical structures, i.e. house damage, water connection, electricity disruption took place
Tidal Surge	• Agricultural Labourer	• People unable to go for their livelihood options
	• Fishermen	• Standing crops damaged
	• Prawn and Crab Collection	• Fish farms and cattle, poultry damaged
	• Wage Labourer (Farm & Non-Farm activity)	• Physical structures, i.e. house damage, water connection, electricity disruption took place
	• Cattle and Poultry rearing	• Embankment failure and damage of roads
Sea level rise and Salinity intrusion	• Farm based activity, i.e. agriculture, horticulture, homestead gardening	• Increased salinity an water and soil
	• Cattle and Poultry rearing	• Lack of irrigation water
	• Wage Labourer (Farm activity)	• Specific problem related to drinking water and sanitation • Fodder and pasture not available
Coastal flooding	• Agricultural Labourer	• People unable to go for their livelihood options; no possibility of wage labour
	• Fishermen	• Standing crops damaged
	• Prawn and Crab Collection	• Fish farms damaged
	• Wage Labourer (Farm & Non-Farm activity) • Cattle and Poultry rearing	• Physical structures, i.e. house damage, water connection, electricity disruption took place
Inundation due to storm and monsoonal rainfall	• Agricultural Labourer • Fishermen	• Livestock died • People unable to go for their livelihood options; no possibility of wage labour
	• Prawn and Crab Collection	• Standing crops damaged
	• Wage Labourer (Farm & Non-Farm activity)	• Fish farms damaged
	• Cattle and Poultry rearing	• Physical structures, i.e. house damage, water connection, electricity disruption took place

Source: Developed by the authors.

agriculture, must first understand the impact of environmental changes in order to develop appropriate transformation strategies to mitigate their weaknesses and improve the overall strength of the agro-natural framework (Ahmed et al., 1999; Ericson et al., 2006). Farmers and fishermen, who predict negative consequences as a result of environmental change, are likely to support tactics and projects aimed at addressing it (Gopinath and Seralathan, 2005; Costello et al., 2009). In this context, studies in the Bengal delta are quite scarce. Physical vulnerability, deltaic morphology and tidal wave propagation are the subjects of the majority of the investigations. A few researches are focused on low-lying and saline-inclined areas to identify the changing pattern of mangrove health (Nicholls et al., 2007; Kovats et al., 2005). Some research offers helpful identifiers for various strategies (ILO, 2007; Karim and Mimura, 2008; Adri and Islam, 2012). In any event, the strategies are unlikely to be acceptable or material to other risk-prone networks due to the variety of the implications of different risks and the financial conditions of the families, as well as the varying degrees of reactivity. This is especially critical for the most vulnerable and under-resourced riparian networks. However, there is a scarcity of thorough research on how asset helpless vulnerability prone households perceive environmental change and volatility and how their perceptions are linked to their neighbourhood's flexible responses (Costello et al., 2009; Adri and Islam, 2010). Recent tropical storms (Fig. 1), as well as their rapid intensification, have encouraged us to investigate the nature of perception and adaptation mechanisms used by various livelihood groups to deal with escalating hydrometeorological extreme events.

3. Methods and materials

3.1. Data collection

The CD blocks (Sub-district named as Community Development block in India) of Sagar, Namkhana, Pathar Pratima and Kakdwip were badly impacted by cyclones like *Bulbul* (in 2019) and *Amphan* (in 2021), according to the data from Govt. of West Bengal, India; thus, these four areas have been chosen as the study region. The household has been provided as the unit of analysis in this study and the household head has performed as the main informant. The Census of India (2011) has provided a detailed list of households in the selected villages. For this empirical analysis, 15 villages from 4 CD Blocks have been chosen according to geomorphological units (island, coastal, riverine and inland). The entire sample of the corresponding villages has been determined using statistical scaling. The total number of households has been used to calculate the sample size. The sample size is calculated using the concept of Kothari (1990). This method of determining sample size has been chosen because it allows a 10% error probability. The total number of households in each union has then been used to establish a representative sample size for each village. With 2% of the true value and 95.5% of confidence level, the total sample size has been sorted out as 705 which have been further developed to 850 as excess of 20% as non-sampling purposes using the following equation:

$$n = \frac{z^2 .p.q.N}{e^2 \ (N-1) + (z^2 p.q)} \tag{1}$$

where, n = total sample size, z = 2.71 (as per table of area under normal curve for the given confidence level of 95.5%), e = 0.01 (since the estimate should be within 1% of true value), N = 19758 (households of total 12 villages as per Census of India, 2011), p = 0.01 and q = 0.99. The village-wise sample size has been determined using a proportionate allocation approach using Equation (2).

$$n_1 = n * (N_1/N) \tag{2}$$

where, n_1 = sample size for selected individual villages, n = total sample size, N_1 = selected village households and N = Total households of the selected villages. For example, in case of Ghoramara village from Sagar block, the sample size has been found = [850*(1136/23401)] = 41.25 = 41 (see Table 4 for details).

In most of the cases, concentration of rural settlements in coastal West Bengal are found along the village road. As a result, the residences near the roadway are the first to be surveyed. If there is no respondent for a particular residence, the house of the next available respondent has been chosen. The questionnaire is divided into three sections: perceptions of multi-hazards, the impact of such catastrophic events on life and livelihoods and the coping mechanisms used. The questionnaire has been translated into the local language (in this case, Bengali) and the interviewers and respondents have communicated in Bangla.

A total of 12 focus group discussions (FGDs) have been conducted in each village to gather in-depth community information. Each focus group

Table 4
Location of the sample villages based on geographical units with sample size.

Block	Geographical Location	Village	Total HHs	Sample Size
Namkhana	Island	Mousani	742	27
Sagar		Ghoramara	1136	41
Pathar Pratima	Coastal	Buraburir Tat	889	32
Sagar		Gangasagar	2206	80
Namkhana		Debnibas	721	26
Namkhana	Riverine	Iswaripur	324	12
Pathar Pratima		Gobindapur Abad	1443	52
Kakdwip		Madhusudanpur	1414	51
Pathar Pratima		Kuemuri	1256	46
Kakdwip		Chandipur	1686	61
Pathar Pratima	Inland	Gopal Nagar Dakshin	1296	47
Sagar		Kirtankhali	830	30
Pathar Pratima		Purna Chandipur	904	35
Kakdwip		Ganespur	7192	261
Pathar Pratima		Dakshin Durgapur	1362	49

Source: developed by the authors.

has lasted about four to 5 h on average. The following are the rules that have been observed during the focus groups: (a) the number of participants is maintained to a minimum of 5 and a maximum of 10 locals; (b) Participants are kept uniform in terms of profession and gender; (c) one Panchayat member (local government), one intermediate and one organizer are present during the sessions; and (d) the sessions are recorded using audio devices with the participants' agreement to make records. The interviewees are told to relate the material to their movement in aspects of judgment call responsibilities, resource endowments and empowerment. The impact of cyclones on various occupational groups, coping techniques during and after cyclones, and information about household activities during normal and extreme-event timelines have also been discussed. The effectiveness of relief and rehabilitation programmes conducted by various governments and non-governmental organizations (NGOs) has also been questioned.

3.2. Data analysis

Statistical analysis like descriptive analysis and parametric test has been done to assess the perception on multi-hazards in the villages located in Indian Sundarban with their adaptation strategies. Initially, the surveyed villages have been categorized as island (8.0%) (68 sample households), coastal (16.3%) (138 sample households), riverine (26.1%) (222 sample households), and inland (49.6%) (422 sample households) for assessing the perception to multi-hazards and adopting strategies based on location. A non-parametric Chi-square analysis has been done to identify the differences between geographical location and adaptation strategies.

4. Results and discussion

4.1. Perception on multi-hazards in the coastal West Bengal

First, we have grouped our study villages into four categories based on the geographical locations: a) island, b) coastal, c) riverine and d) inland, to examine the perception of multi-hazards in our study area. For the perception of the actual scenario of rural livelihoods by the impact of such multi-hazards, six parameters have been used. Over time, the respondents suppose they have noticed changes in the environment and extreme events. The severity of cyclone induced multi-hazards has been worsened as a result of climatic extreme occurrences, particularly the Bulbul and Amphan cyclones. However, water logging and inundation are always visible during severe cyclonic landfall and the peak season of monsoon (Fig. 3).

Table 5 shows the nature of the perceptions of multi-hazards of the questioned households in the coastal Sundarban (Indian part) region. According to island (almost 54%) and riverine (nearly 63%) households, the severity and intensity of cyclonic dangers have been triggered substantially in the last ten years. In every geographical location under inquiry, there has been a smidgeon of dispute about this fact. The 2 result likewise agrees with the changes in respondent opinion based on location (χ^2 – 39.40, p – 0.000). Nearly 75% and 67% of surveyed households from island and inland villages, respectively, agree that salinisation in groundwater is caused by the rise of sea level and the embankment breaching, whereas 20% of all respondents disagree. Furthermore, nearly 75% of families across the country feel that the intensification of cyclones and storm surges has badly destroyed earthen embankments. This type of influence has also increased the likelihood of erosion in island (>85%) and coastal (>60%) villages. However, due to the strengthening of storms over the last ten years, coastal villages have typically seen higher levels of inundation and the results of their opinion clearly show this (Table 5). The majority of the results are found to be significant at the 5% level (p value), indicating that the nature of perception differs from one geographical region to the next.

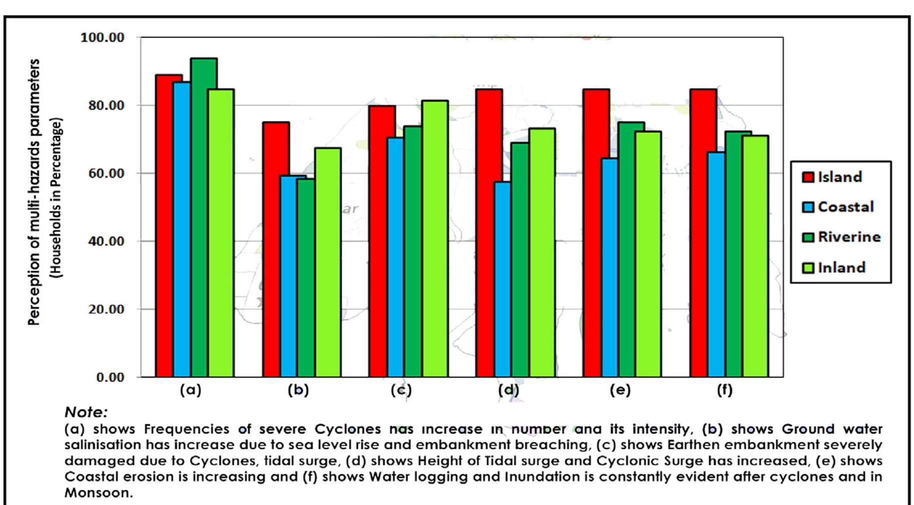

Fig. 3. Perception (agreed and highly agreed options) on multi-hazards in the coastal villages (under West Bengal) of Indian Sundarban.

Table 5
Perception of multi-hazards parameters.

Perception of multi-hazards parameters	Location of the Villages	Strongly Disagree (1)	Disagree (2)	Neither Agree nor Disagree (3)	Agree (4)	Strongly Agree (5)	χ^2 value	'p' value
Frequencies of severe Cyclones has increase in number and its intensity	Island	0.00	0.00	11.00	35.00	54.00	39.40	0.000
	Coastal	0.00	3.00	10.00	48.50	38.50		
	Riverine	0.00	0.00	6.00	63.00	31.00		
	Inland	0.00	0.80	5.20	41.80	43.20		
Ground water salinisation has increase due to sea level rise and embankment breaching	Island	0.00	19.00	9.00	42.00	33.00	164.73	0.000
	Coastal	0.50	18.50	21.50	36.50	23.00		
	Riverine	2.00	18.50	21.00	35.50	23.00		
	Inland	2.40	16.80	13.20	38.80	28.80		
Earthen embankment severely damaged due to Cyclones, tidal surge	Island	1.00	8.00	11.00	43.00	37.00	19.77	0.071
	Coastal	0.50	10.00	19.00	39.00	31.50		
	Riverine	2.00	7.00	17.00	41.50	32.50		
	Inland	0.40	3.60	14.40	50.80	30.80		
Height of Tidal surge and Cyclonic Surge has increased	Island	0.00	4.00	11.00	48.00	37.00	39.01	0.006
	Coastal	0.50	12.00	30.00	36.50	21.00		
	Riverine	2.00	8.50	20.50	38.50	30.50		
	Inland	0.40	3.60	22.80	44.00	29.20		
Coastal erosion is increasing	Island	2.00	1.00	12.00	47.00	38.00	56.75	0.000
	Coastal	0.00	16.50	19.00	33.50	31.00		
	Riverine	0.50	8.50	16.00	43.00	32.00		
	Inland	0.00	7.60	20.00	39.20	33.20		
Water logging and Inundation is constantly evident after cyclones and in Monsoon	Island	2.00	3.00	10.00	45.00	40.00	139.33	0.000
	Coastal	3.50	15.50	14.50	39.50	27.00		
	Riverine	1.00	17.50	9.00	38.50	34.00		
	Inland	1.20	14.80	12.80	41.20	30.00		

Source: Primary Survey during December, 2019 to January, 2020 (After Cyclone Bulbul) and June–September 2020 (After Cyclone Amphan).

Salinity has grown and intruded inland in several South-east Asian deltas over the last few decades, notably in surface water (Mondal et al., 2013; Noh et al., 2013). Rising sea levels, more frequent and/or strong tropical storms, and land use change are all likely to enhance the danger of groundwater salinisation (Hoque et al., 2016; Rahman et al., 2018). In coastal blocks, man-made embankments protect inhabited islands from the entry of saltwater. Agriculture and aquaculture are now impossible on the islands (Danda et al., 2019). Out of a total of 3500 km of embankment on the Indian side of the Sundarbans, 800 km is liable to breach during the events of high-intensity weather (Mondal and Bandyopadhyay, 2014). During high tide, the water level in most of the rivers remains above the surrounding inhabited regions. During such events, river water rushes into the islands, destroying practically everything in minutes and causing irreversible damage to people's assets, lives and livelihoods (Mondal et al., 2020). According to the IMD assessment, Aila caused a storm surge of more than 2 m along the Sundarban and approximately 3 m in the Bangladesh region. The astronomical tide is 4–5 m high at the time of landfall and the combined effects of tide and storm surge (also known as storm tide) result in a total water level of over 4 m, causing severe inundation and destruction to coastal areas (Gayathri et al., 2016).

The extent of storm surge impacts is determined by the exposure of shoreline to a surge occurrence. The southern Baltic Sea areas submerged and soft coastline relief are the most vulnerable; the rate of retreat is determined by the frequency and strength of storm surges. Due to sea-level rise and the loss of beaches, the rate of coastal retreat has accelerated in recent years (Tomasz, 2015). Hazards related to climate and sea level are having a negative impact on coasts (very high confidence). Extreme events, such as storms, make coasts extremely susceptible, imposing significant costs on coastal societies (Quesada-Román and Pérez-Briceño, 2019). Tropical cyclones affect roughly 120 million people annually and kill nearly 250,000 individuals between 1980 and 2000 (Nicholls and others, 2007). The rate of erosion between 1996 and 1999 was calculated to be 5.47 km^2 $year^{-1}$ (Gopinath and Seralathan, 2005) in Indian Sundarban. Water logging is a major worry in the face of climatic change which is worsening the situation for the inhabitants of southwest Bangladesh. Long-term flooding has resulted in major displacement, posing humanitarian concerns in terms of safe drinking water, sanitation, shelter, food security and job opportunities. People in some locations are forced to live in wet conditions for nine months of the year and many farmed croplands are permanently flooded, resulting in the loss of vital agricultural produce, particularly rice. Water logging has severely impacted socioeconomic and agricultural activities (Adri and Islam, 2012).

Tropical cyclones, rapidly intensified, are often associated with the largest forecast errors and result in disproportionately large human and financial losses (Bhatia et al., 2019). Due to high population density, packed around low-lying areas along coastal areas, the impact of tropical storms is disproportionately severe and deadly, especially when they reach the eastern part of the Indian and Bangladesh coast bordering the North Bay of Bengal (Gupta et al., 2019). The availability of fresh water is critical for subsistence livelihoods and protected habitats in the fertile Ganges-Brahmaputra-Meghna (GBM) delta, which crosses the border between India and Bangladesh. The delta endures increased river salinity and salt intrusion, as well as seasonal flooding during the monsoon, due to enormous tides and widely varied river discharge (Bricheno et al., 2021). They are also an interface between the high-salinity water of sea and the fresh water of river, and the quality of brackish water of the delta distributaries can have significant ramifications for human health and agriculture. In many deltas throughout the world, salt intrusion is increasing due to rising sea levels paired with changing river discharge (White and Kaplan, 2017). Climate change is putting pressure on deltaic coastal plains all around the world, causing sea-level rise, tidal flooding and storm surges. They are also vulnerable to things like land subsidence, coastal erosion and land loss, groundwater salinisation, and environmental (Ericson et al., 2006; IPCC, 2007; Acuña-Piedra and Quesada-Román, 2021). Salinity has increased by 38 and intruded inland in various Southeast Asian deltas over the last few decades, notably in surface water (Mondal et al., 2013; Noh et al., 2013). Milliman and Meade (1983) identified eleven mega-deltas along the Asian 34 coastline that have comparable geophysical characteristics and are home to millions of people (Woodroffe et al., 2006). These are especially susceptible to salinisation and future climatic change is predicted to exacerbate the problem (Hoque et al., 2016).

4.2. Impact of multi-hazards on life and livelihoods in the coastal West Bengal

The impact of multi-hazards in the coastal region is heavily reliant on access to various livelihood assets (Mondal et al., 2021). Access to the usage of livelihood capital, such as natural, physical, financial, human and social capital, has been considered to comprehend the true scenario of harmful effects of multi-scale hazards on the vulnerability of rural households. As a result, the impact of cyclone and the other challenges of climatic change are broadly classified depending on the capital assets that support the livelihood of the households (Table 6). It is worth noting, too, that access to and judicious uses of these financial assets are critical for successful adaptation processes to offset the negative effects of climatic change. Policymakers will be able to identify appropriate intervention options and so support households in building up their livelihood assets and becoming more resilient once they have a better understanding of the size of the impact on livelihood capital (Alam et al., 2017). Primary data has been obtained, particularly after the cyclones, devastating *Bulbul* and *Amphan*, to estimate the true impact of multi-hazards on rural livelihood capital.

In terms of food security, malnutrition and unemployment, the impact on human capital has been found to be larger (2.57 and 2.20) in island villages, but migration has been found to have an especially higher impact in inland communities. In every scenario of human capital-related repercussions, island settlements are shown to be the most impacted geographically (Table 6). Nearly all the geographical places have perceived a high impact on educational and religious institutions in terms of social capital. Only island settlements have seen a significant influence on medical facilities compared to the other geographical areas since they are separated from the main land and hence have a higher level of susceptibility and risk, as a result of climate-related extreme events. As the surveyed households are heavily reliant on agricultural and fishing livelihoods, the residents of each geographical location have observed a larger degree of multi-hazards impact on income from agriculture and savings. On island residents, a higher level of vulnerability is plainly seen (Table 6). However, many stakeholders' activities (e.g., central and state agencies working with NGOs) have reduced vulnerability in the region slightly. Climate change risks are assessed to have a far bigger impact on island and coastal settlements in almost every area of physical capital. Only in the case of electricity, riverine and inland residents feel a greater level of danger. When natural capital is taken into account, island, coastal and inland residents experience a greater influence on land and water, which has a significant impact on their lives and livelihoods. Only inland residents have a greater impact on agricultural land loss due to other factors (Table 6).

Due to low agricultural production and livelihood income, food insecurity and malnutrition have grown. This percentage ranges from 40 to 50 in Asia and the Pacific's densely populated countries, while two-thirds of the working populations in Sub-Saharan Africa still rely on agriculture (ILO, 2007). Climatic change has a negative impact on agricultural productivity in low-income developing countries of Asia and Africa and the livelihoods of a huge number of the rural poor would be jeopardized with increasing vulnerability to food insecurity. An increase in the mean seasonal temperature can shorten the growing season of many crops, lowering production. Warming will have a more direct impact on yields in locations where temperatures are already near to physiological maximum for crops (IPCC, 2007). Small and landless farmers, in particular, have seen their employment possibilities restricted. Unemployment, disease/health conditions under the same capital have a strong impact on island villages, whereas the other three types of villages have a moderate impact. Small and landless farmers are prone to disease and have poor health due to household food poverty and restricted access to health services (Kovats et al., 2005; Costello et al., 2009). The situation has worsened as the number of waterborne infections associated to sea-level rise, floods and saline intrusion has increased (Sikder and Jian, 2014). Migration is another key human capital characteristic, with a strong impact in island and inland communities and a moderate impact in coastal and riverine villages. Around 170 million out of 1.4 billion people of the country are experiencing sea-level rise, erosion and natural disasters such as tropical storms and cyclones as a result of a changing climate. The most recent indication of this susceptibility came in May 2020, when Cyclone Amphan, the biggest storm in the Bay of Bengal in decades, hit, forcing several million people to flee (Plate 1).

Table 6
Perceived impacts of Multi-hazards in the study area.

Assets	Impact/risk	Description	Location of the Villages			
			Island	Coastal	Riverine	Inland
Human capital	Food security and malnutrition	Food insecurity and malnutrition increased due to low production and income	2.57	1.62	1.88	1.97
	Unemployment	Employment opportunities reduced mainly for the small and landless farmers	2.20	1.66	1.81	1.84
	Disease/health condition	Due to food insecurity and limited access to health facilities, small and landless farmers are prone to many sicknesses and possess poor health	2.17	1.72	1.88	1.91
	Migration	Induced seasonal migration to cities and other places due to a lack of employment	2.10	1.83	1.85	2.02
Social capital	Educational institutions	Many educational institutions have been damaged or eroded	2.51	2.08	2.05	2.08
	Religious	Religious institutions damaged	2.55	2.14	2.02	2.09
	Medical facilities	Access to health services reduced	2.01	1.98	1.83	1.96
	Organizational involvement	Limited co-operation among farmers' groups. Small and landless farmers hardly get help from affluent farmers	1.91	1.92	1.89	1.93
Financial capital	Credit facilities	Limited involvement with different organizations	1.77	1.84	1.88	1.94
	Market access	Access to market reduced	1.89	1.88	2.00	2.02
	Income from agriculture	Income from agriculture reduced due to loss of land, crops, and yield	2.27	2.05	2.08	2.00
	Savings	Reduced the ability of savings	2.36	2.08	2.09	2.15
Physical capital	Homestead	Loss of homestead property	2.34	2.11	1.89	2.07
	Latrine facility	Deteriorated latrine facilities	2.39	1.96	1.98	1.96
	Transport	Deteriorated transport facilities	2.34	2.01	2.13	2.04
	Electricity	Deteriorated electricity facilities	2.31	2.02	2.09	2.06
	Market place	Loss of marketplaces	2.21	1.97	1.83	2.03
	Embankment	Damage to embankment	2.31	1.99	1.85	1.98
Natural capital	Land	Agricultural Land loss	2.08	2.02	1.86	2.00
	Water	Reduced availability of safe drinking water	2.06	1.85	1.91	1.93
	Livestock	Shortage of fodder and poor animal health	1.86	1.90	1.92	1.86
	Soil	Soil quality deteriorated except emerging 'char land' where no agriculture was possible previously.	1.88	1.88	1.91	1.87

Source: Primary Survey during December, 2019 to January, 2020 (After Cyclone Bulbul) and June–September 2020 (After Cyclone Amphan).

In the study area, four types of villages, organisational engagement of social capital have a moderate impact. Due to insufficient organizations, rural residents' organisational activity is severely limited. To comprehend financial capital, credit facilities, market access, agricultural revenue and savings are taken into account. Credit and market access have a moderate impact on four types of villages in this area. Their financial capital is lowered due to restricted cooperation with several organizations for a credit facility and limited market availability. Agricultural and savings revenues, on the other hand, have a strong influence on Island, Coastal and Riverine communities, and a moderate impact on Inland villages. All farming communities have a significant impact of highly damaging Tropical Cyclones and other multi-scale Hazards on the agriculture sector, which is their primary source of income. Appropriate agricultural adaptation is required to boost their resilience. The loss of land and homestead, which exacerbates their vulnerability, is the most significant consequence felt by small and landless farmers. Small and landless farmers have also seen a significant influence in securing financing and market access.

4.3. Adaptation measures are taken to cope with multi-hazards

Table 7 shows the nature of various coping techniques used by the residents of various geographical places to deal with the impact of many dangers. Based on the local consequences and shifting multi-hazards scenario, the study has revealed 13 coping methods used by the surveyed households. According to the results of the survey, the residents from various geographical locations use multiple coping mechanisms to deal with multi-hazard impacts. An ANOVA test has been used to check if there are any differences among the residents of different geographical regions based on the results of survey datasets. There is a significant difference among the inhabitants of different geographical locations (χ^2 test, $p < 0.002$). After doing a Post-Hoc analysis, it has been discovered that the island and coastal communities mostly use financial and asset-related approaches, whereas island and riverine villages rely on food-related adaptation ($p < 0.001$). The findings show that inland and riverine households are in a better position to develop coping mechanisms than those in other geographic areas.

As a good option to coping strategies, the majority of the residents from all geographical locations lower their food/meal intake. The majority of food-related difficulties have been viewed as a part of their susceptibility (Table 7). Borrowing has been identified as one of the key coping strategies used by the residents when it comes to financial coping strategies. Although selling life stocks or livestock is not the most common coping method used by the residents of all locations in long-term combat, such resources provide valuable food and asset features. One of the most widely accepted adaptive techniques for dealing with the escalation of cyclonic impacts is migration. Most of the villages studied have lost a significant portion of their agricultural and fishing livelihoods, forcing them to relocate to the nearest urban area (in short-term adaption towards Kolkata and its surrounding urban areas) and outside of West Bengal to South India (in long-term adaptation). When it comes to the amount of coping strategies used, it has been discovered that most inhabitants outside of islands use 1–3 techniques, but island dwellers use 4–6 strategies (Fig. 4). This diagram depicts the nature of the risk associated with climate changing vulnerabilities among the people living in West Bengal, India's coastal district of India. Thus, it is clear from the analysis that the higher the degree of strategy adoption is, the greater the risk to their livelihood will be (see Fig. 4).

It is worth noting that access to these capital assets is crucial for successful adaptive processes to offset the negative consequences of climatic change. Understanding the magnitude of the impact on livelihood capital will allow policymakers to devise effective intervention options to help households increase their livelihood assets and resilience. Agricultural output is mostly dependent on physical and natural capital, both of which have been impacted to varied degrees. Household human capital is found to be influenced in terms of education and skills, social capital in terms of access to health facilities, social bonding and organizational activity, and financial capital in terms of access to NGOs and government

Table 7
Coping strategies to address Post-Hazard situations in the study area (Respondent can go for Multi options).

Coping strategies		Location of the Villages			
		Island	Coastal	Riverine	Inland
Food related	Reduce the amount of food per meal	71.00	74.50	59.00	74.80
	Reduce the number of meals per day	58.00	58.50	46.50	66.00
	Go bed without food	23.00	29.50	17.50	27.20
	Rely upon less expensive or less preferred food	36.00	65.50	60.50	50.00
Finance related	Reduce buying children food (i.e. milk) from market	35.00	50.50	40.50	41.60
	Purchase food on credit	36.00	25.00	25.00	36.40
	Borrow money from NGOs/GB/money lenders	36.00	27.00	27.00	31.20
	Borrow from relatives/friends and neighbours	33.00	37.00	23.00	20.80
	Rely on casual labour for food	29.00	6.50	12.00	12.80
Asset related	Sell labour in advance	23.00	7.00	10.00	7.60
	Sell cattle/livestock/land and other assets	31.00	7.50	12.50	6.80
	Spend money from deposit	32.00	19.00	19.50	22.80
	Migrate to city or other areas	72.00	25.00	27.00	27.20
Number of adopting strategies by an individual households in the surveyed villages	1–3	12.00	56.00	44.00	52.00
	4–6	78.00	33.00	38.00	31.00
	7–10	8.0	9.00	15.00	15.00
	>10	2.0	2.00	3.00	2.00

Source: Primary Survey during December'2019 to January'2020 (After Cyclone Bulbul) and June–September 2020 (After Cyclone Amphan).

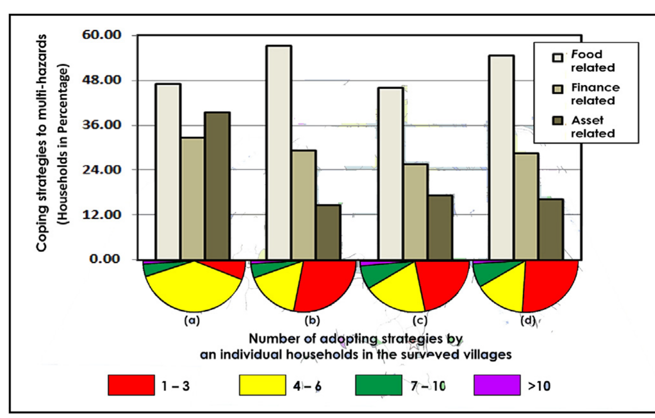

Fig. 4. Coping strategies to address Post-Hazard situations (Respondent can go for Multi options) in the coastal villages (under West Bengal) of Indian Sundarban [(a) Island, (b) Coastal, (c) Riverine and (d) Inland Villages].

financial institutions. This could hinder the ability of a family to cope and push them farther into risky situations. The impact on human capital in terms of diminished household food security and job losses are felt most acutely by small and landless farmers, who are compelled to migrate to cities and other regions to maintain their livelihoods (Plate 1).

5. Summary and policy suggestions

Many of the institutions in the study area, including schools and hospitals, have been found to be deteriorating. The school and health facilities are a greater distance away for the residents. One of the limiting

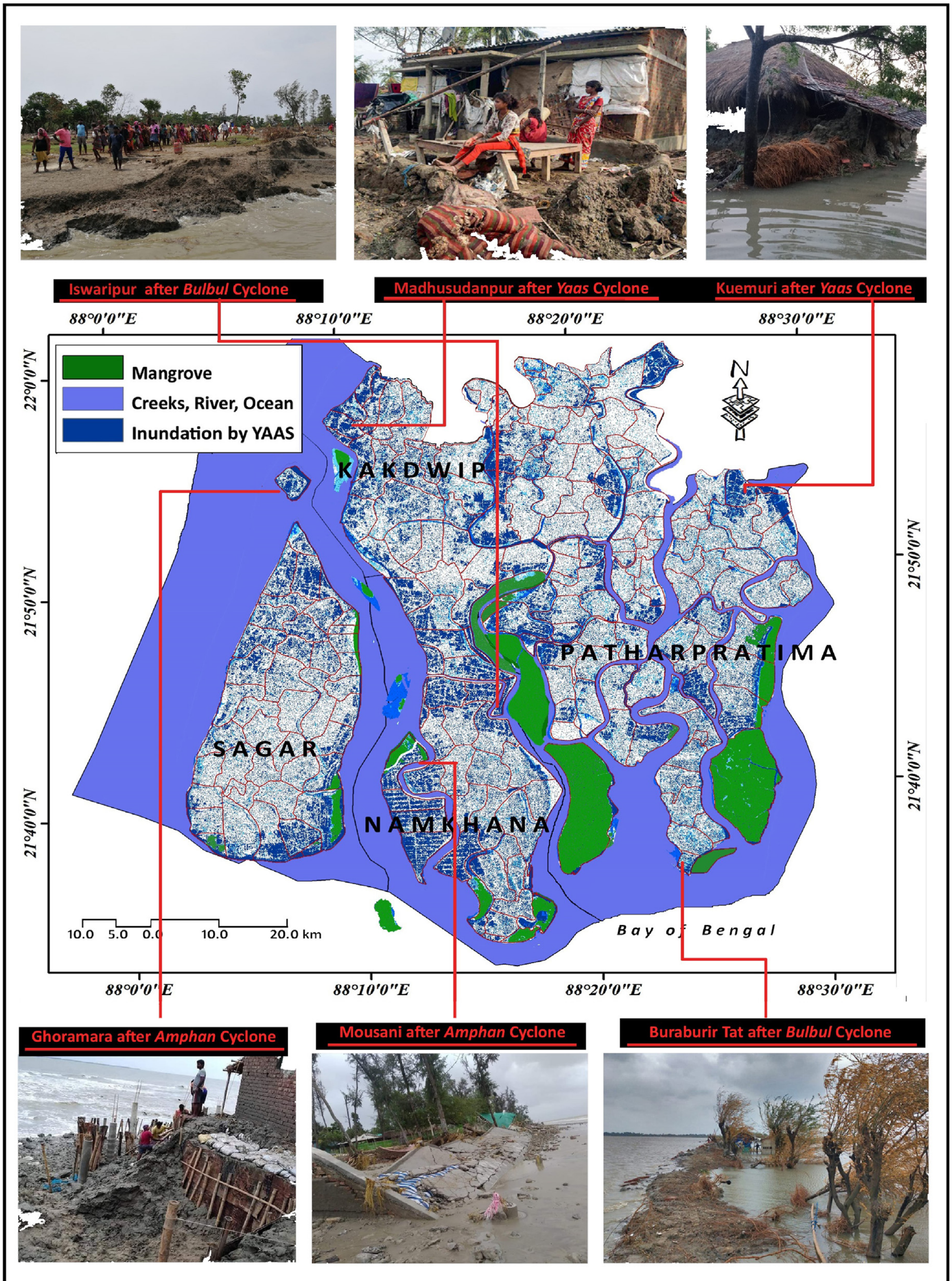

Plate 1. Glimpses of some images showing the aftermaths due to several cyclonic storms in the study during 2019–2021 (case of Bulbul, Amphan and Yaas cyclones).

elements in building household resilience is access to education and health services (Alam et al., 2017). As a result, a primary policy priority in the research area should be invested in education and health care. Coastal and riverbank erosion, as well as the other challengers for climatic change, are thought to have a significant influence on the agricultural sector, which is their primary source of income. Appropriate agricultural adaptation is required to boost their resilience. The loss of land and homestead, which exacerbates their vulnerability, is the most significant consequence felt by tiny and landless farmers. Small and landless farmers have also seen a significant influence in securing financing and market access. Their connection with non-governmental organizations (NGOs) is limited. As many of the farmers have no stable income, NGOs are unwilling to lend them money. Household ties to government agencies and non-governmental groups; on the other hand, it can help them to be more resilient (Pethick and Orford, 2013; Alam et al., 2017). Climatic change, according to all farming groups, has a negative influence on crops and harvests, reduces soil fertility and produces a scarcity of safe drinking water, all of which have an impact on their livelihood.

According to the 5th IPCC (2014) assessment, the severity and frequency of cyclonic storm surges in the Bay of Bengal region would increase soon. We have explored the impression of multi-hazards on the coastal vulnerability of the study area in this study. Based on the aforementioned findings and discussion, we may conclude that the negative impact of climatic extreme occurrences has a significant impact on a big number of respondents. The majority of the respondents in our study area live in poverty. Their low-profile economic situation has a negative impact on their lives. Several measures (identifying and mapping potential risk zones, reinforcing shore protection, formulating adaptation mechanisms, maintaining a record of displaced persons, developing case studies, regulating migration, devising rehabilitation programmes, sustainable development conserving natural resources, utilizing renewable energy to meet the energy needs of a coastal community) are needed to cope with the projected loss and improve the resilience and adaptation capabilities of a coastal community.

Low productivity is the biggest issue of India in agriculture. Increased productivity in all aspects of agriculture is critical to meeting the growing food demand of India. However, for coastal vulnerability to climatic change, farm methods must be reoriented to provide improved climatic resilience. Coastal areas must increase public investment in the research and spread of crop types that are more resistant to temperature and precipitation changes, as well as more water and nutrient efficient. To deal with the hazards of climatic change, agricultural policy should focus on increasing crop productivity and building safety nets.

Conflicts of interest

The authors have declared that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Manas Mondal: Conceptualization, Formal analysis, Writing - original draft. Anupam Biswas & Subrata Haldar: Funding acquisition & Formal analysis. Somnath Mandal: Funding acquisition. Pintu Mandal: Funding acquisition. Subhasis Bhattacharya: Conceptualization, Design of study, Formal analysis, Writing - original draft, Writing-review & editing. Suman Paul: Conceptualization, Design of study, Funding acquisition, Formal analysis, Writing – original draft, Writing - review & editing.

Funding

This article is one of the outputs of a research undertaking by the Dept. of Geography in collaboration with Dept. of Economics, Sidho-Kanho-Birsha University, Purulia, West Bengal, India, funded by the Dept. of Science & Technology & Biotechnology (**WB-DSTBT**)- (DSTBT Grant Number: ST/P/S&T/5G-12/2018 dated 25.02.2019).

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