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*Climate change in a Mingling-State: Sea Level Rise
Confronts Social Susceptibility and Justice in the
Southwestern Coastal Region of Bangladesh*

Md. Ashrafuzzaman

Orientadores:

Doutora Carla Maria Gomes

Doutor João Francisco Charrua Guerra

Tese especialmente elaborada para obtenção de grau de Doutor em Alterações
Climáticas e Políticas de Desenvolvimento Sustentável, especialidade em
Ciências do Ambiente.

2023

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Abstract

Shyamnagar Upazila, within the Southwestern part of Bangladesh encompassing the entire Sundarbans, is located in the deltas of the Ganges, Brahmaputra and Megna rivers in the Bay of Bengal and is an area extremely vulnerable to climate change, with serious consequences at the socioeconomic level. This doctoral research involved collecting data on physical, hydrological, geographical aspects, land cover change, rainfall changing patterns, water and soil trace elements, and tidal gauges. These data were complemented with the analysis of social and economic vulnerability dimensions through qualitative methods (interviews, focus groups and observation). Qualitative data collection techniques, including focus group discussions (FGDs), case studies, PRA (Participatory rural appraisal) questionnaires, workshops, in-depth interviews, key informant interviews and participant observation, was undertaken in the Shyamnagar Upazila from 2017 to 2019 (through Skype + messenger + over telephone 2020 to 2022). A survey with a close ended questionnaire was applied at the first stage in nine unions (series-based analysis), at the second stage in 12 unions (risk, hazards, vulnerability and adaptation analysis) and at a third stage in 3 unions (safe drinking water and health analysis) with a total of (320 +387 +1579) household samples (n= 2286). Sea level rise has negative impacts on agriculture, riverbank erosion, and salinity, loss of natural ecosystems, gender vulnerability, poverty, food security, fisheries, safe water resources, migration, and public health factors that affect the development of SWCRB populations and cause climate injustices. This thesis analyzed the implications of coastal risks and hazards to the vulnerability of the local populations, while also addressing their perceptions of justice and adaptation strategies.

Keywords: Sea level rise, socioeconomic impact, climate adaptation, justice; Southwestern coastal region of Bangladesh

Resumo alargado

A subida acelerada do nível médio do mar (SLR) é o impacto mais importante das alterações climáticas nas zonas costeiras do Bangladesh. Esta investigação de doutoramento centrou-se na região costeira do sudoeste do Bangladesh (SWCRB), que enfrenta um perigo iminente com a subida do nível do mar, com consequências directas nas desigualdades sociais e na justiça climática. Com enfoque nos temas-chave dos ODS, esta compilação de artigos contribui para a implementação da Agenda 2030 das Nações Unidas, nomeadamente para os ODS1 – “Erradicar a pobreza”, ODS2 – “Erradicar a fome”, ODS3 – “Saúde de qualidade”, ODS5 – “Igualdade de género”, ODS6 – “Água potável e saneamento”, ODS10 – “Redução das desigualdades”, ODS13 – “Ação climática” e ODS16 – “Paz, justiça e instituições eficazes”. Para analisar a vulnerabilidade induzida pela subida do nível do mar, esta investigação considerou a atual e futura modelização da subida do nível do mar. A metodologia utilizada é interdisciplinar e foi baseada numa abordagem de métodos mistos.

Esta investigação inclui quatro artigos publicados em revistas revistas revistas por pares, integrados no corpo da tese como capítulos de resultados (capítulos 4 a 7), tendo o autor submetido ainda durante o período do doutoramento dois outros artigos e dois capítulos de livros que foram aceites e que, por conseguinte, estão incluídos como material suplementar a esta tese (anexos).

O primeiro artigo (capítulo 4) centrou-se na modelação da subida do nível médio do mar (NMM). As projeções locais do nível do mar indicam que o este pode aumentar em meio metro ou até mais de um metro até ao final do século XXI. A região da Baía de Bengala revela taxas superiores às médias globais, devido à fusão dos glaciares dos Himalaias. Contudo, devido à natureza não linear da subida do NMM, é de esperar que as projeções sejam ultrapassadas, o que representa uma ameaça para a vida de milhões de pessoas no Bangladesh.

Além disso, as zonas costeiras do sudoeste do Bangladesh são altamente vulneráveis à intrusão de água salgada, sobretudo devido aos ciclones e à subida do NMM, especialmente a região de Shyamnagar Upazila, e espera-se que isto se agrave durante o próximo século devido às alterações climáticas. Por conseguinte, este estudo analisa a geoquímica da água salgada e compostos relacionados, a resposta à intrusão salina nos sistemas fluviais e as possíveis áreas afetadas pelos eventos climáticos extremos nas condições actuais e em 2100. Esta análise mostrou que os níveis de salinidade do solo e da água são já altamente inadequados para os padrões de fertilidade do solo e a qualidade da água na região.

Além disso, analisaram-se os principais impactos das alterações climáticas na saúde pública, começando pelo global e passando pelo local, estudando as comunidades costeiras na área de influência das Sundarbans. Discutimos quais são os principais desafios enfrentados pelos diferentes atores a nível local, incluindo o agravamento de certos riscos para a saúde da comunidade com os

impactos das alterações climáticas. Os países em desenvolvimento estão a enfrentar grandes desafios em termos de mitigação e adaptação, no entanto são os que têm contribuído menos para as causas das alterações climáticas.

Verificou-se que a maioria dos inquiridos vive abaixo do limiar da pobreza, com níveis de desigualdade relativamente baixos baseados num coeficiente de Gini de 28,5 (capítulo 5). Algumas das questões mais graves que afetam a subsistência das populações locais são os ciclones e as inundações, bem como o aumento da salinidade do solo e da água doce. Os mais pobres estão muito mais expostos aos eventos extremos, têm reduzidos recursos económicos para prevenir e recuperar dos seus impactos, e as suas fontes diretas de rendimento, na sua maioria baseadas em recursos naturais, são também duramente afetadas.

Os resultados mostraram que o impacto das alterações climáticas difere entre homens e mulheres nas comunidades examinadas (capítulo 6). Entre os principais fatores que influenciam a vulnerabilidade da comunidade estão os níveis de escolaridade, as normas culturais locais. Ainda assim, estas mulheres têm potencial para participar em planos de conservação ambiental, para liderar movimentos sociais e ambientais, e para promover estratégias de gestão sustentável dos recursos naturais, uma vez que são consideradas como as guardiãs do conhecimento local. Finalmente, esta investigação propõe que, a fim de reduzir a vulnerabilidade feminina, as mulheres devem ser capacitadas e integradas em medidas de mitigação e planos de adaptação, tanto como partes interessadas como agentes de mudança.

Ao analisar o impacto socioeconómico das alterações climáticas, esta investigação contribui para o debate sobre a justiça climática, que é uma problemática social, política e económica (capítulo 7). Os países industrializados que mais contribuíram para o problema através da emissão excessiva de gases com efeito de estufa (GEE) são os menos propensos a sofrer as consequências. Tanto a abordagem baseada nos direitos humanos como a abordagem baseada nas capacidades são aqui discutidas, mas concluímos que esta última é a mais adequada para compreender a realidade no Bangladesh. Esta área está a sofrer enormes mudanças devido aos efeitos devastadores das alterações climáticas e da subida do NMM. Com base em extensivos estudos locais, a tese conclui que as populações locais gostariam de estar mais envolvidas na conceção, planeamento e implementação de estratégias para reforçar a resiliência das suas comunidades. A população local destaca como as suas principais necessidades ter acesso à água doce a preços acessíveis, a segurança alimentar e as infra-estruturas sustentáveis, tais como estradas, casas, escolas e unidades de saúde. Nestas áreas, muitas vezes as formas de assistência centram-se na ajuda de emergência após grandes catástrofes; contudo, isto não é suficiente. A intensidade da subida do nível do mar torna cada vez mais difícil a reconstrução após a ocorrência de cada catástrofe.

Foram ainda efetuadas análises para avaliar o estado da água, da vegetação e do solo na região. O estudo analisa os dados pluviométricos recolhidos pelo BWDB entre 1968 e 2018, mostrando as mudanças no padrão de precipitação ao longo dos anos e a diminuição da produção agrícola no SWCRB e reforçando o diagnóstico de declínio das terras agrícolas durante o período 1989-2019. Como forma de diversificar as suas fontes de rendimento, alguns agricultores converteram as suas terras para a criação de camarão, o que aumenta ainda mais a salinidade do solo. Além disso, a Barragem Farakka afecta negativamente a população da SWCRB ao reduzir o fluxo do rio Ganges para o Bangladesh. As medidas adaptativas utilizadas pelos agricultores incluem a construção de aterros, a recolha das águas da chuva, a drenagem adequada para reduzir o alagamento, o controlo da expansão das explorações de camarão e a introdução de culturas de alto rendimento mas que são mais tolerantes à salinidade, bem como o emprego de novas técnicas de irrigação. Além disso, as técnicas agrícolas Sorjan e o cultivo flutuante, a pecuária e a agricultura apoiadas pela comunidade, são vistas pelos agricultores das zonas costeiras como uma forma de mitigar os impactos climáticos.

A análise de vulnerabilidade revela que a população local já implementou com sucesso oito estratégias de adaptação baseadas na comunidade para reduzir a vulnerabilidade causada pela subida do mar e pelas inundações. Tem sido testemunhado que as práticas de adaptação implementadas com a participação direta das comunidades tem contribuído para a redução das vulnerabilidades e o reforço da resiliência das populações locais. Após as catástrofes, a reabilitação dos aterros costeiros com o envolvimento da comunidade local é uma resposta favorecida nos processos de adaptação estrutural, bem como a reflorestação costeira e os abrigos polivalentes construídos pelo governo para os furacões. Concluiu-se também que o governo deveria ter em consideração as propostas da comunidade local para ajudar no processo de adaptação.

Já há um vasto número de vítimas das alterações climáticas na SWCRB. Ao mesmo tempo, estas regiões tornaram-se um campo de ensaio para estratégias de adaptação que são particularmente adequadas para as comunidades de pequena escala. Considerando as contribuições empíricas de todos os artigos incluídos nesta tese, pode argumentar-se que as estratégias de adaptação e resiliência, até à data, não têm considerado plenamente indicadores sociais tais como pobreza, desigualdade de género, empoderamento ou desigualdades de rendimentos. A subida do nível do mar, agravada pelas alterações climáticas, tem impactos negativos na agricultura, na erosão das margens dos rios e no aumento da salinidade, levando à perda de ecossistemas naturais, a uma menor segurança alimentar das populações e a maiores fluxos de migração, contribuindo ainda para agravar problemas de saúde pública que afectam o desenvolvimento das populações da SWCRB e geram crescentes injustiças.

Palavras-chave: Subida do nível médio do mar; impactos socioeconómicos; adaptação às alterações climáticas; justiça; região costeira do sudoeste do Bangladesh

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Acronyms and Abbreviations

AILA- Extremely Severe Cyclonic Storm
BIWTA- Bangladesh Inland Water Transport Authority
BWDB- Bangladesh Water Development Board
BCCSAP- Bangladesh's Climate Change Strategy and Action Plan
Ca- Calcium
CC- Climate change
CCSLR- Climate change Sea level rise
CBOs -Community-based organizations
CIDA- Canadian International Development Agency
Cl- Chloride
CMIP5- Coupled Model Intercomparison Project
CM- Centimeter
CO₂- Carbon Dioxide
COP- Conference of the Parties
CSOs- Civil Society Organizations
DEM- Digital Evaluation Model
DRR- Disaster Risk Reduction
EC- Electrical conductivity
ECCO- Estimating the Circulation and Climate of the Ocean (<https://podaac.jpl.nasa.gov/ecco>)
EEA- European Environment Agency
FGD- Focus Group Discussion
PgC– Petagrams Carbon
GBM- Ganges, Brahmaputra, and Meghna
GDP- Gross Domestic Product
GIS- Greenland Ice Sheet
GIS- Geographic Information System
GHGs- Greenhouse Gases
GNSS- Global Navigation Satellite System (GNSS or Global Navigation Satellite System is a type of satellite system which is widespread global coverage and It uses satellites to provide independent geospatial positioning)
GT- Gigatonnes
GoB- Government of Bangladesh
GCM- Global Climate Model (GCM developmental research focuses on sensitivity to parameterizations of clouds and moist convection, ground hydrology, and ocean-atmosphere-ice interactions).
HMA- High Mountain Asia
HYV- High-Yielding Variety
HCO₃- Bicarbonate
IPCC- Intergovernmental Panel on Climate Change
IDI- In-depth Interview
IAP- The Institute of Atmospheric Physics
JPL- Jet Propulsion Laboratory (JPL is leading a project for NASA that brings satellite observations into a format that makes them easier to compare with climate models) [<https://www.jpl.nasa.gov/>].
K- Potassium
KII- Key Informant Interview

IMO- International Migration Organization
 IMI- International Migration Institute
 LSA- Laboratory for Satellite Altimetry “The NOAA/STAR Laboratory for Satellite Altimetry (LSA) specializes in the application of satellite altimetry to a wide array of climate and meteorological problems, including global and regional sea level rise, coastal and open-ocean circulation, weather forecasting hurricane intensity. Predicting El Niño and La Niña events and monitoring the changing conditions of the Arctic Ocean. LSA hosts the NOAA Jason Science Program, the Sea Surface Height Science Team, and the Sea Ice and Polar Dynamics Science Team”.
[\[https://www.star.nesdis.noaa.gov/socd/lisa/index.php\]](https://www.star.nesdis.noaa.gov/socd/lisa/index.php)
 LDC- Least developed countries
 MAXQDA- Computer Assisted Qualitative Data Analysis software
 MOEF- Ministry of Environment and Forest
 MSL- Mean sea level rise
 MASL- Meters above sea level
 MM- Millimeter
 MMR- Mixed method approaches
 MLR- Multiple Logistic Regressions
 Na- Sodium
 NAPA- National Adaptation Programme of Action
 NASA- United States civil space and aeronautics agency
 NCEI- National Centers for Environmental Information
 NOAA- National Oceanic and Atmospheric Administration
 NGOs- Non-governmental organizations
 NorESM- Norwegian earth system model
 OHC- Ocean Heat Content
 OM- Organic Matter
 P- Phosphorous
 pH- Acidity or alkalinity
 PRA- Participatory Rural Appraisal
 RCPs- Representative Concentration Pathway (greenhouse gas concentration)
 RSET- Rod surface elevation tables
 RVCC- The Reducing Vulnerability to Climate Change
 SLR- Sea level rise
 SIDR- Extremely Severe Cyclonic Storm
 SWCRB- Southwestern coastal regions of Bangladesh
 SPSS- Statistical Package for the Social Sciences
 SRDI- Soil Resources Development Institute
 SDGs- United Nation's Sustainable Development Goals
 TG- Tide Gauge
 TN- Total Nitrogen
 TDS- Total Dissolved Solids
 TOPEX- Ocean Topography Experiment (The Topex/Poseidon and Jason-1 and Jason-2 satellites, Jason-3 provide highly detailed measurements of sea level on Earth to gain insight into ocean circulation and climate change)
 UNFCCC- United Nations Framework Convention on Climate Change
 UN- United Nations
 UNESCO- United Nations for Education, Sciences, and Culture
 UDMC- Union Disaster Management Committee

VLM- Vertical Land Motion

WDMC- Ward-level Disaster Management Committee

WMO- World Meteorological Organization

1. Introduction

1.1. Climate change and sea level rise

Climate change refers to the evidently serious change in the average environments of climate or its inconstancy in regards with temperature, rainfall and wind within an extensive time span (IPCC, 2014). Climate change has been labeled many times as one of the major problems for mankind over the impending hundred years. Increased concentrations of carbon dioxide (CO₂) and other greenhouse gases (GHG) in the Earth's atmosphere from anthropogenic activities are the cause of rising temperatures, global climate change and associated sea level rise (IPCC, 2014). The global average surface temperature at the latter part of the 21st century (2081-2100) is forecasted to average between 1.5°C to 2°C, along with excessive rainfall occurrences, warming of the world oceans, and sea level rise (SLR) up to 8-16 mm/year (IPCC, 2014). At the same time, the atmosphere is experiencing a concentration of carbon dioxide; methane, and nitrous oxide at levels never seen in the last 800,000 years, and projections for sea level indicate a continuous increase even after GHG emissions decline (Warrick et al., 1996). The main reason for global warming determined by the Intergovernmental Panel on Climate Change (IPCC) is the release of CO₂, especially from urban localities. The SLR from the ocean's increasing temperature is an effect of the Earth's reaction to GHG accumulation. There are lots of activities of human-being proving strongly that the main reasons for increasing of greenhouse gases which in turn warms world temperatures (IPCC, 2019). Rising global mean air and sea temperatures, wide spread of snow and ice getting melted, and rising worldwide average sea level-all show warmth of worldwide temperatures on the rise (IPCC, 2014). The seas have retained the majority 90% or higher of this increased temperature driving to a rise in sea temperatures. Simultaneously, surface temperatures in the land have also experienced a rise.

The average global temperature in 2019 was 1.1 °C higher than the average for the pre-industrial period of 1850–1900, with a 0.85 °C rise from 1850 to 2012. Also, 2016 was the hottest year ever recorded partly due to a severe El Niño occurrence, followed by 2019 (Zhongming et al.,2020). Temperatures from the previous thirty years were progressively warmer than the previous timeframes since 1850 (Cheng et al., 2018; WMO, 2019). Since the 1980s, each consecutive decade has been hotter than the last. If current CO₂ emissions continue, the temperature rise will be between 3 and 5 °C for the 21st century (Cheng, et al., 2019a; WMO, 2019). Acceleration in the loss of sea ice and ice sheet has been reported and ocean levels are rising rapidly. It is worth mentioning that the 2015 Paris Agreement has set the target to keep a global temperature below 2 °C over the next 100 years with the ambition to maintain it at 1.5 °C (Maurer et al., 2019; Farmer, 2019). During the 20th century, global SLR experienced an increase of about 2 mm/yr., comparatively greater than in the last three thousand years (IPCC, 2014). From 1901 to 2018, the worldwide average sea level rose by 0.20 (0.15 to 0.25) mm and the regular proportion of SLR was 1.3 (0.6 to 2.1) mm/yr from 1901 to 1971, swelling to 1.9

(0.8 to 2.9) mm/yr from 1971 to 2006, and additional swelling to 3.7 (3.2 to 4.2) mm/yr from 2006 to 2018 (IPCC, 2022).

It is important to identify possible future sea levels for different greenhouse gas pathways. Figure 1 show observations based on sea level from tide gauges (dark gray) and satellites (light gray) for a period between 1800 and 2015, with the next decades of sea level until 2100 according to six probable future scenarios (colored lines). Scenarios differ according to the potential future frequency of GHG-emitting scenarios and gaps in the likely speed of glacier and ice sheet loss (Sweet et al., 2017). The U.S. Climate Change Science Program in 2012 projects, based on the lowest possible GHG emissions, a global average SLR of 0.2 m above 1992 levels by 2100 (Figure 1). A higher level of CO₂ and GHG emissions would result in greater SLR, up to 2.0 m above the 1992 levels (IPCC.2014; Hall et al., 2019). Under a projected “worst-case scenario” with the largest amount of GHG emissions, SLR has the potential to increase to 2.5 m above the 2000 levels by 2100 (Zickfeld et al., 2017; Sweet et al., 2017). Such a prospect implies a dire consequence for the urban settlements around the coast, deltas, and regions with lower plains.

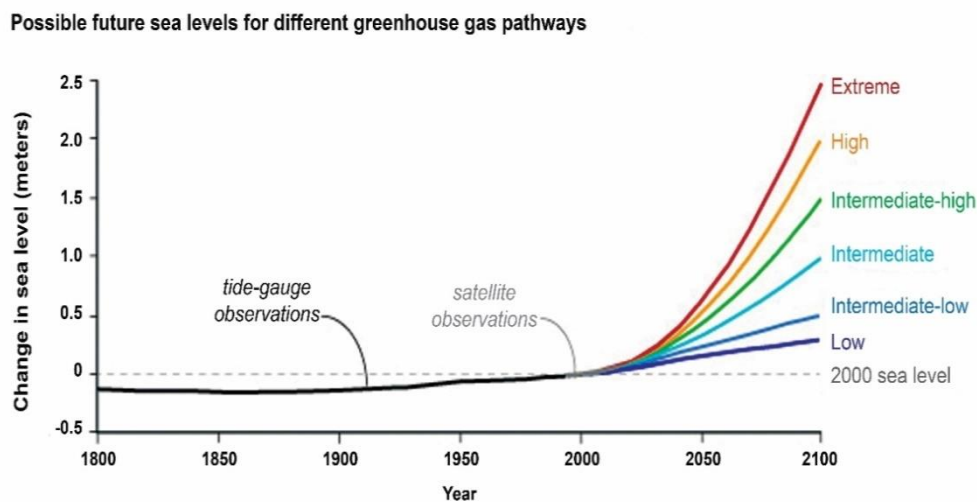


Figure 1: Adapted from Sweet et al., 2017; National Oceanic and Atmospheric Administration (NOAA) climate.gov graph.

Different regional climatic anomalies such as ENSO, associated with heat exchange between the ocean and the atmosphere, can impact a single annual SLR record or induce instrumental errors (Dogar et al., 2017; Cheng, 2019b; Cai et al., 2021). Thus, long-term trends are essential for demonstrating climate change; and such trends have been computed in this effort. Such is the example of the latter part of 2018 to the beginning of 2019, when El Niño formed, after the summer of 2019, the El Niño event slowed, entering an impartial stage which continued through the second part of the

year (fig. 2). From La Niña (early 2018) to El Niño (post 2019), heat travelled from the South Pacific Sea (20°S–5°N) into the Northeast Pacific Ocean (5°–20°N) (Cheng et al., 2020; Cai et al., 2021).

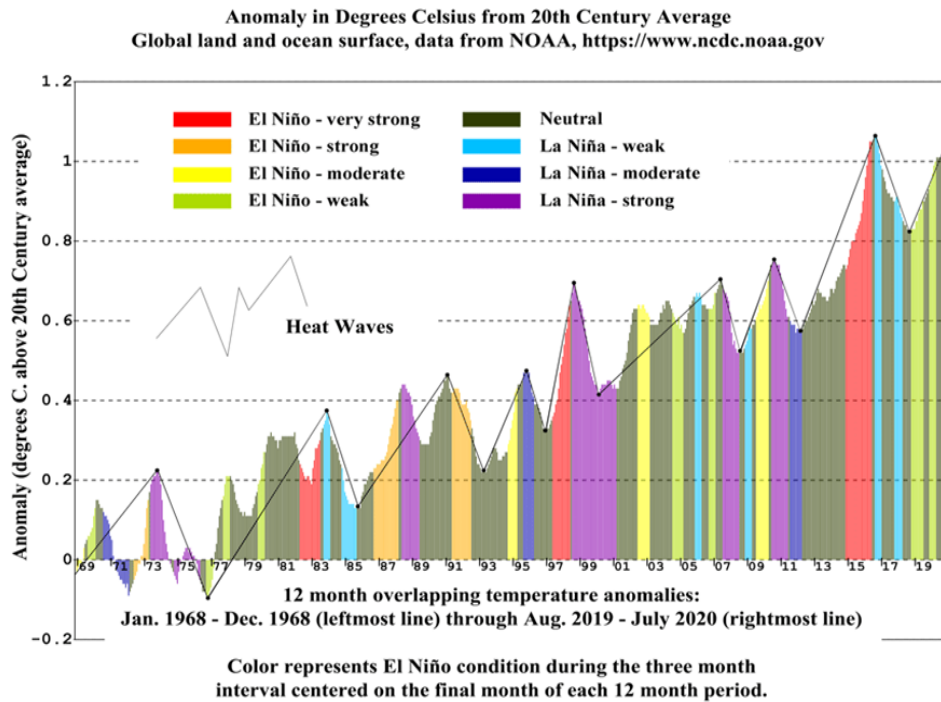


Figure 2: Retrieved from NOAA (2020). El Niño–Southern Oscillation related temperature anomalies from 1968 to 2020.

Since single annual ocean heat content (OHC) value can be impacted by internal variabilities (i.e., El Niño–Southern Oscillation, ENSO) which are depicting a major increment within the rate of worldwide climate change (Cheng et al., 2020). ENSO is connected to both warm rearrangement within the marine and heat trade between the ocean and atmosphere. Extended duration of sea temperatures push towards growing sea levels (thermal expansion of the sea and incorporated accumulation of melting ice) (Cheng, 2019b; Cai et al., 2021). Over 90% of global heat is absorbed in the ocean, promoting molecular thermal expansion, and, thus, promoting SLR (Cheng, 2019b; Cheng et al., 2021).

The IAP and the ocean heat content values are the inconsistencies.

Rank	Year	IAP	NOAA/NCEI
1	2019	228	217
2	2018	203	196
3	2017	193	189
4	2016	185	180
5	2015	180	164

Table 1. Adapted from Cheng et al., 2017 through 2019 and NOAA/NCEI information; upgraded from Levitus et al., 2012 through 2019 (Levitus et al., 2012; Cheng et al., 2017; Cheng et al., 2019a). Top five warmest years in the ocean since 1955 comparative to the 1981–2010 average.

As a result of global warming, SLR is driven by two primary mechanisms. First, glaciers and ice sheets melting at faster rates contribute to the release of large volumes of freshwater into the oceans. Second, ocean water volume is increasing due to the molecular expansion of water. A third minor mechanism is the net transfer of water from freshwater lakes and rivers to oceans (Church, 2013).

Glacial melt

Mountain glaciers react fast to environmental triggers and the rate of melting mountain glaciers and ice sheets is increasing, with rates five times higher in 2018 than four decades ago; from as much as 171 mm of water in the 1980–1989 period, to 850 mm in 2010–2018 (Davies et al., 2020). The loss of mass of the Greenland ice sheet (GIS) reached up to 7 times, or 247 billion tons annually, in the time period of 2012–2016, compared to 34 billion tons annually in 1992–2001 (IPCC, 2014; Davies et al., 2020). The GIS softening due to global SLR was ~ 1.0 mm for every year, in addition to the 0.6 mm every year stated in the IPCC’s AR5 for the 2002–11 phase (Cheng *et al.*, 2018; WMO, 2019). By the end of this century, sea level will be likely rise in more than 95% of the ocean’s expanse (IPCC, 2014). Should the GIS melt entirely, sea level would raise ~ 7 m (Gregory et al., 2004; IPCC, 2014). In the event of the melting of the entire Antarctic ice sheet, sea level would increase by ~ 57 m (Weber et al., 2014).

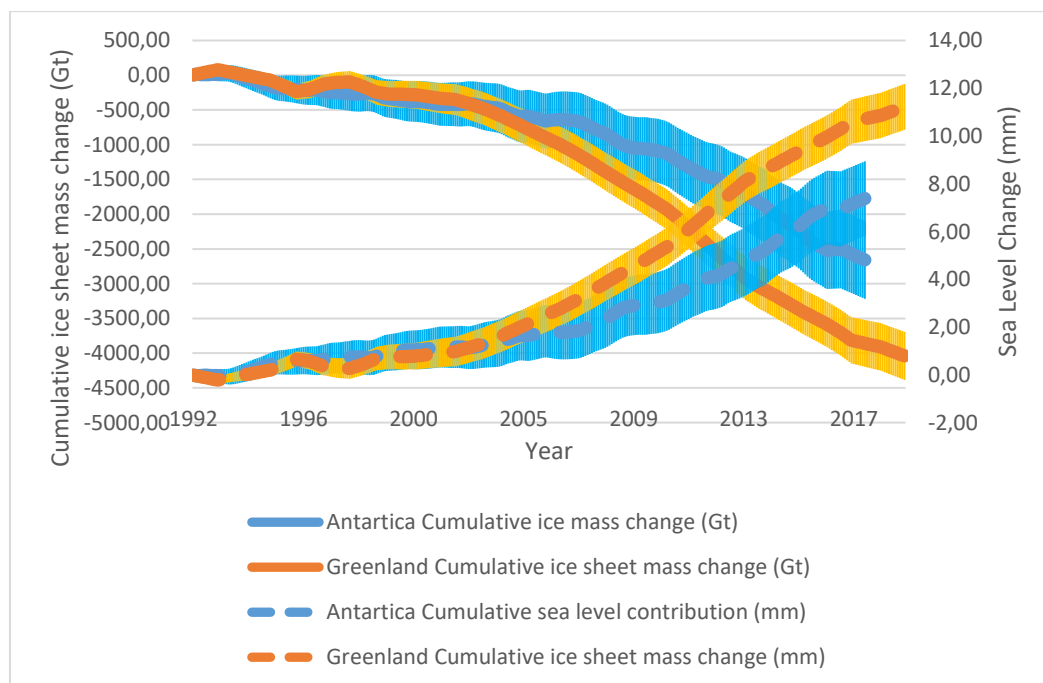
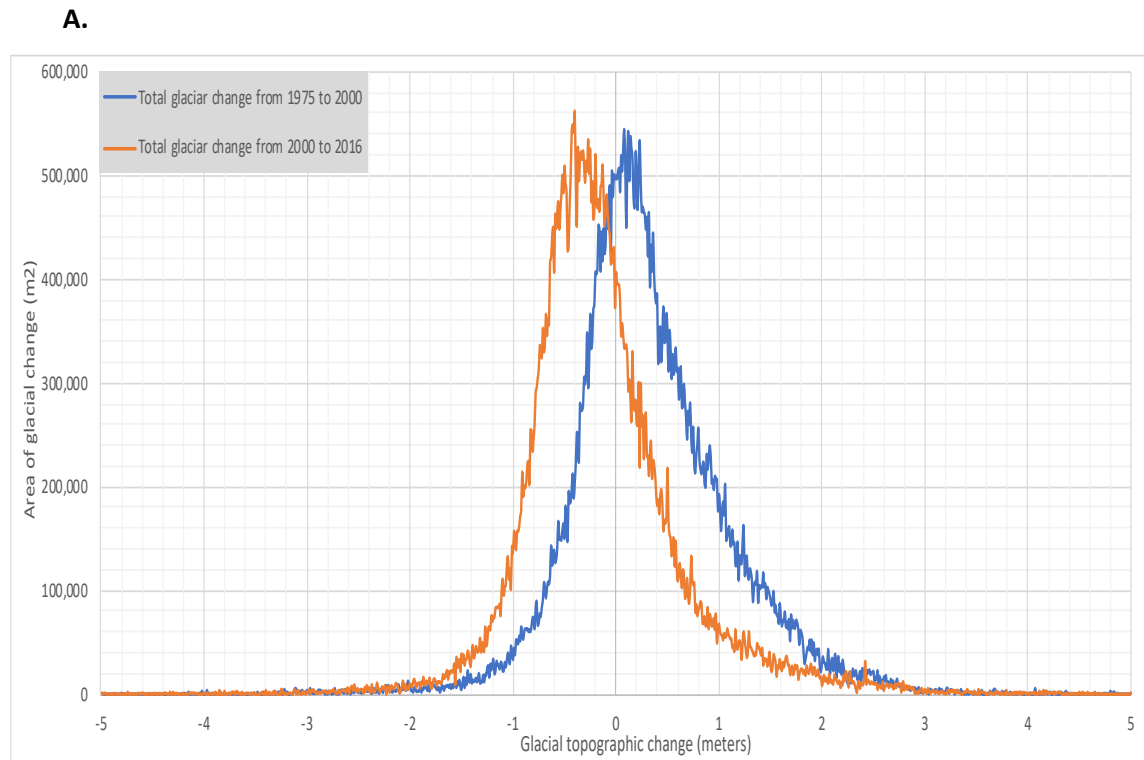


Figure 3: Self-made with data retrieved from Shepard, 2020a; Shepard, 2020b. The cumulative ice loss of Greenland and Antarctic ice sheets and the equivalent glacial mass translated to total SLR in mm. Graphs show an increase, especially from 2000 to 2010. It is expected that this pattern will continue to increase through the 21st century.

Compared to the first decade of 1997–2006, the ice mass loss of the GIS doubled from 2007–2016, while the ice mass loss of the Antarctic ice sheet more than tripled. Since the 1990s, ice sheets have contributed to one-third of the total SLR (Figure 3) (Mouginot et al., 2019). Finally, between 2003 and 2007, loss of ice contributed to approximately 80% of the entire SLR (Zhongming et al., 2013).

Between 1975 and 2000, global glaciers lost 0.25 m of ice mass (Pieczonka, and Bolch, 2015). Glaciers have experienced a massive decrease, with about half a meter of ice loss every year as of 2000, equivalent to 8 billion tons of water (Weston, 2019). Along with this, spring freshwater ice melts occur nine days earlier compared to 150 years ago, and autumn frosts are ten days later in the northern hemisphere. Softened permafrost is found below 15 ft (4.6 m) in segments of Alaska. Gigantic ice fields are vanishing from the Arctic, Peru, Switzerland, and the equatorial glaciers of Man Jaya in Indonesia; more than 80% of Kilimanjaro’s snows have disappeared since 1912, and majority of the glaciers of the Garhwal Himalaya in India could disappear in 2035 (Glick, 2004; NASA, 2019; Weston, 2019).

Himalaya glacier melt



B.

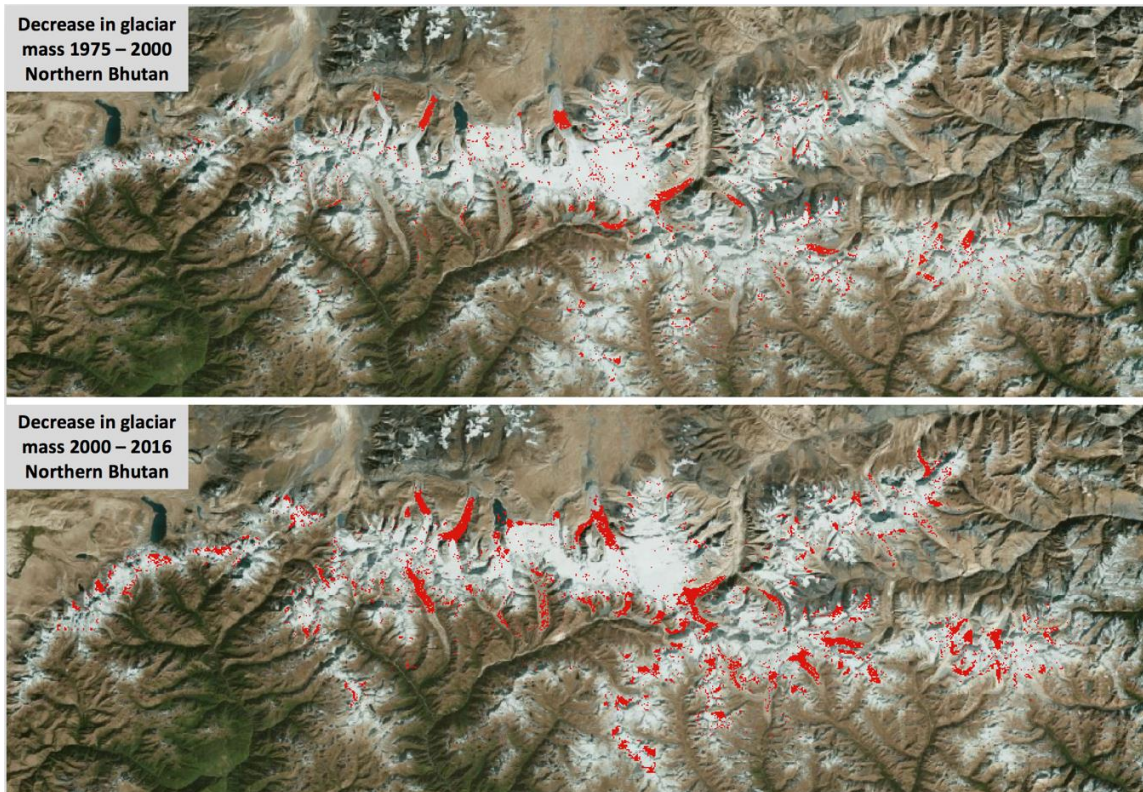
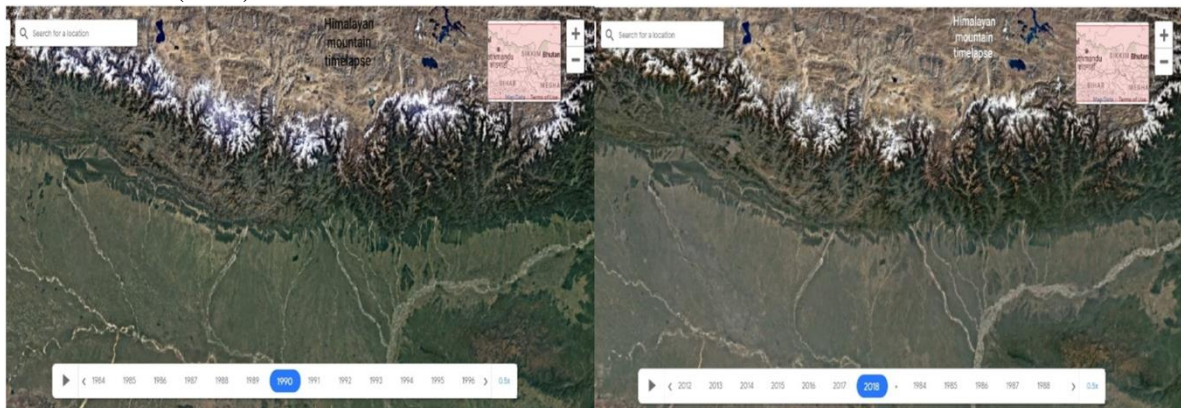


Figure 4: Histogram showing glacier topographic changes from 650 glaciers of the Himalayas for the period from 1975 to 2000, compared to 2000 to 2016, (A) Map of a section of the Northern Bhutan Himalayas showing the area of retreat for the period from 1975 to 2000, compared to 2000 to 2016, (B) Figures show a huge increase in glacier mass loss from two 15-year time periods. Data retrieved from Maurer et al. (2019).



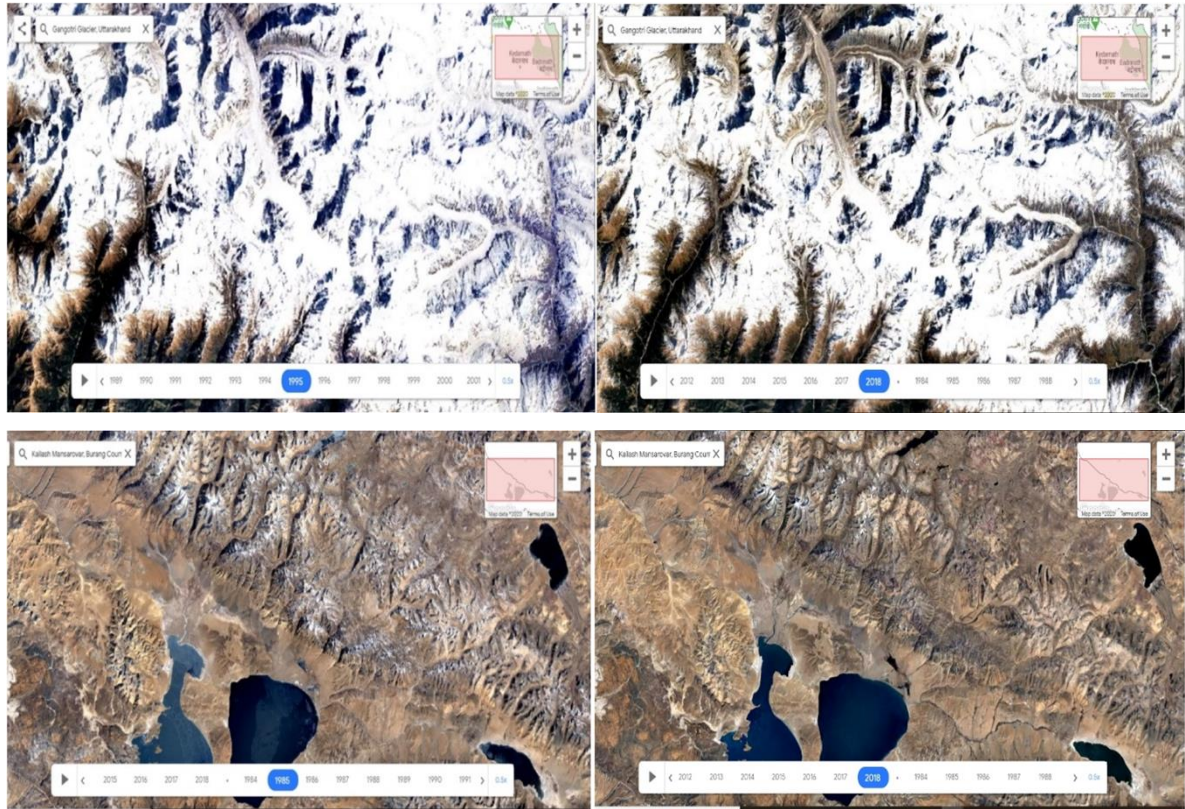


Figure 5: Time lapse of glaciers disappearing in the Himalayan range from 1990 to 2018 (A), Gangotri glacier from 1995 to 2018 (B), and the Kailash Mountains from 1985 to 2018, (C) due to temperature rise glaciers mass disappearing which is contributing local sea level rise in South Asia. Data retrieved from Google Earth time-lapse (2020a, 2020b, 2020c) (Google Earth Time-lapse, 2020a, b, c).

High Mountain Asia (HMA) adjoining the Tibetan plateau feeds the fluvial system of the Indus, Ganges, Yangtze, Irrawaddy, and Mekong with seasonal glacial melt (Lutz et al., 2014; Azam et al., 2018; Wester et al., 2019). The HMA acts as a freshwater reservoir, crucial to ecology, cultivation, and hydropower, as well as being essential to more than a billion people (Maurer, 2020). The retreat of glaciers will cause a series of effects as these provide a steady source of water to South Asia, where the population is dense. Political and social issues will arise with the reduction of freshwater and increasing flash floods (Lutz et al., 2014). Along with this, ice in the Himalaya vicinity alone would raise sea level by 1.5 m (Wester et al., 2019; Maurer, 2020).

The Himalayan glaciers, whose origins date to 70 million years ago, are very sensitive to temperature changes. Beginning in 1970, they have thinned and moved with a loss of snow covering the landscape and reduced snowfall frequency, and the 21st century cessation rate was double than the previous century (Figures 4 & 5) (Azam et al., 2018; Maurer, 2020). Major inter-annual inconsistencies in mass equilibrium and steady melt velocity on rubbish-covered glaciers are a concern for the region (Vincent et al., 2016). Continuous trends of ice loss along the 2000 km long transect within the period 2000–2016 show a -0.43 ± 0.14 m water equivalent decrease per year in

comparison to -0.22 ± 0.13 m water equivalent per year for 1975–2000. However, considerable breaches in understanding the dynamics and linked climate triggers in HMA exist (Azam et al., 2018). Around 36% of landscape ice will undergo a melting process by 2100 even if the states fulfil the 2015 climate accord goals to limit heat release increase to 1.5 °C (Wester et al., 2019).

However, it is important to note that sea level rise will not be uniform, and the origins of glaciers may not experience sea level rise as extremely as other locations further from the melting source. This is due to surface mass load self-gravitation where, near ice, water piles up due to the gravitational attraction, and flows away as the ice melts (IPCC, 2014). Thus, the melting of the Himalayan glaciers will, more than likely, contribute to more drastic increases in sea levels at locations further away from the Bay of Bengal which is disproportionately affects the developing countries and especially the marginalized populations such as SWCRB and most impacted bare is soil and water salinity. The population of coastal areas and their assets will be impacted by upcoming rising sea levels and its involved perils and all the scientific estimation give an indication of high and increasing exposure for low-lying coastal belts. When comparison is made to other localities, Asia demonstrates the highest exposure on the basis of population and wealth (Jongman et al., 2012). Increasing sea level affects marine ecosystems by means of making some plants and animals plunge along with inducing modifications of some factors, for example, given amount of light, temperature, and salinity (Cazenave, and Cozannet, 2014). The effect of sea level is associated largely with the capability of animals (e.g., corals) and plants (e.g., mangroves) to maintain the level with the vertical ascent of the sea level rise. Mangroves and offshore wetlands can have sensitivity to these shifts and could release a few of preserved compounds, exacerbating the supply of atmosphere of these greenhouse gases.

In all circumstances, however, the coastal flood risk is caused by heightened sea level which already is termed as a grave trouble for coastal communities, and it is only expected to get much serious in the days to come with prevailing rising sea level; in a natural setting, rising sea level give rise to strain on coastal ecological systems that provide peril, increase tornado, and effects on habitation for fish and wildlife, including commercial value carrying fisheries. As sea level rises, saltwater is also vast in the freshwater aquifers.

Sea level rise in Bangladesh

Bangladesh boasts a coastline of 710 kilometres around the Bay of Bengal (Ahmed, 2013). Besides, Bangladesh a low-lying South Asian country is highly susceptible to the adverse impact of global climate change particularly to sea level rise due to its unique geographical settings and poor socio-economic conditions of the vulnerable communities. In the recent past, in the fifth assessment Report of IPCC, it was stated that each year the sea in Bangladesh is rising by around 1.5mm. One of the most vulnerable nations is Bangladesh, with half of its population residing 5 m below sea level; according to future projections (IPCC, 2014). Earlier scientific projections showed that sea level rise

ranged from 0.53 to 0.97 m in 37 coastal stations at the Bay of Bengal for the year of 2100, where the predicted global sea level rise is 0.09–0.88 m (Haque, 2019). World Bank assessed that 1.5 to 1.54 million people would be affected by 2070 by sea level rise of 1 m causing permanent relocation of 13 million people. The coastal area is ~1.5–11.8 m above the mean sea level. The estuarine islands constantly change shape and position due to river erosion and new alluvial deposition. These areas are subject to flooding in the monsoon season and waterlogging in parts of the basin areas in the dry season (Feist et al., 2021). In addition, a sea level rise of 30–100 cm is predicted by 2100 as compared to 1990 levels, which will permanently flood massive swaths of land near the coast and extend the saline soils and water sources farther inland (Awal, and Khan, 2020). By 2050, sea level rise will directly affect one million people and will specifically affect the availability of jobs and income related to agriculture, fishing, and secondary services (De Lellis, et al., 2021). Rashid and Mehruba 2011 studied with current mold of sea level and the basic of a decade (1998-2008) calculated sea-level data the SLR in the Bay of Bengal and sea levels at Hiron Point, Sundarban Char Changa and Cox's Bazar (Location: Hiron Point is situated in the western coast in the Ganges delta, Char Changa lies the Central coast and Cox's Bazar is the eastern coast of Bangladesh rate of sea level increase has been seen to be 4.32, 2.34 & 3.39 mm respectively. The investigation obtained data indicating that during the monsoon season (June- September) sea level is goes up 5.5, 6.6 and 7.8 mm/year (Rashid, 2014). Approximately 6 million cubic feet per second (cfs) of water and 2,179 million tonnes of sediment flow through the GBM river system each year in Bangladesh (Shamsuddoha and Chowdhury, 2007). During the monsoon period, the rise of the local mean sea level, rise of river water levels, and the presence of dams, bridges, railways, and homesteads in the floodplain affects water drainage and results in waterlogging. This leads to flooding and salinity increases, which affects drinking water quality and causes harm to human life through waterborne diseases and drowning. Tidal statistics at three gauge location on the Bangladesh coast has discovered that the pace of sea level rise for 1977-98 of 4.0-7.8mm/year (Sarwar, 2013) was significantly greater than that of global sea level growth, 1.7 ± 0.3 mm/year over the 19th century (IPCC, 2014).

Coastal communities in South Asian regions, including Bangladesh, are becoming more than ever susceptible to the impending danger of SLR (IPCC, 2014). Coastal zones in Bangladesh encompass approximately one fifth of the entire land surface, and more than 30% of arable lands in the country (Hoque, et al., 2022). This includes especially rich ecosystems, such as the world's leading single expanse of mangroves (the Sundarbans), beaches, coral reefs, dunes and wetlands (Hasan, et al., 2018). In the near future, SLR will lead to the disappearance of 17% of the territory of Bangladesh, create 20 million refugees, and 220,000 km² of land will be underwater following a 150 cm SLR projected to take place within 150 years (New Study 42 million People, CGTN's, 2019; Ashrafuzzaman et al., 2022). Moreover, Bangladesh is considered one of the most vulnerable countries of climate change due to its dense population in the coastal zone and feeble economic conditions (IPCC, 2007), and its geographical location and low topographic relief, associated with

tropical climate conditions, can exacerbated the risks of human and material losses, including damages on agriculture production (Haque et al., 2018). Furthermore, the coastal region is also experiencing subsidence due to sediment compression from construction loading, soil eroding activities, as well as underground extraction of groundwater, natural gas, and petroleum resources (Syvitski et al., 2009). Adverse outcomes of SLR include increased flood risk, inundation of habitable land, loss of coastal ecosystems, loss of coastal buffers for hurricanes and flooding, exposed coastal waters to land-stored waste, saltwater incursion into freshwater aquifers, as well as economic losses in fisheries, recreation, tourism, and industry sectors (IPCC, 2014).

Climate change is expected to increase global temperatures, with more recurrent hot extremes and heat waves, trigger an increase in sea-levels, and push towards more strong weather happenings like storms, floods and droughts, rising sea levels that render coastal areas vulnerable or even uninhabitable. The effects of CCSLR, which is bearing on migration, will be scattered directly around the planet. Nevertheless, the rate and magnitude of SLR will not be equally distributed among the world's coastal regions. Local factors such as ice cover, groundwater, topography, etc., will influence local coastal vulnerability to rising oceans (Church et al., 2013). Approximately 70% of the coastal areas globally are predicted to undergo remarkable rise in sea level (ibid: 62), and this is valid for the coastal regions of Bangladesh.

Saltwater intrusion

The southwestern coastal regions of Bangladesh (SWCRB) are highly exposed to saltwater intrusions brought about through cyclones, storm surges, and contributing to soil and water salinity in the coastal areas. Saltwater intrusion has detrimental impacts on land by increasing the soil and surface water salinity (Dasgupta et al., 2015). The increase in soil and water salinity causes problems within the coastal ecological setting, affecting the cultivation of crops, thus increasing food insecurity and unavailability of water sources (Ahsan, and Bhuiyan, 2010) also has magnified the scarcity of drinking water and decreased freshwater quality significantly. Many evidences show that climate change has caused sea level rise and salt intrusion, causing all cultivatable land in the coastal areas of Bangladesh is not being utilized due to soil salinity plus 1.02 million ha (about 70%) of the cultivated land in the coast are affected by varying degree of soil salinity besides, risking more than 20 million people to suffer the adverse effects of salt through food and water sources (Halder et al., 2017). This has affected regional rice cultivation, which is the area's established occupation moreover different environmental threats affect almost every aspect of life and limit livelihoods choice of people (Mallick et al., 2017). Water is fundamental to all forms of living components of the world. Currently salinity intrusion in drinking water, as well as its related health problems, is a critical issue for the majority of the population living in the coastal region of Bangladesh, who drinks water from sources with higher salinity level (Nahian et al., 2018). Household drinking water safety is a crucial concern within the coastal community in Bangladesh. Extreme shortage of drinking water is a serious concern, and local populations have been impacted by water-linked illnesses due to the continuing consumption of water that is full of contaminants. Salinity trouble in drinking water and associated health implications have been greater than before, considerably in the last several years. Additionally, climate change and its related perils, together with sea level rise, storm surges due to cyclones, occurrence of floods, and consequent inundation difficulties have deepened the drinking water shortage and health crisis at the neighbourhood level.

Coastal erosion

Many issues directly affect erosion in the coast, such as ocean level, currents, airflow, and waves (particularly on the occasion of storms, which include energy to these influences). River deltas' erosion is additionally affected by precipitation trends inland which change the course of action for freshwater input, runoff, and sediment supply coming against the current (IPCC, 2014). Climate change affects all these factors of coastal erosion. According to the most simplified of models, an increase in mean sea level generally causes the coastline to retreat inland due to the consequence of coastal erosion. Rising wave heights can induce coastal sand bars step away from the coast as well as out of ocean. Tall storm streams (ocean levels increased by storm winds and climatic pressure) also have tendency to move coastal sand offshore. Increased level of waves and surges raise the possibility

that coastal sand barricades and dunes will be over-washed or broken (Mimura, 2013). More vigorous and/or regular storms intensify all these impacts. Wave direction changes resulted by inconstant climate may cause movement of sand and sediment to several areas on the coast, changing consequent trends of erosion. Vegetated offshore living areas are on the decline throughout the world (Duarte et al., 2005), causing coastlines increasingly vulnerable to erosion because of increased ocean level rise and increasing wave action (Alongi, 2008) and eventually contributing to leakage of carbon preserved in sediments. Collectively, the ruin of coastal marshlands and seagrass meadows comes about in the discharge of 0.04 to 0.28 PgC yearly from organic deposits (Duarte, 2016). Acknowledgment of the significant results of the destructions of these living spaces for coastal safety and carbon burial (ibid) has driven to wide-scale forest rehabilitation efforts in a few countries (e.g., Thailand, India, and Vietnam).

Main socio-economic impacts of SLR

Agriculture

In Bangladesh and in low-lying island countries, one of the primary problems for traditional cultivation is seawater flooding. The combined effect of rice yield decrease brought about by climate change and flooding of surface areas by seawater induces a significant decrease in agriculture production (Miah, et al., 2020). In spite of a range of mitigating principles already taken, it is apparent that detrimental consequences of climate change are creeping up at an alarming rate (Giddens, 2009). Coastline of Bangladesh will be critically impacted by climate change in the coming decades, with hike of air and sea heat amount, increase of sea level and more frequent cyclone all looming danger for earning means, ecology and human survival (Brammer, 2014; Bhadra, 2020). The detrimental effects of climate change on local inhabitants and with the vulnerable coastal communities, small island people, women, child, young population, the land use system, agriculture, impoverished segment of the society, physically and mentally challenged people and the aged population is bring uncertain future. Recent studies indicate that agricultural production in developing countries is extremely vulnerable to climate change (Khanom, 2016; Haldar et al., 2017; Chen and Mueller, 2018; Hasan et al., 2018). Agribusiness in Bangladesh is the largest sector of the economy, representing approximately 14.23% of the absolute gross domestic product (GDP) and providing about 45.1% of the labour force (BBS, 2017). Bangladesh suffers an annual loss of GDP of approximately 1.81% due to damage to food and cash crops from natural disasters. The total annual damage between 1990 and 2017 was estimated at \$2.56 billion (Anonymous, 2017). Salinity intrusion leads to agricultural losses and salt-affected land has increased by approximately 27% between 1973 (83.3 million hectares) and 2009 (105.6 million hectares) (SRDI, 2012).

The changes in temperature and precipitation patterns due to climate change have a major impact on crop yields (IPCC, 2014). Coastal regions of tropical and subtropical Asia, such as the SWCRB,

are expected to be disproportionately and negatively impacted by climate change and sea level rise (IPCC, 2014; IPCC, 2019). Additionally, south western Coastal Bangladesh is particularly at risk due to low elevation, the confluence of three major rivers, (the Ganges, Brahmaputra, and Meghna (GBM) and the reduced supply of upstream freshwater from the Farakka Barrage (Mia, 2009). The region experiences cyclones, tidal surges, floods, droughts, salinity intrusion, and changes in the monsoon calendar (Dasgupta et al., 2017).

Due to sea level rise (SLR), in the Southwestern coastal region Bangladesh (SWCRB), salinity has increased over the years, causing significant pressure on agriculture and livelihood; SLR has had a negative impact on the farming systems and the economy (Islam et al., 2020). Currently, a quarter of Bangladesh still lives in poverty, and most of the affected sectors include the agricultural rural sector (Hill & Genoni, 2019). On the other hand, the distribution of wealth in Bangladesh has increased in favor of greater inequality (World Bank, 2020). Farmers in this region typically cultivate Aman paddy, a monsoon dependent rice variety that is sown in June–July and harvested in December–January (Ashrafuzzaman, et al., 2022). For the rest of the year, due to high salinity, farmers can leave their land fallow for fish production, growing vegetables, or seeking alternative forest-based livelihoods. On an average, households in the region own between 0.13 to 0.2 hectares of land, but most people in the coastal area are landless (Parvin et al., 2017). The size of land holdings is not sufficient to meet household needs; so many farmers rent other lands to expand their farming capacity.

Poverty

Much rural economic activity in Bangladesh is highly dependent on natural resources and the stable availability on the services they provide (Lázár et al., 2020). The fishing and agricultural communities work in extracting and harvesting these services and are the primary makers of wealth, which is then distributed among other types of jobs, which provide services and transportation (Roy & Sultana, 2010). Thus, this economic ecosystem depends on the wellbeing of the environment and ecosystem that provides these services. Consequently, any changes or modification in the dynamics of the ecosystem and environment will have a direct effect on the livelihood of people who live and depend upon it. Furthermore, these communities are located along the coastal area of the country, which is considered one of the most susceptible areas in the world to be affected by natural disasters and climate change (Roy & Sultana, 2010).

Although poverty is an observable phenomenon in rural areas as well, it is strongly linked to coastal settings, where the majority of households – at least in the southwestern coast of Bangladesh, are still facing poverty mainly caused by climate change and sea level rise (Mullen, 2008). While a range of analyses have been conducted and climate models designed, many experts emphasize that sound information on the changing climate conditions is still largely missing (Atkinson, 2008). It is

unquestionable that a lack of reliable information (especially at regional level) might contribute to the complexity of designing effective counter measures, however, when following the debates on environmental and climate change, it seems that the above argument is often used as a pretext to defend political, social, or economic interests.

Water and Health

Inadequacies in water supply not only have direct adverse health consequences but also prevent good sanitation and hygiene (Hunter et al., 2010). Any change in the quantity or quality of water resulting from pathogens, toxins and chemical contamination can lead to water-related health problems such as diarrhea, typhoid, hepatitis and arsenicosis. Moreover, being an integral part of human livelihoods and world economies, water can also affect health indirectly (ibid), for example affecting food security and fisheries and livelihoods.

Climate change is probably going to expose coastal communities to numerous dangers with escalated severity and recurrence and being a low-lying deltaic nation, Bangladesh is inclined to the multidimensional health perils. Saltiness in clean water and soil is one of numerous complexities in coastal Bangladesh (Nahian et al., 2018). The upstream redirection and decrease of clean water stream in Ganges delta (Rahman et al., 2022), are exceptional usual lively coastal systems, related with both land-based fluvial and coastal ocean progression (Islam et al., 2021.). Specifically, climate change and its perils are currently of immense alarm for preserving safe water reserves. To fulfil the United Nation's Sustainable Development Goals (SDGs), safe drinking water is one of the vital prerequisites to guarantee public wellbeing, living, and food safety (Sojobi, 2016). CCSR has critical effect on world water assets (IPCC, 2007). Combined with human strain, regional water emergencies are steadily rising, with grave ramifications for general wellbeing, natural durability, food and energy security and economic progress (Chellaney, 2011; UNESCO, 2015).

Food security

Climate change is deeply related to food security, water resources protection and public health, factors that influence human development, and has become one of the biggest challenges faced by human society (Lake et al., 2012). Food security is the circumstance where all people have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (Desai, and Potter, 2013). However, this definition is not always applicable for those in the SWCRB as food security is dependent upon small-scale farmers who are both food-crop producers and food consumers (McMichael, 2009). Additionally, CC creates a major challenge for agriculture, food availability and food security for millions of people (Holt-Gimenez, 2009). Many argue that food security projects are inefficient as they mostly support the

political stability of consumer societies and open new opportunities of capital for those who are already privileged, which results in continued price instability and inequity (McMahon and Johra 2011). There is a need for integrated natural resource management, agro-ecologically based extension and education programs, as well as institutional and policy options to provide technical support to farmers for adjusting to and mitigating the effects of CCSLR (McMichael, 2009).

Gender issues

In addition to, climate change seem to involve a gender inequality at a predominantly natural impact because changing environmental conditions continue to alter the impact on women. Women, adolescent girls, female children are the most vulnerable during natural catastrophes and representing more than 75% of the displaced persons (Plan International, 2021). About two-thirds of the female labor force in developing countries is engaged in agricultural work (FAO 2011). 60-80% of the food in developing countries is produced by women (Terry 2009:12). It will therefore, to a significant extent, aggravate gender-inequalities. Moreover, Bangladesh is one of the most significant casualties of climate change and SLR, as approximately half of Bangladesh's population resides 5 meters below sea level and is the world's sixth top calamity-stricken nation (Kreft, et al., 2016), besides, coastal area mendacities nearby 1.5- 11.8 directly above the mean sea level rise (Feist, et al., 2021). Cyclones and sea level rise, combined, are responsible for worsening freshwater conditions in Bangladesh coastal zone. Due to Cyclone Bhola in 1970, Cyclone Sidr in 2007, Cyclone Aila in 2009, and the 1998 great flood, Bangladesh has witnessed millions of people left homeless and hundreds of thousands of casualties (Kabir, 2014; Haque, 2018; Islam, et al., 2021).

Justice implications of climate change and SLR

Additionally, most of the countries most affected by SLR are not the main GHG emitters. According to the World Bank, Bangladesh is rated 147th out of 184 countries in terms of CO₂ emissions, demonstrating the disproportionately severe effects of climate change (Eckstein et al., 2019; CO₂ Emissions Bangladesh, 2021). Also, South Asia's volatile political environment is a major obstacle to climate rehabilitation efforts and will be exacerbated by climate change and SLR (Campbell, 2009). The urgent necessity to identify and comprehend the mechanisms of sea level rise in Bangladesh is highlighted by these situations. Across the various indicators of climate injustice, the discussion above compares the scenarios of climate change and sea level rise. At international talks held under the auspices of the UNFCCC, climate justice has been a major topic of discussion. Social factors have been linked to varying degrees of climate vulnerability, but we should increase them at the local level (Li, 2007). By describing local susceptibilities and the effects of CC on people's fundamental needs in various geographical and social circumstances, an approach emphasizing capacities could pursue

justice while also having a discernible impact on society and politics (Sen, 2001; Schlosberg, 2012). The capability-based approach offers room for an effective investigation of risk factors and their effects, as well as the creation of adaptable mechanisms for local adaptation (ibid.).

According to the UN, in order to achieve the goals of the Sustainable Development Agenda for 2030, measures that enhance resilience to the dangers posed by SLR and address issues of poverty, social isolation, and climate injustice must be promoted (UN, 2016). Social factors like income or wealth, ethnicity, gender, life cycle, schooling, class, territory, or geography, which in turn are reflective of the multidimensionality of climate injustice, can help us better understand the disproportionate impact of SLR on coastal residents in SWRCB (Sen, 2001; Frazer, 2009). Social vulnerability and inequality are made worse by exposure to SLR effects (Pelling, 2010), and this will affect coastal communities' ability to adapt (Schmidt et al., 2014).

In the context of the SWRCB, the significant impacts of extreme weather events and SLR reproduce inequalities in evolving aspects of regional development as well as social justice concerns (Mason and Rigg, 2019), affecting various facets of society at social, cultural, and political levels (Adger et al., 2013). According to Brammer (2014) and Mallick and Rahman (2020), life-threatening events have significant effects on agriculture, riverine erosion, salinity, the loss of natural ecosystems, gender vulnerability, poverty, migration, food security, fisheries, safe water resources, and public health factors that affect human development. As a result, the SWRCB is prominent in cases of serious social injustice.

Local adaptation strategies

These areas have also developed into a sample ground for small-scale adaptation strategies that are particularly well suited for small groups. Floods, eroding coasts, more frequent and intense storms, rising water tables, saltwater intrusion into aquifers, and changes in ecosystems are just a few of the phenomena that the (SWRCB) is experiencing as a result of sea level rise (Akter and Ahmed, 2021). As an example of (SWRCB), local populations deal with new problems like climate change through adaptation. Namely, it entails a comprehensive strategy to boost resilience to risks and shocks, which might not afterwards have higher or similarly detrimental effects on the community (Islam et al., 2019). The SWRCB has the largest number of glaciers in the world that supply the glaciers with fresh water and sediment to the Ganga (ibid). Based on global warming projections, Bangladesh will experience a receding glacial landscape above the global average, driving SLR in the Bay of Bengal and its river deltas. Knowing precisely how local areas will be affected by the global sea level rise in comparison to regional and global areas is vital. The adage "justice delayed is justice denied" calls attention to the situation of climate justice globally at this time (Sourdin & Burstynier, 2014), and it also applies to the problems with climate justice that exist in the study area that was selected. Hence, for SWRCB, climate change and climate justice have become crucial issues. Many organizations deal

with societal susceptibility connected to climate change; however, in the SWRCB, local data are largely lacking, creating a significant research gap that the proposed initiative seeks to solve. Nonetheless, ongoing monitoring and modeling of climate dynamics are necessary for the accurate projection of future sea level rise (IPCC, 2014). To track accurate data from tide gauges, satellite altimeters, and independent ocean observation systems, a strong initiative is required. To cope with these major concerns, such as enhancing the historical records of sea level rise, more multidisciplinary research is also required.

1.2. Study area

The southern coastal region in Bangladesh belongs to a highly dynamic area in the Bay of Bengal, which is a northern protracted branch of the Indian ocean with the location between latitudes 5'N and 22'N and longitudes 80'E and 100'E (Rizwan, 2021). It has boundaries around the west to east coasts of Sri Lanka and India, bound by the north with the deltaic region of the Ganges-Brahmaputra-Meghna (GBM) river setting, and on the eastern side with the Myanmar peninsula having an extension up to the Andaman-Nicobar elevations (Chaturvedi, and Sakhuja, 2015). The Bay is bound in the southern boundary, roughly along the edges from Dondra Head in the southern part of Sri Lanka to the north pinnacle of Sumatra (Curry, et al., 2002). The Bay covers an area of approximately 2.2 million sq. km and the typical depth is 2,600 m with an extreme depth of 5,258 m. Bangladesh is located at the front of the Bay of Bengal (Roy, 2003). This basin gets inflow from the Ganges in the northwest, and the Brahmaputra from the northeast, while the Meghna provides input from flowing into the Brahmaputra (after entering the Sylhet Trough and part of the Tripura hills), and finally, into the Bay of Bengal (Mukherjee, et al., 2009). The Ganges and Brahmaputra rivers originate from different basins in the Himalayas and converge in the Bengal Basin of Bangladesh, where they form one of the largest deltas in the world. Delta sediments form a shallow area that extends about 200 km south from the coastline, i.e., GBM Rivers (ibid).

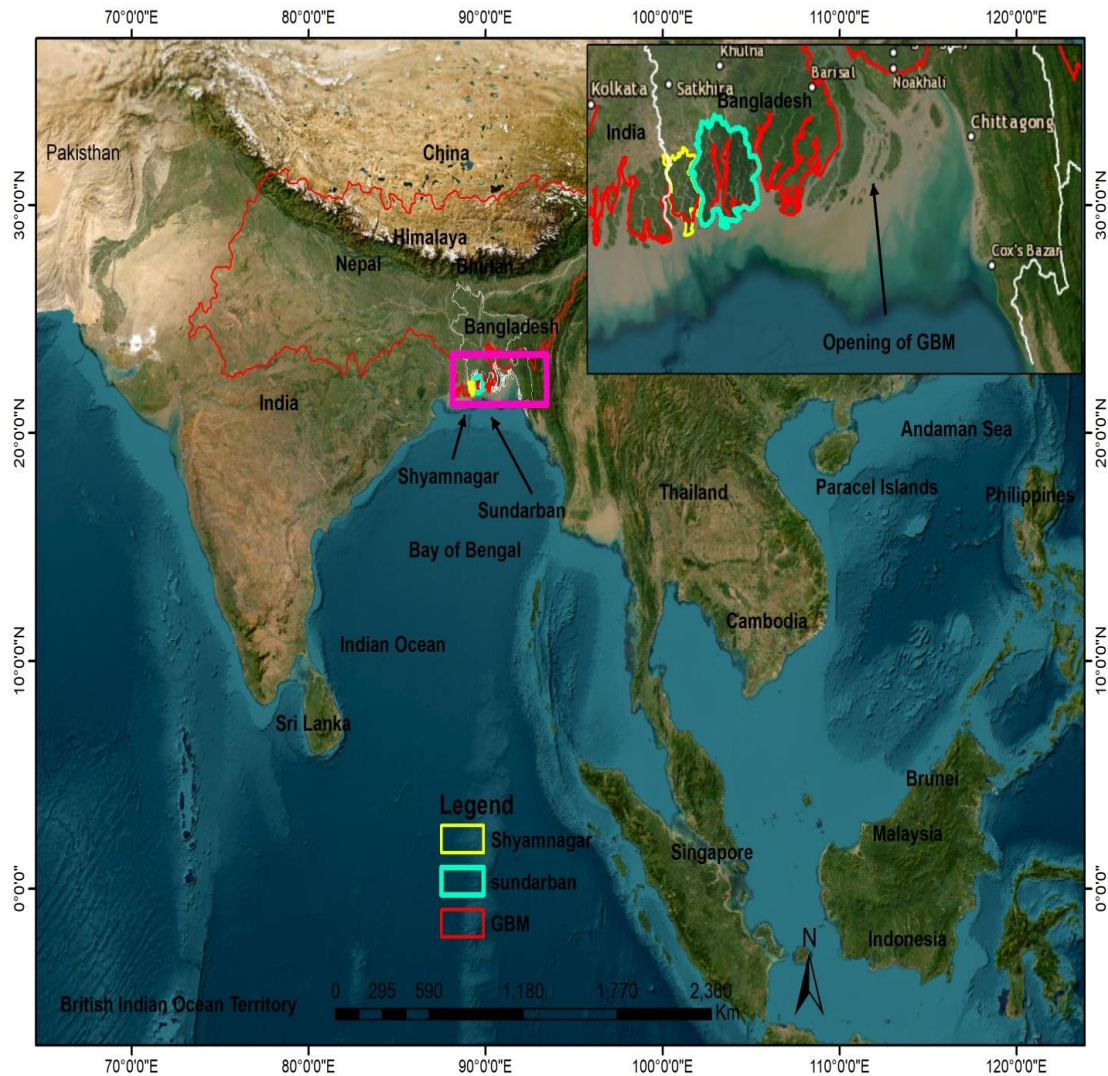


Figure 6A: The GBM delta, Himalaya Mountain ranges, the mouth of the Ganges, Ganges basin, Brahmaputra basin, Meghna basin, Bay of Bengal, Andaman Sea, and the Indian Ocean.

It is estimated that about 1.1 gigatonnes (GT) of accretionary sediments from the Bengal Basin spread into the Bay of Bengal, resulting in the world's largest submarine fan, the Bengal Fan (Hossain, et al., 2019). The Himalayas deposit sediments in the GBM delta, which is the source of most of the sediments, while the Himalayan front, the uplift of the Shillong Plateau in the north, and the accretionary fold belt in the east may have produced tectonic effects on the GBM delta (Reitz, et al., 2015). Less than half of the total sediments trapped in the Bengal basin are sources of flexural subsidence, faulting, folding and local compression (Hossain, et al., 2019). These accumulated sediments have prograde more than 300 km since the Eocene (35 Ma) throughout the Bengal basin (Reitz, et al., 2015).

High Mountain Asia (HMA) adjoining the Tibetan Plateau feeds the fluvial system of the Indus, Ganges, Yangtze, Irrawaddy, and Mekong with seasonal glacial melt (Azam, 2018; Wester, et al.,

2019). The HMA acts as a freshwater reservoir, crucial to ecology, cultivation, and hydropower, as well as being essential to more than a billion people (ibid). The retreat of glaciers will cause a series of effects as these provide a steady source of water to South Asia where the population is dense. Political and social issues will arise with the increasing scarcity of water and flash floods. Along with this, ice in the Himalaya vicinity alone would raise sea level by 1.5 meters (Maurer et al., 2019). However, considerable breaches in understanding the dynamics and linked climate triggers in HMA exist (Azam, 2018). Around 36% of landscape ice will undergo the melting process by 2100 even if states fulfill the determined 2015 climate accord goal to limit heat release increase to 1.5C (Wester, et al, 2019).

The Shyamnagar Upazila occupies an area of 1,968.23 square km, located between 21°36' and 22°24' north latitude, between 89°00' and 89°19' east longitude, adjacent to the Sundarbans mangrove forest which is one of the largest forests in the world (140,000 hectares), located in the deltas of the Ganges, Brahmaputra and Megna Rivers in the Bay of Bengal and that borders the Bay of Bengal to the South and West in western India (Yeasmin, et al., 2022). The overall population of the Upazila was 313,781 in the year 2010 (Abedin, et al., 2019). There are 46,592 households in the area, spread around 1968.24 km². The Upazila is bounded to the south by the Bay of Bengal and to the west by India. The Upazila consists of 12 unions and 216 villages (BBS, 2011). There are a few mayor rivers that cross the area, including Kobadak, kholpatua, Sonai, Raimangal, Morischap, Hariabhanga, Ichamati, Betrabati, Kalindi and Jamura (Ashrafuzzaman, 2022). The Bangladeshi climate consists of four seasons: pre-monsoon (March–May), monsoon (June–August), post-monsoon (September–November) and winter (December–February). Approximately 85% of the total rainfall (annual) occurs during monsoon (Hossain et al., 2014). The mean annual rainfall in south-western Bangladesh is 1,730 mm, 78% of which occurs within the monsoon months (ibid). Monsoon rainfall is essential for providing moisture to soil and sufficient water for irrigation, as well as eliminating soil salinity. The annual temperature is 25.5, with a low of 21 and a high of 35 degrees Celsius, and the average annual precipitation amounts to 1,689 mm with a humidity range of 79.5% (Islam et al., 2019). Rakib (2018) predicted an increase in temperature, and the temperatures over the SWCRB are expected to rise at a minimum by 1.26°C and maximum by 2.16°C by the end of the 21st century. This region was formed by sedimentation of the Ganges floodplain and has a moderate population density. The mean height above sea level (MASL) ranges from 1 to 5 m, with 45% of the study area having a high chance of inundation from a 1 m storm surge (Rakib, 2018).

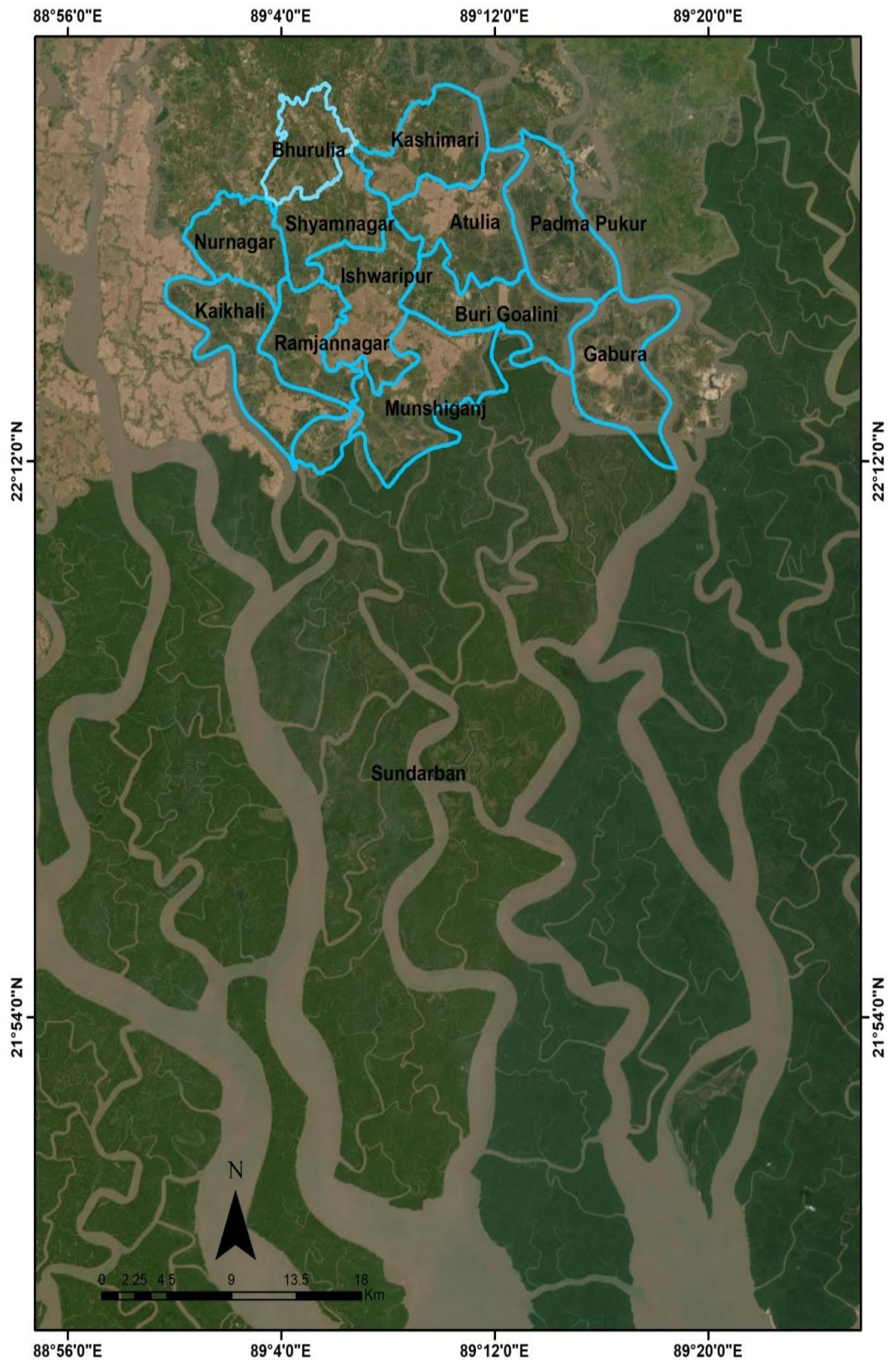


Figure 6B: The Shyamnagar Upazila 12 Unions

The SWCRB is a part of the Ganges Delta and is composed of alluvial soil carried by upstream water. This part mostly consists of coastal wetlands (70% of the landmass) and is connected by a network of rivers in the Bay of Bengal. This coastal region forms the lowest landmass (0–30 cm mean sea level), is part of the delta of the extended Himalayan drainage ecosystem and is highly vulnerable to multiple threats from climate change, such as hurricanes, storm surges, floods, and tsunamis (Mallick, et al., 2017). The Sundarbans mangrove forest, which is adjacent to the world's largest mangrove forest and a UNESCO world heritage site, protects this region from tidal surges (Brammer 2014). Natural calamities such as tidal surges, cyclones, land subsidence, and water logging are a common occurrence in this part of Bangladesh, and they play a major role in the lives and livelihood of the people (Mallick, et al., 2017).

Farmers in this region typically cultivate Aman paddy, a monsoon dependent rice variety that is sown in June–July and harvested in December–January (Ashrafuzzaman et al., 2022). For the rest of the year, due to high salinity, farmers can leave their land fallow for fish production, growing vegetables, or seeking alternative forest-based livelihoods. On an average, households in the region own between 0.13 to 0.2 hectares of land, but most people in the coastal area are landless (Parvin et al, 2017). The size of land holdings is not sufficient to meet food and economic needs, so many farmers rent other lands to expand their farming capacity. FGDs, workshop's respondent mentioned that landless farmers represent 41%, small farmers represent for 5%, marginal farmers represent for 3%, middle-class farmers represent for 18%, and wealthy people accounted for 33% among the local farming community; the per capita arable land was 0.11 ha.

The present study was performed in 12 unions (Buri Goalini, Ramjan Nagar, Gabura, Kaikhali, Atulia, Ishwaripur, Munshiganj, Kashimari and Nurnagar) of the Shyamnagar Upazila of the Satkhira District in the SWCRB (Figure : 6b). Data was obtained from surveys completed in 320+387 + 1579= 2286 households in these 12unions. Shyamnagar Upazila of Satkhira District in the southwestern region of Bangladesh has been selected for this research due to the reliance of local economy on natural resources, as main occupations. This means that more than half of the population is completely dependent on the environment for income, and the rest are directly or indirectly dependent on the well-being of these primary jobs. Most of the population is just above or below the poverty line, making them more vulnerable to changes in the environment. Similarly, this area was also chosen as it is one of the regions of the country and the world most affected by natural disasters such as cyclones, storm surges, floods and salinity intrusion, partly due to their location and an extremely regular and flat topography (Ashrafuzzaman, 2022). These factors will reveal local people's perceptions of poverty and their relationship to environment changes, especially with climate change, sea level rise and natural disasters.

1.3. Objectives of this doctoral research

Drawing from the problems identified in the sections above, and focusing on the key concerns and socio-economic issues raised by SLR and climate change, this doctoral research has as its main objectives:

To improve the understanding of the link between climatic based and sociodemographic factors that influence vulnerability to SLR in SWCRB.

To analyse the risk perceptions of coastal communities, at the local level, as well as their practices and adaptive capacities.

To better understand how social exposure to SLR and adaptive capabilities link to various aspects of society, economy, institutions, regional development, and cultures of resilience.

Furthermore, the study will aim at co-producing strategies to cope with SLR, including for instance traditional knowledge. It will explore different notions of SLR, the social reactions that it triggers, as well as the robustness of existent coping capabilities of coastal populations and livelihoods.

The study also recommends new mechanisms for achieving adaptation and mitigation goals, in face of SLR scenarios.

1.4. Hypothesis

As a consequence of such change in the climatic system, episodes related to extreme weather events became more frequent, such as heat waves, severe droughts and floods, tropical storms, cyclones, ice melting, sea level rising and salinity, desertification processes, among others. Increasing the warmth of the atmosphere, globally sea level is rising due to the enormous emanation of heat trapping gasses. The increasing heat is causing to melt glaciers and ice expanses and increasing more water into the oceans. Due to the sea level rise and the incidence of saltwater contamination as a result of climate change, the adverse geochemical effect of salinity is intensifying. Nevertheless, the forecast for cyclone-related storms will increase significantly and may make cultivation and stable settlement in the Shyamnagar Upazila region very challenging. Farmers will have limited adaptive capacity to adapt to the climate change impacts; furthermore, we rely on the judgment of the local population for future agricultural adaptation in the SWCRB that we test in this research through the Multiple Logistic Regression (MLR) Model. Moreover, we hypothesize that people of SWCRB, economy, health, safe drinking water, gender, agriculture, farmer's vulnerability and adaptation are linked to climatic events, such as temperature, SLR, salinity, rainfall, droughts and riverbank erosion as well as other climatic events such as salinity, in addition to anthropogenic causes such as shrimp farming. We assume that people of the SWCRB will have limited adaptive capacity to adapt to the climate change impacts because of frazil socio economic condition. We also hypothesize that in the frequent canvas of climate change and sea level rise, poverty and wealth inequality will increase. Climate change is deeply related to food insecurity, absence of safe drinking water and women, child and public health, factors that influence SWCRB people, has become one of the biggest challenges faced by SWCRB

society. Moreover, on the interactions between natural climate systems and societies and recognizes that climate change has gender inequalities in areas such as the SWCRB.

In view of these concerns, the thesis analysed the indicators of climate change vulnerability through the perceptions of people living in the South-Western Coastal region as well as tidal gauge, satellite altimetry, statistical analysis, and laboratory testing, because the climate stressor is being take place in most of the coastal region. This PhD research exploration domain adopted an inductive and deductive study approach, whereas research aim and test are done to infer a theoretical understanding and trend from a visible data set.

This research gives emphasis not only to the analysis of risks perceptions, but also to informing coping strategies at the level of neighbourhood, region, nation, and globe; it involves a diversified range of understandings into one domain, while overtly engaging the diverse fields of society, ecology, gender and health; and stresses the importance of community and societal efforts, rather than individualistic aspects of human and ecological aspects analysed in their isolated form; assess specific options and measures within each sector, so that define how to prevent unexpected results and perceive net impacts across various levels of decision making.

In terms of the deductive approach, the target of my study was to find out the validity of the conceptual framework and trends available through the collection of new empirical information. In addition, research resorted to the scientific methods applicable to the social sciences, encompassing a range of study strategies, tools, and techniques, both focusing on qualitative and quantitative data, including statistical analysis, field surveys, participant observation, and case studies, and in addition to, from natural science method I use laboratory testing , such as soil and water testing , long term trend analysis, tide gauge data modelling, DEM analysis and Satellite altimetry (Ex. Soil salinity, pond water, river water , harvested rain water). Under my PhD contemporary publications, research have used the above-mentioned methods which is contribute in the SDG-13 (Climate Action) academia because this type of research rare in the study of SWCRB last one decade.

This study would play a pivotal role in attaining the UN Agenda for 2030, especially the Sustainable Development Goals (SDG) 1 (Eliminate Poverty) which helps to reduce SDG 2 (No Hunger), SDG 3 (Establish Good Health and Well-Being) , SDG5 (Enforce Gender Equality), SDG6 (Improve Clean Water and Sanitation),10 (Reduce Inequalities), SDG 14 (Develop Life Below Water), SDG 15 (Advance Life On Land), SDG 13 (Climate Action), and SDG16 (Peace, Justice, and Strong Institutions) which is contributing to fill a gap in current social research in Bangladesh.

As emphasis was given to sea level rise (SLR), a broader understanding of adaptation & mitigation was also be relevant for SDGs 13, 1, 2, 3, and 5, while consequences of SLR such as salinity intrusion in soil, water, and to erosion of land mass was eventually contribute to SDGs 3, 6, 14, and 15. Furthermore, my endeavour was give emphasis to the mechanisms of climatic fairness and justice, which are relevant for SDG 14, 15 and specifically 7 and 16. Then, I built my research through the earlier mentioned tools and techniques that strengthen this PhD thesis.

This research aims at contributing significantly to climate-induced hazard reduction and to generate and document knowledge on reducing the vulnerability of coastal livelihoods to climate change. It also aims to provide policy recommendations to decrease the vulnerability of people in every aspect of life to the increasing effects of changing climate in the SWCRB. However, precise projection of future sea level increase necessitates continuous observational trend, along with remarkable advancement in making models of the integrated ice, ocean, land, atmosphere climate. So, this PhD research consider a strong initiative to have a data tracking from the tidal gauge and satellite altimeters to know sea level rise global to local level.

1.5. Research questions

Deriving from the objectives outlined above, this thesis responds to a main research question, organised into three sub-questions that have been complementary analysed by each peer-reviewed article published during the period of the doctoral research.

Box 1: Research Questions and the list of published papers

Overarching research question – How does climate change driven SLR affect the prosperity and livelihoods of local populations on the Southwest Coastal Region of Bangladesh (SWCRB)?

Sub-research questions (deriving from the main RQ):

**SQ1 – Which are the dynamics and principal impacts of SLR on the SWCRB?
- Chapter 4**

Paper 1 – Dynamics of SLR (Journal of Marine Science and Engineering)
<https://www.mdpi.com/2077-1312/10/6/779?fbclid=IwAR2Vo2-TqCsFwB9iGinEVLsvwf-QKouF8frB9IYzUFk6azwwHTDL6G6bH5Y>

Paper 2 – Salinity intrusion (Spanish Journal of Soil Sciences)
https://www.frontierspartnerships.org/articles/10.3389/sjss.2022.10017/full?fbclid=IwAR1dUOSfuESm8tk8D6OG9ICNoCKAj_vmA9LY5Sm_RrGvjyxti8JA2pwttM

Paper 3 – Health impacts (Environmental International)
https://www.sciencedirect.com/science/article/pii/S0160412018319275?via%3Dihub&fbclid=IwAR1tP-3nU2jVIUhd0Et4_KoUNdLvoawtwGhi2AxrCBgGxx6h3Gh8VjZAi8Y

SQ2 – Which socioeconomic issues and factors most critically influence vulnerability to climate change driven disasters and SLR in SWCRB?

Paper 4 – Poverty (Springer Social Sciences)
https://link.springer.com/article/10.1007/s43545-022-00351-6?fbclid=IwAR0wN1k11WYxo4tbbm8TxOwSkGYDM1YsOlSuG7Sy-gK0nUBrQx3PF3k_qe4

Paper 5 – Gender and Climate change (Journal ‘Climate’)
https://www.mdpi.com/2225-1154/10/11/172?fbclid=IwAR2uB1aPaFP8spfEIk3-inZYg3mMtdx9pTo26cxGK_ehK_JaruObhMLj1-4

SQ3 – How do local communities perceive the climate justice problem and what are their principal local-based adaptation responses?

Paper 6 – Climate justice ([Frontiers in Climate](#))
<https://www.frontiersin.org/articles/10.3389/fclim.2022.881709/full?fbclid=IwAR2Vo2-TqCsFwB9iGinEVLsvwf-QKouF8frB9IYzUFk6azwwHTDL6G6bH5Y>

Paper 7 – Local Context of Climate Change Adaptation in the South-Western Coastal Region of Bangladesh

Sustainability **2023**, *15*(8), 6664; <https://doi.org/10.3390/su15086664> (registering DOI)

Received: 8 January 2023 / Revised: 16 February 2023 / Accepted: 13 March 2023 / Published: 14 April 2023

Paper 8 – Agricultural vulnerability and adaptation (book chapter)
https://link.springer.com/chapter/10.1007/978-3-030-98617-9_8?fbclid=IwAR2-kSlxbuB2z8j0f4mtJ5QTb-ZUmNWr6Doig5IZqapSPNtG5tlUYBCmmXs

In the present thesis, four research papers have not been included due to limited space. These papers cover important topics related to climate change and its impacts. The topics include: "Climate change

and human health linkages in the context of globalization" "Current and Future Salinity Intrusion" "Agricultural vulnerability and adaptation" "Local context climate change adaptation" .Although these papers are not included in the thesis, they represent valuable contributions to the field. Furthermore, two additional research papers derived from this PhD are currently under review. These papers focus on the topics of "lack of safe drinking water and impact on human health" and "migration and climate justice."

The structure of the present thesis consists of an introductory chapter, a chapter detailing the overarching conceptual framework, and a chapter outlining interdisciplinary approaches in the natural and social sciences. The included papers are organized according to the sub-research questions they address. The thesis also includes an integrated discussion of the findings from these papers and concludes with a chapter on conclusions and recommendations. While the limited space prevented the inclusion of all research papers, the thesis still provides a comprehensive overview of the topic, supported by the included papers and the integrated discussion of their findings.

2. Conceptual framework

The introduction chapter of this thesis discussed the impact of climate change on sea level rise, and therefore also on salinity increase on low-lying coastal areas, as well as the consequences for key livelihoods in SWCRB. The present chapter will introduce the interdisciplinary conceptual framework employed in the analysis of the research results, across the papers integrated in the thesis. This will lead up to the discussion chapter, where the insights of each article are discussed in an integrated way, and then to common conclusions and recommendations to address the justice and inequality issues that have been raised in this doctoral research. The thesis combines two main components: an assessment of the problems already caused by sea level rise and salinity in the livelihoods of the coastal communities of SWCRB, based on methodologies from the natural sciences; and an analysis of justice issues and local perceptions about climate change and risk, in this case grounded on methodologies from the social sciences, such as qualitative interviews and quantitative surveys carried out in the field. From the context outlined above, it results that the conceptual framework of the thesis has gained inspiration from multiple disciplines, and therefore proposes a multidimensional perspective on the environmental and socio-economic vulnerability to climate change and sea level rise in the SWCRB.

Scholars have analyzed risks of climate change and sea level rise (CCSLR) in Bangladesh from different perspectives like human security risk (Rashid and Altaf, 2020; Islam, et al., 2020), adaptation, and mitigation (Rawlani, and Sovacool, 2011), the involvement of local institutions (non-governmental organizations (NGOs), civil society organizations (CSOs) and community-based organizations (CBOs) (Ayers, et al., 2014); however, limited studies discussed the issue of CCSLR vulnerabilities and climate justice in the coastline of Bangladesh.

Developing countries have become the biggest victims of carbon emissions from rich nations, an aftermath of global hegemony or a good example of domination from core over periphery. But long-term damage caused by global warming are expected not to be limited to the periphery. Poor countries are more vulnerable and the first to feel the consequences like sea level rise, frequent cyclones, floods, but all on earth are prone to be affected by global warming (IPCC, 2014) and its consequences, including decline in agricultural productivity, poverty, inequality, gender imbalances, migration, lack of safe drinking water and multiple health hazards. Therefore, globalization also poses global governance and its norms as fundamental to deal with climate change and this challenge is wider than the single action of central governments (Zimmermann, and Smith, 2011). The key actors on the global stage include governments (national, sub-national, local), intergovernmental organizations and institutions, non-governmental organizations (NGOs) and transnational corporations. We are still far from reducing emissions, therefore we all, policymakers, stakeholders, should interrogate what commitment we are willing to make to our existing world and to future generations.

2.1. Climate risk and vulnerability in Bangladesh's Southwest Coastal Area

It is not sufficient to only consider the findings of scientific risk assessments to comprehend the climate hazards for SWCRB. As a result, an integrated vulnerability assessment incorporates a scientific evaluation of climatic threats as well as evaluations of socioeconomic effects and the concerns of the local community. Three elements make up the assessment in this thesis: hazard identification, cause and effect analysis, and risk evaluation (including exposure and vulnerability analysis). The term "risk assessment" refers to all of the knowledge needed for risk characterization, assessment, and management (Avenn and Renn, 2010). Moreover, risk analysis reveals the following components: risk characterization and risk assessment. The evaluation of adaptability and local people's willingness to accept risk reduction are included in this assessment of climatic risk. The following components make up the risk characterization: risk profile and risk seriousness. The goal of these stages is to gauge how much risk is perceived to be there and/or how much is tolerable.

Standards and evidence are the two basic inputs that influence judgments regarding acceptability and toleration. The amount of risk that can be tolerated or accepted is not simply determined by the information. At this point, risk assessment broadens the scope to consider factors including scientific analysis, social effects of a certain climatic risk, the trade-off between risks and profit, political priorities, the possibility for conflict resolution, and the potential for social mobility.

The major goal of this study is to arrive at a tolerance and acceptance judgment based on a balance of benefits and drawbacks, to explore potential effects on quality of life, to discuss various possibilities for the economy and society's development, and to fairly weigh opposing claims with data analysis. Additionally, risk management is comprised by the following elements: implementation and decision making. In the implementation are considered three parts, namely, realization of alternatives, monitoring and control, feedback of risk management procedures. While the identification of possibilities and their development and evaluation are found during decision-making process. Risk assessment, which combines risk assessment with evaluation of concern and is based on studies of risk perception, economic impact assessment, and the scientific characterization of social responses to the source of the risk, reviews all pertinent information.

The likelihood of catastrophic consequences, or the anticipated loss of lives, property, livelihoods, and disruption of the economy (or damage to the environment), as a result of collisions between man-made or naturally-induced hazards and vulnerable conditions, such as earlier warning of Sidr 2007 and Aila 2009 in coastal Bangladesh, which is meant by "disaster risk," according to an expanding body of literature on natural disasters and climate change (Habiba, and Shaw, 2018). The last cyclone Amphan in SWCRB is an example of how disaster risk manifests when hazards interact with social, physical, economic, and environmental vulnerabilities.

The calculation for risk is presented as in Menoni, et al., 2012 & Mechler, and Bouwer, 2015

$$\text{Risk} = \text{Hazard} \times \text{Vulnerability} \dots\dots (1)$$

When hazards interact with social, physical, economic, and environmental vulnerabilities, disaster risks become existent. A risk is an occurrence, a phenomenon, or an event that has the potential to result in death, environmental damage, or property loss (Smith, 2013). A community's susceptibility to risks is known as vulnerability. It also refers to the socioeconomic, political, and physical conditions that have an adverse impact on a community's ability to respond to such events (Davies et al., 2015). "Community-based disaster risk" refers to a community's overall vulnerability to potential harm from a given hazard during a given timeframe (ibid).

Physical, environmental, and socioeconomic vulnerability risk assessment and management should be ongoing processes (Wisner et al., 2014). Measures for managing disaster risk include mapping and assessing risks, identifying risk factors and their vulnerability to hazards, and creating risk-reduction strategies. Together with capacity, vulnerability, and dangers, risk is also calculated (Van Riet, 2009). The climatic catastrophe has caused people whose livelihoods depended on the Sundarbans Forest to change their professions. Following climate change, there will likely be a wide range of negative effects, particularly for coastal communities. Most respondents also report facing difficulties supporting themselves due to salt intrusion, tidal surges, high and insufficient rainfall, and quick flooding, which has led to local adaptation strategies. They are fixing or building high, sturdy pond walls to stop saltwater water, as well as employing netting to shield crabs from flooding and severe rain. Parts of the tidal and estuarine coastal plains are affected by flooding by salt water during a storm surge or breach of a coastal embankment. In the pre-monsoon season, when the soil is comparatively dry, salt intrusion from flood water penetrates into the soil (Ahmed et al., 2019).

43% of the population in the SWCRB lives below the poverty line and is vulnerable to multiple dangers (Islam, 2015). SWCRB must take into account more than just the findings of (scientific) risk assessments, it is necessary to make adaptation discussion in relation to hazards. The adaptation process needed to comprehend the worries of various actors and audiences as well as the effects of activities' immediate repercussions should be the main emphasis of risk management. Because of this, in this doctoral dissertation we also consider the numerous local adaptation tactics used by SWCRB residents and how they could reduce their sensitivity to hazards in the future. Some people who were fisherman or honey collectors who relied on the Sundarbans Forest for their livelihoods have changed their professions as a result of the climate calamity. SLR, flooding, cyclones, erosion, salinity, changes in water quality, infrastructure changes along the coast, changes in aquaculture and agriculture, and changes in groundwater chemical trace elements all are an impact factors, how the communities in these areas will survive (Islam et al., 2020). These three aspects of a system exposure to climate change, sensitivity to climate change, and adaptive capacity can be adjusted collectively to control vulnerability to climate change. A widespread definition of exposure includes things like sea level rise, cyclones, salinity incursion, and communication between a structure and the climate. The structure is affected by and altered by external climatic events (IPCC, 2014).

Two examples of how everyone is exposed to climate risk are climate change and extreme events. Moreover, susceptibility is a multifaceted phenomenon that is influenced by both meteorological and non-climatic elements, political ideologies, cultural and socioeconomic origins, and ecological characteristics (Dilshad, et al., and 2019). According to O'Brien et al. (2014), socio-economic, biophysical, and climatic stressor effects all have an impact on how vulnerable a region is to the effects of climate change. The interrelated amplifications of vulnerability caused by climate change are dependent on the impacts, such as the concentration of carbon amplifying climate change, as well as the sensitivity of particular communities (O'Brien, et al., 2014).

Vulnerability in the context of climate change is described as a function of the kind, amount, and rate of climatic change as well as the sensitivity of a system to exposure and its potential for adaptation (IPCC, 2007). By elaborating on adaptive capacity as a measure of the extent to which a system is able and unable to cope with the negative effects of climate change, including climate variability and extremes, IPCC (2007) gives general principles. Environmental change, the type, scope, and speed of change to which a structure is visible, as well as its influence and diverse capacities, all contribute to vulnerability. In general, the ability to adapt to climate change depends on available physical resources, access to information and technology, and larger systems as well as institutional capability and resource allocation (Keskitalo, et al., 2011).

Within a 1 to 5 km circle of the sea the SWRCB community is adjacent. Cyclones, sea level rise, and aquifer saltwater intrusion are all threats to these populations. Sensitivity is the degree of how a system is affected by risk exposure. They will be especially susceptible to cyclones if they live below sea level, rely heavily on natural resources for their livelihood, or don't have many wind-resistant homes in their villages. The ability of a person, family, or community to develop resilience and deal with climatic challenges is referred to as "adaptive capacity."

Adaptive capacity defines the possibility of an individual, family or community to build resilience and cope with climate threats. The ability to adapt is impacted by one's access to economic, technological, educational, and communal resources. Communities in the SWCRB are considered to have a high capacity for adaptation if they have early warning of cyclones and can move quickly to a shelter facility. Together, these three system components can reduce vulnerability to climate change (IPCC 2014). The area, which is adjacent to the Bay of Bengal, exhibits a high level of exposure to climate change-related phenomena, including tropical cyclones, storm surges, sea level rise, saline intrusion, coastal floods, coastal erosion, and anomalous rainfall. Furthermore, because crops depend on rainfall and farmers on climate, and because crops are harmed by saline intrusion or untimely drought, farming systems are extremely susceptible to these effects.



Figure 7: Flowchart for vulnerability determination; retrieved from the IPCC, 2007; Gitz, and Meybeck, 2012. (Source: Author's configuration)

SWRCB has a highly fragile ecology; it has a high sensitivity and exposure, and a low adaptability. As represented in Figure 7, the combination of sensitivity and exposure leads to a potential negative impact (Fellmann, 2012). Adaptive capacity is defined as the capability of a system to adapt to severe climatic conditions (IPCC, 2022).

Agriculture

Bangladesh has long been considered one of the most vulnerable countries in the world in terms of human-induced climate change and sea level rise. In terms of population exposure to sea level rise, it is considered the third most vulnerable nation (Bomer, et al., 2020). A coastal Bangladesh is the epicenter of climatic disasters such as cyclones, tidal waves, floods, droughts, saltwater intrusion, and waterlogging and land subsidence. This directly affects livelihoods as agriculture employs more than 60% of Bangladesh's population (Statistics, B.B.O., 2011), and is a major source of income for the 40 million people living in coastal areas (Mallick, and Vogt, 2014). During the monsoon season, rain fed rice is the main crop, and during the dry season irrigation is required to grow rice, pulses, oilseeds and vegetables. Rainfall timing, intensity and distribution, soil salinity, and freshwater accessibility for irrigation are some examples of environmental factors that have a significant impact on agriculture. Total rainfall in coastal areas will decrease in the future as a result of expected climate change (Barua, and Rahman, 2020). Increased temperatures, changing rainfall patterns and timing, sea level rise, and land degradation from natural and human activities, will make farming less secure as a means of support if farm management is not improved. A recent study estimated that when glaciers melt into the world's oceans, about 200,000 coastal farmers in Bangladesh will be forced inland by rising sea levels due to climate change (Crane, 2018). Frequent saltwater flooding is already causing many Bangladeshi farmers to switch from rice farming to shrimp and other seafood, but not all coastal people will be able to continue their agricultural livelihoods.

Bangladesh will inevitably experience loss of coastal land, which is predicted to disappear at a rate of 10 to 18 millimeters per year due to rising sea levels and increased frequency of destructive storms (Crane, 2018). More than 30% of Bangladesh's arable land is in the coastal region, which is covered by a deltaic plain. A total of 1.056 million hectares of coastal land, or about 1.689 million acres, are affected to varying degrees by soil salinity (Miah et al., 2020). Due to salinity resulting from the formation of excessive soluble salts, agricultural land use in these areas is considerably lower than the average cropping intensity across the country. Normal crop production is therefore limited by inadequate irrigation water sources, lack of salt-tolerant crop varieties, trends in local farming practices, increased climate-related natural disasters, and lack of regionally adapted salinity management technologies. Additionally, environmental concerns related to increased salinity and reduced agricultural intensity is frequent in the region, especially during the Rabi season. Salinity intrusion causes loss of crop yield as well as loss of total crop production in severely saline soils. Thus, major crops in salinity-prone coastal areas lose significant yields, averaging 20 to 40%. (Cereals, potatoes, pulses, oilseeds, vegetables, species and fruit crops) (ibid). Locally, Ropa Aman is the main crop in the saline-prone region of southwestern Bangladesh, followed by HYV boro rice (Ashrafuzzaman et al., 2022). Due to salinity and the removal of native fish species from open and freshwater bodies, rice-based agricultural systems are increasingly being replaced with shrimp, prawn and crab farming, which contributes to food insecurity. Therefore, the extent, soil characteristics and

important effects of salinization on crop production are discussed, as well as its possible causes and pathways in southwest Bangladesh. Recommendations are also given.

2.2. Climate Justice Theory

Regardless of political disagreement, those who are directly touched by the ongoing effects of climate change (increased temperatures, rising sea levels, and severe weather) to create something new, or invent adaptation strategies right away (IPCC, 2014; IPCC, 2022). The fundamental fairness of the climate system, which means that those industrialized countries that caused the crisis suffer less than poor countries and must take responsibility for this unfairness, is the central issue of disputes about climate justice. This idea is the foundation for strategies that support a unique polluter payment standard that equally distributes the burden across highly industrialized nations (Schlosberg, 2012; Pellow, 2017). All human adaptation efforts to the worsening effects of climate change must be subject to the equity principle (Schlosberg, 2012).

The allocation- or rights-based approach and the capability-based approach are two of the approaches that are used in the climate justice theory. Allocation- or rights-based approaches to achieving climate justice emphasize fundamental human rights, rights to advancement, and rights to the environment. According to Caney (2010), climate change violates people's rights to life, health, and survival. The right to progression is reformulated as an ethical argument for having the necessary conditions for human progress, which calls for a more stable environment (Vanderheiden, 2008) In line with Shue (1999), Vanderheiden contends that industrialized nations have a responsibility to fully recoup the costs of their own actions in addition to not discouraging underdeveloped countries from developing (Shue, 1999; Vanderheiden, 2008). This rights-based approach to climate justice has two major flaws: 1) it ignores other important issues of justice, like social and political appreciation and necessities (that the capability-based approach encompasses), and 2) it articulates ethical urging for global strategy to avoid or lessen climate change and its diverse rights outcomes (Sen, 1999; Lafontaine, and Sipowo, 2013).

The recognition-based approach to addressing climate justice focuses on the unequal allocation of rights brought about by corporate control and coercion (Schlosberg, 2012). The major difficulty that results in unfairness and poor distribution is the inability to identify the issue itself (Fraser, 2014). But justice cannot simply be realized by recognizing unequal allocation and a lack of appreciation. In addition to denial, other problems that lead to destruction include abuse, indifference, and undervaluing people or their areas (Honneth, 1996). For instance, the UN Framework Convention on Climate Change (UNFCCC) disregarded the Alliance of Small Island States' (AOSIS) concerns of being submerged by rising sea levels in 1991. In 2007, when it was debated at the COP 13 (Conference of the Parties), wealthy countries refused to acknowledge loss and damage; nevertheless,

this practice did not really take off until the COP 16 in 2010 (Shamsuddoha, et al., 2018). Hence, for almost two decades there was no action as a result of this denial by industrialized countries.

Even with the Convention on Biological Diversity and the International Declaration on the Rights of Indigenous Peoples, awareness of the relationship between the environment and cultural distinctiveness to a group is severely lacking or disregarded in the UNFCCC. Many indigenous social workers and organizations find it frustrating because none of the traditions, practices, or ecosystems that give groups of indigenous people a sense of belonging are recorded or valued in today's strategic debates on climate change (Raftopoulos, and Short, 2019). Fraser (2014) argues that the drawback of recognition is that it is frequently employed to gain control over people who are already the target of discrimination, mockery, or neglect.

A capability-based approach, on the other hand, recognizes various social and political contexts and takes into account regional susceptibilities and the basic needs of people in various locations (Holland, 2008). According to this line of reasoning, a capability-based approach to justice can help with a variety of concerns brought on by climate change, including vulnerability distribution, recognition of individuals, places, and their connections, and basic rights. Justice, in the opinion of Sen (1999) and Nussbaum (2006), should be centered on enabling individuals to live free, active lives that they have created. A partnership that is based on competence must have a shared foundation of respect for oneself and for others.

The two main ways to expand the capability-based approach are either to propose a broader definition of capabilities or to build a visible policy that acknowledges the ecological reinforcement of already existing human talents. According to Holland (2008), a healthy environment is a "meta-capability" that eventually makes all others possible. Impacts on the natural world must be at the center of a capabilities-dependent pathway to climate justice once our focus shifts from the principles of preventing and mitigating to the practical details of adaptive mechanisms (Schlosberg, 2012). By taking a direct approach, climate justice is presented in a way that acknowledges and considers human involvement in non-human domains. Sen and others assert that it is the right of the next generations to acquire environmental conditions that are the equivalent to those of their parents' generation.

Local community members can be associated in dialogue about neighborhood susceptibility, as realized via a range of parties involved. Community members are required for complete engagement in both the mapping of their own susceptibilities and the planning of adaptive strategies. Such inclusive approach fulfills both acknowledgment and ability to participate (Heltberg and Osmolovskiy, 2011; IPCC 2014). As understood by a variety of parties engaged, local community members can participate in a discussion concerning neighborhood susceptibility. Community members are necessary for full participation in both the formulation of adaptive strategies and the mapping of their own susceptibilities. Such an inclusive strategy satisfies both recognition and participation needs (Heltberg and Osmolovskiy, 2011 ; IPCC, 2022).

Climate researchers, health organizations, emergency management organizations, agricultural and parallel bodies, and other stakeholders can provide data that policy-making bodies can use to identify mechanisms and then make very precise changes to the tangible environment that will affect how well those environments can support a particular human skill range (Heltberg and Osmolovskiy, 2011). Moreover, risks and issues frequently overlap and reinforce one another, and authorities must take appropriate measures to fairly compensate for these numerous disadvantages as those who are susceptible to losing abilities are also likely to lose others (Chuang, and Peterson, 2016).

At the national level, Bangladesh's Climate Change Strategy and Action Plan (BCCSAP) was established in 2008 with a focus on the long- and short-term goals of the previous National Adaptation Programme of Action (NAPA) of 2005. (Bhuiyan, 2015). According to the revised BCCSAP 2009 report (Islam et al., 2009), 6–8 million people may be uprooted by 2050 as a result of declining income and farming productivity, mainly in coastal areas. Moreover, slums in large cities have been mentioned as a profoundly possible goal for those who move. This is an impending problem given the peculiarities of Bangladesh's rapid, unplanned urbanization (ibid). Despite the fact that critical migration due to climate change has been acknowledged, neither NAPA nor the BCCSAP have addressed clear strategy rules for these migrants, and there are no guidelines for the general public or local governments to address the protracted friendly and financial effects of climate change. The key obstacles to the local level's existing response to climate change and to ensuring social justice are this approach's shortcomings and the lack of understanding of climate movement and its intricate metropolitan impacts.

2.3. Global climate governance and justice

There is overwhelming evidence that we have reached the upper limit of our ability to emit GHGs without serious consequences where we can suffer serious effects (Ritchie, et al., 2020). An estimated 40% to 70% reduction in anthropogenic GHG levels by 2050 requires stabilizing GHG emissions to the atmosphere at a level that prevents catastrophic climate change, prevent CO₂ from exceeding 450 ppm by 2100 and achieve global zero emissions by 2100 (Meinshausen, et al., 2020). There has been a claim that because global warming has already occurred in the past, it is not a problem. However, in the past, climate change occurred gradually over thousands of years, giving time for flora and fauna to adapt. Global warming is now the most extreme it has been in hundreds of years, and it is putting human lives in jeopardy and reducing the number of species on Earth.

A case will be made for how prioritizing climate change without any political commitment results in climate injustice. Several agreements and accords, like the Kyoto Protocol of 1997, Copenhagen Protocol of 2009, and Paris Agreement of 2015 (Dessler and Parson, 2019), were of great significance. A failure was seen to have occurred at the Copenhagen Climate Change Conference (UNFCCC) summit in 2009 because no formal agreement was reached. The 1997-adopted Kyoto

Protocol, a binding agreement on climate change, was first compelled into effect in 2005. A monitoring committee was established to track the Kyoto Protocol's requirement that industrialized countries reduce carbon emissions by an average of 5%. Nonetheless, this deal was still unsuccessful against growing nations like India and China, which contributed a significant amount of carbon to the atmosphere (Aichele and Felbermayr, 2013). With an objective to not exceed a mean global temperature increase of 2° C and an aspirational target of 1.5° C above pre-industrial levels, the Paris Agreement went into effect in November 2016 (Zahar, 2020).

In November 2016, 160 participants including the USA and China, which together account for around 40% of the world's carbon emissions and are signatories to the Paris Agreement became operational (Hardoon et al., 2016). The accord also established a Climate Fund to aid initiatives that empowered less developed countries to assist them in coping with the effects of climate change by establishing an obligation for industrialized nations to compensate the nations affected by climate change (Sovacool, et al., 2017). CO₂ emissions from coal, oil and natural gas must be kept at 36 gigatons to meet this target, but many academics predict that in the next 20 years, they will likely rise to 41 gigatons, underscoring the importance of swift action (The Economist, 2019).

The complex link between politics and climate justice makes global agreements extremely difficult to implement (Beauregard, et al., 2021). For instance, although the Paris Agreement goal of 2° C was agreed upon, this temperature increase is expected to submerge Bangladesh's coastal regions, which are already experiencing life-altering effects from sea level rise (Lyster, 2017). Political issues have also made this accord difficult, since the USA withdrew from the Paris Agreement in 2020 before rejoining in 2021 to coincide with the transition in their presidency.

Also, the USA's decision to withdraw from the climate agreement is an example of privilege, allowing people to downplay or ignore the implications of climate change and even to disregard them entirely (Mahaseth and Pandey, 2021). This also illustrates how unjust climate change in general is, as does the "denialism" mentality. According to Klean (2015) a worldview centered on stewardship, which is already prevalent in indigenous cultures, should replace the extractive mindset that holds humans in charge of nature. The Paris Agreement does not have enough impact to prevent the average temperature from falling by 1.5°C, which would lead to catastrophic reactions including floods and heat waves (Kim et al., 2020).

Many states repeated their promises at the COP26 climate summit in Glasgow, which was held by the UN in 2021. Experts and campaigners, however, contend that none of these updated accords is sufficient to address the impending effects of climate change (Arora and Mishra, 2021). It can help make the agreement stronger and more effective in combating climate change.

Glasgow's efforts to reduce greenhouse gas emissions have achieved significant progress, but aid for the weaker nations is still needed (Jacobs, 2021). According to the United Nations, in order to achieve the goals of the Sustainable Development Agenda for 2030, measures that increase resilience to sea level rise threats must be promoted in order to address issues of poverty, social exclusion, and

climate injustice (Aleksandrova, 2020). Through disaster risk assessment and social categories like income or wealth, ethnicity, gender, the life cycle, education, class, territory, or geography, which in turn are expressive of the multidimensionality of climate injustice (Sultana, 2022), this allows for a better understanding of the differential impact of sea level rise on coastal populations in the SWCRB.

In the SWRCB, the well-known impacts of extreme weather events and sea-level rise reflect regional development dynamics as well as a disparity of social justice concerns that affect different aspects of society at the social, cultural and political levels (Mason and Rigg, 2019; Adger, et al., 2013). According to Lázár et al. (2020), extreme events have significant impacts on a variety of factors that affect human development, including agriculture, salinity, riverbank erosion, gender vulnerability, poverty, migration, food security, fisheries, safe water resources, and public health. As a result, social injustices are particularly severe in the SWCRB. Furthermore, this study is done using both the Gini wealth inequality index and the capability approach, which Sen (1996) defined by considering a multidimensional definition of poverty. These two approaches provide a thorough understanding of both the ways in which poverty is fostered and the ways in which social classes generally distribute wealth. Hence, the social and economic structure of the study area is revealed. Climate change has many negative impacts, particularly on food, water and health systems in the world's poorest countries. Millions of individuals will be affected, which will have a negative impact on the nation's economic expansion. According to Chen and Mueller (2018), SWCRB would be among the most impacted due to its sensitive hydro-geophysical location and socioeconomic conditions. From an international standpoint, Bangladesh is frequently seen as one of the country's most vulnerable to climate change (Mehzabin and Mondal 2021). A sizable number of climate change victims already exist in these areas. At the same time, these areas have developed into a testing ground for modest adaptation strategies, which are especially well suited to small groups.

A necessity had to give more importance in this research, for the climatic impact in the inhabitants of SWCRB, in addition to special environmental situations, extending the vulnerability of people in the neighbourhood from climate threats, this research believe that environmental justice scholars are principally emphasis the better placed to come up with a remarkable input to this all above aspect, which is focuses in this following section of theory considering the above discussion.

3. Methodological approach

This research doesn't restrict itself to any one procedure of disciplinary method and reality or as such, this research follows neither a pure positivist nor a pure constructivist approach. While the constructivist approach would be adequate for analyzing social inequities, climate injustice and vulnerability, how the local communities adjust to climate change threats, it should be supplemented by a pragmatist viewpoint with regards to the appraisal of other examination items, for example, the situation with sea level rise, coastal floods, increased salinity and temperature. Along these lines, this research utilizes an interdisciplinary methodology that recognizes the relationship between the risk factors themselves and the social perceptions about them (Garschagen, 2014). Consequently, this interdisciplinary doctoral research follows the approach of critical realism approach and resorts to mixed method research (MMR). Moreover, both qualitative and quantitative research approaches were consolidated through triangulation, as I gathered information iteratively along the three phases of field research.

The utilization of the MMR approach allowed for a comprehensive perspective (Tanyanyiwa, and Kanyepi, 2015; Bryman, 2017) and guaranteed that all research questions were extensively addressed through utilizing multiple and complementing data sources. As to initial sources, quantitative information was gathered from climate vulnerable local area households using a structured close ended questionnaire (Bryman, 2017). Then again, FGD, IDI, KII, meeting, case study, and so on for the most part utilized for gathering qualitative data from stakeholders such as community people, students, teacher, civil society members, NGO, CSO, elected representatives, etc (Hennink et al., 2020; Clark et al., 2021;). The study was involved documental and statistical analysis, tide gauge data, satellite image (Ablain et al., 2017), and the evaluation of nearby SLR through 3 tide measures on the coast and 10 checks inside the southwestern Bay of Bengal, just as utilizing documental and statistical analysis, tide gauges, satellite altimetry information to examine local and worldwide SLR averages in the new past and through the 21st century (Benveniste, et al., 2019). In this investigation, water and soil samples were collected and analyzed for pH, electrical conductivity (EC) and other trace elements. A Digital Evaluation Model (DEM) predicts the salinity induced by storm gushes in the corresponding impacted zones. Land Cover Analysis using ArcGIS, rainfall patterns analysis through BWDB data. MAXQDA (Computer Assisted Qualitative Data Analysis software) and IBM-SPSS-25 were used for analysis of qualitative and quantitative data, respectively.

The geographical region selected for this study was the SWCRB, an area extremely vulnerable to the detrimental consequences of climate change and socioeconomic progression obstacles. The 12 unions, situated at Shyamnagar Upazila, were chosen as the specific fields of research. All the respondents are living in the poor and remote SWCRB, people that have been facing several direct climatic challenges. This research was undertaken from 2017 to 2021, having started with an early scoping visit to the research region, in order to set up the techniques for data collection that would be

adequate to respond to the research questions (Bryman, 2017). A triangulation method was utilized to address the research questions (Flick, 2018). Data collection included local surveys, interviews, focus group meetings (FG), participatory rural appraisal (PRA), and narrative surveys (Bryman, 2003; Bryman, 2016). All questionnaires and interview questions were pre-tested and edited before used in the field (Bryman, 2007).

This research assesses climate change, sea level rise, the extent of impacts, risk, vulnerability, and adaptation. Moreover, in the directed content analysis, the researcher analyses the data from the predefined literature review (Coners, and Matthies, 2014). A literature search was carried out to identify journal articles and books published between 1910 and 2022, through academic search engines PubMed, Scopus, Google Scholar, Lisbon University online library (B-ON) and the University of Valencia online library. There were inclusions of other literature from the past as it bore significance to the study. The key words that were used to conduct the research were: climate change, sea level rise, disasters, salinity, safe drinking water, risk, vulnerability, health, poverty, agriculture, inequality, gender, empowerment, adaptation, and Southwestern coastal Bangladesh. Citations and references of these articles were cross checked to ensure that no relevant information was left out.

Significant information sources were gotten from neighborhood networks with regards to the notable impacts of severe climate events on agriculture, riverbank erosion, salinity and loss of natural ecosystems, gender vulnerability, poverty, migration, food security, fisheries, safe water resources and public health factors. Different data sources were gotten from experimental researchers who work on the climate related issues, field expansion staff and from the third parties supporting the local communities, like the public authority and non-government organizations (NGOs) (Bryman, 2017). The involvement of local communities in this research was basic as it offered them a chance to introduce their perspectives.

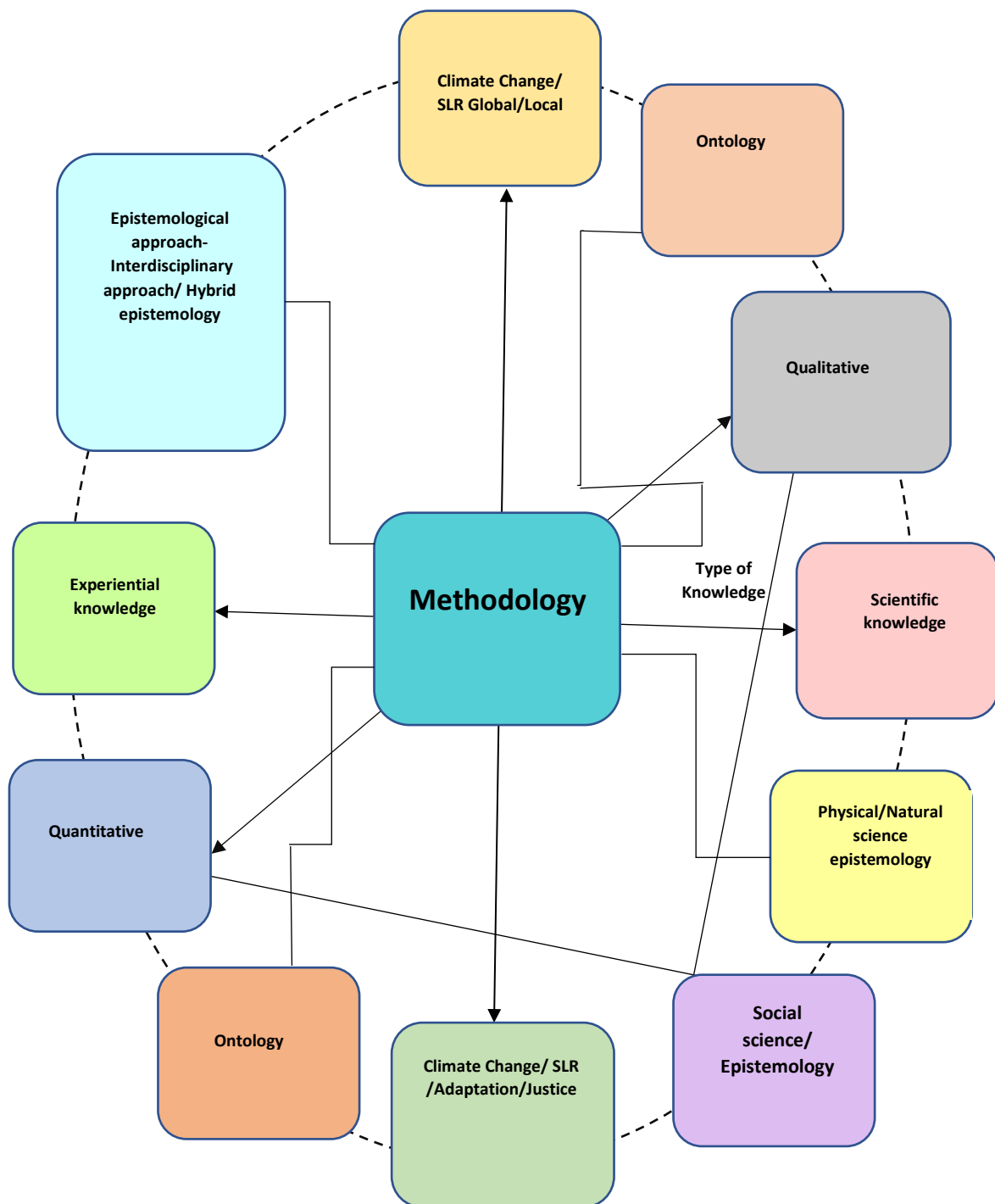


Figure 8: Combined Interdisciplinary approach/ Multidisciplinary /Hybrid epistemological framework/ MMR approach. (Here, Ontology is the philosophical study of existence, and related concepts such as existence, becoming, and reality. Ontology questions address how entities are grouped into categories and which of these entities exist at the most essential level. Ontology often

tries to define what the types or highest categories are and how they create a system of classification that includes the classification of all entities).

3.1. Epistemological approach: interdisciplinary and critical realism

Researching interdisciplinary and climate change is one of the most difficult problems we face nowadays. Its distinctive stance is founded on the understanding that effective and coherent interdisciplinary is required to address the problem of climate change, and the plethora of related phenomena that both make up and connect to it. To articulate a comprehensive framework for multidisciplinary, interdisciplinary, transdisciplinary, and cross-disciplinary understanding, Roy Bhaskar draws on the extensive resources of critical realism (Bhaskar, 2010). This framework appropriately considers ontological and epistemological considerations (Goldman, et al., 2018). Using this strategy, we were able to intellectually make sense of the complex phenomena surrounding the problem of climate change. This research tackles a wide range of integration-related issues, including integration between the natural science and social sciences, integration between (relatively) adjacent sciences, whereas natural science deals with satellite , tide gauges, statistical analysis and laboratory test analysis that is applicable to know sea level rising , carbon emissions and status of soil and water salinity; sea level rise, conceptualization and measurement of the relationships between human activity and climate outcomes in the pursuit of greenhouse gas policy, quantitative households close ended questioner survey represent to achieve the credibility and authenticity of the research and according to objectives and goals of this research, from respondents answer were help achieve accurate results; case studies, FGD, in-depth interviews, key informant interviews, workshops and literature review focusing on crucial climate debates like social vulnerability , and thematic studies of strongly climate-related issues such as health, poverty, gender ,agriculture, migration and justice .

Understanding and responding to significant systemic occurrences across a variety of reality domains also poses new problems for philosophy, strategy, policy, and action. According to Roy Bhaskar's "Contexts of Interdisciplinary," only a thorough and articulated interdisciplinary approach can adequately address the urgent issues of climate change. To intellectually support and develop such an interdisciplinary approach, critical realism, or a similar philosophical stance, is necessary (Bhaskar, 2010).

Critical realism is, thus, uniquely equipped to see the flaws in actuality, reductionist, monodisciplinary views of science and the need for an interdisciplinary effort when addressing complicated concrete phenomena like climate change (Cornell, and Parker, 2010). Through the codification of knowledge in models and system science in the middle of the 20th century, Sarah Cornell provides an engaging historical narrative of how modern climate science developed from its parent disciplines of oceanography and meteorology (Cornell, 2010). Despite the astounding results

that can now be obtained from modern earth system models, the uneasy coexistence of great confidence and deep uncertainty in our understanding of climate has clear political ramifications. Human science now needs to be integrated with climate settings, a task that has proven difficult and where a critical realism viewpoint is crucial which is described by Bhaskar and J. Parker (Bhaskar, and Hartwig, 2016). The IPCC, for example, now integrated climate challenges into different study areas (e.g., science/arts), reflecting and reinforcing traditional disciplines and cultural distinctions in climate research. Original and critical realism's central claim (the foundation of what has been referred to as "original," "basic," or "first wave" critical realism) was built on a dual justification from experimental and applied work in natural sciences like physics and chemistry.

Effective responses to the effects of climate change necessitate to acknowledging that different people realize different way experience of climate changes, moreover, natural science and social science contribution most of time people explain in the basis of one disciplinary based, so, it is necessitate the support of a variety of global-to-local interdisciplinary efforts that enable communication between the biophysical and social sciences (López, et al., 2017). Therefore, we employ a hybrid epistemological framework in this study that combines scientific and local knowledge systems, methodological approaches, and geographic scopes to:

1) highlight the SWCRB's climate change according to natural science and social scientific knowledge and local systems, and 2) it helps to combine the analysis of how climate change influences multi-sectoral natural and social systems such as water, soil, health, poverty, gender, migration, land use and agriculture in the communities in the area that depend on natural resources. We observed that there are two important primary methods for determining sea level: tide gauges and satellite altimeters. Moreover, we resort to statistical analysis, spatial analysis, geo spatial sequential climate trends, land cover analysis, rainfall pattern, laboratory testing for soil and water samples, DEM analysis for cyclonic storm surges, etc. We also used both qualitative and quantitative methods to assess climatic variability.

Research analysis shows significant trends in the region's salinity increase, which is supported by accounts from the local population as well as data from natural science. According to the same local population in this research region, precipitation data reveal considerable decreasing trends and high inter-annual variability in rainfall patterns recorded from BWDB. Research demonstrates that while it may appear that climate change is a factor influencing gender inequality, poverty, and farmers' agricultural and livelihood practices, other local anthropogenic climate change and non-climatic drivers are also significant in determining their intensity and adoption.

Natural science and local knowledge systems can be knitted together to increase our understanding of the physical and human appearances of climate change, despite site-level variances and junctions (López et al., 2017). By combining scientific and local knowledge systems in this study, we are able to better understand how climate change is affecting vulnerable populations in the SWCRB that are dependent on natural resources.

To determine sea level trends in the Bay of Bengal between 1993 and 2019, our hybrid approach uses tide gauges, satellite analysis, statistical and geographic analyses of instrument data, incorporates about sea level change. Even if statistical tools have helped identify climatic trends in the region despite the variable outcomes and directions and the SWCRB population is not always aware of or engaged in this type of information. Additionally, despite being susceptible to direct observation, long-term changes in the climate are difficult for laypeople to perceive. Local people navigate and respond to environmental pressures through their perceptions, experiences, and belief systems, which are closely tied to their knowledge (Ford et al., 2020). However, responses should be regarded as long-term processes that, depending on their scope, may affect a socio-ecological system's ability to absorb disturbances and retain its structure and function. Responses can take many different forms (for example, socio-economic, cultural, or political). Perhaps because of these factors, local knowledge of climate change may shed light on the nature and applicability of adaptation measures.

Additionally, incorporating local knowledge into statistical, GIS program ArcGIS 10.3, satellite, laboratory analyses, land cover analysis, and rainfall of climate variability may aid in bridging gaps between different types of knowledge (Nightingale, 2016), reconnect meaning to climate knowledge through the analysis of individual experiences, and balance the epistemic power of the frequently praised scientific view (López et al., 2017).

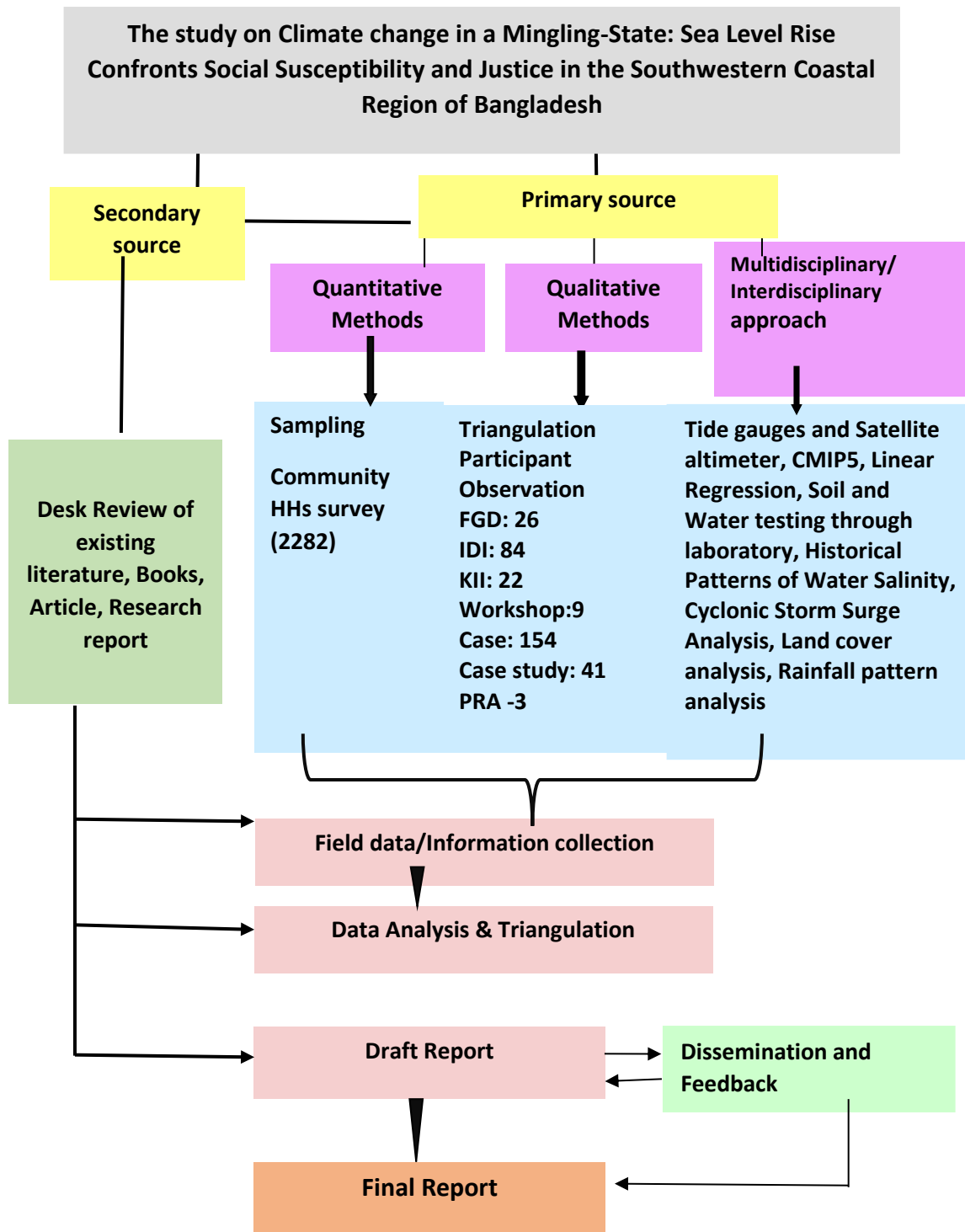


Figure 9: Design and framework of the study

3.2.Triangulation as a research approach

Triangulation not just alludes to the utilization of various research methods, but more unequivocally to the mixing of reciprocal methods for information assortment and hypothesis construction to work on the quality, and for sure the legitimacy, of observational examination (Turner et al., 2017; Santos et al., 2020), discussed four types of triangulation approaches, namely methodological triangulation, data triangulation, investigator triangulation and multiple triangulations. Methodological triangulation involves using more than one method to gather data, such as FGD, case study, interviews, observations, questionnaires, and documents (Bekhet, and Zauszniewski, 2012). In this research, methodological triangulation involves the utilization of more than one method for data collection. It is methodological triangulation if more than one research method is used for measuring the same object as for example to know the climate change and sea level rise. In this study, social science methods as well as natural science methods were used, as well as participatory research tools.

Data triangulation alludes to a process of data collection which utilizes diverse sampling strategies, so that cuts of information which inspect specific factors, such as impacts of climate change through time, the experiences of individuals and social responses, are gathered (Turner et al., 2017).

In this research, data triangulation included the collection of data at various levels of investigation, at the beginning from the local union porishod, district agriculture office, and the local level (e.g. village leaders, farmers, various occupational people, DRR units like UDMC, WDMC) to acquire experiences in regards to various on-going climate changes at various scales. It additionally involved analysis in different viewpoints which including those of the research scientists, NGOs authorities, specialists, instructors, students and field expansion officials, who have various stakes in the field of climate, change. Data triangulation was incorporated to keep up with the lucidity of the research results, in which all meetings with specialists, researchers, teacher, and student were contrasted and cross-checked, and household surveys and records for interviews and focus group discussions. Theoretical triangulation' alludes to the most common way of utilizing different theoretical viewpoints to concentrate on a similar context of climate change and sea level rise (Santos et al., 2020). This was embraced in this research from the start of the research and information understanding system. The utilization of various theoretical ideas takes into consideration in this research to seen with different focal points, and widens the comprehension of the research issue. 'Analysis triangulation or multiple triangulations alludes to the different strategies of data analysis that were utilized to analyze the qualitative data. Multiple triangulations refer to using more than one triangulation method in research. This was done to guarantee the legitimacy and breadth of the research (Denzin, 2012). 'Researcher triangulation', alludes to the contribution of more than one scientist, observer, or data analyst in a similar report for research affirmation purposes (ibid).

3.3. Quantitative methods

Sampling

The main objective of quantitative research is to take a broad view. In this quantitative research, it was unimaginable to know the whole impact of climate change and sea level rise induced vulnerability, risk, and inequality and adaptation link with SWCRB people. To get data about the SWCRB population of interest and to draw inferences about the people, this investigation resorts to a sample of the population (Bryman, 2016) to conduct a survey and collect in depth data that would not be accessible through other means.

Sampling methods in quantitative research are broadly divided into two categories, probability sampling and non-probability sampling. In this study, quantitative research sampling was undertaken by means of a non-probability sampling (purposive sampling) – a technique where the examination is permissible to opt individuals in accordance with a precise trait (Flick, 2022). In this study the key climatic characteristic considered was the vulnerability of the SWCRB. This characteristic serves as a preliminary criterion due to the fact that grounded theory requires that the research is flexible enough to allow the researcher to develop a theoretical based sampling as the research evolves and new data and key findings are made which is earlier discussed in grounded theory section (Oktay 2012; Charmaz, 2014). A trouble that crops up in the study is the right of scope to inhabitants who to take part in the study. Hence, research utilized an extra sampling means called snow-ball sampling (non-probability sampling). Initially, the research involved communicating with a union porishod member and a journalist in a local newspaper for locating potential individuals for interviews. Snowball sampling highlighted the preliminary participants who were to assist this research and recommend other participants (Taherdoost, 2016). The sample was obtained following the grounded theory principles and built on a theoretical basis (Charmaz, 2014) in accordance with what is being obtained from the questioner during the carrying out of the survey respondent's answer. In this research sampling approaches followed two steps: the first one was to select research zones from the coastal neighborhood of Bangladesh; next participants were selected following theoretical sampling methods recommended by grounded theory (Bryman, 2016). Theoretical sampling was also used.

For gathering essential information and data, Shymnagar sub-district under Satkhira district was picked utilizing purposive sampling (non-probability sampling) as region most vulnerable to climate change along the Bangladesh coast and near the Bay of Bengal (Taherdoost, 2016). At the first stage of this research Quantitative survey data were collected from 320 different respondents from different places in 9 unions under respective sub-districts for this research focusing on social vulnerability (overall research consisted of 128 questionnaires on people from 9 unions out of 12 unions), 9 Unions for Social vulnerability, justice, adaptation. The designated respondents were recognized to be

selected utilizing quota sampling method measured the basic of non-probability sampling studying procedures to address the objective populace with focus inclusion (Vehovar, et al., 2016). Such as women-centered adaptation measures, thus out of 320 household 98 women respondents from SWCRB were approached and included in the study as the sample units. Moreover, respondents were chosen according to proportion of ratio sample units, from the different categories of people (male, female, youngsters, teenagers, or adult) (quota) (Taherdoost, 2016).

1st, 2nd and 3rd stage of this research of this research in the same Shymnagar sub-district, information and data were gathered from 12 (100%) Union's specifically-Gabura, Ramjan Nagar, Kaikhali, Atulia, Ishwaripur, Munshiganj, Kashimari, Nurnagar, Poddo pukur, Buri Goalini Bhurulia, and Shyamnagar. Quantitative data were collected from n=387 respondents from different places in 12 unions under respective sub-districts for this research focusing on ranking of hazard risk observed in the 12 Unions of the Shyamnagar Upazila, and the disaster risk assessment (Aven, and Renn, 2010) e.g., the effects of such amplified hazards upon the SWCRB exemplify the concept of climate injustice (Holden, 2018). Moreover, research collected data on sorting based on climatic occurrence, vulnerability, risk and ability in the SWCRB, existing practices for safe drinking water adaptation, structural adaptation of people daily life, public anticipation of their upcoming adjustment mechanism. For this investigation research we consider respondents voting through participatory approach.

And the 3rd stage of this research we realized that health and safe drinking water as one of the major problem in this SWCRB. Later especially we have chosen out of 12 unions 3 unions (Gabura, Burigoalini, and Poddo Pukur) situated at Shyamnagar upazila, as the particular domains of research on the basis of accessibility of pure water and health impact on climate change. Moreover, to know the status of safe drinking water, child health, general health and women health, we given priorities to 3 unions because these 3 unions were near to the Bay of Bangle (adjacent with GBM delta), and most vulnerable (Unions are the smallest rural administrative and local government units in Bangladesh).From (Gabura, Burigoalini and Poddo Pukur) these 3 unions, n=1579 household's persons in total nominated for being interrogated for a set of survey questionnaires (Bryman, 2007) to know general health, women health, child health and safe drinking water as a quantitative research approach whereas research were collected data various indicators such as source of water for drinking, water demand for drinking and cooking per household per day, distance of Safe drinking water from household, challenges of the respondents, general health, women suffered from diseases, children suffered from the diseases.

Quantitative Sample size determination:

Quantitative analysis was performed via a field survey in 2017 and 2019 for 320+ 387+1579 households to obtain 95% confidence level, with an accuracy rate or amount of admissible error

margin of +5% as we had exact beneficiary count and to sample the sample representative equally for each union and distributed proportionately in accordance with population size. The household survey was carried out through close-ended structured questionnaires to capture the response of respective respondents (Bryman, 2016) for capturing social vulnerability, risk and hazard and lack of safe drinking water and health impact. The following sampling approach and statistical formula has been applied for the sample design:

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

Whereas,

- n = Sample size
- N = Targeted Population size
- e = Admissible error in the estimate
- p = Proportion of defectiveness or success for the indicator
- q = 1- p
- z = Standard normal variable at the given level of significance

For ensuring representative sample size from each Union equal proportion of sample size was selected. Sample size distribution through stratified random sampling as follows:

Table-2: The detail of quantitative sample size distribution

Sample size distribution							
Type of respondents	Unions coverage	N=Total population	e=Admissible error in the estimate	Sample size=n	Female	Male	Of them Youth
Risk hazard and adaptation analysis	12	318,254	5% admissible error margin	387	189	198	35.5%
Social vulnerability, Justice and Adaptation	09	242392	5.5% admissible error margin	320	98	222	25.5%
Health Impact (General Health)	03	79579	4% admissible error margin	915	631	248	20%
Health Impact (women and Maternal health)	03	79579	5% admissible error margin	420	420	00	42%
Child Health	03	79579	5% admissible error margin	240	104	140	0%
Total	12	318,254		2282	1416	830	

Households Survey

The household survey carried out through structured questionnaires to capture the response from respective respondents (Huynh et al., 2018) for capturing Risk and hazard, social vulnerability, adaptation, justice and Health Impact (General health, child health, Maternal health) of the surveyed respondents. A close ended structured and mostly pre-coded questionnaire developed through a rigorous and systematic process. The survey covered a total of n=2282 (320+387+1575) households

from (9Unions + 12 Unions + 3 Unions) , 12 Unions of Shaymnagar Sub-district. In total, 2282 households were surveyed using random sampling techniques with a 95% confidence level. Respondents' size is distributed proportionally depending on population size in the respective area using simple random sampling. Questionnaires composed with around 100 to 150 climate change driven variables where at least around 40 minutes needed to fill-up a questionnaire from n=320 households. And 2nd and 3rd stage research where at least around 10 to 15 minutes were needed to fill-up a questionnaire from the (387 + 1575) households, because small amounts of climatic variables were included for the questioner of risk, hazards, adaptation and health and safe drinking water. These were conducted through field work interaction with the respondents.

The close-ended questionnaire consisted of household survey data collection (Choptiany et al., 2017) from household heads together with interviews of household members (where is permissible), such as Poverty and environmental disasters are a multi-dimensional issue, and affect the communities at the household level, so this study analyses the response at the household level. The poverty level of households in the same area and community is unequal, and inequality restricts the coping strategies of poorer households. These are common with many low incomes, marginalized, and natural-resource-dependent societies, and are also obvious in the in-depth households' interviews conducted in the study area.

The questionnaire is based on a series of questions related to the perception of effects of climate change, sea level rise, natural disasters, salinity, riverbank erosion, flood, rainfall, waterlogging, land use change, and the connection of these elements to climate change, which were divided into 'health', 'agriculture', 'poverty', 'gender', 'inequality', 'adaptation', 'economy', 'justice' and 'environment' sections. The analysis includes the primary and secondary occupation and income of the responders, their socioeconomic level per household, the housing structure, loss, the damage suffered by homes, upcoming adjustment mechanisms, as a result of natural disasters over the last 5 to 50 years. The 'environment' section research includes a series of yes or no questions and single and multiple response questions per responder included (See annex). Finally, Excel's statistical software and SPSS were used to analyze the collected data and create tables and graphs in order to present the data.

Here introduced an example, the data gathered from the income per household was used to calculate the general inequality amongst the 320 households. This was carried out by creating a Lorenz curve based on the Gini inequality index. This index plots the proportion of total population on the y axis, and the cumulative percentage of income (x axis) in this case of the 320 households, which is earned by the lowest percentage of the population (Ashrafuzzaman, 2022). This gives outcomes of the general inequality, going from 0, representing complete equality, to 1, representing complete inequality. First, respondents' answers were placed in bins according to income level, from 0 to 5,000, 5,000 to 10,000, and so on until 30,000. The percentage of the sum of the 320 participants' income was calculated, and the percentage of the total income of the entire population in all the bins was then calculated based on this. The table was sorted according to income per bin and the

cumulative percentage of all income and the cumulative percentage of all the population were created (Ashrafuzzaman, 2022). Finally, this was used to calculate the Lorentz curve and the respective area in order to calculate the Gini coefficient.

During the close-ended questionnaire surveys, interviews were focused on male and female respondents from each household; however, the women were generally hesitant to give interviews with male researchers due to religious taboo. Moreover, women felt shy to express themselves in front of strangers. At the first stage in this research household survey, 31% of the female respondents willingly responded to the close-ended questionnaires. Considering these issues, for the next 2nd and 3rd stage of this research were to contact local 2 (two) female students for survey data collecting who earlier had short term expertise of data collection national and international NGOs in the field of climate change.

Sampling for Qualitative research

Quantitative close ended structured questionnaires which was used in this research, is also applied for qualitative analysis, like FGD, case study, interviews, KII, IDI, and workshops was done in light of marisco approach, and guideline were designed as per research key questions and based on grounded theory. After the initial design, the draft tools were shared with supervisors and practitioners and finalized based on the feedback received. Moreover, under the base of climate events this research applied situation based questions. To analyze the effect of local climate, at first a random sample is considered to generalize the results. Research uses a random sample that is defined by the nature of the population and all community members have an equal opportunity to respond to their vulnerability options. Stratified random sampling and area sampling are variants of random sampling that allow subgroups to be studied in more detail (Llewellyn, et al., 2004).

There are no hard and fast rules regarding sample size for qualitative research (Marshall et al., 2013). It depends on the purpose of the research, what is at stake, what is useful, what is credible that can be done within the time frame and the resources at hand. A large sample was used in this study to ascertain the climatic phenomena employed for in-depth analysis. Two other types of sampling techniques used in this qualitative research are theoretical and purposive sampling (Llewellyn et al., 2004; Bryman, 2016). For collecting primary data and information, the Shyamnagar sub-district under Satkhira district was chosen using purposive sampling as the most climate vulnerable area in the SWCRB.

Purposive sampling is used in the proposition that information rich samples were selected to look at the climate change phenomenon in depth (Robinson, 2014.). The selection of respondents in this study was done only after several observational visits to the study area and the visit helps to select and identify the sample that fits well with the aim and objectives of the study. Respondents were chosen according to the proportion of ratio of gender, age, knowledge, individuals with inability, practical

role, nationality/minorities and monetary isolation status. Purposive sampling was used in this research for case study and actively selects the most important sample to answer the research question.

This study also considers theoretical sampling to generate explanatory theory from emerging data and to select a new sample to test and elaborate this theory (Oktay 2012; Charmaz, 2014). This is the main technique for grounded theory methods but it has also been used for these research qualitative investigations in terms of requiring interpretation. For theory building was processed by collecting codes and analyzing data and deciding what data to collect next and where to find them, to develop the theory as it emerges (Turner et al., 2017) and the sampling process was completely governed by emergent theory. Moreover, for qualitative research approaches like case study, workshops, FGD, Interview and KII we selected 12 Unions of Shyamnagar upazila. These were conducted through field work, skype, messenger, telephonic interactions or interaction with respondents.

Qualitative sample size distribution:

Qualitative study carried out to get more detailed and more specific information from relevant stakeholders to get the qualitative reflection using diversified tools and techniques, namely Focus Group Discussion (FGD), Workshop, Key Informants Interview (KII), In-Depth Interview (IDI), observation, case collection, case study, etc. For qualitative information collection the study followed data saturation and data redundancy approach. A sample size distribution table is given below:

Table 3: Qualitative Sample distribution

Qualitative Sample distribution		
Tools	Target groups and criteria	Sample size
FGD	Risk /Vulnerability / hazards	
	Justice /Adaptation	Total Mixed 26 FGD
	Farmers group /Fisher flock group	
	Community people /Doctor /Teacher /Journalist	
	Gender /women / women partitioner /Gov/ NGO	
	Health/ Safe drinking water / Salinity / erosion /poverty	
	Civil society / Local government/ NGOs	
Interview &In-depth Interview (IDI)	Teacher	07
	Community leader	12
	Gender /Women/ Representative	10
	NGO representative	13
	Fisher flock	11
	Farmers	14
	Journalist	12
	Doctor	5
Workshop	School students	3
	College students	3
	Mix participants (Local People, Farmers, Shrimp farmer, Honey collector , Women Representative, Local government, Government Official, Journalist, NGO worker, UDMC, WDMC, Tiger team, Tiger widos)	9
PRA	Risk & Hazards	3
Key informant Interview (KII)	Member of parliament (MP)	1
	Government departments /Secretary of Ministerial	5
	Local Government representative/UDMC/WDMC/Tiger team	16
	Local Poet/ Catholic Father	3
Case	Gender, salinity intrusion, safe drinking water, Water, Housing Structure, Toilet Facilities, Diseases, Migration, poverty, hazards, sea level rise, cyclone , health ,food security , Bangladesh media and climate, climatic resilient, Farakka Dam ETC Agriculture, adaptation varieties, mitigation steps, Biodiversity/ Forest/ fish availability/ River Erosion, rainfall pattern, preparedness against hazards, warning system, training, Climate Change & Gender, traditional livelihood, salinity, shrimp or fish enclosure, land use of shymnagor, vulnerability of coastal indigenous community, climatic injustice, flood, social inequality . economic activities, drought,	154
Case study	Agriculture, Poverty, SLR, Climate Change, Gender, Climate Justice, Salinity, Health, Migration, Local Adaptation, Food Security, Shrimp Farming, Drinking Water, Livelihood, Adaptation	41
Total		345

Statistical analysis

The methodology for study is the statistical method of Linear Regression Trend, considering the complex dynamic of the area with the lack of the essential record information to make a better analysis as the annually rate of glaciers retreat and land subsidence that could be put altogether with the tide gauges and satellite altimeters data. The objective of this study is to demonstrate the significance of creating detailed information on the data of glaciers retreat and land subsidence and compare the results with the CMIPC model. Currently, reliable information of tide gauges and satellite altimeters is based on the method used in the case of Valencia in 2019, Spain in the study of “Accuracy measurement of sea level rise due to effect of Climate Change through tide gauge data and NASA Topex-Poseidon/Jason satellite series-The case of Valencia”.

The daily high SLR/water level and daily low SLR/water levels (in meters (m)) were obtained from the Bangladesh tide gauge data. Mean SLR was calculated by averaging the daily high and low SLR in m, which was further converted to mm scale. Yearly mean SLR was calculated from these data and plotted in Excel. Finally, trends of MSL were calculated by linear regression with the regression coefficient and the equation as R^2 and $y = B + M \cdot x$. Sea level information at Sundarban/Hiron Point and Char Changa from 1993 to 2019 and at Cox’s Bazar from 1993 to 2011 was obtained, and both the lowest and highest tide records were retrieved.

For each tidal gauge record and satellite data future trends, linear regressions were used to calculate the trend line equation in order to estimate the SLR change for the three tide gauges, the 10 delta gauges, regional, and global sea level change by creating linear trend lines. The equation R^2 and $y = B + M \cdot x$, SLC projections were estimated for the three tide gauges, regional, and global future SLC during the 21st century. After this, both the global and regional data were averaged to annual values, as the original table had a resolution between 30 to 15 days. Following this, through linear regressions, the correlation between the local, regional, and global data was created to analyze possible patterns between different scales.

Satellite imagery retrieval

Satellite data were retrieved from the Laboratory for Satellite Altimetry (Birkett, 1995; NOAA, 2019; Laboratory for Satellite Altimetry, 2020a; Laboratory for Satellite Altimetry, 2020b) including data from TOPEX, Jason -1, -2, -3, and multiple altimeters, which were averaged to create a 1992 to 2020 table (Kuo et al., 2004; UCS, 2013; NASA/JPL,2017; NASA; 2019; Laboratory for Satellite Altimetry, 2020a; Laboratory for Satellite Altimetry, 2020b; JPL ECCO server, 2020; Laboratory for Satellite Altimetry, 1992–2022; URL,1-2;European Environment Agency,2019). Global and local level changes provide a method for evaluating the performance of climate models this was used to measure global average and regional SLR; the regional data were obtained from the average altimetry values of the Bay of Bengal. To visually analyze global and regional SLR, screenshots were obtained from the JPL ECCO server (2020) (Ablain et al., 2017, NASA; 2019; URL,1-2; JPL ECCO server,

2020) which show the change in sea surface topography from 1992 to 2015 (NASA; 2019; JPL ECCO server, 2020 ; URL,1-2; European Environment Agency,2019) Similarly, for the satellite time lapse of the Himalayan glacier change in images from Google Earth Timelapse tool were retrieved from the entire Himalayan range from 1990 to 2018, Gangotri glacier from 1990 to 1995, and Kailash Mountain from 1985 to 2018 (Google Earth Timelapse, 2020a,b,c).

SLR Change Verification and Land Subsidence Projection Using CMIP5 Model

The Norwegian Earth System Model (NorESM1-EM) from CMIP5 (Coupled Model Inter comparison Project Phase 5) was used to compare the mean SLR of regional and global areas. For the mean regional SLR, the mean SLR for the Bay of Bengal was used, and projections of land subsidence were analyzed to determine their relationship. SLR projections (the representative concentration pathways (RCPs) data were downloaded from cds.climate.copernicus.eu (accessed on: 22 December 2021)(UCS,2013; URL, 1-2) and the mean SLR for the Bay of Bengal was simulated using the Global Climate Model (GCM) NorESM1-ME from 2006 to 2100. The estimates were taken from the figures from 1980 to 2005. The GCM model figures were in the Network Common Data Form version 4 (NetCDF4) pattern. The data utilizing the Climate Data Operator means were separated and the Python language was employed to plot the RCP estimates (URL 1).

Sea level is measured using two main approaches

Tide gauges and satellite altimeters. Tide gauges measure low and high tides by utilizing manual and automatic sensors. Satellite altimeter radar measurements are performed using precision-based spacecraft orbits to determine the surface altitude with exceptional accuracy. Global and local level changes provide a method for evaluating the performance of climate models (Ablain et al., 2017). The mean tide level at any location is the average of all high and low water levels at that location over a long period of time. In sea level analyses, there are some advantages to using mean tide level as a locus level instead of mean sea level (MSL) (Ashrafuzzaman et al., 2022). Data from three tide gauge stations from the Bay of Bengal at Hiron Point, Char Changa, and Cox's Bazar (primary data were collected from Government of Bangladesh Inland Waterways and Transportation Authority (BIWTA).

For Hiron point, the highest tide value was considered from March and the lowest from August. The lowest and highest tide values were considered for February and August for both Char Changa and Cox's Bazar. Then, for Hiron point and Char Changa, the average between the lowest and the highest point was considered as the average annual SLR value, and only the highest tide record was used as the annual for Cox's Bazar, due to unreliable low tide records. Data from 10 tides gauge 10 stations from the Ganges Delta (primary data were collected from the Bangladesh Water Development Board (BWDB)).

Tide gauge data for the Ganges Delta was obtained from the Bangladesh Water Development Board (BWDB). Metric data from BWDB was available for 10 stations with a data series from 1968 to 2019 (Figure 6). The list of stations includes Kalaroa, Benarpota, Protapnagar, Basantapur, Kaikhali, Tala Magura, Chandkhali, Elarchari, Kobadak Forest Office, and Shakra, which include a timeframe from 52, 50, 49, 51, 52, 51, 49, 34, 43, and 39 years, respectively. The monthly data was taken into consideration for tidal documentation if a minimum of 15 days of data was obtained, and yearly data was considered if a minimum of 11 months of data was obtained. Time extent of these statistics is significantly high-quality. Usually, data from the past 20 years was examined for SLR tendency assessment and the data quality verified before scrutiny (Ashrafuzzaman et al., 2022). The inaccuracy in tidal statistics was rectified manually. In case of an over-inference of tidal rank, flawed data was removed from the dataset.

In this study, we showed how Global Navigation Satellite System (GNSS)-derived vertical velocities contribute to the correction of tide gauge (TG) measurements used for sea level rise estimation in the Ganges–Brahmaputra–Meghna Delta (GBMD) (Bitharis et al., 2017). At the Ganges–Brahmaputra–Meghna Delta (GBMD), vertical land motion (VLM) and GNSS (co-located) are used when estimating the geocentric sea level rise. TGs use a landbased monitored geodetic benchmark to measure the height of water. Thus, VLM can be determined using GNSS-based methods. The absolute geocentric sea level trend is the conversion of the TG correction of relative sea level heights and GNSS vertical velocities from the same location (Bitharis et al., 2017; Kleinherenbrink et al., 2018).

Soil and Water Sampling

Soil and water samples were collected between the 10th and 13th of July 2019 at the three unions. Samples were collected in bottles that were shaken overnight with 20% nitric acid and rinsed with deionized water to remove internal and external contaminants. Soil samples were collected using a manual auger at a depth of 10 to 15 cm deep (Soil Survey Staff, 2014). Eighteen soil samples were collected within these areas from agricultural fields, ponds, riverbanks, and shrimp ghers. The coordinates and land use information for the soil samples are displayed in (Table 1, p: 4) and the water samples are displayed in (Table 2, p: 4). Photographs of the sites are also shown in (Figures 2 & 3, p: 5) for soil and water samples respectively.

After the samples were collected, all samples were sent to the laboratory of the Soil Resources Development Institute (SRDI) within 21 hours and kept in a refrigerator at a temperature below four degrees Celsius (Soil Survey Staff, 2014). Analysis of the soil and water samples was conducted from July 14 to August 21, 2019, at the SRDI. Soil samples were analyzed for pH, electrical conductivity (EC), calcium (Ca), organic matter (OM), total nitrogen (TN), potassium (K) and phosphorous (P). Water samples were analyzed for pH, EC, total dissolved solids (TDS), sodium (Na), bicarbonate

(HCO₃) and chloride (Cl). Areas where soil samples were collected and GPS coordinates with land use coded according to sampling source where A_f = Agricultural field soil, P_s = Pond soil, SG_s = Shrimp gher soil, R_b = River-bank soil. (Data Annex or text)

Twenty-nine water samples were also collected in these areas from tube wells, pond sand filters, and rainwater harvesting tanks. The coordinates and land use information for the soil samples are displayed in Water sample collection areas and GPS location with land use coded according to sampling source where RHw = Rain harvested water, PSFw = Pond sand filter water, SGw = Shrimp gher water, Rw1 = Kholpatua River water, Rw2 = Chuna River water, Sw = Supply water, Pw = Pond water, and HTw = Hand pumped tube well water (Annex or text).

Soil and Water Sample Analysis

The major chemical constituents of soil and water and their quality factors were analysed using standard methodologies. Standard saturation paste method was used to determine the E_{Ce} where 350g air-dried soil was taken for each sample to prepare the saturated paste, left it in room temperature for 24 h for equilibrium then the saturated paste extracts were collected by subsequently using Buchner funnel and applying suction (Rhoades, 1996; Soil Survey Staff, 2014). In this research E_{Ce} soil sample was measured in saturated paste as E_{Ce}, dS/m at 25 °C and for the EC water sample was measured as EC, dS/m at 25 °C respectively. The EC was measured by means of the Jenway EC meter from the extracts (ibid). pH was measured using the Jenway pH metre as described by (Tan, 1996). The salt content (Total Dissolved Solids) was calculated using the following formula (Sparks, 2003):

$$\text{Total Dissolved Solids (TDS) \%} = 0.064 * EC$$

The Olsen Sodium Bicarbonate test was used to determine soil phosphorus. Soil potassium and sodium were determined separately by flame emission spectrophotometer (Jenway Model: PEP-7), using potassium and sodium filters, respectively, as outlined by (Jackson, 1973). Chloride and bicarbonate contents were determined by the titrimetric method described by (Jackson, 1973). The sample was determined by the Kjeldahl method described by (Bremner, 2009) and organic carbon was analysed using the (Walkley and Black, 1934) wet oxidation method (Ghosh et al., 1983; ibid).

Additionally, historical data for electrical conductivity (EC) and chloride concentration was obtained from the Bangladesh Water Development Board (BWDB) for the South-western coastal region with data ranging from 1968 to 2019. Data from the BWDB was available from 3 stations: Kalaroa (SW 23; 2001-2018), Elarchar (SW 254.5; 2001-2018), Benarpota (SW 24; 1980 -2018). The EC and chloride data from the BWDB was averaged on yearly basis for low and high-water levels. This data was plotted in Microsoft Office Excel 16 as the levels of chloride and EC at high and low tide over time in years.

Statistical Analysis

The results of the soil and water samples were analysed using Pearson's correlation coefficient using the computer software IBM SPSS 25. Pearson's correlation coefficient is a linear correlation model using two sets of data that produces a value, r , by accounting for the covariance and standard deviations within the data sets. The r value produced indicates how highly one dataset is correlated or influenced by another with high values being more significant. The standard Pearson's r is calculated as follows:

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}} \dots \dots \dots (3)$$

Standard deviation and other general calculations were also conducted. A standard linear regression, using historical data, was created to determine the R^2 value for chloride and EC at low and high tide for the Kalaroa, Elarchar, and Benarpota stations. This was done to identify variables that correlate with each other to find statistical patterns that might reveal evidence of the physical mechanism underlying them. Most calculations were conducted in Microsoft Excel 16 unless otherwise stated.

Cyclonic Storm Surge Analysis

To calculate the areas affected by different seawater surges, three different storm surge heights were used, 1.5 m, 5.25 m and 9 m as the minimum, mean and maximum surge height (Huq, 2013). A 90-metre resolution Digital Terrain Model retrieved from (Jarvis et al., 2008) with a 1-metre resolution altitude data were used. However, due to the 1-metre altitude resolution of our data, the numbers were rounded to 1, 5 and 9 all of the areas within 1-metre, 5-metres and 9-metres of mean sea level in the DEM were used to estimate the respective affected areas. The 1-metre sea-level change was calculated using the same process, 1, 5 and 9-metre surge 1-metre above the current sea levels, similar to the methodology used in the study by (Karim and Mimura, 2008). This 1-metre sea-level rise projection were taken from (ibid) where a study puts the sea-level change in 2100 between 30 to 100 cm, as well as the IPCC's RCP8.5 estimating a rise of 52 to 98 cm in sea level by 2100, based on (Mukul et al., 2019). Due to the constrained nature of the data resolution, a 1-metre sea-level rise was used. Then, each affected area was counted by converting the raster DEM pixels into a vectorised matrix and selecting the pixels with the desired elevation values of 1 metre, the sum of pixels from 1 to 5-metres for the 5-metre surge, and the sum of the pixels from 1 to 9 for the 9-metre surge scenarios (Jarvis et al., 2008). This same technique was used with the 1-metre sea-level rise scenario but taking the values from 1 metre above, so by taking the pixel count from 2 metres for the 1-metre surge, the sum of 2 to 6 pixels for the 5-metre surge, and the sum of 2 to 10 pixels for the 9-metre surge. The pixel count then was multiplied by 8100 to calculate the area in square metres, and then divided by 1,000,000 to get the square kilometres (Huq, 2013; ibid).

Rainfall and Land Data

To analyse the changes in rainfall patterns, data was provided by the Bangladesh Water Development Board; a month-wise resolution record from 1968 to 2018 was retrieved from three different rain gauges, CL506, CI508 and CL515, belonging to the SWCRB. Then, the monthly record was summed to create an annual record for each station. To analyse the trend changes per year, a linear regression was created for each of the three gauges using Holt's linear regression equation (1957). This equation was originally intended to create a levelling-exponential method and a simple diagrammatic technique to allow a trend-based data forecast. However, here it was used to obtain the change in the trend of annual rainfall in millimetres.

Land Cover Analysis

To analyse the changes in the land cover and particularly, the increase in water levels, a supervised image classification was created for the Shyamnagar region in 1989, 1999, 2009 and 2019 using ArcGIS. This method was retrieved from Loog (2018), from a set of polygons containing training data. This training data gives the pixel values of the different satellite bands corresponding to different land uses. Then, the image classification algorithm uses this pixel information for the given land uses and tries to find similar pixel values to predict the land uses. Images used were retrieved from Landsat Image-United States Geological Survey; Google Earth Engine; Google Earth; GIS software 10.5, by collecting Landsat satellite imagery and three classifications were created: bare soil, water and vegetation.

Table : 4 Water and Soil characteristics Scientific lab testing (primary) sample size distribution						
Tools	Criteria test	Tested by	Upzila			Total
			Satkhira			
Primary data						
Soil	pH, EC, OM, TN, P, Ca, and K) and water (pH, EC, Na+, HCO3-, and Cl	Tested by the laboratory of the Soil Resources Development Institute (SRDI)	Soil samples (18)	18		
Water	water (pH, EC, Na+, HCO3-, and Cl-)	Tested by the laboratory of the Soil Resources Development Institute (SRDI)	Water samples (29)	29		
Primary Data (BWDB, BIWTA)						
Bangladesh Water Development Board (BWDB),	Surface Water Salinity EC, Concentration of Cl-	Station name: BENARPOTA (SW 24)	Kalaroa (SW 23)	Satkhira Khal at Elarchar (SW254.5)		3 river station salinity in study area
BWDB	Rainfall	Station CL506	CL508	CL515		3station Yearly rainfall in study area
BIWTA (Bangladesh Inland Water Development Board)	Sea level rise	BIWTA, BWDB	3 tide gauge Char Changa, Hiron Point and Cox's Bazar (BIWTA)	10 deltaic gauge stations (BWDB).		

Table : 5 Sea level rise, Rainfall and Land cover analysis primary data sample size

Landsat image USGS (United States Geological Survey); ArcGIS (Software Version: 10.5)	https://earthexplorer.usgs.gov https://www.arcgis.com
Statistical Analysis Linear regressions, logistic regression; Holt's Linear Trend Equation	To calculation SLR, land cover, poverty line, adaptation
JPL ECCO server (2020); Google Earth Timelapse tool; Laboratory for satellite altimetry	Sea level change; Global & local
CMIP5	The Norwegian Earth System Model (NorESM1-EM) from CMIP5 (Coupled Model Inter comparison Project Phase 5)
Digital Terrain Model (DEM)	Cyclonic Storm Surge & SLR Analysis

3.4. Qualitative methods Participant Observation

In comparison to the quantitative part of the research design, the aim of the qualitative part is to move 'beyond' explicit and easily articulated information and reveal the tacit or implicit common vulnerability. Participant observations is the data assortment method that permits an analyst to find out with regards to various events of a specific local area being scrutinized by noticing and partaking in those events (Bryman, 2016). Participant observations give the researcher a way to check for nonverbal speeches of views, to perceive how various individuals connect and convey, just as to perceive how local people deal with their livelihood through various events (Musante, and DeWalt, 2010). One key goal of this study is to understand how SWCRB populations perceive vulnerability to

the jeopardy posed by SLR at different scales, and how SLR impacts their daily lives. We were done this by identifying families' daily practices and people's life experiences in relation to SLR, as well as better understand the impacts on their quality of life. Participant observation entails that the researcher (me, we, and I) has become a part of the reality in coastal people which help me to collect information and systematically observed how they act in the vulnerability of climate change (Bryman, 2016; Flick, 2022). Hence, the method is particularly suitable for studying (inter)relations among people in climate situations (Clark et al., 2021). Thus, the method allows an insight into the climate change dynamics and Impact on Livelihood in Coastal Region of Bangladesh. In short; there are three main reasons for the relevance of participant observation as a research method in this research design. First, in contrast to, especially, the quantitative methods that rely on 'manufactured data', participant observation provides 'natural data' (Silverman, 2015). Second, the method enhances the quality of the interpretation of data given that the researcher gains an insight into tacit knowledge of the given field (Musante, and DeWalt, 2010). Third, the method encourages the formulation of new research questions and hypotheses based on on-the-scene observation (ibid.). This method permits researchers to examine neighborhoods local terms and expressions, and to see the sign language that respondents might be reluctant or unable to share. Respondents through the discussions were informed by researchers what they think, what is their long-term climatic problem, and what is the actual truth (Given, 2008; Silverman, 2015). Since participant observation permits a researcher to observe the practices from person to person, the issues of intentional and unintentional expression from respondents are kept away from. As the lead researcher I joined various different farming, livelihood keeping activities and stayed in the study region. This strategy helped me in building up a good affinity with the local people, farmers, and various occupational people.

Focus Groups discussions

In this research, the locals got together to discuss on climate change, sea level rise, vulnerability, risk, agriculture, poverty, migration, health, gender issues, justice, adaptation and the discussions were guided by a moderator (author) (Morgan, 1996). The focus group discussion and the meetings were held at a convenient place like school, youth club, community organization where the concerned respondents were able to discuss issues and express their idea and concerns independently. The group is called a focus group, and the recorder was used by the author for writing the discussion, at the same time we took their consent to record the discussion and explained them to purpose of the research (Morgan, 1996; Flyvbjerg et al., 2012; Bryman, 2016). They were well informed that the participation is completely voluntary and they also had the right to refuse to answer any questions, if needed. The participating members of the community established respectful appreciation by providing their valuable contribution for this research. All members were encouraged to talk freely and ask questions at any time during the session and each participant's consent were recorded using predetermined

format (O. Nyumba et al., 2018). Then, with the consent of the participants, climate change, climate justice checklist was used demonstrating other benefits (Morgan, 1996) This driven a guided discussion helps that one single respondent cannot dominate the discussion and everyone gets an opportunity to contribute in the discussion session to develop the exposure factor of climate change for the climate justice issues. The interactions and discussions amongst people we carefully evaluated and analyzed (Van, and Angehrn, 2017). The study coordinated 26 (twenty six) Focus Group Discussions with various gatherings of pre-chosen respondents of homogenous nature with semi-structured guideline and the utilization of participatory tactic. The guidelines prepared for each group of respondents purposely to draw out the specific information related to the research objective. Each FGD consisted of 8-12 participants like women, men, youth, elders, doctor, teacher, stakeholders from government and non-government organizations, farmers, honey collectors, member UDMC, member WDMC, poet, NGO practitioners, member of civil society, journalist, people with disability etc. (Morgan, 1996; Bryman, 2016). FGD catch information related on climate shocks and weakness, openings like calamity and environment versatile practices (DRR, climate changes adaptation and mitigation). This research is a series-based analysis to assess climate change, sea level rise, the extent of impacts, vulnerability, and risk adaptation. The FGDs consisted primarily of mixed male and female respondents. For instance, to identify vulnerability of women and the importance of female empowerment in climate adaptation process in each union of the study area, there was an arrangement of the FGD session consisting solely of female participants. All other essential information was collected through face-to-face FGD session. Since patriarchy shapes up women's status to remain in obscurity, discouraging women candidly from expressing their concerns in the presence of men, focus groups exclusively targeting women was very effective in the context of Bangladesh. Information gathering through FGDs and informant interviews were conducted for females in the age range of 70 years. Considering the need to have participants with exposure to climate aspects and long-term trends, the focus group interactions focused on eight to ten individuals. With a view to ensuring research participants being aware of long-term scenario, a minimum age-limit was set (Morgan, 1996; O. Nyumba, et al., 2018). The principal information provider's interactions were selected after suggestion from rural inhabitants, since such individuals were more aware about the neighborhood with completion of minimum academic learning. From each focus group discussion, we came to know from the respondents, which is include: their everyday changes and impression of various on-going changes, causes of climate change, climate driven distinguished changes, diverse different adaptation strategies to withstand these changes, information collecting from the local people how they use local adaptation, how they networking with the community for adaptation (Van, and Angehrn, 2017). All of the focus gatherings were led in Bengali language then after cautiously it was converted into English.

Through focus groups we can learn the unknown factors which we cannot identify easily. Here focus groups act as Problem Based Learning (PBL) (Morgan, 1996; O. Nyumba, et al., 2018). Another

example for safe drinking water and health, Focus group discussion was analyzed after the conversation and this process played an important role to understand the research on climate change, salinity, fresh water and health impact. Focus groups gave us a clear concept of our research and they informed us about the different changes over time. In each FGD, 8-12 people participated and equal importance was given to their opinions (Van, and Angehrn, 2017). The data earned through focus groups can also be compared with other qualitative methods. We got a comparative picture of lack of fresh water, and health impact through the discussion with the participants. The collected data from focus group acted same as the data of research interview. Focus groups provided us with first hand data which gave us many new ideas that were helpful as well as necessary for our research. Different participants provided different opinions here.

Participatory rural appraisal (PRA)

Anthropologists and many other disciplines are increasingly using participatory rural appraisal (PRA) methods in a variety of applied contexts, and the potential advantages of such PRA methods, outlines how to use them in this investigation (Chambers, 1994; Omondi, 2020). PRA were combined for collecting qualitative and quantitative data in this research, arguing strongly the need to undertake basic research on participatory methods. This research applied participatory rural appraisal (PRA) to improve knowledge about effects of climate change and sea level rise, and critically analyzed interviewing, discussion/visualization and ranking/scoring in terms of their relation to established qualitative and quantitative research (Omondi, 2020).

Participatory rural appraisal (PRA) is a common strategy of data assortment in SWCRB. Additionally, PRA was able to identify the past and present climate change from questionnaires of surveys to information collected by SWCRB people. It is grounded on SWCRB people's knowledge where local people adequately deal with their own experience of climate change (Jull et al., 2017). With the PRA technique, it was feasible to get familiar with the risk, hazards and the main climatic exposure in this research. As a researcher I acted as a facilitator to know the local people's present situation, their own climatic background through the PRA approach, which also enriched this study. In this research PRA was positioned on the statute that local people are inspired to contribute in their own knowledge. PRA is a technique that discovers rural life, their knowledge and conditions by rural communities as well as its stretches out into analysis, planning, and action (Chambers, 1994; Jull, et al., 2017). Hence, it was a reasonable technique to apply in this study as it intently includes nearby communities in recognizing diverse on-going changes, especially climate related events.

To provide the socio-cultural setting in the SWCRB, very petite was understood as a researcher (newcomer) with respect to their view of various on-going climate changes, especially climate change, how they are adjusting to the present circumstance (Bryman, 2016). It was apparent that the best source of data with respect to climate change and sea level rise were nearby community members

themselves. The PRA was utilized for data assortment to get applicable data that is ideally accomplished by observing diverse on-going changes, especially climate change and explicit local adaptation systems. This research utilized a blend of PRA procedures; for example, transect walks, resource mapping, historical climatic events, interviews, and focus group discussions (Flick, 2022; Narayanasamy, 2009). These strategies empowered local people to partake completely by sharing, upgrading and scrutinizing their insight into life, just as to observe and assess diverse on-going circumstances (Bryman, 2016). We gave up the position to local people to do their own analysis, plan and make a move. The single work we had during the PRA process was to work with the activity. The intention behind the utilization of PRA was to accumulate data that could show the everyday exercises of the SWCRB people where the participatory respondents gathered their own information with insignificant help from the researcher. In this research, utilization of the PRA approach improved on the data assortment process as the data was gathered by utilizing non-intricate strategies, for example, conversing with individuals, interacting around the local area, and observing (Narayanasamy, 2009). There are a few tools and techniques of PRA approaches, these tools are portrayed beneath and their contribution in this research is clarified (Omondi, 2020). Transect walks: We visit 12 Unions through utilizing local people guides who best comprehend their Union and represents different climatic issues in the community (Chambers, 1994). During this walk, significant social and actual provisions of the area are recorded (Narayanasamy, 2009). In this research, transect walks included slanting strolls across the researching union, and I had the option to observe, talk about, and pose open-ended inquiries, to the union's people. This methodology was valuable to this review as it assisted the analyst with acquiring the trust of the SWCRB. It was additionally useful to recognize conditions under which climate change might have huge effects in a village. Transect walks were joined with field perception in evaluating the amount of hazard from climate change.

However, transect walks also helped in this research to observe other livelihood activities, which were established as alternative sources of adaptation after the increase of salinity. Some of the activities observed like fish farming in, and small businesses. While undertaking transects walks, we consider using community guides to establish the boundaries of the unions. Local people in SWCRB were then asked questions regarding the findings of the transect walks to give in this research information on level of vulnerability. During transect walks was helpful since it allowed for discussion and further probing on issues related to field observations, which contributed to the positive attitudes of the respondents (Chambers, 1994; Omondi, 2020). Generally, transect walks covered distances of about six kilometers per day.

Resource mapping: We consider resource mapping through the drawn aggregation of the accessible assets in a given local area. They are typically drawn by local people on large pieces of paper for example; housing patterns, water sources, agricultural landscapes, as well as Sundarbans forest area (Jull et al., 2017). This Resource mapping additionally centers around portraying the home layout, nature of lodging in a specific local area, causes of reducing agricultural land in SWCRB,

water filter how far from each village or unions, how they gather natural resources from forest. Resource maps vary from other normal guides as they were made by the local community people themselves and not by researchers. We give permits to local community people to portray just what is imperative to them. Local community members are assumed to have wide information on the environmental factors where they have lived for a long time. Along these lines, the resource map drawn by the local people is viewed as definite and exact (Omondi, 2020).

Resource maps mirrored local community’s perceptions on their changing environment. Mapping was trailed by concentrated conversation on the current circumstance in regards to normal assets in their village, in which the issues and effects of on-going ecological changes were raised (Narayanasamy, 2009). Many local people were given to their opinion that the rainfall is decreases, increasing temperature, sea level rising, salinity increase, increasing shrimp farming and agriculture production decline were the leading problems. Local people informing us that though the awareness on conserving the environment by stopping deforestation had been taken up, the measure was not effective in arresting shrimp farming. As needs be, resource mapping assisted the local people with understanding that the deterioration of climate change and sea level rise had prompted ongoing increment of saltiness in the SWCRB just as different levels of vulnerability through sea level rise.

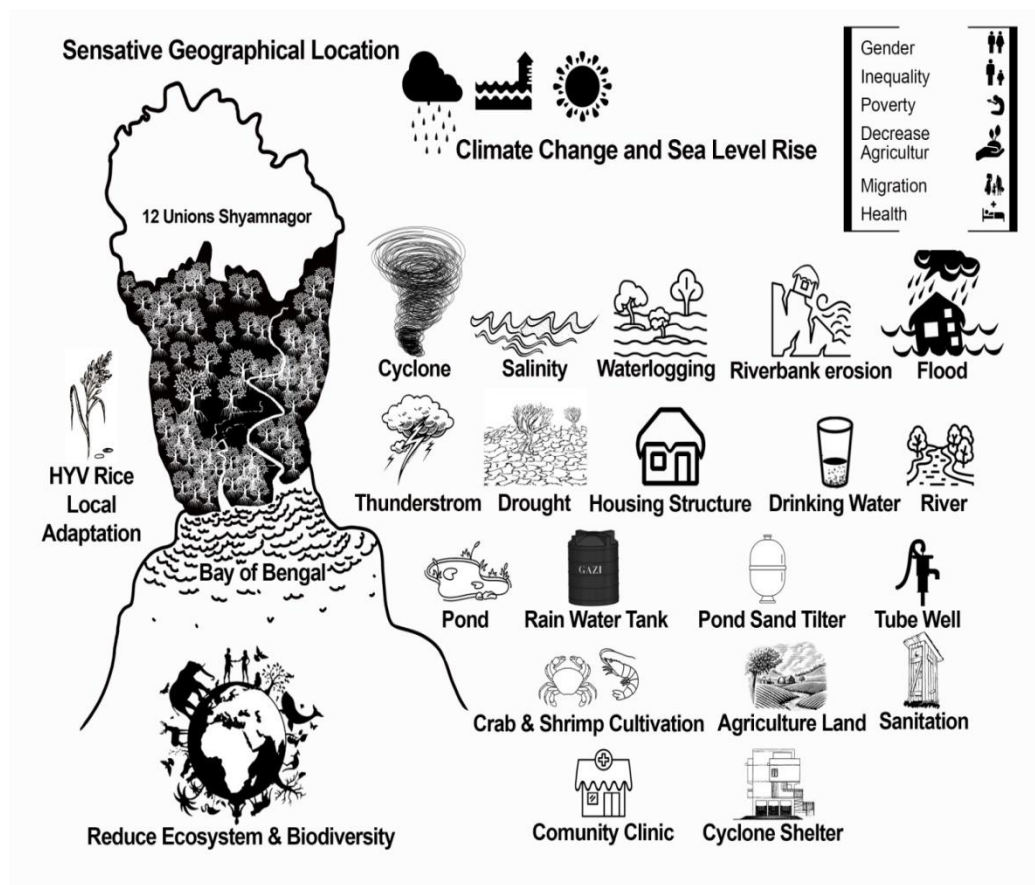


Figure: 10 Local community members portraying a hazard assessment map at SWCRB

A detailed close ended questionnaire all-inclusive of economic, social and environmental aspects of the current justice protocol was used for data collection. Along with literature review and initial desk study, a broad range of Participatory Rural Appraisal tools were used, which included detailed interviews of the key informants (Flick, 2022). Numerous communities meeting with multi-stakeholders were conducted at all the unions under the scope of the study, where stakeholders were asked to present the status of climate change. Following participatory approach, (Bryman, 2016; Jull, et al., 2017) the hazard risk in the exposed SWCRB were identified through 387 respondents voting. We ensured the collection of comprehensive ideas and qualitative information from all types of participants including under-privileged and vulnerable communities, government, and non-government actors.

Interviews

Initially, we talk about how to choose interviews based on different patterns of respondent expertise. The second takes into account the interview as a technique for investigating the reflexivity of human agents in relation to climate change (Flick, 2022). It is important to use interviews as sources of understanding various facets of a layered social world like SWCRB.

From the earliest starting point of my study, an interview was intended with an open inquiry and a testing question toward the end (Flick, 2022). It was Bryman (2007 ; 2016) who recommended some of the pragmatic notional aspects of the interviewees. As leading queries play a pivotal part in qualitative research, we took into account various sections of my investigation questions: (I) general query on Climate Change, (ii) queries about Sea Level Rise and salinity (iii) questions about the mechanism of vulnerability, risk, hazards (iv) questions about cyclone, flood, erosion, waterlogging (v) questions about poverty vi . questions about gender vii. questions about health and safe drinking water viii. questions about migration ix. questions about climate justice, questions about adaptation & mitigation many more. The Interview was providing the basis for the notion of the mechanism of people under research putting up a brave fight towards environmentally stressing elements (Bryman, 2016)—like, cyclones, riverbank erosion, and drought. Also, the ineffective strategies were under scrutiny. With a view to ensuring more sustainability of a resilient approach for Bangladesh, the issues of Disaster Risk Reduction, climate change adaptation and climate justice were put under one umbrella. In order to get an understanding of the contexts in which my interview was carried out, the process of participant observation method was kicked off one month before, the interviews are set to start following conducting of the two methods concurrently so as to underlining an interaction relationship between them (Bryman, 2007). Consequently, more insight was dug out of the involved information providers' perceptions. Then, when it turned out that informants belong to the familiar zone of climate change issues, the field was proven to benefit the interviewer as no considerable amount of time needs to be dedicated for clarification of queries. On top of that, if the data during a relevant interview turns out to

be quite unknown for respondents, the interviewers were equipped with the capability to spot non-verbal visualizing and their everyday livelihood communication instantly (Bryman, 2016).

In-depth interviews (IDI)

Data for this research were drawn from 87 in-depth interviews with individuals from the SWCRB, of all ages (20 to over 70 years old) and a variety of backgrounds (Teachers-7, Catholic Father-1, Community leader-12, Gender practitioner -10 , NGO representative-13 , Fisher flock-11 , Farmers-14, Journalist -12, Doctor -5, Pirates of the Sundarbans forest -1). But all the above-mentioned interviews were included with the Parliament Member, Senior Secretary, Upazila Chairman, Union Chairman, UDMC, WDMC, and indigenous people to gain a broader regional perspective, specifically from climate change and sea level rise perspective. Specifically on climate shocks and vulnerability, and disaster and adaptation like climate resilient practices of their roles, and further needs assessment. At the first stage we contacted high officials, and after we got the appointment we had an interview. Moreover, other participants we communicated through telephone, Facebook messenger and Skype; and after that their convenient time we took the interview. But we took interview one of X- Pirates of the Sundarbans instantly, (when we were in the village for field work, most of the evening time we (researcher) visited local tea stall and that time interchange climate knowledge with other people, once evening one of journalist who always guide to me local area, he told me if want to take an interview with former X-Pirates of the Sundarbans you can take now (Bryman, A. 2003).

Then we (researcher) went to a dark place near the tea stall to take an interview, we discussed with him what the situation of boundless Sundarbans forest is. Why is he in this profession? He answered that the biodiversity status of Sundarbans forest is not very good, people kill the tiger and deer then they sell their skin in black market, in the channel of Sundarbans fisherman mixing the poison with water then they catch fish, to catch a large amount of fish. He said he came to this profession because of poverty but now he did not do it, he surrendered with police but his case was not finished yet. Moreover, we talked about many issues with him for an hour. It's not the climax of Pirates of the Caribbean, every year more or less few natural resource collectors, fish collectors, are kidnapped by the Pirates then they ask their family ransom.

However, a random sample was not attempted; rather, the research team interviewed as many people as possible to ensure a wide-ranging sample of voices, experiences, and perspectives (Morris, 2015; Bryman, 2016). In many cases, people were invited to participate based on their experiences with agriculture, poverty, gender issues, loss of land through river bank erosion ,health issues ,food security status, impact of salinity on water and soil, local adaptation and that interviews were opened during study period for any interested individuals in the SWCRB community. To gather data , interviews were conducted over a various time frame 6-months period July /August/, September

/October / November /December , during study period from 2017-2019, according to the convenient time of researcher(we) and interviewers.

The interviews averaged 30 min in duration, and consisted of a base of 10 semi-structured, open-ended questions, conducted in a free-flowing conversational format to allow for participant elaboration, the personalization of answers, and emergent themes (Bryman, 2007). These questions were created to gain an understanding of community observations and perceptions of changes in climate patterns, fluctuations in seasonal temperatures, sea level rise , rainfall, vulnerability , damage traditional livelihood , loss of home , loss of land, and the socio-economic impacts of these changes in their everyday life , and the in-depth interview were identified effects of these changes on their agriculture production, economy , gender inequality , drinking water , health and migration. All interviews were audio recorded, with consent (Clark, et al., 2021).

The interviews were analyzed descriptively using a rigorous, immersive, constant comparative, multi-step process (Morris, 2015), which consisted of several iterative steps. First, all transcripts were read and reread to discover major topics, community concerns, and overall findings. Second, the interviews were re-read while simultaneously listening to the audio recordings to note nuances and emotions in the voices. Third, a list of key codes and topics was generated from all transcripts to ensure accuracy and authenticity. During this process, the list of codes and topics was refined to produce a final list of codes and topics. Fourth, the transcripts were coded according to this list. Finally, a list of primary findings and quotations was shared with the interviewer to ensure accuracy, authenticity and relevance to the research context (Bryman, 2016). It is important to note that these topics of climate-related vulnerability, risk, adaptation and justice challenges emerged entirely from this PhD research, as this research was primarily structured to explicitly examine the relationships between climate change and sea level rise, and the questions sea level rise directly came from climate change ; rather, some of the most prominent topics emerging from the participant" responses to observed and perceived climate change impacts and variability on their lifestyles, livelihoods, capabilities and overall adaptation were all related to community-defined climate issues. These topics and ideas about sea level rise, salinity, agriculture, health, gender, lack of safe drinking water, migration, adaptation and justice have been consistently tested and re-examined with SWCRB community people, community stakeholders and NGO staff; to ensure that the understanding and dynamics of these themes resonated with the communit"s understanding of climate change and reflected community terminology used to describe climate change issues.

Key informant interviews (KII)

This research was collected using the"key informan" technique which involved discussions with selected key informants during the study period (Phong et al., 2019; Clark et al., 2021). The strategy

follows the collection of qualitative in-depth data on climate-related issues; Instead of bringing simple facts about the subject of this study (Bryman, 2017). Thus, the approach is unlike any other because it helps generate challenging opinions from SWCRB community members who have extensive knowledge and understanding of current and past conditions of climate change and sea level rise. (Eg, family = (activities and capabilities) -livelihood = (agriculture + natural resource collection + others) - impact of climate change (income + social inequality) = poverty, gender inequality, migration and injustice etc. It illustrates the essential stages of the technique which include questions (the same quantitative survey questions used earlier in this study are considered here), as well as observational selection of key informants. An important focus of the strategy is the amount of key informants involved. Quantities were necessary to ensure an acceptable representation of a variety of participant experiences and interpretive concepts. In previous studies, the number varied from 12 to 35 (Bryman, 2016). The current study involved 22 key informants and this number was decided on logistical constraints such as time and resource accessibility to reach appropriate key informants.

An initial list of potential key informants was drawn up in consultation with the local administration (Phong et al., 2019). The Southwestern Coastal Region Bangladesh community comprises people and researchers who have been actively working in the region for more than 2 years.. Key informants were then selected based on their availability of knowledge and issues related to vulnerability, risk, hazard, and adaptation. Key informants were first contacted by telephone, Facebook Messenger, and Skype; Study information was clarified and verbal consent was obtained to participate during the interview. Key informants were then classified into three groups: communities (both vulnerable and protected), knowledgeable individuals, and government and NGO officials. An interview session began with an overall introduction to the study followed by clarifying the study's objectives and terms used (Clark et al., 2021). These phases were shadowed by employing specific questions in a predetermined order for key informants to answer. Quantitative survey questionnaires from this study were arranged to begin with general topics and then for information that required in-depth thought by key informants. All interviews were conducted under this research. Each discussion, lasting between 30 to 40 minutes, was audio recorded and systematically dictated the question list (Phong et al., 2019).

Workshops

This study draws on qualitative research to illustrate how vulnerability, risk, hazard, adaptation and justice have progressed in SWCRB communities. The primary research exercise was 9 group of workshops with invited participants (Ørngreen, and Levinsen, 2017), between 2017 and 2019 SWCRB. The study organized n=9 workshops meeting with the school students, college students, mix participants, and guidelines were prepared to sort out on climate shocks and vulnerability, adaptation practices , justice , gather local people experiences, knowledge, and climate resilient practices. As

well as research were searching validations of qualitative and quantitative information (Shaw, 2006). The workshop began with an introductory presentation to clearly define (Ørngreen, and Levinsen, 2017) climate change, sea level rise, adaptation and justice. The researchers (we) discussed historical climate trends, data on regional climate variability, and future climate projections for the region. This presentation was provided as a discussion for participants to review prior to the workshop (Thoring et al., 2020), and the discussion of climate information served as an important capacity building tool among local SWCRB populations. Full participation of respondents by this research was encouraged who are interested in how climate change affects sea level rise, salinity, local infrastructure, land use, agriculture, poverty, health issues, gender imbalances, adaptation, and social justice. Workshops are a rapid, and often enjoyable, research method that encourages communication among participants to produce quality feedback (Ørngreen, and Levinsen, 2017). This Research facilitated people to share their ideas effectively and to encourage dialogue among participants.

Each workshop was divided into three groups, so each group had an experienced facilitator who was briefed beforehand on the purpose of the exercise (Thoring et al., 2020). Groups prioritized ten top influential vulnerability and adaptation of climate change and could have indicated two more important influences. These findings were used to develop a key list of priorities (Shaw, 2006) for adaptation, mitigation and justice. Prioritizing and outlining implementation, researchers compile workshop outcomes into a dominant list that represents all relevant Climate change and sea level rise impacts, and presented by workshops plenary for finalization. After that participants explained the key factors of vulnerability, risk, and their local adaptation methods, a detailed outcome of the research information which is included in different sections of this study.

Participants were then instructed to examine each impact individually from the impact list and assess it (Thoring et al., 2020) in terms of its risk, outline the climate impacts of the SWCRB, indicate top adaptations for implementation, and provide further comments and ideas regarding impacts. Vulnerability, risk and adaptation assessments were the most important findings collected by key participants, and these findings were used to prioritize climate impacts. Finally from top Climate Impacts we collect each participant's written expression for each climate event, such as how climate change affects gender issues /poverty/ agriculture / livelihood/ health/ safe drinking water/ adaptation /justice.

The response was excellent and the delegates were class 10 students, teachers and staff, college students along with teachers and staff and a mix of participants (local people, farmers, shrimp farmers, honey collectors, women representatives, local government, government officials, Journalists, NGO workers, UDMC, WDMC, Tiger Team, Tiger Widows, Fish Collectors). The study yielded tremendous information from the workshops which were duly presented by the above mentioned respondents.

Case study

Case study is used for in-depth investigation. It is an ideal methodology that is able to run a holistic investigation (Feagin, et al., 2016; Bryman, A., 2016). Since case study spans its focus on the analytic domain in a comprehensive sense, such an approach is optimum for carrying out the qualitative research within duration of study. Case study research configuration eludes to the system which targets exploring a contemporary scenario inside its genuine setting, especially when limits among scenario and setting are not plainly obvious, like the climate vulnerability and justice (Yin, 1984, 2003; Woodside, 2010). This plan joins information assortment strategies like surveys, meetings, and narratives just as text examination. Both quantitative techniques (generally concerning information and dimensions)) and qualitative information assortments and examination strategies (for the most part generally linking arguments and explanation) were utilized to know how climate change affect the livelihoods of local populations(Yin, 2003).The significant goal of this contextual analysis investigator is to foster a significant comprehension of participants (in a particular case like salinity , safe drinking water , gender inequality , agriculture , poverty , adaptation) through their interactions, opinions, and practices throughout a particular timeframe (Woodside, 2010).

The case study research outline has the accompanying qualities as per Mills; interrelationships establishing the setting of a particular objective (a case); examination of the interchange between basis factors and the element being considered; and the reasonable motivation behind utilizing bits of knowledge (of communications between the logical connections and the relevant climatic objective) to create hypothesis as well as add to existing hypothesis (Mills et. al. 2010; Feagin, et al., 2016). One of the chief components of contextual investigation research is the utilization of different sources of climatic driven events proof, each with their own qualities and shortcomings since any one source of proof is probably not going to be proper all alone (Quintão et al., 2020), therefore we were taken 154 short case and 41-Case study . This is urgent in guaranteeing the legitimacy of the information, wherein the strength of one source can offset shortcoming of another (Mills et. al. 2010). Also, on the off chance that study research plans, pre-imagined thoughts or hypothetical thoughts (deduced) are not appropriate. Until the specialist engages in information assortment and comprehends the setting of a specific scenario it is hard to tell which hypothetical clarifications will be material or bode well for that particular case (Feagin, et al., 2016).

The contextual climate change analysis research configuration is pertinent: when this research are intending to react to an address climate change like how or why, when the author (myself) has little authority over the occasions being noticed, but when there is a gap to address inside a real life situation of climate change and sea level rise issues. This exploration configuration is likewise advantageous when there is a need to cover climatic context-oriented circumstances that are appropriate to the wonders under study or there are obscured lines between the climatic phenomena and the encompassing setting, eg, Vulnerabilities, wealth inequality, empowerment, ‘rendering technical’, justice (Quintão et al., 2020).

One of the vital qualities of a case study research configuration is its variety as far as climatic crucial, influential and collective methods, which were taken into consideration both quantitative and qualitative investigations of the information to compare the collected whole data. Longitudinal examination of individual subjects, for instance, relies upon qualitative information from diaries, which was given these research illustrative records of conduct. Then again, research has distinctive case studies, which used proof from both the factual and unmitigated reactions of individual subjects (Yin, 2003; Woodside, 2010). The qualitative data, frequently delivered in the research that's are not only simply help to clarify the information, in actual conditions, yet additionally help to depict the challenges of the genuine circumstances, which may not be able to took through experimental or survey research, e.g., hidden social Intersectionality (Feagin, et al., 2016). Regardless of these qualities, a case study research analysis isn't liberated from limits as it has gotten criticism from various researchers therefore this research considers multidisciplinary analysis (Yin, 1984, 2003; Mills et. al. 2010). Probably the most grounded reactions were introduced by Yin (1984), who blamed the case study research plan for lacking thoroughness.

As life is not conducive in any aspect for these community people, it is essential to understand how they could survive, what their untold voice is in the SWCRB against the climate change debacle. They have limited alternatives to migrate elsewhere despite worsening circumstances. Thus, it is necessary to note if they will be able to adapt to the change. The case studies in our research were designed based on our research question. For example, primarily, a list of individuals facing vulnerability due to climate change was generated, and their extent of vulnerability was discussed with the participants. If the participant was indeed vulnerable, an appointment was fixed, and the participant was briefed on the further design of the case study. Then the case study was analyzed and the interviewee was mentioned in the research aim and goal. They were briefed regarding the importance of our study topic during data collection and while concluding the study. They were also shown what was written and recorded during the case study, and their permission was obtained to use their case studies in our research.

Short Case studies

Short cases and case studies were collected on climate change and gender, gender vulnerability of coastal communities, social inequality, economic activities, climate justice, community-based adaptation, empowerment, food security, shrimp farming, drinking water, livelihood, adaptation etc, and most of the case studies were audio recorded. This research was facilitated with the knowledge of understanding the survival mechanism for vulnerability of women and their adaptation in the SWCRB. As earlier we mentioned , these study was gathered around 154 sort cases and 41 contextual investigations on Gender, saltiness interruption in drinking water, Water, Housing Structure, Diseases, Migration, destitution, poverty perils, sea level rise, cyclone, health, food

security, Bangladesh media and climate, climatic resilient, Farakka Dam, Agriculture, adaptation varieties, mitigation steps, biodiversity, forest, fish accessibility, river erosion, precipitation design, preparedness against hazards, warning system, training, traditional livelihood, shrimp or fish enclosing setting, land utilization of shyamnagar, weakness vulnerability of coastal indigenous inhabitants, climatic injustice, social inequality, flood, social disparity , economic activities, dry spell, Climate Justice, community based adaptation ,food security, shrimp farming , drinking water, livelihood , adaptation etc. from the community people.

Quality assurance

Team Composition and training for the enumerators

For this 2nd and 3rd quantitative data collection stage, I was organizing collaboration for gathering close-ended survey questionnaires. The investigation group was made up of around 2 female information gatherers whose backgrounds are from investigation region (SWCRB) and they were generally graduates from Shyamnagar College, who are working various NGOs in short term and locally, who have sound information about climate change. Before collecting the data, we were arranging a two days training program where we informed them of the total research plan as well as giving the idea about climate change and sea level rise and to discuss survey questionnaire meaning and how to interact with respondents, how they will collect data independently without any intervention of others. In-depth two days' orientation/training session organized for the data enumerators on understanding tools, data collection ethics, quality control and management of the process of data collection. After orientation study conducted a field test for quantitative questionnaires to gain more understanding on tools accordingly.

The quantitative information was dependent on the household's survey of 2282 respondents under Shyamnagar Upazila 12 Unions which was done with the help of 2(two female) individuals assistants, it could be mention here that at the first stage of research the author was collected 320 household interviews by him. After that, this research involved women mediators to collect data from women because women did not feel comfortable being interviewed by with male researchers and due to social and cultural norms many women were not interested in household surveys. Hence, to collect more information from the study area like risk, hazard, adaptation and safe drinking water, health and local adaptation the author carried out a short term interview with (387+ 1575) households. This weight of quantitative data was analyzed through the SPSS-25 software. Some essential sources had been utilized from measurable reports of Bangladesh Bureau of Statistics.

At the end of quantitative data collection we were collectively visited at field level for Qualitative data collecting from female respondents. A Large number of women agree to give their interview in front male researchers, but who maintain Islamic Veil system they did not come in front of male

researchers. At that time 2 female assistants were taking their case study /interview, and researchers were waiting in and near place to listen to the interview.

Moreover, researchers play the main role to act as overall supervision for all data collection as well as to assist in collecting quantitative and Qualitative data information and data processing. Researcher was also involved in collecting data for every stage and facilitator's, 2 female students, worked under the guidance of Researcher. Researchers are collecting data each day from 9 am to 8 pm. after that we organize collective meetings and scrutinize gathered information. In total 128 quantitative survey questionnaires that were also used for qualitative data collection for cross check data reliability and validity. This weight of quantitative data was analyzed through the MAXQDA software.

A written instruction on data collection was supplied to the enumerators. Following steps took into consideration for the quality control and ethical practices for the study:

- Two days' orientation was provided to understand data collection methods, quality parameters, and overall guideline for field data collection
 - We are deploying local enumerators with local language
 - Author Oversee data collection and provide guidance and feedback to team members
 - Cross checking with questionnaire time to time
 - Mediator team sited every afternoon/ evening to recheck and learning sharing the field information and make a conclusion for qualitative data.
- During field work the author/myself diligently checked for completeness and consistency of the information returned on a daily basis
- The notes from case study, KII, IDI, and workshop was recorded and subjected to content of the indicator in this research
- 30% of total qualitative and quantitative data sample was reinterviewed by myself and compare with the mediator's questionnaire to confirm and re-check the information, data and validity.

An observation guide was used to collect data during the time of Qualitative Methods and the observations were recorded in field notes and to ensure validity, transferability and reliability.

Data treatment and data exploration

Data were collected using offline paper-based application and computed by in Foxpro. Data editing, cleaning, query was done by using MAXCODA, MS-excel. In addition, for analysis, SPSS-25 (Statistical Package for Social Science) used to process the data and produce descriptive table (frequency, average, ration, percentage, classification, cross tabulation), Anova test, Correlation, regression, and other relevant test were taken place for data analysis. Secondary data was sourced

from various written documents including relevant book, research paper, journal, magazine, newspaper so on.

3.5. Research ethics

The data was collected in this research through qualitative and quantitative methods. Qualitative data collection techniques, such as focus group discussions (FGDs), case studies, questionnaires, workshops, in-depth interviews, and field inspections were used. The quantitative data collection technique included (n=320+387+1575) household surveys (Robinson, 2014; Taherdoost, 2016; Bryman, 2017). Both methods of data collection took place during various time frames between 2017 and 2019. A researcher must place the highest level of significance on ethical issues while designing a research agenda and collecting data (Cannella, and Lincoln, 2011). While collecting data from the investigation area (SWCRB) this research put significant value on ethical accounts. First a researcher informed them about the aims and objectives of the research. The recorder was used by the author for writing down the discussion. Consent for recording the discussion was obtained verbally, and the researcher explained to each interviewee the purpose of the research (Miller, et al., 2012).

We asked for permission to use names and to cite their comments for the purpose of this research and made a verbal agreement with them on this regard. Most of them agreed to this research proposal and some of interviewee permitted us to use names and information. They were well informed that participation is completely voluntary, and they also had the right to refuse to answer any questions, if needed (Bryman, 2007; Bryman, 2016). The participating members of the community established respectful appreciation by providing their valuable contribution for this research. All members were encouraged to talk freely and ask questions at any time during the all session and each participant's consent were recorded using predetermined format (Clark et al., 2021). Then, with the consent of the participants, climate change, sea level rise, vulnerability, risk, adaptation, safe drinking water, health issues, migration, agriculture and climate justice checklist was used demonstrating other benefits. Moreover, driven a guided survey and discussion helps that one single respondent cannot dominate the survey and discussion and everyone gets an opportunity to contribute in the survey and discussion session (Vehovar, et al., 2016.) to develop the exposure factor of climate change issues. We have coded the identities of research interviewees where information is personal or sensitive. Most of respondent's names were not included in our research as we used Respondent/Participant-1, 2, 3, 4... or A, B, C... X Y and Z because of qualitative research ethics. A few names were used because she/he did not currently face social challenges, and his/her name was useful to face climate change challenges for many people (Bryman, 2003; Bryman, 2016).

Before making a decision, different variables were verified and cross-checked, and then classified statistics were analyzed in terms of quality and quantity (Sieber, 2012). An observation guide was used to collect data during the case study, FGDs, KIIs, IDIs, and workshops. The data was recorded in

field notes, audiotapes, and transcribed. The data analysis was consistent as it entailed two parts: First, reading the recorded field notes to reinforce hypotheses or themes developed during the data collection phase and to generate new hypotheses or themes (Morgan, 1996; Bryman, 2016; Feagin et al., 2016). The data obtained were further analyzed quantitative and qualitatively. This first step is referred to as initial coding or open coding (Given, 2008). The second part is to notice and systematically create records of patterns in the conversations and activities of people depicted in the notes or create coding frames. The initial coding of the collected data material guidelines for coding (Yin, 2003; Woodside, 2010) was applied to ensure credibility, transferability, and dependability.

Household surveys were carried out through close-ended questionnaires to capture responses from respective respondents for capturing the nexus of climate change. The close-ended questionnaire consisted of household survey data collection from household heads together with interviews of family members (where is permissible) (Table 2) (Bryman, 2007; Given, 2008). During the close ended questionnaire surveys, interviews were focused on male and female respondents from each household. However, the women were generally due to religious taboo and traditional norms they are hesitant to give interviews with male researchers. To realize such a comprehensive understanding of the relationship between gender and climate change, in the 2nd and 3rd stage of research we recruited 2 (two) female facilitators for a short term. The respondent quota was distributed proportionally depending on population size in the respective areas using simple random sampling (Llewellyn et al., 2004; Marshall et al., 2013; Robinson, 2014, Taherdoost, 2016; Vehovar, et al., 2016). For example, primarily, a list of women facing vulnerability due to climate change was generated, and their extent of vulnerability was discussed with the participants. If the participant was indeed vulnerable, an appointment was made, and the participant was briefed on the further design of the case study. Then the case study was analyzed, and the interviewee was mentioned in the research (Yin, 1984; Feagin, et al., 2016). They were briefed regarding the importance of our study topic during data collection and while concluding the study. They were also shown what was written and recorded during the case study, and their permission was obtained to use their responses in our research.

This research was facilitated with the knowledge of understanding the survival mechanism for vulnerability of women and their adaptation in the SWCRB. During the interviews, FGDs, Case studies, workshops and questioner survey when we asked the questions to the respondents, we observed their eyes, body language and their conversation, we try to understand their motivation and information whether it is truthful or not (Bryman, 2016). We also cross checked respondents answers with each and other (for the same questions) for reliability and validation of information (Lavrakas, 2008; Given, 2008; Mills et al., 2010; Morris, 2015; Silverman, 2015; Bryman, 2016; Feagin et al., 2016; Jull et al., 2017). We like to give due credit to the respective writers whose data we used in this research as secondary data and considered them as authentic and reliable sources; and in the list of reference we have mentioned their names with details.

Limitations of the study

Applying multidisciplinary methods of analysis in accordance with examining datasets, this research assesses the "Climate Change in Mingling-State: ..". The assessment of the results is confronted with several challenges, mainly the availability of data, accuracy of the datasets, and the accuracy and interpretation of the analyses. However, SLR and salinity future impact assessment was a prediction, but most of the time it will happen in the coming years. We collected water and soil samples only once, during the early rainy season, and seasonal variability of salinity concentration in water in coastal Bangladesh had been observed with the highest concentration being during the dry season (March -June). This study provides a useful insight into the impact of climate change and sea-level rise on the well-being and livelihoods of local populations. Moreover, vulnerable socio-economic issues are combined with climate change-driven disasters which are create poverty, gender inequality, health impacts, migration and lack of safe drinking water, and thus increases climate injustices. Qualitative and quantitative data provided useful insight into community perspectives on agriculture, gender issues, health impact, wealth inequality, poverty, lack of safe drinking water migration and social injustice. While examining vulnerability, risk and adaptation discussion topic, such as which socio-economic issues and factors most impact climate change-driven disasters and vulnerability to SLR in the SWCRB, information and opinions from respondents are briefly referenced in this research, but all respondents' views from the first to last, it is difficult to support in a study. But this is positive in the sense that research creates a broad foundation with many points of view but a limitation in the sense that it is very difficult to find all socio-economic silent issues. It is a subject surrounded by uncertainty because a small number of people do not want to explain their limitations in front of the researcher.

4. Dynamics and Causes of Sea Level Rise in the Coastal Region of Southwest Bangladesh at Global, Regional, and Local Levels

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Abstract: Global greenhouse gas emissions have caused sea level rise (SLR) at a global and local level since the industrial revolution, mainly through thermal expansion and ice melting. Projections indicate that the acceleration of SLR will increase in the near future. This will affect coastal and deltaic populations worldwide, such as in Bangladesh, where almost half of the population resides in regions lower than 5 m above sea level. This study analyzed three coastal tidal gauges and five deltaic gauge stations, which showed increases in SLR at greater rates than the regional and global averages. This research also used satellite altimetry data to analyze regional and global SLR averages in the recent past and the 21st century. There is a trend towards increasing sea level based on results from three tide gauge stations: Char Changa with 7.6 mm/yr, Hiron Point at 3.1 mm/yr from 1993 to 2019, and 14.5 mm/yr at Cox's Bazar from 1993 to 2011. Based on the linear trend from these time frames, it is projected that SLR in Char Changa will increase by 228 mm cm from 2020 to 2050, and by 608 mm by 2100, at Hiron Point by 93mm in 2050 and 248 mm by 2100, and at Cox's Bazar by almost 435.7 mm by 2050, and more than 1162 mm by 2100. Based on an average from satellite altimeters, assuming a linear increase in SLR, the Bay of Bengal shows an increase of 0.4 mm compared to the global trend. Other river delta stations in the study area also show increasing SLR, specifically, at Kalaroa, Benarpota, Kaikhali, Tala Magura, and Elarchari. Kalaroa and Benarpota show the highest, with SLR of >40 mm/yr. It is also observed that increasing SLR trends are far higher than coastal tide gauges, indicating that physical processes in the delta region are affecting SLR, further contributing to either an increase in water volume/SLR or activating land subsidence. This is partly due to the subsidence of the delta as a result of natural and anthropomorphic effects, as well as an increase in Himalayan glacier melting due to global warming. This indicates that Bangladesh coastal areas will soon experience a far greater SLR than the rest of the Bay of Bengal or other global coastal areas.

Keywords: : South Western Coastal Region (SWCR) Bangladesh; tide gauges; satellite altimetry; land subsidence; sea level rise; river delta

1. Introduction

The rise in average global surface temperature in the later part of the 21st century (2081–2100) is forecast to range between 1.5 °C and 2 °C, along with excessive rainfall occurrences, warming of the world's oceans, and a sea level rise (SLR) of 8–16 mm/yr [1,2]. The continuous trend of greenhouse gas emissions (GHGs) will contribute to temperature rise, increasing the probability of unchangeable consequences for the environment, and exacerbating prevailing threats while creating new perils [1,2].

At the same time, the atmosphere is experiencing higher concentrations of carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) than in the last 800,000 years, and projections for sea level indicate a continuous increase even after GHG emissions decline [1,3]. During the 20th century, global SLR experienced an increase of approximately 2 mm/yr, which is comparatively greater than in the last 3000 years [1]. From 1901 to 2018, the worldwide average sea level rose by 0.20 (0.15 to 0.25) mm and the regular proportion of sea level rise was 1.3 (0.6 to 2.1) mm/yr from 1901 to 1971, swelling to 1.9 (0.8 to 2.9) mm/yr from 1971 to 2006, and additional swelling to 3.7 (3.2 to 4.2) mm/yr from 2006 to 2018 [1,4,5]. However, the precise projection of future SLR needs continuous observation and modeling of the integrated ice–ocean–land–atmosphere–climate dynamics [6,7]. Thus, a strong initiative is needed to have reliable data tracking from satellite altimeters and independent ocean observation systems. Along with this, studies from various disciplinary initiatives are necessary to deal with serious issues which include improving the historical recording of SLR and ocean temperature increase, isolating geophysical processes from sea level increase signals, as well as the comprehensive perception of the interactive relationship between oceanic surface and ice sheets [6,7].

GIA (global isostatic adjustment) is a modeling procedure that is related to the adjustment of Earth's lithosphere and viscous mantle material to past changes in ice loading since the last glaciation [8]. GIA can, thus, contribute to important meridional differences in mean sea level (MSL) change, as is seen in sea level projections for tide gauge locations in the UK [9,10] and Scandinavia [11]. The spatial patterns for GIA in the tropics feature more homogenic and much smaller contributions to local MSL change compared to high latitudes. The contributions from GIA in the South Asia Region to overall sea level rise are generally insignificant [12].

As a result of global warming, SLR is driven by two primary mechanisms. A first, glaciers and ice sheet melting at faster rates contributes to the increase in large volumes of freshwater into the oceans. Secondly, the volume of water in the oceans is increasing due to the expansion of water from the rising temperature. A third minor mechanism is the net transfer of water from freshwater lakes and rivers to oceans [1, 13].

However, the rate and magnitude of SLR will not be equally distributed among the world's coastal regions. Coastal regions, for instance, experience subsidence due to sediment compression from construction loading, soil erosion, and extraction of groundwater, natural gas, and petroleum resources [14]. Adverse outcomes of SLR include increased flood risk, loss of coastal buffers to hurricanes and flooding, exposed coastal waters to waste stored on land, saltwater intrusion into freshwater aquifers, as well as economic losses [3, 15–17]. Furthermore, several nations experiencing the highest repercussions of SLR are not the primary emitters of GHGs. Bangladesh is ranked 162nd of 199 nations by the World Bank with regards to CO₂ release, revealing exceptionally disproportionate consequences of climate change [18,19]. Moreover, resettlement efforts are severely hampered by the turbulent geopolitical atmosphere in South Asia, which will be exacerbated by climate change and SLR [20–23]. These circumstances underscore the urgent need to diagnose and understand the dynamics of sea level rise in Bangladesh.

Furthermore, one of the most significant casualties of climate change and SLR is reported in Bangladesh, as approximately half of its population resides 5 m below the sea level and is the world's sixth top calamity-stricken nation [23–27]. Due to Cyclone Bhola in 1970, Cyclone Sidr in 2007, Cyclone Aila in 2009, Cyclone Amphan, in May 2020, and the great flood of 1998, millions of people in Bangladesh have been rendered homeless, with hundreds of thousands of casualties [28–34]. In the near future, SLR will lead to the disappearance of 17% of the territory of Bangladesh, create 20 million refugees, and 220,000 km² of land will be submerged following a projected SLR of 1500 mm

to take place within 150 years (According to CGTN, new research assumes that SLR will create 37 million refugees in Bangladesh) [33,34].

The impact of sea level rise in the southwest coastal region of Bangladesh (SWCRB) is exacerbated by phenomena such as floods, eroding coastlines, increased storm frequency and intensity, rising water tables, saltwater intrusion into aquifers, and ecosystem changes [35]. Simultaneously, the SWCRB receives freshwater and sediments from northern glaciers in the Himalayas that flow into the Ganges. Based on global warming predictions, Bangladesh will experience a dwindling glacial landscape outside the global level that would cause an SLR in the Bay of Bengal and its river delta [35, 36].

It is also essential to observe the sea level and its fluctuations, especially along coastal areas due to the number of inhabitants occupying these areas. To do this, self-recording tide gauges (TGs) were used to gather the first historical sea records in the mid-18th century. *In this study*, to assess coastal SLR changes, tide gauge (TG) records serve as the main source of available information, as they were designed to measure Regional Sea Level (RSL) at their locations [37]. Thus, TG measurements also record Absolute Sea Level (ASL) changes that reflect local vertical land movements in geoid changes. In our analyses, annual averages of TG data were used to identify SLR in the Bay of Bengal. The tide gauge data for all station on the Bangladesh coast are limited by short recording periods, missing data (from certain years), and station instabilities. The three stations that provide data for about two decades without major interruptions are: (a) Hiron Point in the Sundarbans mangrove forest area (southwestern Bangladesh), (b) Char Changa in the Meghna estuary (central Bangladesh), and (c) Cox's Bazar on the southeast coast. The original tide gauge data are monitored and collected by the Government of Bangladesh Inland Waterways and Transportation Authority (BIWTA), while the tide gauge data for the Ganges Delta were obtained from the Bangladesh Water Development Board (BWDB) [38, 39].

Tide gauges have been the standard method to measure coastal sea level changes. The last few decades, however, have seen advancements in space-borne radar altimetry that provides new outlooks on global sea level changes. The use of satellite altimetry to monitor sea level was revolutionized when the US/French mission TOPEX/Poseidon (CNES/NASA) was launched in August 1992 [40]. Using a geocentric terrestrial reference frame to measure the sea surface height and estimate sea level temporal variation is a main advantage resulting from the satellite radar altimetry mission [41,42]. However, the in-situ sea level temporal variation is measured from TG references to a particular ground station [43]. The readings provided by the satellite altimetry provide more precise measurements in a low temporal sampling rate, and wide resolution, with a well-defined geocentric reference frame, compared to the low spatial and high temporal resolutions of tide gauges. Due to the satellites taking periodic measurement, usually 10–35 days, the altimeter measurements can determine global mean sea level change superiorly to tide gauges. This is because tide gauges describe high-frequency variations, such as tsunamis or any extreme sea level event that has long-period processes. Spatial and temporal coverage have been provided by satellite altimetry for almost a decade, providing important information on a one-month to several-years' time scale on mean sea level changes [39]. As such, it is essential to study the long-term changes in sea level on the coastal zone, as much of the world's population resides in these areas, as well as for other environmental and socio-economic reasons [44, 45].

Our study showed variations in sea level and trends in the Bay of Bengal and globally, using multi-mission satellite altimeters. This research aims to determine the future sea level rise in Bangladesh and its coastal river deltas, which will be compared to global sea level rise and sea level rise in the Bay of Bengal, its river deltas, and its impact on local, regional, and global levels.

Relative Sea Level Rise

Relative sea level rise (RSLR) is a reaction to climatic as well as non-climatic contributors and differs with situations [46, 47]. RSLR depends on local shifts in water flow, air flow, saline concentration, and water temperature [48]. The relative sea level is defined by the limit of the subsiding delta plain (considering that the delta is close to or at the base level), and the seaward gradient of accommodation. The pattern of subsidence is found for the Ganges–Brahmaputra–Meghna Delta (GBMD) using its Holocene relative sea level history. The results show that there is Holocene subsidence over the delta, and that it increases from the Hinge Zone (landward) to seaward from <0.2 mm/yr to 2 ± 0.7 mm/yr in the middle fluvial delta and, in the lower tidal delta, to 4 ± 1.4 mm/yr. This provides us the opportunity to create a first millennial-scale map of the GBMD on its subsidence pattern [49,50]. RSLR is more rapid than typical global patterns in collapsing coastlines, inclusive of deltaic regions such as the Mississippi, the Nile, and the great deltas of South and East Asia (e.g., the Ganges deltaic region in Bangladesh) [48]. Nevertheless, RSLR is attributable to a more neighboring or regional extent, such as crustal deformation, tectonic shifting, volcanic activity, ground subsidence from nature-induced reasons (e.g., sediment filling rivers and deltaic areas), or human actions (groundwater or oil/gas extraction). Some communities and nations may face faster or higher RSLR than the global average rate due to complicated interplay between geomorphological and ecological features of the coastal setting, as well as mitigating capacity [50,51]. Due to this, understanding the extent of RSLR in coastal environments is essential. For instance, the Bay of Bengal was created after the India–Asia collision, thickening of the Tibetan Plateau, and the uplift of the Himalayas. Furthermore, the Bengal Basin is divided into three geotectonic provinces: 1. The northwest consists of a stable shelf, and the west has a passive-to-extensional continental margin. 2. The center has a deep basin. 3. The east has a fold belt, namely, the Chittagong Tripura Fold Belt (CTFB) [52]. It is argued, however, that the northern Bay of Bengal is considered “thin continental” after it endured continental rifting and was exposed to volcanic activity from the Kerguelen hotspot [53]. When it comes to the deposition of sediment in the Bay of Bengal, it has been speculated that tectonic cycles or stages regarding the interaction and collisions of major plates plays a role. There have been five phases thus far: 1. Syn-rift stage 2. Drifting stage 3. Early collision stage 4. Late collision stage 5. Latest collision stage. Furthermore, sediments originating from Himalayas and the Indian Peninsula that are transported by the Ganges and Brahmaputra Rivers are considered to be mostly detrital than biogenic [52]. As the Bengal Basin accumulates a large amount of sediment through faulting, folding, and compaction, the Bengal Basin margin shows a prograde of more than 300 km in the last 35 million years. When it comes to human interactions, the geological exploration in the Chittagong Tripura Fold Belt (CTFB), for instance, has increased due to more earthquakes and structural complexities (i.e., thrust faults and mud volcanoes) [54]. Furthermore, national and international oil and gas companies have conducted seismic surveys and drilling due to the presence of anticlinal folds and faults related to gas seepages [52].

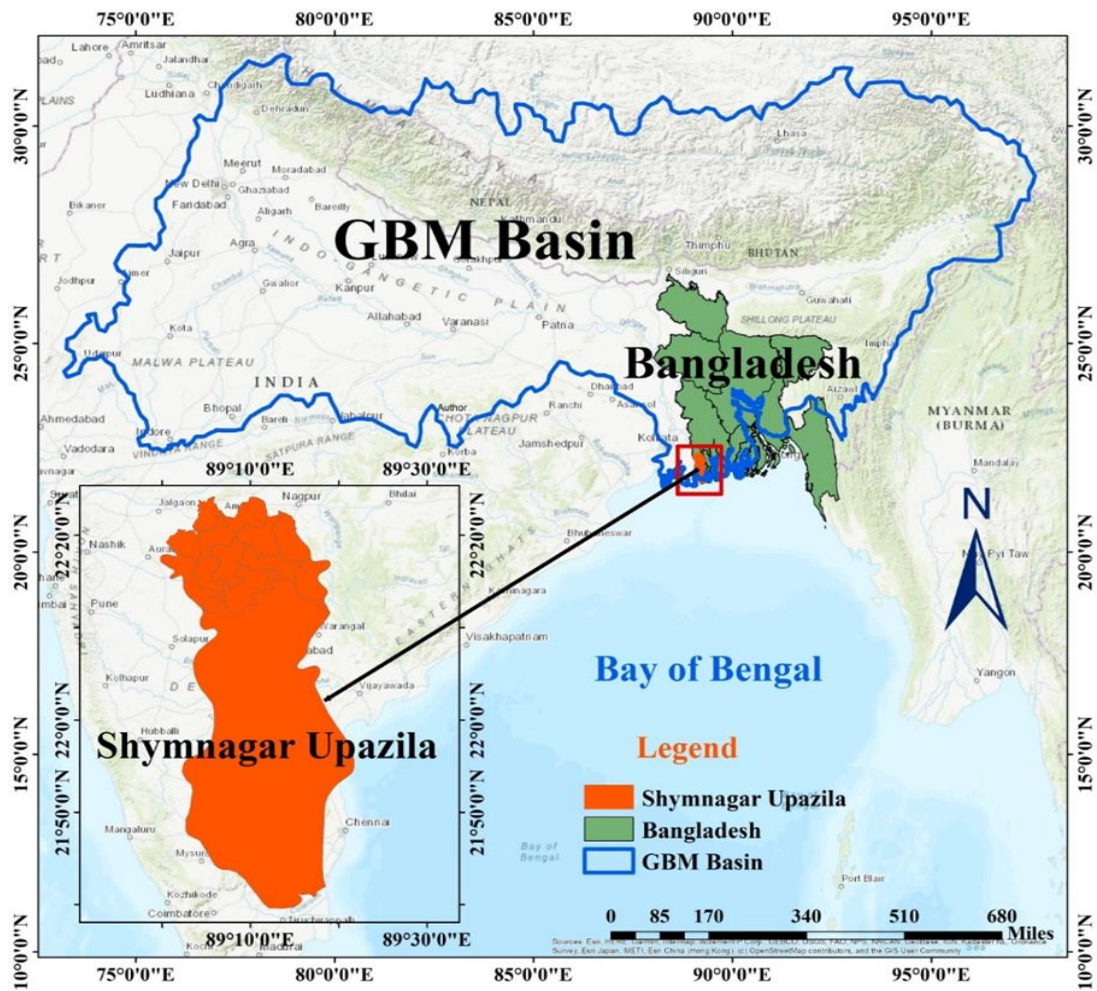
One of the major instances of relative sea level changes is seen in the vicinity of the Bay of Bengal, depending moderately on changes in the measurements of the ocean where sea level increases at a risky rate in comparison to land [55–57]. South Talpatti Island, or Purbasha, was a coastal island in Shyamnagar Upazila of Satkhira district in Bangladesh. However, due to SLR in Bangladesh, South Talpatti was lost to the sea in the Bay of Bengal in the late nineties [58,59]. This indicates that the southern part of Bangladesh, especially Gabura and Padmapukur unions, will be submerged. Both of these unions were under water at the time of Cyclone Aila. Moreover, the inhabited island of Lohachara, located at the mouth of the Hooghly River in India, adjacent to the Ganges Delta, gradually sank in the 1980s [60–62]. During the previous 30 years, the relative sea level has increased quicker than the global mean sea level (GMSL) (high confidence) in the area near Asia. Within the timeframe 1984 to 2015, the entire region of the coastal neighborhood diminished and the coastline

attenuated; however, some coastlines drifted towards the Russian Far East, East Asia, and Southeast Asia such as the Southern Coastal region in Bangladesh [48, 55, 63].

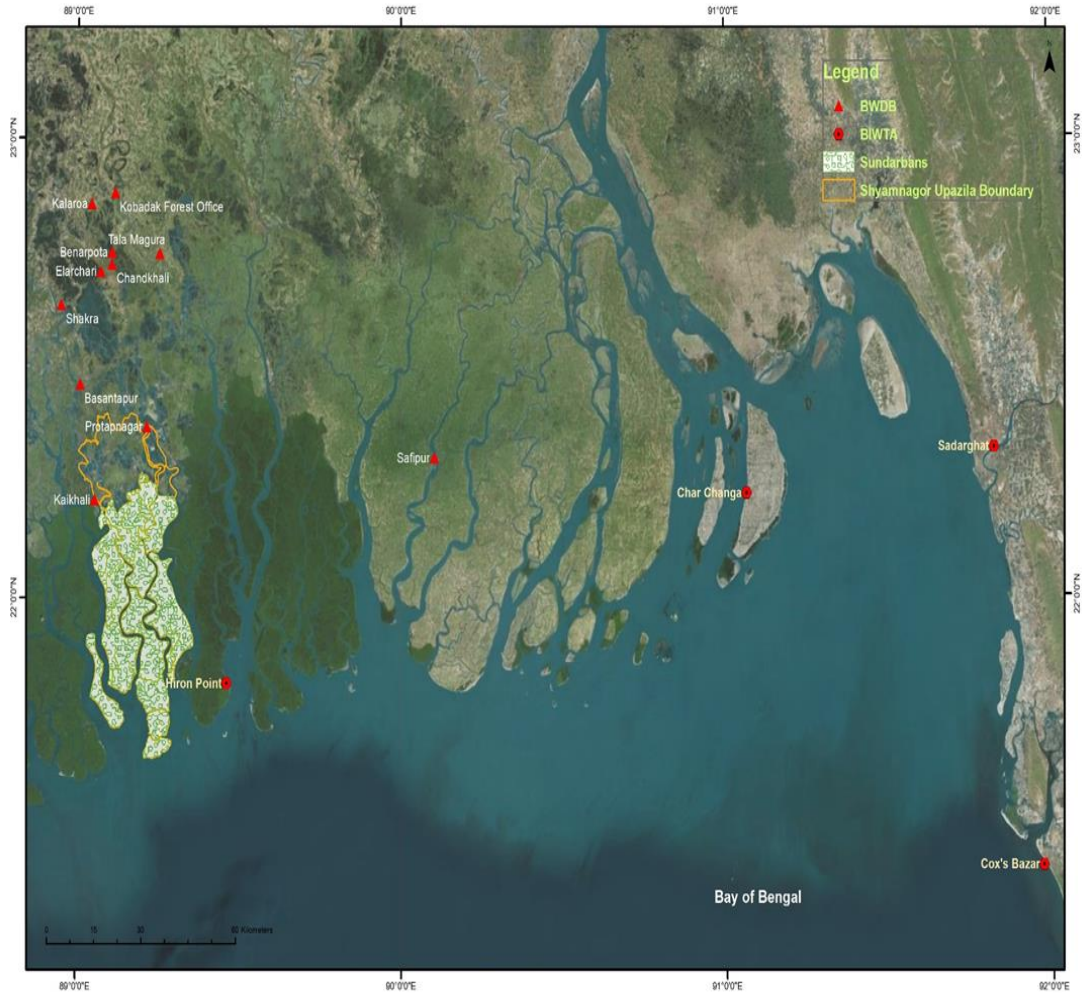
Study Area and Methodology

Study Area

The study area is within the southwestern part of Bangladesh between 22.3306' N and 89.1028' E, encompassing the entire Sundarbans (Figure 1A, B) [62, 64]. Delta sediments form a shallow area that extends about 200 km south from the coastline. In the western part of the Indian Ocean, beyond the narrow coastal zone, the seabed quickly drains to a depth of 2000 m or more. In the east, the Andaman Sea forms a shallow water area [65,66]. The largest fluvio-deltaic-to-shallow marine sedimentary basin of the world is the Ganges–Brahmaputra–Meghna (GBM) Delta. This basin receives inflow from the Ganges in the northwest, and the Brahmaputra from the northeast, while the Meghna provides input from flowing into the Brahmaputra (after entering the Sylhet Trough and part of the Tripura Hills), and finally, into the Bay of Bengal. From the Bengal Basin, it is estimated that about 1.1 gigatons (GT) of cumulative sediments are dispersed into the Bay of Bengal, resulting from the largest submarine fan in the world, the Bengal Fan [67,68]. The Himalayas shed sediments into the GBM Delta, the source of most of the sediments, while the Himalayan front, Shillong Plateau uplift in the north, and the accretionary fold belt in the east can create tectonic influences on the GBM Delta [67]. Flexural subsidence, faulting, folding, and localized compaction are sources for less than half of the total sediment trapped in the Bengal Basin [68]. This accumulated sediment has resulted in a prograde of more than 300 km since the Eocene (35 Ma) in the entire Bengal Basin [67-68].



(A)



(B)

Figure 1(A) The Ganges–Brahmaputra–Meghna (GBM) Delta with study area. **(B)** The study area with the three tide gauge stations of Hiron Point, Char Changa, and Cox’s Bazar, along with the 10 Ganges Delta river gauges of Kalaroa, Benarpota, Protapnagar, Basantapur, Kaikhali, Tala Magura, Chandkhali, Elarchari, Kobadak Forest Office, and Shakra. Data obtained from the Bangladesh Water Development Board (BWDB) and the Bangladesh Inland Water Transport Authority (BIWTA).

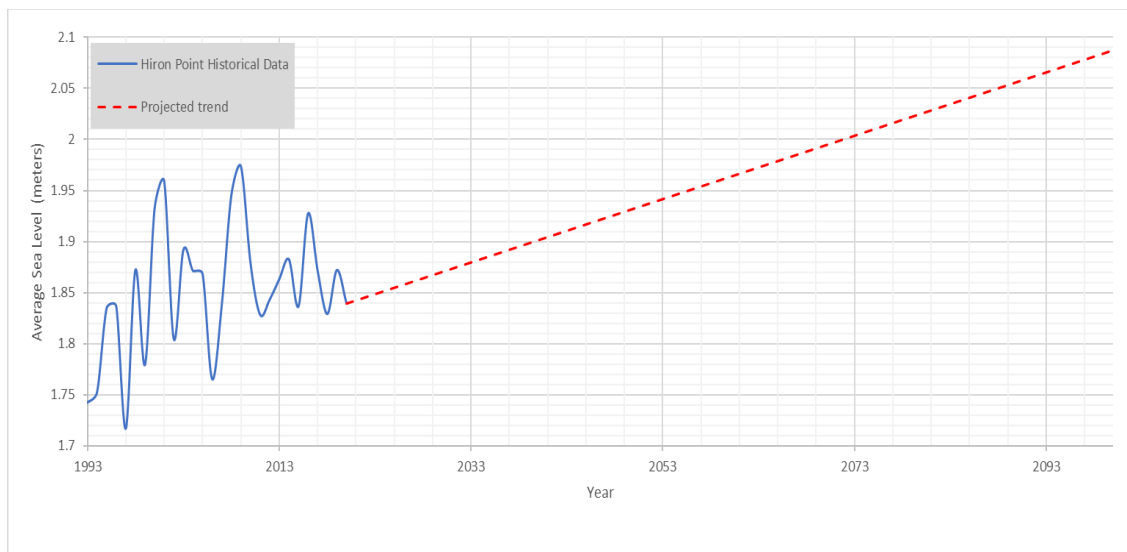
Methodology

Sea level is measured using two main approaches: tide gauges and satellite altimeters. Tide gauges measure low and high tides by utilizing manual and automatic sensors. Satellite altimeter radar measurements are performed using precision-based spacecraft orbits to determine the surface altitude with exceptional accuracy [69,70]. The mean tide level at any location is the average of all high and low water levels at that location over a long period of time. In sea level analyses, there are some advantages to using mean tide level as a locus level instead of mean sea level (MSL) [71].

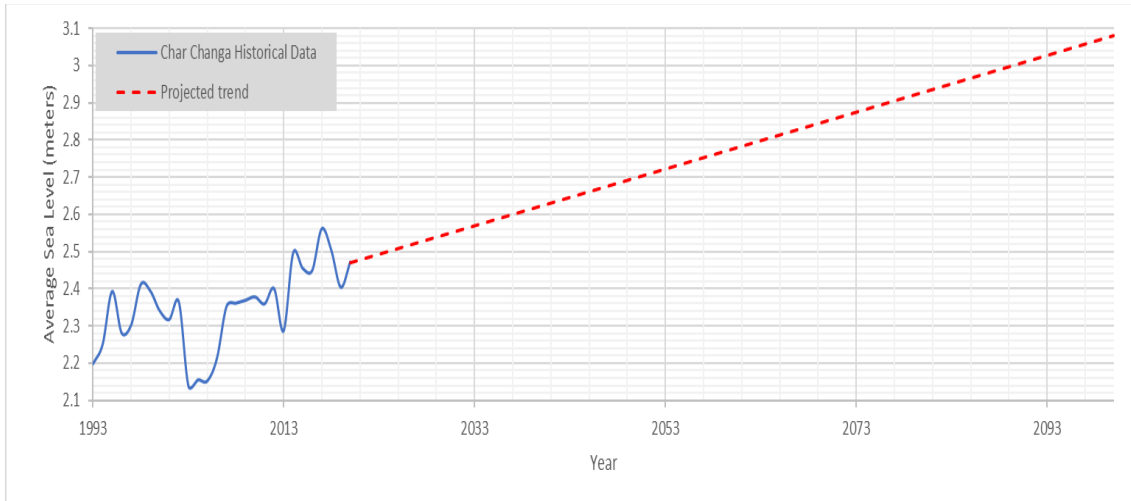
The daily high SLR/water level and daily low SLR/water level (in meters (m)) were obtained from the Government of Bangladesh Inland Waterways and Transportation Authority (BIWTA) tide gauge data. Mean SLR was calculated by averaging the daily high and low SLR in m, which was further converted to mm scale (Table 1). Yearly mean SLR was calculated from these data and plotted in Excel. Finally, trends of MSL were calculated by linear regression with the regression coefficient sea level information at Sundarbans/Hiron Point and Char Changa from 1993 to 2019 and at Cox’s Bazar from 1993 to 2011 obtained, and both the lowest and highest tide records were retrieved. (Figure 2A, B, C).

Table 1. Data from three tide gauge stations from the Bay of Bengal at Hiron Point, Char Changa, and Cox's Bazar (primary data were collected from Government of Bangladesh Inland Waterways and Transportation Authority (BIWTA)).

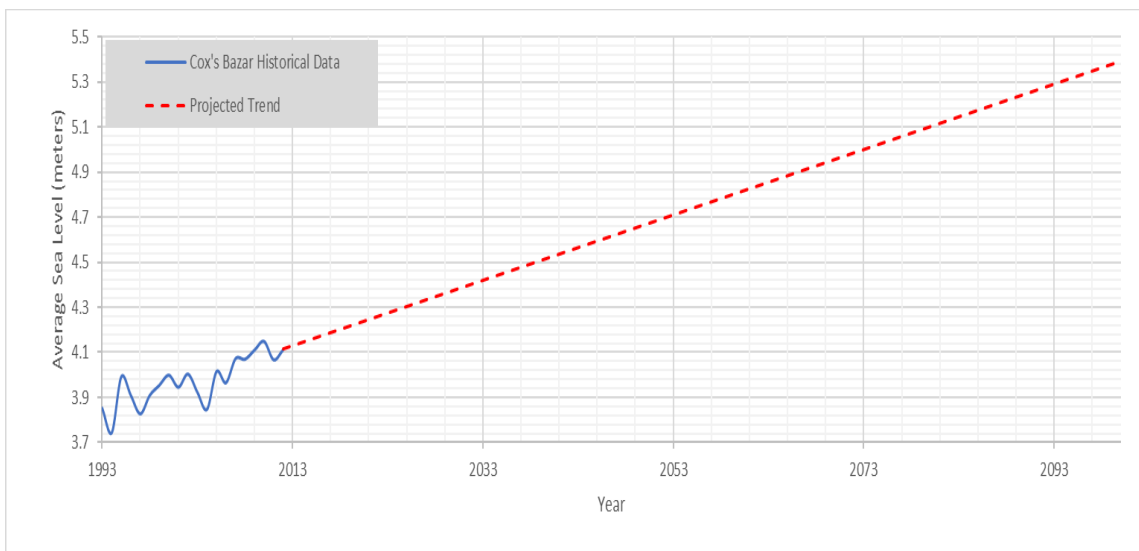
Year (Char Changa)	Latitude	Longitude	Lowest	Highest	Average	Year (Hiron Point)					Year (Cox's Bazar)				
						Latitude	Longitude	Lowest	Highest	Average	Latitude	Longitude	Lowest	Highest	Average
1993	21.78	89.47	0.58	3.82	2.20	1993	22.23	91.05	0.28	3.20	1.74	1993	21.45	91.83	3.85
1994	21.78	89.47	0.52	3.98	2.25	1994	22.23	91.05	0.26	3.25	1.75	1994	21.45	91.83	3.75
1995	21.78	89.47	0.67	4.12	2.39	1995	22.23	91.05	0.37	3.30	1.84	1995	21.45	91.83	3.99
1996	21.78	89.47	0.66	3.90	2.28	1996	22.23	91.05	0.38	3.29	1.84	1996	21.45	91.83	3.91
1997	21.78	89.47	0.58	4.03	2.30	1997	22.23	91.05	0.21	3.22	1.72	1997	21.45	91.83	3.83
1998	21.78	89.47	0.64	4.18	2.41	1998	22.23	91.05	0.41	3.33	1.87	1998	21.45	91.83	3.91
1999	21.78	89.47	0.70	4.08	2.39	1999	22.23	91.05	0.29	3.27	1.78	1999	21.45	91.83	3.96
2000	21.78	89.47	0.61	4.07	2.34	2000	22.23	91.05	0.43	3.44	1.93	2000	21.45	91.83	4.00
2001	21.78	89.47	0.67	3.96	2.32	2001	22.23	91.05	0.48	3.44	1.96	2001	21.45	91.83	3.95
2002	21.78	89.47	0.66	4.07	2.36	2002	22.23	91.05	0.33	3.28	1.80	2002	21.45	91.83	4.01
2003	21.78	89.47	0.55	3.72	2.14	2003	22.23	91.05	0.41	3.38	1.89	2003	21.45	91.83	3.92
2004	21.78	89.47	0.52	3.79	2.16	2004	22.23	91.05	0.34	3.41	1.87	2004	21.45	91.83	3.85
2005	21.78	89.47	0.53	3.78	2.15	2005	22.23	91.05	0.37	3.37	1.87	2005	21.45	91.83	4.02
2006	21.78	89.47	0.56	3.86	2.21	2006	22.23	91.05	0.26	3.27	1.77	2006	21.45	91.83	3.97
2007	21.78	89.47	0.68	4.02	2.35	2007	22.23	91.05	0.29	3.39	1.84	2007	21.45	91.83	4.07
2008	21.78	89.47	0.70	4.02	2.36	2008	22.23	91.05	0.41	3.48	1.95	2008	21.45	91.83	4.07
2009	21.78	89.47	0.74	4.00	2.37	2009	22.23	91.05	0.43	3.52	1.97	2009	21.45	91.83	4.11
2010	21.78	89.47	0.70	4.05	2.38	2010	22.23	91.05	0.41	3.34	1.88	2010	21.45	91.83	4.15
2011	21.78	89.47	0.68	4.04	2.36	2011	22.23	91.05	0.37	3.29	1.83	2011	21.45	91.83	4.07
2012	21.78	89.47	0.73	4.07	2.40	2012	22.23	91.05	0.36	3.33	1.84	-	-	-	
2013	21.78	89.47	0.60	3.97	2.29	2013	22.23	91.05	0.40	3.32	1.86	-	-	-	
2014	21.78	89.47	0.84	4.15	2.50	2014	22.23	91.05	0.37	3.40	1.88	-	-	-	
2015	21.78	89.47	0.78	4.13	2.45	2015	22.23	91.05	0.35	3.33	1.84	-	-	-	
2016	21.78	89.47	0.75	4.15	2.45	2016	22.23	91.05	0.38	3.47	1.93	-	-	-	
2017	21.78	89.47	0.79	4.33	2.56	2017	22.23	91.05	0.34	3.41	1.87	-	-	-	
2018	21.78	89.47	0.76	4.24	2.50	2018	22.23	91.05	0.30	3.36	1.83	-	-	-	
2019	21.78	89.47	0.64	4.17	2.40	2019	22.23	91.05	0.28	3.47	1.87	-	-	-	



(A)



(B)



(C)

Figure 2. Sea level rise changes for three tide gauges on the coast of Bangladesh, along with the projected trend until 2100, based on the equation for the linear trend line of the historical record. Hiron Point (A) and Char Changa (B) records from 1993 to 2019, and Cox's Bazar (C) from 1993 to 2011. All stations show an increasing SLR trend (Data Source: BIWTA, 2020, Table 1).

For Hiron Point, the highest tide value was considered from March and the lowest from August. The lowest and highest tide values were considered for February and August for both Char Changa and Cox's Bazar. Then, for Hiron Point and Char Changa, the average between the lowest and the highest point was considered as the average annual SLR value, and only the highest tide record was used as the annual value for Cox's Bazar, due to unreliable low tide records.

Tide gauge data for the Ganges Delta were obtained from the Bangladesh Water Development Board (BWDB). Metric data from the BWDB were available for 10 stations, with a data series from 1968 to 2019 (Table 2). The list of stations includes Kalaroa, Benarpota, Protapnagar, Basantapur, Kaikhali, Tala Magura, Chandkhali, Elarchari, Kobadak Forest Office, and Shakra, which include timeframes of 52, 50, 49, 51, 52, 51, 49, 34, 43, and 39 years, respectively. The monthly data were taken into consideration for tidal documentation if a minimum of 15 days of data were obtained, and yearly data were considered if a minimum of 11 months of data were obtained. Time extent of these statistics is significantly of high quality. Usually, data from the past 20 years were examined for SLR tendency

assessment and the data quality verified before scrutiny [51]. The inaccuracy in tidal statistics was rectified manually. In case of an over-inference of tidal rank, flawed data were removed from the dataset. Some impractical values, such as the same value for high and low tides, were removed from the dataset before obtaining a sea level rise trend (Table 2). Some data points were identified as erroneous and removed manually.

Table 2. Data from 10 tide gauge 10 stations from the Ganges Delta (primary data were collected from the Bangladesh Water Development Board (BWDB)).

Data BWDB	Kalaroa	Benarpota	Protapnagar	Basantapur	Kaikhali	Tala Magura	Chandkhali	Elarchari	Kobadak Forest	Shakra
Latitude	22.87		22.39	22.46	22.19	22.73	22.52	22.66	22.22	22.63
Longitude	89.05		89.19	89.03	89.08	89.27	89.25	89.05	89.31	88.95
Year	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
1968	1527.89	913.85	567.36	838.18	563.74	619.38	657.13	1529.89	343.53	1030.49
1969	1279.15	806.88	579.05	752.12	514.53	607.27	577.26	1659.47	255.51	1088.18
1970	1566.59	1000.82	628.79	802.01	588.03	523.10	532.79	1087.67	305.44	1148.69
1971	1705.26	969.78	388.94	785.92	540.31	572.65	548.63	1402.27	334.85	1233.60
1972	1045.22	682.91	560.60	705.82	533.71	493.55	543.09	1286.23	266.49	996.73
1973	1293.06	765.27	656.79	824.48	532.23	569.12	572.29	1554.44	302.78	980.34
1974	1357.07	808.53	591.01	686.57	668.48	754.71	697.34	1335.00	383.81	927.81
1975	1275.89	780.21	572.85	908.60	609.77	550.44	624.35	1704.02	353.40	822.71
1976	1241.86	642.79	524.21	1167.65	1419.70	310.33	624.86	1683.58	302.16	1021.16
1977	1331.37	789.60	588.42	1193.64	1668.00	575.45	652.51	1564.43	142.79	1059.70
1978	649.44	636.54	415.36	838.89	451.11	597.28	403.45	1600.52	298.63	1527.30
1979	1712.67	874.36	467.49	1160.55	392.36	1144.42	805.58	1567.53	349.36	1759.69
1980	1518.58	760.46	419.02	1080.30	496.20	994.74	711.84	1579.56	339.43	1855.33
1981	1816.70	852.62	748.79	1124.03	549.62	899.73	702.41	1519.89	416.33	1718.40
1982	1133.10	691.83	350.49	961.55	464.73	141.50	581.69	1586.99	331.20	455.56
1983	1290.90	879.98	-81.25	799.07	397.38	653.56	675.29	1641.07	413.97	956.51
1984	1700.44	935.71	-88.52	855.89	808.55	672.87	666.21	1515.33	456.37	930.81
1985	1372.66	754.90	64.26	803.49	793.44	564.23	598.04	2056.00	372.63	924.70
1986	1834.37	983.37	-12.67	747.22	742.59	631.41	566.47	1969.01	394.21	901.99
1987	1734.32	905.40	151.18	784.32	643.14	581.30	730.29	2040.64	496.15	858.79
1988	1732.86	994.78	335.31	900.05	522.14	805.77	667.55	2010.27	399.32	1159.39
1989	1589.96	949.67	498.32	866.04	820.92	876.33	438.74	1883.10	522.07	848.96
1990	1828.48	997.44	270.38	886.25	821.85	937.61	625.59	1865.23	600.70	880.15
1991	1735.01	981.60	329.25	784.78	785.64	1274.89	567.86	1752.11	442.23	865.22
1992	2479.36	1072.17	568.41	788.73	784.55	183.35	585.08	1638.68	281.69	541.32
1993	2176.78	1337.95	342.66	804.12	805.32	827.93	446.59	1272.42	325.71	834.87
1994	1889.36	1328.38	277.89	777.01	557.97	671.29	540.40	1793.14	232.47	747.05
1995	2304.25	1477.07	198.75	842.45	742.64	658.44	196.01	1825.93	138.27	781.49
1996	2647.88	1454.39	48.20	778.14	927.32	674.11	309.08	2144.30	182.24	899.85
1997	2530.64	1481.29	66.89	691.71	726.33	670.75	572.11	2148.46	16.01	748.45
1998	2509.67	1266.26	-172.55	794.10	814.99	784.44	578.29	2419.32	-130.89	880.55
1999	2597.43	1537.21	-299.93	905.36	849.25	752.15	579.08	2552.59	-42.00	898.19
2000	1935.81	1795.58	29.60	968.90	844.21	767.82	611.81	2685.87	-67.77	1055.65
2001	2823.40	1559.10	97.34	855.89	825.78	643.26	676.10	2455.96	-337.12	917.13
2002	2380.10	1519.29	370.98	862.07	813.40	544.03		2342.51	308.86	890.71
2003	2629.24	1080.77	202.69	933.16	787.06	444.80		1744.33	180.93	867.64
2004	2880.26	1233.98	363.43	821.58	777.26	846.49		1992.79	-311.65	949.47
2005	3391.31	1382.43	118.53	714.00	851.40	996.15		2161.86	-175.15	1203.61
2006	2799.31	1424.37	761.31	717.53	806.12	750.72		2032.76	-279.02	1177.83
2007	2879.91	1166.62	1124.29	876.79	711.85	-31.98		2740.13	-82.51	743.25
2008	3193.69	1647.87	759.71	869.00	870.13	224.62		3447.50	-289.85	761.57
2009	2304.01	1560.83	575.12	795.97	897.74	642.56			-306.34	846.13
2010	1870.99	1789.15	395.86	945.67	981.10	454.66			-377.69	930.70
2011	2273.29	2421.52	416.34	1104.51	1007.99	829.60				924.81
2012	2274.03	2761.69	309.34	1155.52	1027.43	511.34				1105.99
2013	2983.97	3237.05	291.93	1270.08	1034.08	1621.39				1069.86
2014	3406.19	2857.87	439.44	1114.84	986.51	2824.77				983.64
2015	3438.19	2751.72	765.30	896.21	1031.63	1833.07				971.21
2016	3470.18	3232.11	868.99	888.36	1015.98	1478.88				1101.93

2017	3169.51	3712.50	772.99	996.15	1298.65	943.99
2018	2946.99		700.60	954.79		893.25
2019	2446.49		559.94	792.66		650.80

In this study, we showed how Global Navigation Satellite System (GNSS)-derived vertical velocities contribute to the correction of tide gauge (TG) measurements used for sea level rise estimation in the Ganges–Brahmaputra–Meghna Delta (GBMD) [72–74]. At the Ganges–Brahmaputra–Meghna Delta (GBMD), vertical land motion (VLM) and GNSS (co-located) are used when estimating the geocentric sea level rise. TGs use a land-based monitored geodetic benchmark to measure the height of water. Thus, VLM can be determined using GNSS-based methods. The absolute geocentric sea level trend is the conversion of the TG correction of relative sea level heights and GNSS vertical velocities from the same location [72–74].

Satellite Imagery Retrieval

Satellite data were retrieved from the Laboratory for Satellite Altimetry [75–77], including data from TOPEX, Jason -1, -2, -3, and multiple altimeters, which were averaged to create a 1992 to 2020 table [5,76–85]. Global and local level changes provide a method for evaluating the performance of climate models. This was used to measure global average and regional SLR; the regional data were obtained from the average altimetry values of the Bay of Bengal. To visually analyze global and regional SLR, screenshots were obtained from the JPL ECCO server (2020) [5,78–81] which show the change in sea surface topography from 1992 to 2015 [79–83].

SLR Change Verification and Land Subsidence Projection Using CMIP5 Model

The Norwegian Earth System Model (NorESM1-EM) from CMIP5 (Coupled Model Intercomparison Project Phase 5) was used to compare the mean SLR of regional and global areas. For the mean regional SLR, the mean SLR for the Bay of Bengal was used, and projections of land subsidence were analyzed to determine their relationship. SLR projections (the representative concentration pathways (RCPs) data were downloaded from cds.climate.copernicus.eu (accessed on: 22 December 2021) [82–84] and the mean SLR for the Bay of Bengal was simulated using the Global Climate Model (GCM) NorESM1-ME from 2006 to 2100. The estimates were taken from the figures from 1980 to 2005. The GCM model figures were in the Network Common Data Form version 4 (NetCDF4) pattern. The data utilizing the Climate Data Operator means were separated and the Python language was employed to plot the RCP estimates [82].

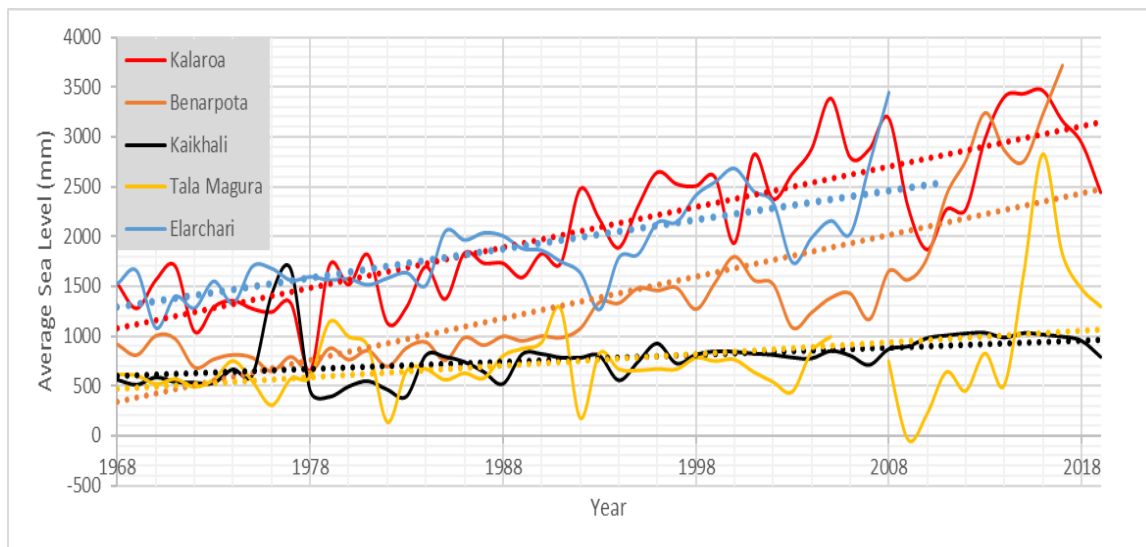
Results

The results from the three tide gauge stations indicate a trend towards increasing sea level, with Changa at 7.6 mm/yr and Hiron Point at 3.1 mm/yr from 1993 to 2019, and a staggering Cox’s Bazar at 14.5 mm/yr of SLR from 1993 to 2011 (Figure 2, Table 3). A significant correlation exists for Char Changa, with an R^2 value of 0.307, and an extremely significant correlation exists for Cox’s Bazar, with an R^2 of 0.610. Based on the linear trend line from these time frames, it is projected that SLR in Char Changa will increase by 228 mm from 2020 to 2050, and 608 mm in 2100, Hiron Point by 93 mm in 2050 and 248 mm by 2100, and Cox’s Bazar almost 435.7 mm by 2050, and more than 1162 mm by 2100, assuming a linear increase in SLR. Cox’s Bazar has an SLR projection similar to those in the intermediate–high region. The detailed statistical analyses are in Supplementary Materials. According to the monthly average sea level data from 1993 to 2011, the MSL trend of Cox’s Bazar was +14.5 mm/yr. ($R^2 = 0.6097$). The increase in sea level from 1993 to 2011 was 206 mm. Using regression analysis, the trend of sea level rise was predicted (Figure 2, Table 3). As per the predictions, after 100 years, the sea level may rise by 1450 mm from the existing sea level.

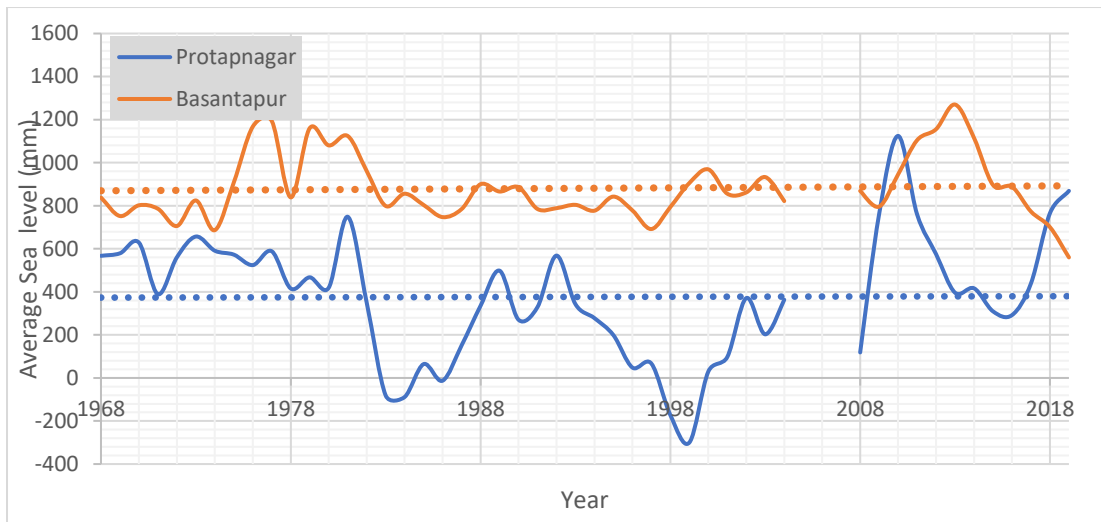
Table 3. Timeframe, sea level rise trend, correlation, trend line equation, and estimated level in 2050 and 2100, and sea level rise from 2020 to 2050 and 2100 for tide gauges at Char Changa, Cox’s Bazar, and Hiron Point. Cox’s Bazar shows a significantly higher rate of SLR through the 21st century, with >1 m of rise during a period of 80 years (Data Source: BIWTA, 2020).

	Time Frame (Years)	Water Level Trend (mm/yr)	Correlation (R ²)	Trend Line Equation	Estimated Level in 2050 (mm)	SLC from 2020 to 2050 (mm)	Estimated Level in 2100 (mm)	SLC from 2020 to 2100 (mm)
Char Changa	1993–2019	7.6	0.3066	$y = 0.0076x - 12.881$	2699	228	3079	608
Cox’s Bazar	1993–2011	14.52	0.6097	$y = 0.0145x - 25.1079$	4665	435.7	5391	1162
Hiron Point	1993–2019	31	0.1466	$y = 0.0031x - 4.4224$	1932.6	93	2087.6	248

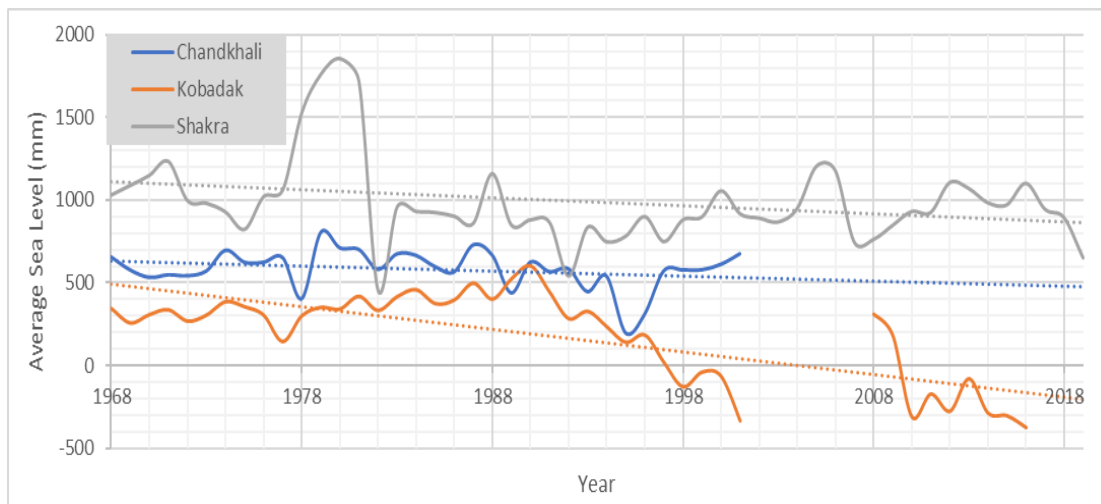
Tidal statistics at the three-gauge locations on the coast of Bangladesh have shown an SLR of 4.0–7.8 mm/yr for 1977–1998 [61,86-87]. This is significantly greater than the pace of global SLR during the 19th century, i.e., 1.7 ± 0.3 mm/yr [1,3]. SLR statistics retrieved from the three tidal checkpoints in the SWCRB reveal that Hiron Point has an increasing SLR of 3.1 mm/yr, Char Changa of 7.6 mm/yr, and Cox’s Bazar of 14.52 mm/yr, showing a significant increase from 5.5 and 7.5 mm for the same regions from 1970 to 2005 [86-87]. Verification of SLR statistics from 10 tide gauge watch points within the coast of Bangladesh for intermittent time points (14–44 years) details a mean SLR of up to 38.8 mm/yr, near the central coastal belt. These trends can be derived from a number of factors, as shown in Tables 3, 4, and 6.



(A)



(B)



(C)

Figure 3. The historical records of deltaic regions within the study area; the trend line indicates the trend of sea level. Stations with increasing sea level (A); no significant change (B); and decreasing sea levels (C). These patterns show a lot of variation in sea level rise, which can be attributed to the highly dynamic geomorphological processes of deltaic regions (Data Source: BWDB, 2020).

Several of the stations show increasing SLR, specifically, Kalaroa, Benarpota, Kaikhali, Tala Magura, and Elarchari, (Figure 3 and Table 4). Most of them have very high rates of SLR, especially the first two, which show a rise in SLR of >40 mm/yr. At the same time, the river gauges show significant correlations of SLR data among the given stations, in particular for Kalaroa and Benarpota, of $>R^2 = 0.6$ (Table 4). Two stations, Protapnagar and Basantapur, showed no significant SLR change or correlation, with a trend of <0.5 mm/yr. Chandkhali, Kobadak Forest, and Shakra showed a decrease, with -3.03 mm/yr, -13.59 mm/yr, and -4.92 mm/yr, respectively. Overall, this indicates that half of the stations' SLR are increasing at rates between 7.27 mm/yr and 41.75 mm/yr, rates much higher than the three stations with their corresponding decreasing rates, suggesting general RSLR within the Delta. At the same time, increasing SLR trends are far higher than the coastal tide gauges, indicating that other physical processes within the delta region are affecting SLR, which could contribute to either an increase in water volume/SLR or active land subsidence.

Table 4. Trend in sea level rise, equation of the trend line, and correlation of 10 stations measuring sea level rise (SLR) at the Ganges Delta. The green color indicates positive SLR, red indicates negative SLR, and yellow indicates no significant trend. Four of the five positive SLR trend stations show a significant correlation with their timeframe, indicating more reliable predictions than those with little or no correlation. Data retrieved from BWDB.

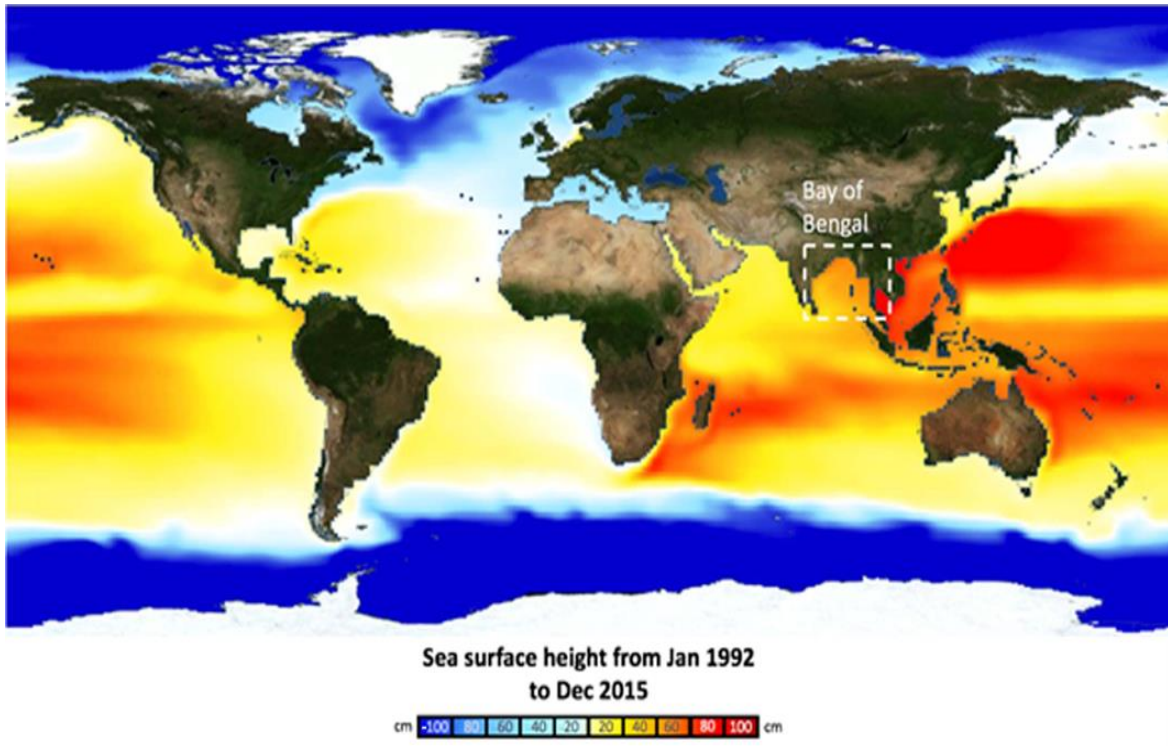
Station Name	Kalaroa	Benarpota	Protapnagar	Basantapur	Kaikhali	Tala Magura	Chandkhali	Elarchari	Kobadak Forest	Shakra	Legend
Trend (mm/yr)	40.41	41.749	0.127	0.0898	7.2704	11.528	-3.0327	29.343	-13.59	-4.9207	Positive sea level change
Correlation	0.7241	0.665	0	0	0.2149	0.148	0.0644	0.578	0.533	0.081	No significant sea level change (<1 mm/yr)

The global data showed an increase of 2.94 mm/yr based on an average from satellite altimeters, with an extremely high correlation of 0.919 from 1992 to 2020, as seen in Table 5. The trend is not constant across the globe, with Polar Regions showing decreasing SLR rates and places near the equatorial Pacific having the highest increasing rates, approaching up to 1000 mm in certain regions (Figure 4). The linear projection of global sea level change in 2050 indicates an SLR of 88.04 mm compared to 2020 and 234.76 mm by 2100 (Table 5).

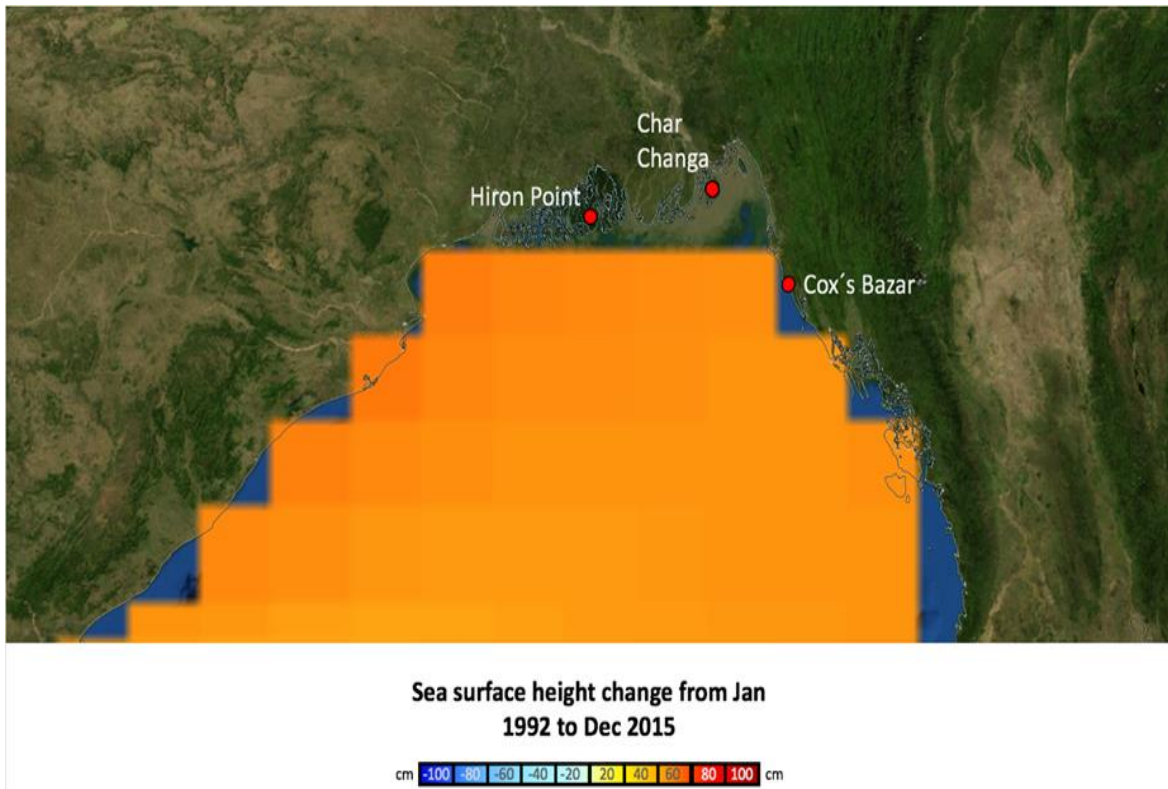
Table 5. The timeframe, sea level rise (SLR) trend, correlation, trend line equation, estimated level in 2050 and 2100, and SLR from 2020 to 2050 and 2100 for global and regional sea surface topography from 1992 to 2020. The regional data are based on the Bay of Bengal region. Data from altimeters from TOPEX/Poseidon and Jason-1, -2, -3 were averaged to create the historical record. Data obtained from the Laboratory for Satellite Altimetry (2020a and 2020b) [76–78, 80].

	Time Frame	Trend (mm/yr)	Correlation	Tread Line Equation	Estimated Level in 2050 (mm)	SLC from 2020 to 2050 (mm)	Estimated Level in 2100 (mm)	SLC from 2020 to 2100 (mm)
Global	1992–2020	2.935	0.9192	$y = 2.9345x - 5869.4$	146.325	88.035	293.05	234.76
Regional (Bay of Bengal)	1992–2020	3.366	0.3516	$y = 3.3664x - 6733.6$	167.25	100.992	335.84	269.312

The regional data show an increasing trend of 3.37 mm/yr, with a correlation of 0.352 (Table 5). The regional trend is higher by 0.4 mm than the global trend. Based on the map and graph (Figures 4 and 5), higher regional levels exist along the coastal region of the Ganges Delta. The future trend for the region of the Bay of Bengal indicates a 100.99 mm rise from 2020 to 2050, and a rise of 269.31 mm from 2020 to 2100, which is higher than those of global values. However, both predictions have SLR trends where the regional trend is slightly higher than the global average and relatively mild compared to both the river and coastal tide gauges. Average river gauge trends are higher than global and regional trends, with two coastal gauges projecting a change of more than 1000 mm from 2020 to 2100. Only Hiron Point presented trends and future projections similar to those of regional and global ones.

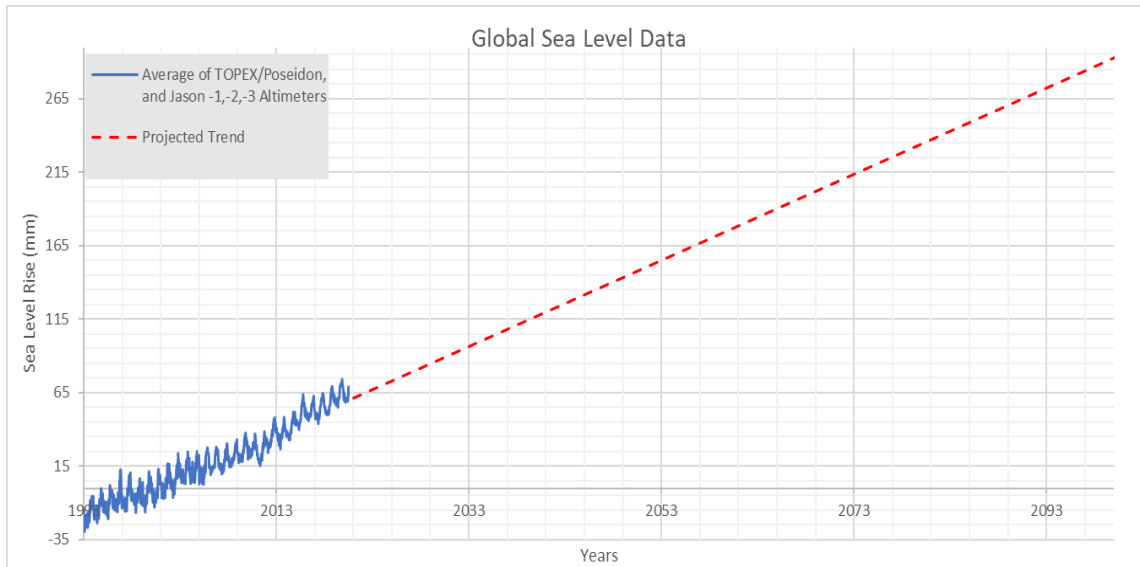


A

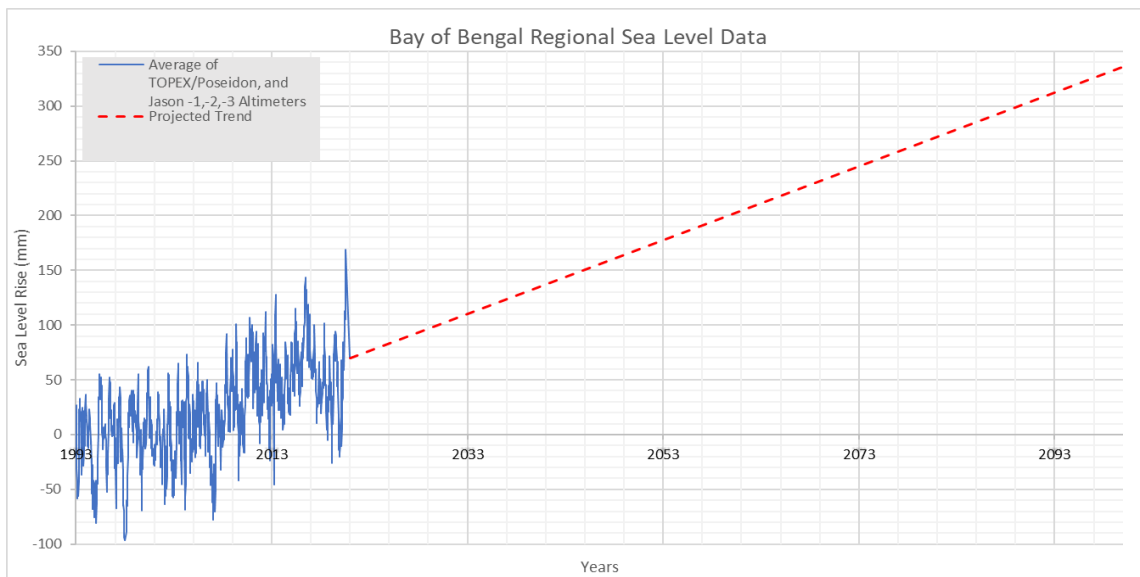


B

Figure 4. Sea level changes from 1992 to 2015 with the global pattern (A) and RSLR from the southern Bay of Bengal region (B). High latitudes show a decrease in sea level rise, which can be attributed to the lowering of gravitational attraction due to the loss of glacial mass. Data retrieved from JPL ECCO server (2020) [5, 79].



(A)



(B)

Figure 5. Sea level change for the global average (A) and the region of the Bay of Bengal (B) from 1993 to 2020, along with the projected trend until 2100, based on the linear trend line equation of the historical record. Data retrieved from the Laboratory for Satellite Altimetry [76–78].

The Bay of Bengal (regional data) and global data have a strong correlation of $R^2 = 0.70$ (Table 6); based on this timeframe, the lineal trend is similar for both regional and global data, but the trend for Bay of Bengal SLR is higher than that for the global average. Both the global and Bay of Bengal SLR have a correlation of $R^2 = 0.32$ and 0.30 with Char Changa, and 0.58 and 0.56 with Cox’s Bazar, respectively. Hiron Point only had a significant correlation, of 0.39 , with Cox’s Bazar. This indicates that although the rates for local regions have higher SLR trends, the local changes in SLR are statistically consistent with the regional (Bay of Bengal) and global SLR patterns, except for Hiron Point.

Table 6. Correlation of annual SLR data from global data, Bay of Bengal, Char Changa, Hiron Point, and Cox’s Bazar. The green color indicates correlations above $R^2 = 0.2$, yellow for $R^2 = 0.1$ and 0.2 , and red for correlations less than $R^2 = 0.1$. Data retrieved from the Laboratory for Satellite Altimetry [76–78,88,89] and BIWTA.

	Global SLR	Bengal Bay SLR	Char Changa	Hiron Point	Cox's Bazar	Legend
Global SLR	1	0.70	0.32	0.12	0.58	>0.2
Bengal Bay SLR	0.70	1	0.30	0.19	0.56	0.1–0.2
Char Changa	0.32	0.30	1	0.04	0.23	<0.1
Hiron Point	0.12	0.19	0.04	1	0.39	<0.1
Cox's Bazar	0.58	0.56	0.23	0.39	1	<0.1

Comparison with the CMIP5 Model

Under RCP 2.6, RCP 4.6, RCP 6, and RCP 8.5, the global MSL shows 0.30, 0.35, 0.37, and 0.48 m, respectively, in 2100. Furthermore, in the Bay of Bengal, the MSL is indicated to be higher than the global mean SLR. Under RCP 2.6, RCP 4.6, RCP 6, and RCP 8.5, the MSL shows 0.6, 0.7, 0.83, and 1.0 m, respectively, in 2100, in the Bay of Bengal (Figure 6)

Comparison with tide Gauge, Satellite Altimetry, and RCP, CIMP5

The results from the three tide gauge stations indicate a trend towards increasing sea level. It is projected that SLR in Char Changa will increase 228 mm from 2020 to 2050, and 608 mm in 2100. In Hiron Point, the increase is 93 mm in 2050 and 248 mm by 2100. In Cox's Bazar, the increase will almost be 435.7 mm by 2050 and more than 1162 mm by 2100, assuming a linear increase in SLR. Global data also show increasing SLR, based on an average from satellite altimeters. The linear projection of global sea level change indicates an SLR of 88.04 mm in 2050 and 234.76 mm by 2100. The highest rate of increase is in the Equatorial Pacific, reaching almost 1000 mm in certain regions. For RCP, the values indicate that the MSL is higher regionally compared to globally. For instance, in the Bay of Bengal, RCP 2.6, RCP 4.6, RCP 6, and RCP 8.5, MSL shows 0.6, 0.7, 0.83, and 1.0 m, respectively, in 2100. Globally, RCP 2.6, RCP 4.6, RCP 6, and RCP 8.5 show 0.30, 0.35, 0.37, and 0.48 m, respectively, in 2100. Thus, it can be perceived that regional levels of SLR are almost higher than global levels.

Discussion

Sea Level Rise

This study compares historical and projected sea level change trends for the coast of Bangladesh, the Bay of Bengal, and globally. Averages were calculated using satellite altimeters, and tide and river gauges. The coast of Bangladesh presents the highest amount of sea level rise, which is a direct consequence of both natural and anthropogenic events, related to subsidence in the deltaic environment, along with higher rates of glacial melt water from the Himalayas, resulting in sea level rise in the Ganges Delta. However, it is important to note that sea level rise will not be uniform, and the origins of glaciers may not experience sea level rise as extremely as other locations further from the melting source [88]. This is due to surface mass load self-gravitation where, near ice, water piles up due to the gravitational attraction, and flows away as the ice melts [88]. Thus, the melting of the Himalayan glaciers will, more than likely, contribute to more drastic increases in sea levels at locations further away from the Bay of Bengal. The Bay of Bengal region has rates higher than global averages due to the increase in Himalayan glacial meltwater, with a chance of reaching more than 200 mm by the end of the 21st century. However, due to the non-linear nature of sea level rise, projections can be expected to be much higher, threatening the lives of millions of people living in Bangladesh. The Bay of Bengal had a sea level trend of 3.4 mm and global averages of 2.9 mm per year. River delta sea level trends were of 3.1 to 41.7 mm per year, but many were above 7 mm per year. The sea level could rise by more than half a meter (500 mm) from 2020 to 2050, and from 2050 to 2150 by

more than 1000 mm on the coast of Bangladesh, resulting in millions of Bangladeshi inhabitants possibly being submerged by 2100 (Tables 3–6)

Sea level is eventually rising from west to east over the Bay of Bengal, and it progresses towards the North Bay of Bengal, causing subsidence over the coastal and adjacent regions. It has been projected that by 2040, the MSL over the Bay of Bengal will be 0.1 to 0.4 m under RCP 4.5. It will again increase by between 0.2 to 2 m during 2060. During 2080, the mean SLR range will be between 0.2 and 3.3 m. (Figure 6). Land subsidence over Bangladesh shows the highest magnitude over the southern and north-eastern parts as compared to the other parts. Barishal, Chattogram, and Khulna division will experience prominent SLR. Mainly, Khula, Satkhira, Pirojpur, Bhola, Patuakhali, Jalokathi, Barishal, Cox’s Bazar, Feni, Cumilla, Dhaka, Faridpur, Hobogonj, and Sylhet will face land subsidence during 2040 to 2080, according to the RCP 4.5 projection (Figure 7). Furthermore, the components and grain size of sediments play a role in subsidence [49]. In deltas, for instance, it was thought that plate-driven tectonic processes served as the main sources of subsidence [49]. However, compaction plays a more significant role on subsidence than before [89]. Thus, it is important to consider the compaction of strata (in deltas for instance), as this may also affect water levels [90]. As is evident from Figure 7, SLR determines the surface land area submergence, and land subsidence plays an important role, exacerbating the effect. It is also difficult to determine the true causes and patterns of subsidence due to the number of possible causes and patterns, including sediment loading, human activities, and decrease in soil from root decomposition [49, 89].

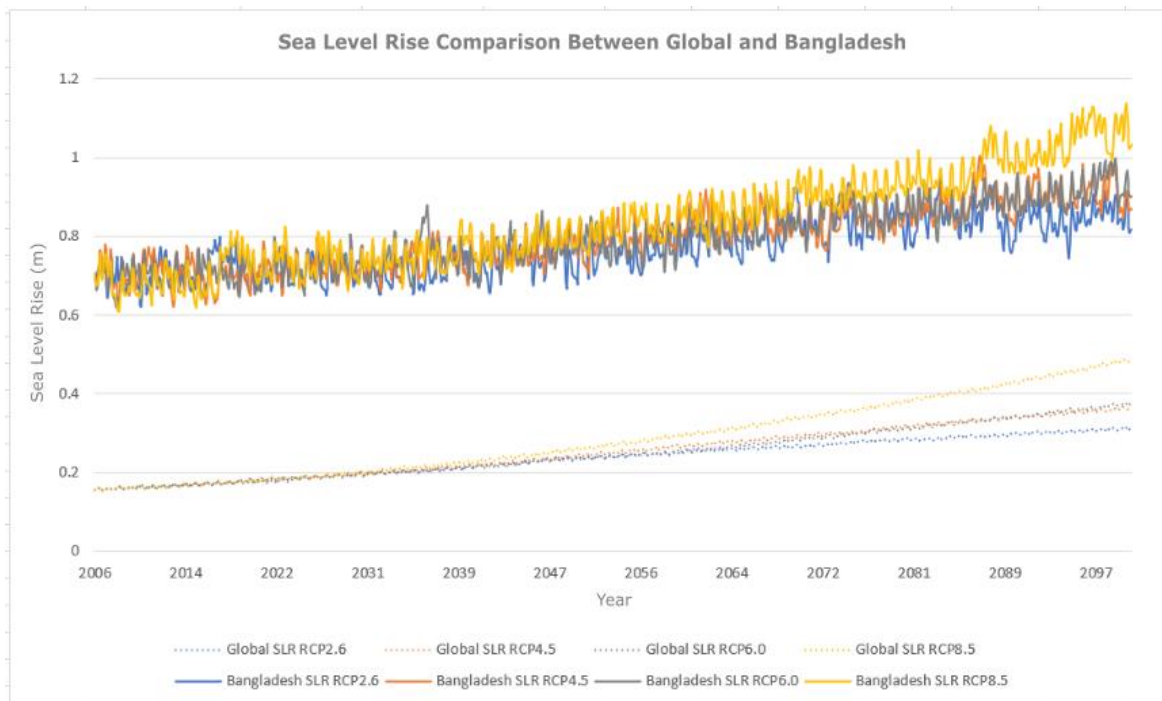


Figure 6. Projected time series of global mean sea level rise and mean sea level rise over Bay of Bengal for different representative concentration pathways (RCPs) (NorESM1-EM model from CMIP5) [82–84].

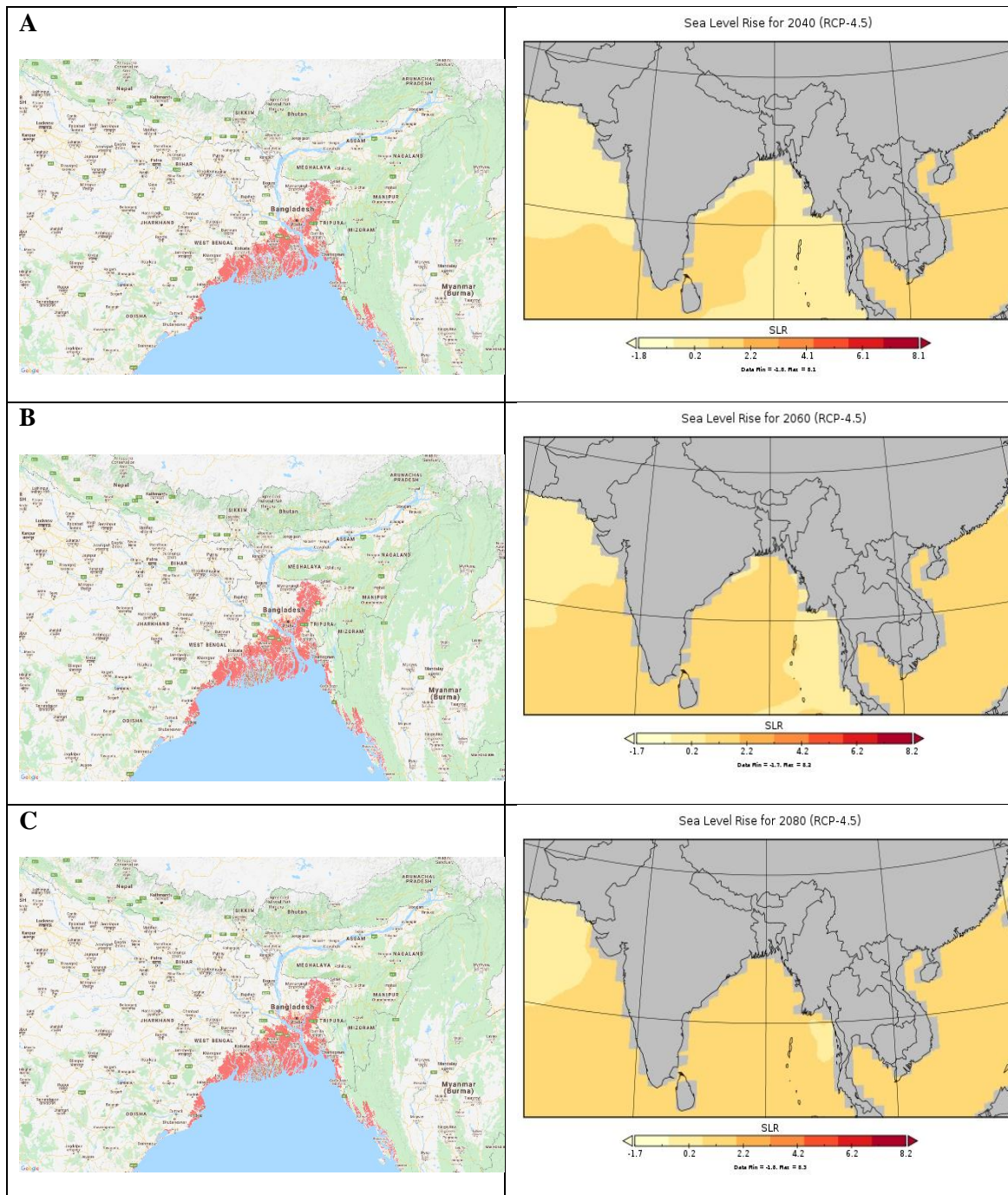


Figure 7. Projected land subsidence (left) and sea level rise (right) for 2040 (A), 2060 (B), and 2080 (C) over Bangladesh and Bay of Bengal using CMIP5 model's RCP 4.5 scenario [82–84].

As mentioned, sizes of locations, sediment composition, in-and-out fluxes of water and runoff, and grain sizes all play a role in how localities will be affected by a rise in sea levels. For example, subsidence factors in local areas occur faster than those over a greater area, and loose material in deltas easily compacts, resulting in slow sinking of the land and RSLR to rise 3.37 mm/yr (Table 5) [49,89]. The Ganges–Brahmaputra Delta, for instance, receives a lot of water and sediment input from the Himalayas, with an input of more than 1 billion tonnes/yr [49,90–94]. The subsidence levels for the lower delta showed 3 mm, the western ranged from 9 to 12.3 mm, and up 3.6 to 4 mm in the eastern, and it was also discovered that, within the first 10 years of the 21st century, immense flooding affected 85% of the largest deltas in the world, as shown in Figures 7 and 8, [93–97].

Further, it is projected that the risk of flooding will increase by at least 50% by 2100 [49, 93–98]. Thus, this delta is sinking so rapidly that the RSLR may reach 20 mm each year [96–99]. Subsidence rates for this delta range from 0 to >18 mm/yr [49,100–101].

Furthermore, the melting of glaciers may lead to a shortage of fresh water in the region, which will force humans to satisfy water needs from underground sources for both agricultural–industrial and domestic use. Excessive extraction of underground water will exacerbate land subsidence. Considering the impact of agriculture in water extraction, according to an article made in 2006 by the Ground Water Hydrology and the Bangladesh Water Development Board, 75% of the cultivated land is irrigated by groundwater; simultaneously, it also states that ~70 to 90% of abstracted groundwater is used for agricultural purposes [98–100]. A major cause of concern is that, since 2004, the groundwater in Bangladesh has not been recharging, as reported by the Bangladesh Agricultural Development Corporation in 2011. The rate of extraction was around 53 billion cubic meters per year, while the recharging rate was merely 50 billion cubic meters per year in 2011 [98-99]. The main occupation of the people in the Shyamnagar Upazila is agriculture and shrimp farming, resulting in an average land subsidence in Bangladesh of ~5 mm/yr [98–100].

Additionally, the areas submerged beneath the ocean will vary in different SLR situations. It has been confirmed that 0.5, 1, and 1.5 m of SLR will submerge ~4.3%, 8.4%, and 11.3% of the coastal regions of Bangladesh, and the number of impacted inhabitants will be 112 million [1,49,97,100–103]. The greatest risk of SLR is on the Sundarbans—the largest mangrove forest in the world—because it is not secured by coastal polders. It has been predicted that approximately 12%, 43%, and 60% of the Sundarbans will be submerged 0.5, 1, and 1.5 m, respectively (Figures 7 and 8) [101–103]. Since the Sundarbans are significant from the biological, environmental, geological, and financial perspectives for Bangladesh, its submergence with distinctive SLR circumstances will have devastating consequences.

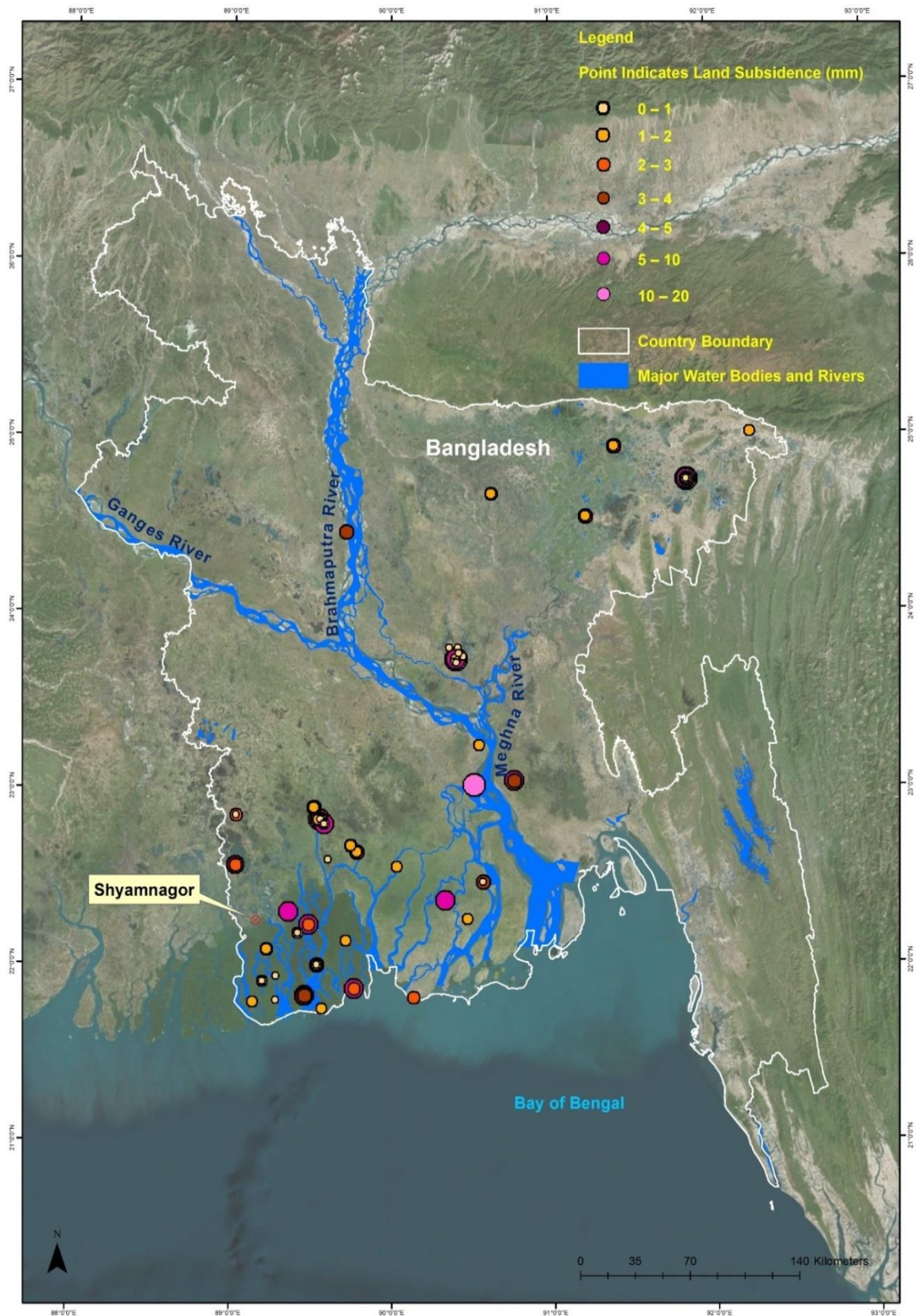


Figure 8. Focal areas of subsidence in the GBM Delta (Source: Rates of subsidence retrieved from Brown and Nicholls, 2015) [100]. [<https://www.mdpi.com/authors/rights>]

Map shows the magnitude of land subsidence, with 3 mm for the lower delta, up to 9 mm of subsidence in the western delta, and up to 4 mm in the eastern delta. Additionally, subsidence values

are 12.3 mm (in the western delta) and 3.6 mm (in the eastern delta). As is evident from Figure 8, SLR determines the surface land area submergence, and land subsidence plays an important role, exacerbating the effect.

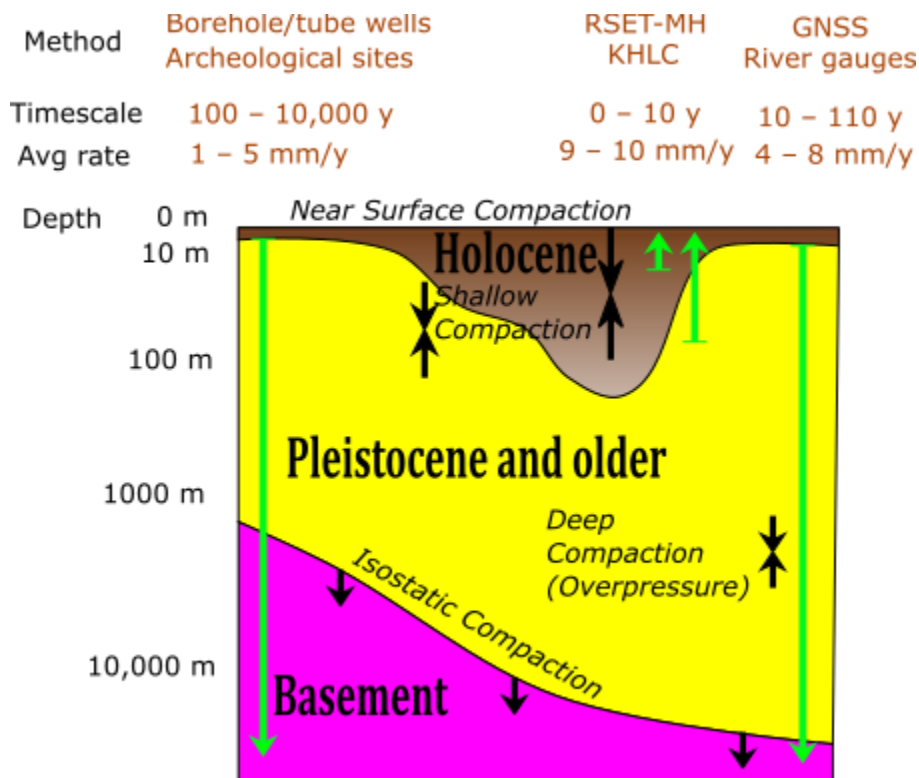


Figure 9. Illustration of subsidence measurements in the GBM Delta (Source: subsidence and compaction dimensions retrieved from Steckler et al., 2022) [93]. <https://www.mdpi.com/authors/rights>

Summary illustration of subsidence and compaction measurements for a section centered on the Brahmaputra incised valley is shown in Figure 9. Compacting sediments are in shades of brown to yellow, with brown indicating faster compaction. The methods applied to distinguish rates and their timescales and values are shown in green. The RSET and KHLC measure compaction from their base to the surface (upward arrows), while the other system measures subsidence below their base (downward arrows). At the bottom, values for long-term subsidence, shallow compaction, and short-term subsidence for the area around the polder, where we have all these systems, are given.

Though subsidence does play a role, it is important to consider the tide gauge and vertical land motion. For instance, tide gauges are affected by geocentric sea level and vertical land motion [102–106]. Thus, both are required to use satellite altimeters, as the observed sea level needs to be converted into a geocentric reference frame [93,104–106]. Local estimates of vertical land motion are also needed to derive an accurate estimate of ocean volume change, as mean vertical land motion at tide gauges is not the same as that of the basin [104].

Comparison between Global, Regional, and Local Sea Level Changes and Impacts

The coastal systems were considered to be affected mainly by higher sea levels. Sea levels will likely rise for many centuries at rates higher than that of the current century in the global and regional contexts [1]. It is also essential to compare regional sea level rise with the Bay of Bengal.

The satellite radar altimeter data in the table show that sea level rise in the Bay of Bengal is higher than other regions Table 7. The statistical study of river gauges shows that five of the ten rivers measured are showing increased SLR at far higher rates than the global SLR averages (Figures 2–6;

Tables 3–7). Our data suggest considerably higher rates of SLR increase within the coast of Bangladesh as compared to that of either global rates or the rates for the Bay of Bengal. Both the tidal and the river gauges indicate far higher rates of SLR, with two having an order of magnitude with higher rates, looking at Figures 2–6. RSLR can increase beyond the global mean sea level rise by an order of magnitude and is able to reach more than 100 mm/yr, and it is estimated that 50% of 33 deltaic regions have the potential to rise above global averages by 2100, according to the IPCC [1,2]. This explains the vast variation observed in our data, with rates considerably higher for sea level rise than the global average in the Bay of Bengal region. In addition to, regional sea level rise in Table 7 considerably higher in the Bay of Bengal region

Table 7. Regional sea level rise time series. Estimates for sea level rise were measured using satellite radar altimeter data retrieved from the Laboratory for Satellite Altimetry NOAA. Time series are available on TOPEX/Poseidon (T/P), Jason-1, Jason-2, and Jason-3 (launched in 1992), and altimeters launched in 1991 including T/P, Jason-1, Jason-2, Jason-3, ERS-2, GFO, and Envisat [76–78]. [<https://www.mdpi.com/authors/rights>]

Region—TOPEX and Jason-1, -2, -3 Seasonal Signals Retained	MSL Trend mm/yr (1992–2022)
Pacific Ocean	2.8 ± 0.4
North Pacific Ocean	3.0 ± 0.4
Atlantic Ocean	3.1 ± 0.4
North Atlantic Ocean	2.7 ± 0.4
Indian Ocean	3.3 ± 0.4
Adriatic Sea	2.2 ± 0.4
Global Sea	3.0 ± 0.4
Baltic Sea	3.8 ± 0.4
Bay of Bengal	3.9 ± 0.4
Bering Sea	1.8 ± 0.4
Caribbean Sea	3.0 ± 0.4
Gulf of Mexico	3.9 ± 0.4
North Sea	2.8 ± 0.4
Mediterranean Sea	2.3 ± 0.4
Sea of Okhotsk	2.1 ± 0.4
Sea of Japan	3.0 ± 0.4
South China Sea	3.8 ± 0.4
Southern Ocean	3.2 ± 0.4
Yellow Sea	2.7 ± 0.4

The statistical study of river gauges shows that five of the ten rivers measured are showing increased SLR at far higher rates than the global SLR averages (Figures 2 and 3; Tables 4 and 5). The SLR in the river delta of the study area could be explained by the sinking and rising of the land, as the sinking of the land plays a role in the sea level rise in Bangladesh [1,49,94,100–105]. A probable 1.6 billion tones/yr of alluvial content streams towards Bangladesh through the Ganges and the Brahmaputra. Similarly, higher rates of ice melt in the Himalayan region would cause SLR in the Bay of Bengal and its river delta [103–106]. However, the subsidence of the deltaic landscape is considered to have been stabilized by the replenishment of dredges pushing towards a gross SLR and, in some regions, could rise due to an increase in river discharge by glacial meltwater. This could explain the three gauges with rising SLR trends and the two with no trends (Table 4). Our data suggest considerably higher

rates of SLR increase within the coast of Bangladesh as compared to that of either global rates or the rates for the Bay of Bengal. Both the tidal and the river gauges indicate far higher rates of SLR, with two having an order of magnitude with higher rates Table 7 (Figures 2–5). Strain from huge construction and engineering projects can equally give rise to compacted sedimentation and land sinking, such as in eastern Tokyo, Po Delta, Shanghai, and Bangkok [1,2,11]. It is also important to consider the size of the delta, as their size and composition rely on how much water is entering and leaving, with humans having an impact on this gradient [1,2]. RSLR can increase beyond the global mean sea level rise by an order of magnitude and is able to reach more than 10 cm/yr, and it is estimated that 50% of 33 deltaic regions have the potential to rise above global averages by 2100, according to the IPCC [1.2]. This explains the vast variation observed in our data, with rates considerably higher for SLR than the global average or the Bay of Bengal region.

In Figure 6, the RCPs indicate a global SLR projection in a non-linear fashion. Although the data are limited to local tide and river gauges, their trends will not be constant in the near future but are instead going to increase in a non-linear fashion, and are important to keep in mind, as flooding from tides can affect more areas.

As the global and the Bay of Bengal regional trends are correlated with local gauges in Bangladesh, it is safe to assume that the RCP non-linear trend will be reflected in the tide gauges, especially the coastal ones. Our global average linear projection falls below the lowest RCP on the lower standard deviation estimates of RCP 2.6 (Figure 6). This prediction is an underestimation of the other predictions, which would indicate that the regional Bay of Bengal and the coastal tide gauges are underestimating future trends. These are ultimately coupled, statistically, in our analysis based on Tables 3, 5, and 6, where Cox’s Bazar and Char Changa have quite significant correlational values with respect to global averages and regional Bay of Bengal values. Furthermore, due to the exacerbation of many factors causing RSLR during the 21st century, the local SLR trends will have an even more pronounced exponential curve than their comparison with the RCP prediction in Figure 6. Therefore, both Char Changa and Cox’s Bazar, with estimates of more than half a meter for the former and over a meter for the latter in a linear trend based on the relatively little historical record, could expect a few meters (Figures 2 and 3) of SLR for Cox’s Bazar and well over a meter for Char Changa. This situation is critical for Bangladesh, and the scarce local data from gauges have a relatively short temporal range, scarce locations of gauges, and a highly dynamic environment with multivariable sources of RSLR, which together reduce the possibility of a confident prediction of local SLR. The Table 8 provides a summary of the principal climate-associated factors for the coastal setting, showing different climate related drivers, their physical/chemical effects, trends, projections, and progress. It’s indicated whether the climate related driver affects global, regional, or local SLR

Table 8. Summary of different effects, projections, etc., for local, regional, and global sea level changes. [Adopted by IPCC, 2014] [1,2]

Climate-Related Driver	Physical/Chemical Effects	Trends	Projections	Progress	Scale of Effect
Sea level: global and local southwestern coastal region, Bangladesh	Submergence, flood damage, erosion; saltwater intrusion; rising water tables/impaired drainage; wetland loss (and change)	Global mean sea level very likely to increase and SLR in Bay of Bengal higher than global	Global mean sea level likely increases and SLR in Bay of Bengal will much increase	Improved confidence in contributions to observed sea level. More information on regional and local sea level rise such as the southwestern coastal region in Bangladesh	Global, much effect regional and local
Storms: tropical cyclones (TCs),	Storm surges and storm waves,	TCs high confidence in trends in frequency,	TCs likely increase to no change in frequency;	Lowering of confidence of observed trends in	Global, much effect regional and

extratropical cyclones (ETCs) in SWCRB	coastal flooding, erosion; saltwater intrusion; rising water tables/impeded drainage; wetland loss and change. Coastal infrastructure damage and flood defense failure	ETCs likely poleward movement of circulation features but low confidence in intensity changes	likely increase in the most intense TCs. ETCs high confidence that reduction in ETCs will be small globally and in Bangladesh. Low confidence in changes in intensity	TCs and ETCs since AR4. More basin-specific information on storm track changes	local
Winds	Wind waves, storm surges, coastal currents, land coastal infrastructure damage	Low confidence in trends in mean and extreme wind speeds	High confidence in projected mean wind speeds. Likely increase in TC extreme wind speeds such as Amphan in India, Bangladesh	Improved atmospheric observations and simulations for wind	Global and Local
Waves	Coastal erosion, overtopping, and coastal flooding	Likely positive trends in Hs in high latitudes	Low confidence for projections overall but medium confidence for Southern Ocean increases in Hs	Large increase in number of wave projection studies since AR4	Global and Local
Extreme sea levels	Coastal flooding erosion, saltwater intrusion	High confidence of increase due to global, regional, and local mean sea level rise	High confidence of increase due to global, regional, and local mean sea level rise, low confidence of changes due to storm changes	Local subsidence is an important indicator of regional sea level rise in many locations	Regional and local
Sea surface temperature (SST)	Changes to stratification and circulation; reduced incidence of sea ice at higher latitudes; increased coral bleaching and mortality, poleward species migration; increased algal blooms	High confidence that coastal SST increase is higher than global SST increase	High confidence that coastal SSTs will increase with projected temperature increase	Emerging information on coastal changes in SSTs	Global, regional, and local
Freshwater input	Altered flood risk in coastal lowlands; altered water quality / salinity; altered fluvial sediment supply; altered circulation and nutrient supply	High confidence in a net declining trend in annual volume of freshwater input in study area	Medium confidence for general increase in high latitudes and wet tropics and decrease in other tropical regions	Emerging information on freshwater input	Regional and local
Ocean acidity	Increased CO ₂ ; increased seawater pH and carbonation concentration (or “ocean acidification”)	High confidence of overall increase, with high local and regional variability	High confidence of increase at unprecedented rates but with local and regional variability	Coastal ocean acidification increase	Global, regional, and local

This information also explains the smaller variations in SLR trends observed in the three river gauges, as these effects can be extremely localized, even within a single delta. The SLR in the river delta of the study area could be explained by the sinking and rising of the land, as the sinking of the land plays a role in the sea level rise in Bangladesh Table 8 [1, 2,100]. A probable 1.6 billion tones/yr of alluvial content streams towards Bangladesh through the Ganges and the Brahmaputra. Similarly, higher rates of ice melt in the Himalayan region would cause SLR in the Bay of Bengal and its river delta [106–109]. However, the subsidence of the deltaic landscape is considered to have been stabilized by the replenishment of dredges pushing towards a gross SLR and, in some regions, could rise due to an increase in river discharge by glacial meltwater Table 8. This could explain the three gauges with rising SLR trends and the two with no trends (Table 4). Strain from huge construction and engineering

projects can equally give rise to compacted sedimentation and land sinking, such as in eastern Tokyo, Po Delta, Shanghai, and Bangkok [1,2,12]. It is also important to consider the size of the delta, as their size and composition rely on how much water is entering and leaving, with humans having an impact on this gradient Table 8[87–89, 105–106].

Another topic of interest is how shorelines may be affected by sea level rise. For coastal areas, the subsidence is known as sinking land, and can result in increased sea level and risks of flooding Table 8 [1]. However, sea level is reduced with uplifting of land and increases coastlines migrate seaward migration [35]. From our results, we can predict that shorelines will shrink and become smaller compared to the past as water levels increase. The shoreline of Kuakata, in Bangladesh, for instance, is shown to be affected by sea level rise and erosion Table 8 [82,85]. These could result in difficulties using the land, maintaining a healthy coastal ecosystem, biodiversity, and economic livelihood Table 8 [1,35]. This may require humans to re-structure and extend into the land to ensure a shoreline is always accessible. This ties back to the human interaction with the land with regards to land disruption and possibly drilling, depending on the means necessary to maintain the shoreline.

Table 9. A new study estimates that the number of people affected by rising sea levels has almost tripled [34] [Adopted by Gupta, 2019; CGTN's].

Country	Previous Study	New Study	Change
1. China	29 million people	93 million people	+67 million people
2. Bangladesh	5 million people	42 million people	+37 million people
3. India	5 million people	36 million people	+31 million people
4. Vietnam	9 million people	31 million people	+22 million people
5. Indonesia	5 million people	23 million people	+18 million people
6. Thailand	1 million people	12 million people	+11 million people
Total, global	79 million people	300 million people	+221 million people

Rising sea levels can affect three times more people by 2050 than earlier assumed. Additionally, 300 million people living in the coastal areas of China, Bangladesh, Vietnam, and Indonesia will be recurrently flooded, a new study informs Table 9 [1,34]. Besides, the SWCRB area, with a density of 1300 people per square km, will increasingly be impacted by floods, coastline erosion, and storms, phenomena exacerbated by rising sea level, where storm surge and sea level rise can indirectly result in dramatic effects Table 8[35]. Predictions and probable underestimation of SLR trends in previous studies threaten the habitable zone of tens of millions of people within Bangladesh. It is thus essential to constantly observe the warming of the oceans as well as the Earth's average surface air temperature as they could affect more than half of the Bangladeshi population if not maintained below 2 °C throughout the 21st century [1,2, 49]. The population of coastal areas and their assets will be impacted by SLR and its involved perils, as is strongly suggested by several studies Table 8-9. These calculations are, however, reliant on uncertain scenarios implicated with global altitude and population data [1,2,101]. All the estimations provide an indication of high and increasing vulnerability of low-lying coastal belts Table 8. It is reported that ~2% of the covered global land area containing 10% of the global population, i.e., 600 million, is constituted by the low-elevation coastal zone, with 13% of the global population in the urbanized locality, i.e., 360 million, as per the estimations for the year 2000 [1,2,34,85]. Greater portions (~65%) of global metropolises with a populace of more than 5 million are inhabitants in the low-elevation coastal zone [1, 2, 85–86]. However, the global population manifested in the 1-to-100-year peak sea level—the sea level that has a 1% chance of being surpassed each year—has risen by 95% from 1970 to 2010, with approximately 270 million inhabitants and USD 13 trillion equivalent of properties exposed to the 1-in-100-year peak sea level in 2010 [1,85–88]. In 2002, there was approximately USD 1.9 trillion less wealth in the 1-in-100-year extreme sea level and it was spread in these 10 port urban localities—Miami (USA), New York–Newark (USA), New Orleans (USA), Osaka–Kobe (Japan), Tokyo (Japan), Amsterdam (Netherlands), Rotterdam (Netherlands), Nagoya (Japan), Virginia Beach (USA), and Guangzhou

(China). When compared to other localities, Asia demonstrated the highest exposure based on population and wealth Table 8-9[1, 85–86].

Conclusions

Long-term measurements for three tide gauges located in the Bay of Bengal at Hiron Point, Char Changa, and Cox's Bazar, Bangladesh, showed that sea level rise in Bangladesh is significantly higher than previously expected. This study found that in 2050 and 2100, Hiron Point SLR will be 93 mm and 248 mm, respectively, Char Changa 228 mm and 608 mm, and Cox's Bazar SLR 4665 mm and 1162 mm. Using satellite radar altimeters, this study also found that SLR predictions in the Bay of Bengal are higher than globally, as 2050 and 2100 SLR in the Bay of Bengal shows 100.99 mm, 269.31 mm, respectively. For the CMIP5 model, RCP 2.6, RCP 4.6, RCP 6, and RCP 8.5, the MSL shows 0.6, 0.7, 0.83, and 1.0 m, respectively, in the Bay of Bengal region for the year 2100. The TOPEX and Jason-1, -2, -3 seasonal signal retained model shows an MSL trend in mm/yr (1992–2022) of 3.9 ± 0.4 mm in the Bay of Bengal. Data retrieved from NOAA show SLR at Hiron Point is +3.09 mm/yr (307.85 mm in 100 yrs), Char Changa +7.04 mm/yr (704.09 mm in 100 yrs), and Cox's Bazar in Bangladesh +2.52 mm/yr (252.98 mm of change in 100 yrs). Our results for yearly, 2050, and 2100 closely reflect tidal data from 10 stations (Kalaroa, Benarpota, Protapnagar, Basantapur, Kaikhali, Tala Magura, Chandkhali, Elarchari, Kobadak Forest, Shakra) of the Ganges Delta (GBM). The SLR in the river delta shows an increase, specifically, for Kalaroa, Benarpota, Kaikhali, Tala Magura, and Elarchari. The SLR is especially high for Kalaroa and Benarpota, showing a rise of >40 mm/yr.

Thus, sea level rise is one of the most pressing issues for low-lying coastal countries and especially for Bangladesh, one of the most populated and vulnerable deltas in the world. This demonstrates why assessing, comparing, and creating projections of local, regional, and global data is necessary to have a much clearer understanding of the complex dynamics of relative sea level change (RSLC). This study proved that local variability differed greatly from both regional and global localities, with five river delta stations having much greater SLR trends than global and regional values, and two of them being up to a greater order of magnitude. Similarly, invariant and even decreasing trends were recorded. The coastal tide gauges had greater trends than regional and global averages, but not as great as river gauge records. This is due to several factors, as deltaic regions are highly dynamic geomorphological environments, where subsidences by sediment loading and anthropomorphic effects are counterbalanced by an influx of fluvial sediments from glacial meltwater. This explains the differing values of the deltaic and coastal gauges, the latter having a greater influence on oceanic components. Similarly, increased Himalayan glacial meltwater was found to increase the sea level at the Bay of Bengal, reflecting on higher regional trends compared to global values. This situation is dire for the Bangladesh coast, as RSLC indicates higher patterns than global averages, and a population extremely vulnerable to even minor SLR, that can potentially leave millions of climate refugees. This situation is far from fair, as Bangladesh is among the countries that releases the lowest amount of emissions. However, the future will be determined within the coming decades, as the predictions of future SLR are influenced by the activities of more industrialized countries, and their commitment to the 2015 Paris Agreement. To overcome the detrimental effects of climate change on the most vulnerable nations, including developing nations near low-lying coastal regions, such as Bangladesh, observation at different scales is essential, as well as establishing possible future predictions.

Supplementary Materials

The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/jmse10060779/s1>, Supplementary Materials: data analysis, statistical analysis, graph, table.

Author Contributions :Conceptualization, M.A.; methodology, M.A.; software, M.A.; validation, M.A., F.D.S., J.M.D. and A.C.; formal analysis, M.A.; investigation, M.A. and J.M.D.; resources, M.A., F.D.S. and J.M.D.; data curation, M.A.; writing—original draft preparation, M.A.; writing—review and editing, M.A., F.D.S., A.C. and J.M.D.; visualization, M.A. and A.C.; Supervision, F.D.S., A.C. and J.M.D.; funding acquisition, F.D.S. All authors have read and agreed to the published version of the manuscript.

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5. Climate change driven natural disasters and influence on poverty in the Southwestern Coastal Region of Bangladesh (SWCRB)

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Abstract

The southwestern coastal region of Bangladesh is constantly affected by cyclones, storm surges, and saline soil due to its geographical location and low-lying topography. Furthermore, climate change and sea level rise are expected to increase the frequency and intensity of these natural disasters. These disasters constantly devastate local rural communities, affect their income sources, and destroy local infrastructure, thus, promoting high rates of poverty, which prevent these communities from investing in disaster-resilient lifestyle. Thus, this study aims to visualize the population's perception on poverty and the effect of natural disasters exacerbated by climate change within the Shyamnagar Upazila region to highlight the most pressing issues and propose policies to increase community resilience. A total of 320 households were surveyed for their observation through a qualitative questionnaire and quantitative in-depth interviews, FGD, case study, and group workshops. It was observed that 65% of the population was below the poverty line with a relatively low Gini coefficient of 28.5, and most of the infrastructure and livelihood options were extremely vulnerable to natural disasters. Cyclones, storm surges, and increased soil and freshwater salinity were identified as the main issues affecting the community livelihood and income sources. Similarly, the population was aware of anthropogenic climate change and sea level rise, as well as the subsequent present and future effects. However, the introduction of policies, such as microfinances and educational programs, can vastly increase the resilience of these communities through additional disaster-resistant income sources and adaptation measures presently and in the future.

Keywords Climate change · Natural disaster · Poverty and inequality · Community perception · Adaptation

Introduction

The irregularities in weather and climate trends are pronounced in many regions of the planet. This is primarily a hindrance for individuals in low-income coastal societies due to lack of resources and a reduced capacity to cope with the associated stressors (Uddin et al. 2021). Bangladesh, with its 180 million inhabitants and limited capacity to reduce or curtail the bearings, is extremely vulnerable to weather and climate inconsistencies and unstable hydro meteorological events (Stepherd et al. 2013). The public is at a risk of losing crops, property, and life (Uddin et al. 2021). Low income increases the vulnerability to means-controlled societies as they are not equipped to deal with the associated stress issues; however, coastal areas in southwestern Bangladesh are resilient to climate-induced disasters even though the entire country is not protected (Ahmed 2018; Bianchi and Malki 2021).

Individuals from the vulnerable regions have to face several challenges in harsh climate-bearing zones. The scarcity of regions is shaped by both climatic conditions and socioeconomic dynamics. The coastal area of Bangladesh is approximately 47,201 km², or 32% of the country's total land area (Rokonuzzaman and Hattori 2021). This part is densely populated, similar to the other parts of the country. In 2000, ~63 million people lived in coastal Bangladesh, and by 2030, this number is predicted to reach 84 million (Neumann et al. 2015). Nonetheless, the region also has a few distant islands sporadically such as Gabura and Podma Pukur Union which is more vulnerable in the canvas of climate change. As climate volatility is increasing vulnerability to poverty in many developing

countries (Ahmed 2018), climate-induced poverty can be described as a situation in which people regress into poverty as a result of impending natural/climate disasters.

Besides, extreme poverty in Bangladesh has significantly reduced from an extreme poverty rate of 24.3% in 2000 to 12.9% in 2016 with most of the changes occurring in rural areas (Chowdhury and Hossain 2018). This reduction in poverty is greater in rural communities, accounting for ~ 90% of the drop, and as compared to ~ 10% in urban areas (Hill and Genoni 2019).

In contrast, the distribution of wealth in Bangladesh has increased in favor of greater inequality (World Bank 2020c). The Gini score for the year 1983 was 25.9, which rapidly increased to 32.4 in 2016 depicting increasing wealth inequality as the country industrialized and urbanized, as can be observed in Fig. 1 (World Bank 2020c). This indicated that although Bangladesh showed reduced poverty, most of the recent economic growth was concentrated in the middle and upper socioeconomic classes (Fig. 2).

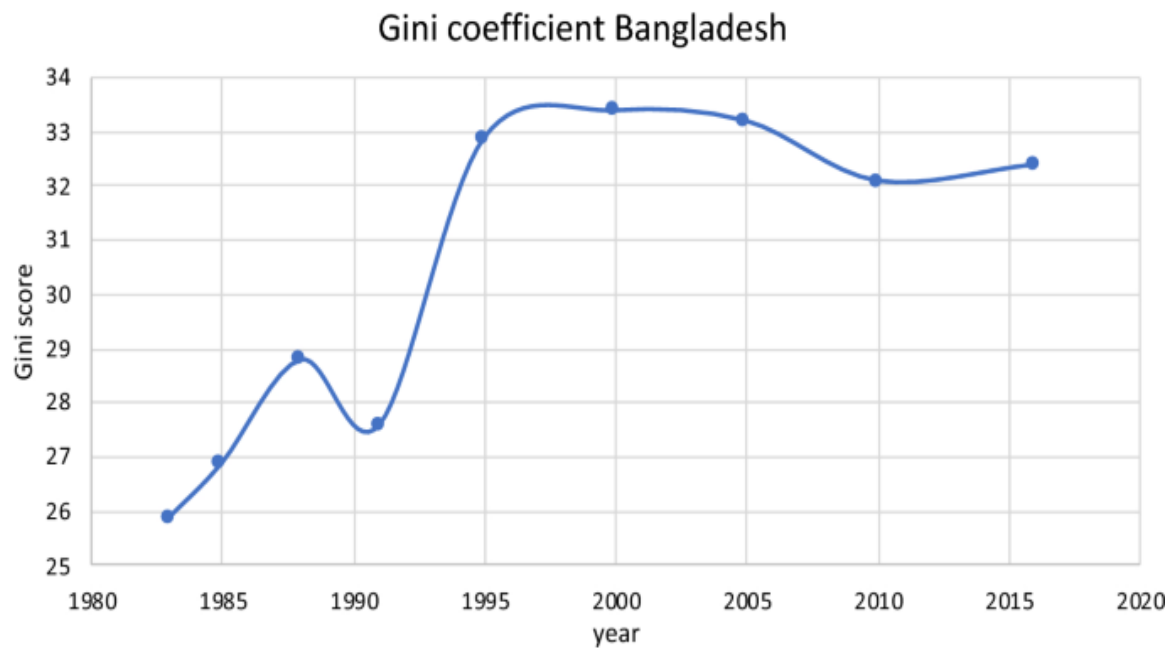


Figure 1: Gini score of Bangladesh from 1983 to 2016. This graph shows a massive increase in the amount of wealth inequality, especially from 1991 to 1995. Self-made graph with data retrieved from the World Bank (2020b).

Currently, a quarter of Bangladesh still lives in poverty, and most of the poverty-affected sectors include the agricultural rural sector, of which percentage contribution to GDP dropped drastically from > 50% in 1960 to marginally over 10% in 2019 (World Bank 2020b). The decrease in rural poverty was the lowest in farming and fishing communities (Hill and Genoni 2019). In addition, due to the unequal consumption patterns in urban and rural areas, the Gini coefficient increased by approximately two points in rural areas as compared to national averages. Furthermore, fishing communities along the coast of Bangladesh are among the poorest in the country (Barbier 2015;

Dasgupta et al. 2017). Both agriculture and fishing, among other rural activities, are highly dependent on natural resources and the stable availability of the services they provide (Lázár et al. 2020a, b). The fishing and agricultural communities extract and harvest these services and are the primary contributors of wealth in most rural communities (Roy and Sultana 2010). Consequently, any change or modification in the dynamics of the ecosystem and the environment is likely to have a direct effect on the livelihood of people directly dependent upon it. Unfortunately, Bangladesh is one of the countries most affected by natural disasters with devastating effects on the economic stability of the communities dependent on these activities (Lázár et al. 2020a, b).

Ha-Min and Hossain (2020) revealed that vulnerability to natural catastrophes and their environmental impacts was negatively correlated with income and socioeconomic levels, indicating that poor households are much more vulnerable to the impacts as compared to higher income households. This is because vulnerable communities are more likely to reside in relatively fragile dwellings due to the lack of resources to build cement houses, causing this population to be more likely affected by natural disasters (Ahsan and Takeuchi 2015; Charles et al. 2019). In addition, these communities lack the economic means to adapt and respond to calamities, and are, thus, less economically resilient to changes in their environment.

Cyclones and tropical storms are a common phenomenon in Bangladesh. Between 2000 and 2020, 14 tropical cyclones caused great infrastructural damage on the SWCRB, mainly by storm surges with waves > 7 m (Huq et al. 2010; Biswas et al. 2016). Cyclone Sidr affected approximately 3.45 million people in Bangladesh in 2007 (Huq et al. 2010; Hossain and Mullick 2020; Rahman and Missingham 2018). Many vulnerable communities with poorly constructed houses suffered comparatively more casualties and structural damage than in wealthier communities (Ahsan and Takeuchi 2015). In addition, fertility of vast areas of land, fish population, and community equipment were vastly damaged, causing extreme poverty (Roy and Sultana 2010; Hossain et al. 2018). These natural disasters are one of the main factors for widespread poverty within the coastal regions of Bangladesh (Adnan et al. 2020).

Furthermore, saltwater storm surges and seawater floods during cyclonic events not only have a potential destructive effect on infrastructure, but also long-term negative effects on agriculture by increasing soil salinity (Mondal et al. 2015)). About 37% of the seaside farmland was affected by various levels of soil salinity due to these surges (ibid). Roy and Sultana (2010) reported that both Sidr and Aila cyclones resulted in a reduction of ~23% in agricultural income in subsequent years among farmers in affected areas. In addition to this, ground water salinity is one of the most latent issues in the southwestern coastal region of Bangladesh (SWCRB), as many communities have to depend upon highly saline Water for domestic usage and irrigation (Dasgupta et al. 2017). This salinity increase in fresh water sources is seasonal and highly correlated with the appearance of tropical cyclones, and high salinity levels can last for several years after an associated storm surge from a big cyclone (Islam et al. 2018).

Pluvial floods caused by monsoon precipitations and fluvial floods from river discharge also pose a threat to local populations. From 1978 to 2008, the amount of rain increased by 4 mm with increased irregular patterns, thus, contributing significantly to some of the most severe freshwater floods in 1998, 2004, and 2007 (Islam et al. 2018). Also, it is predicted that the Himalayan meltwater due to global warming will cause increasingly unpredictable and intense runoff patterns, further exacerbating floods (Dasgupta et al. 2017).

An increase in sea surface temperature in the northern Bay of Bengal caused by global warming is predicted to cause an increase in the average magnitude and frequency of tropical storms and

cyclones, which will enhance the wind force and size of sea water surges (Mondal et al. 2016; Mathew et al. 2018). In addition, a sea level rise of 30–100 cm is predicted by 2100 as compared to 1990 levels, which will permanently flood massive swaths of land near the coast and extend the saline soils and water sources farther inland (Awal and Khan 2020; Becker et al. 2020). By 2050, sea level rise will directly affect one million people and will specifically affect the availability of jobs and income related to agriculture, fishing, and secondary services (De Lellis et al. 2021).

Taking this into account, the motivation behind this study is to provide a highly localized account of the most pressing issues that affect the livelihoods and income sources of the most marginalized communities in the SWCRB. This study also aims to provide possible mitigation measures based on the results of the study directed towards policy makers to reduce the vulnerability of these communities. Thus, this study aims to analyze the perception and the effect of the local population on the issues that increase poverty, particularly those caused or exacerbated by natural disasters, climate change, and sea level rise as well as the adaptation measures. The income level and wealth distribution are also analyzed in this regard. Lastly, this paper discusses the possible solutions directly targeting the most pressing issues to create resilient communities that could lead to effective policies in order to reduce the vulnerability of SWCRB communities.

Study Area

The Shyamnagar Upazila, occupying an area of 1968.23 km², is located between 22°36' and 22°24' North Latitudes and between 89°00' and 89°19' East Longitudes. The Upazila is bounded to the south by the Bay of Bengal and to the west by India, and the deltas of the Ganges, Brahmaputra, and Megna Rivers are within this region. The Upazila consists of 12 unions and 216 villages (BBS 2011). There are a few major rivers that cross the area, including Kobadak, Kholpatua, Sonai, Raimangal, Morischap, Hariabhanga, Ichamati, Betrabati, Kalindi, and Jamura (Islam et al. 2018). The annual mean temperature is 25.5 °C, with a minimum of 21 °C and a maximum of 30 °C; the average annual precipitation amounts to 1689 mm with a relative humidity of 79.5% (Islam et al. 2018).

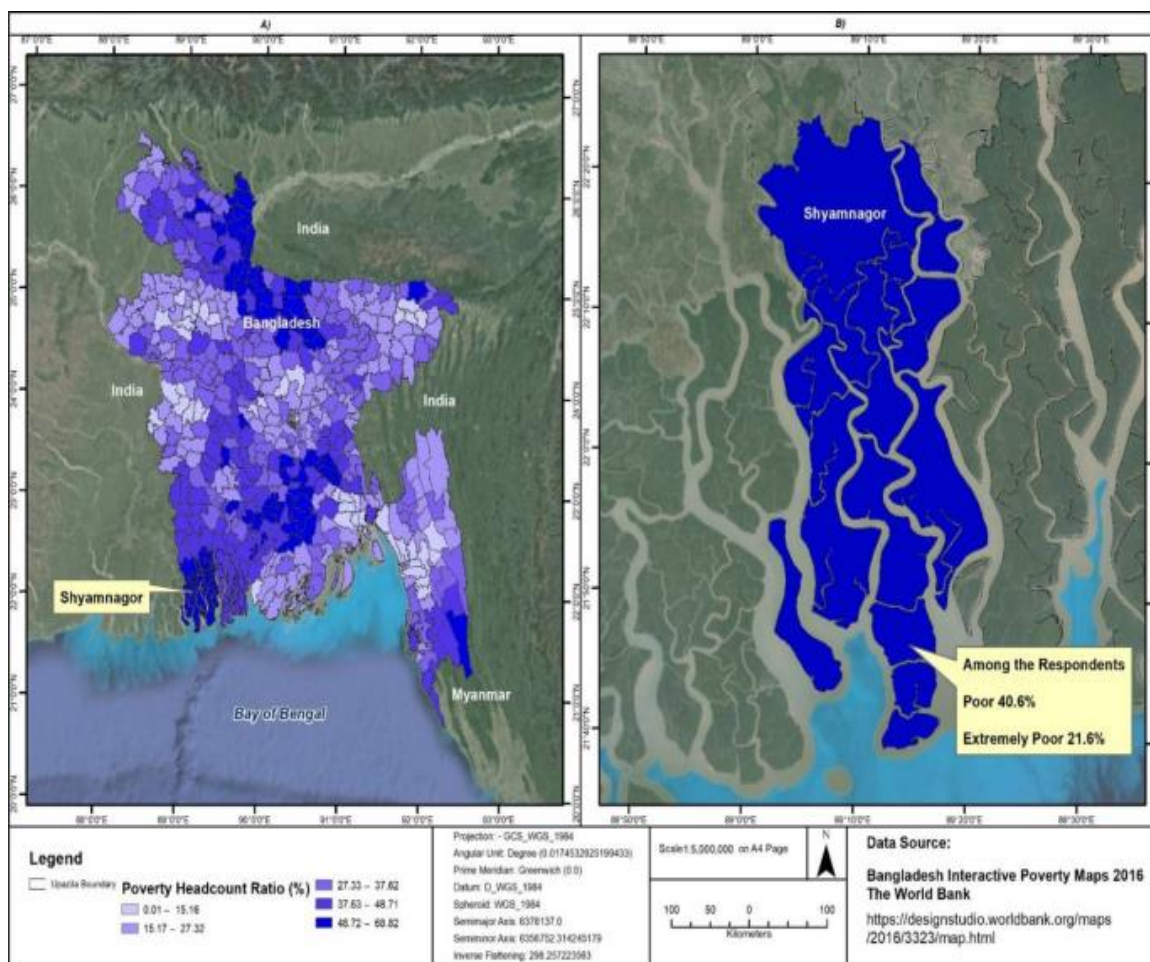


Figure 2: a) Percentage of poverty per Upazila in Bangladesh. b) Location of the Shyamnagar Upazila on the SWCRB. This Upazila has some of the highest percentages of poverty in the country. Self made with data from the World Bank (2016).

Methodology

The methodology followed was identification of SWCRB people, followed by detailed interviews, focus group discussions, case study, workshop, participatory rural appraisal tools, and key informant interview to accumulate data from national and local experts. The data obtained were further analyzed quantitatively and qualitatively. The research transcribed all the field notes and recorded information and ensured accurate interpretation. For subsequent analysis, the main thematic areas were followed as per the checklist. In the data reduction step, content analysis was used to identify themes and code transcripts into sub-themes. All data were manually coded. The data interpretation was established on a mixture of contextual field notes, coding summaries, and description presented by the participants.

This study was carried out in nine unions within the Shyamnagar Upazila from 2017 to 2019 with a total of 320 household samples ($n = 320$). A computer-generated table was applied to randomly select the households from the different Unions. The proportion (p) of households sampled from the 9 unions observed in Fig. 3 and a complete list of riverine households in the selected area was obtained from the nine Union Council (small local government unit in Bangladesh). The subsample size (x) for seven unions was kept between $x = 21-30$ samples per union or $p = 0.0656-0.0938$. 5% of the

population was adequate for cross-sectional household survey through random sampling from each union (Cairns et al. 2009). As in Kaikhali union (n = 21) and Atulia union (n = 22), however, several people responded to this study. On the other hand, a higher proportion of samples were taken in Buri Goalini and Gabura Unions, and the computer-generated table was programmed to select a higher proportion of individuals, with $x = 82$ and 63 or $p = 0.256$ and 0.197 , respectively, due to their proximity to the Bay of Bengal, thus, having a greater influence of cyclone-related natural disasters (Rahman et al. 2020). The sampling technique was partly based on Mwera et al. (2016), where a simple random sampling method was used to select economically active individuals from a single dwelling, as economically active individuals within one household usually share the different incomes and resources as unitary.

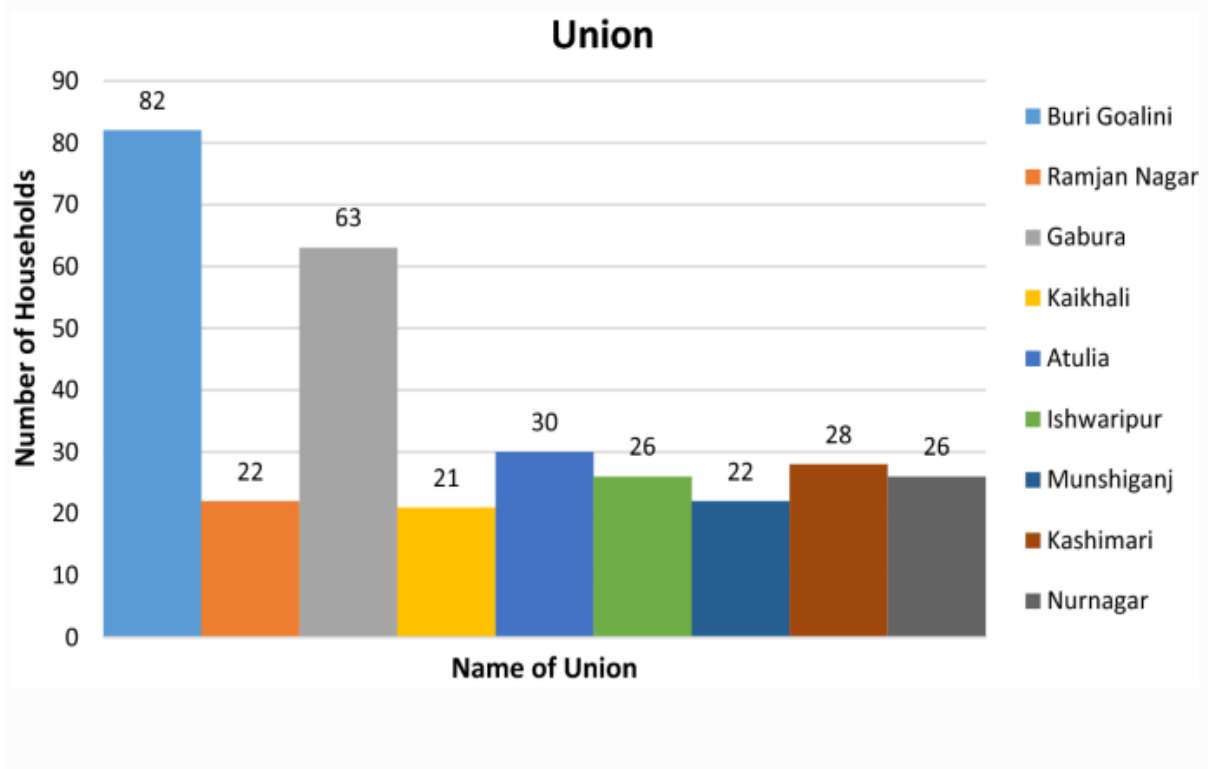


Figure 3: Total number of responders per union within the nine unis selected within the Shyamnagar Upazila. Both Buri Goalini and Gabura have a higher proportion of responders due to their proximity to the The Bay of Bengal (Babu, 1992). Self-made data with data from the 2018-2019 questionnaire.

Every sampled individual was given a structured questionnaire with single and multiple option questions related to the perception of poverty, effects of natural disasters and the connection of these elements to climate change, which were divided into ‘economy’, ‘environment’ and ‘future adaptations’ sections (see annex 1). These questions were partly based on similar studies about environmentally related issues that have negatively affected the livelihood and local economy of people living near the coast (Ali, 1996; Bhuiyan and Dutta, 2012; Huq et al., 2010). Along this, an In-Depth Interview (IDI) was carried out with each of the responders, as well as a workshop per union

with a few of the responders to find out individual testimonies about responders' perception these issues, and the most significant answers were used for this study.

$$B = \sum_{i=1}^n \left(\frac{x_i + x_{i-1}}{2} \right) \left(\frac{y_{i-1} - y_i}{100} \right)$$

Equation 1: The area under the Lorenz curve (B), partly based on Brown, 1994. Where x is the cumulative percentage of income, y is the cumulative percentage of population and i is the rank of values in ascending order.

$$A = 50 - B$$

Equation 2: The area over the Lorenz curve (A), given that the sum of both areas of the Lorenz Curve equals 50, or $A + B = 50$

$$G = \frac{A}{(A + B)}$$

Equation 3: The Gini Inequality Coefficient (G), which is defined as the ratio of the area between the Lorenz curve and the equality line with that of the total area below the equality line (Zubayer et al., 2020).

Along this, a single option question on monthly household income, used to calculate the Gini Inequality Coefficient of the 320 households (Zubayer et al., 2020). The Gini Inequality Coefficient (G) is a value going from 0, representing complete equality, to 1, representing complete inequality (Gini, 1921). Firstly, the area under the Lorenz curve was calculated by sorting the seven monthly household income options bins and estimating the cumulative percentage of income and of population for each of the seven seen in equation 1 (Zubayer et al., 2020). Following this, the area over the Lorenz curve (B) was calculated in equation 2 and used to calculate the Gini Coefficient based on equation 3 (Brown, 1994).

Focus group discussions (FGDs) were further organized with different groups of pre-selected respondents of homogenous nature with semi-structured guideline and the use of participatory exercises. The guidelines were prepared for each group of respondents specifically to obtain concise information related to the research objective. Each FGD consisted of 8–12 participants, including women, men, youth, elders, and people with disabilities (Morgan 1997). FGDs captured the data related to climate shocks and vulnerability and opportunities such as disaster- and climate-resilient practices.

A case study was endorsed to furnish information on all the members representing SWCRB. This case study was considered with the purpose of conducting rigorous analysis as an exemplary approach to understand the SWCRB scenario (Yin 2003; Harrison et al. 2017). This case study was conducted with the purposes of (1) understanding the real scenario in terms of climate change and (2) assessing poverty. Since case study spans its focus on analytic domain in a comprehensive sense, this approach can be used for carrying qualitative research; hence, this was considered as a part of this research. Case studies facilitate the means to understand poverty, which otherwise makes survival difficult.

Moreover, in-depth interview (IDI) was carried out by selecting respondents with relevant occupations, such as teachers, community leaders, farmers, and non-governmental organization (NGO) representatives (Romero et al. 2019). For each of these, an unstructured interview was

conducted to get a detailed qualitative account of the specific issues and vulnerabilities related to natural disasters, poverty, and adaptation measures associated with their profession and lifestyle.



Photo: A.

B.

C.

D.

A) Interview with the priest; B) Focus group discussion with locals; C) Interview with KII (key informant interview); D) Workshop and marisco approach

Similarly, several workshops and marisco approach were conducted in every union with a mixed set of participants, including college and basic education students, local government officials, journalists, and NGO representatives (Picketts et al. 2012; Ibisich and Hobson 2015). These workshops and marisco approach were conducted by asking non-structured questions specifically directed to the type of groups in each workshop to understand the quantitative testimonies about their experiences with the issues already mentioned.

Both the workshop and the IDI served to reveal localized testimonies and accounts that complemented the structured questionnaires with qualitative accounts of individuals and groups. Thus, the most significant testimonies from the IDI and workshops were used for this study.

Results

Poverty analysis

The most prevalent primary occupation of the respondents was fishing, at 33.1%, while it ranked second as subsidiary occupation at 36.9% as seen in Table 1. Day labor was the second most prevalent occupation at 22.2% and fourth in rank as a subsidiary occupation at 10.9%. Only 15% of total households had agriculture as the primary occupation in the third place, and 36.9% of total households had agriculture as a subsidiary occupation, where it was the most popular option (Table 1). These results are contradictory to those of the Shyamnagar Upazila, where 64.98% of the dwelling households had agriculture as their primary occupation (BBS 2011). Our results are also in contrast to a similar study by Islam et al. (2018), where 35% of the responders worked in agriculture and only 17% in the fishing industry. Furthermore, 11.9% households mainly depended on other occupations and 7.5% depended on subsidiary occupations such as tailoring, car painting, house tutoring, and as electrician.

Occupation	Frequency	Percentage
Main Occupation		
Fishing	106	33.1
Day labor	71	22.2
Agriculture	48	15
Others	38	11.9
Driver	23	7.2
Service holder	17	5.3
Livestock Farming	10	3.1
Grocery Shop	7	2.2
Subsidiary Occupation		
Agriculture	118	36.9
Fishing	68	21.3
No Profession	35	10.9
Day labor	32	10
Driver	25	7.8
Others	24	7.5
Livestock Farming	18	5.6
Grocery Shop	0	0
Service holder	0	0

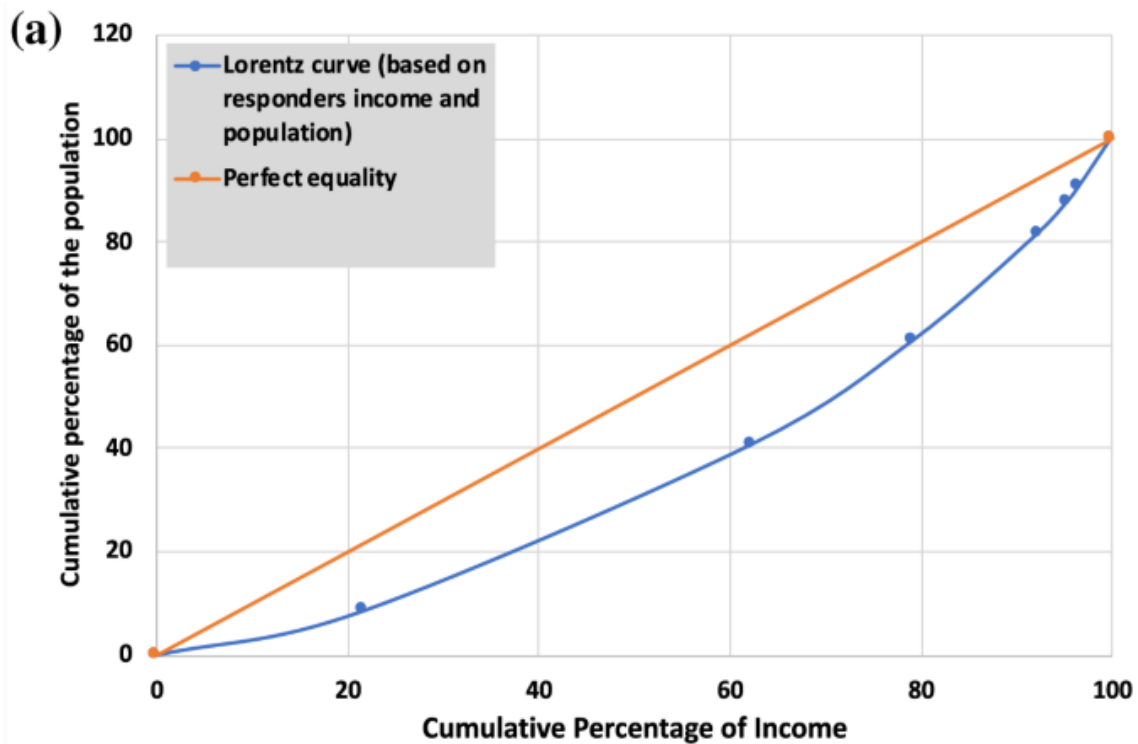
Table 1: Main and subsidiary occupation status of responders. Half of the population depends on fishing, day labor and agriculture. (Data source: 2017–2019 questionnaires).

Approximately 62% of inhabitants are below the poverty line, earning 0 to 10,000 BDT per month, in contrast with only 8% of households in the study area earning > 20,000 BDT per month. Similarly, based on a report by the World Food Program (2011), the poverty rate in the Shyamnagar Upazila was well over half of the population, at a range of 33 to 65% of the population, which indicates that the results obtained in this study are on the upper margin of this range. On the contrary, Islam et al. (2018) reported that in the same Upazila, only 10% of responders earned < 10,000 BDT, with more pronounced results than this study. This rate was also three times higher compared to the national poverty rate of 21.8% in 2018 (Asian Development Bank 2020). In continuation, 21.6% of the population was within extreme poverty, with an income of 5000 BDT per month or less. The results from this study showed an average that was considerably higher than the national average of 12.3% in 2016 (Chowdhury and Hossain 2018).

Didarul Islam of Ward 6 of Burigoalini Union testimony on the workshops indicated that if not unemployed, many women and men in his family work in crab or shrimp farms for 12 h per day, earning approximately Tk. 5500–6000 per month. In addition, many women fish shrimp hatchlings for 4–5 h by pulling the net, which is a very intensive work with a limited income of Tk. 300–400. However, most of the year the family is unemployed. Similarly, Asiya Khatun of Gabura Union, Buli Rani of Padmapukur Union, and Yasin Ali of Bangshipur village are all fishermen by profession

earning approximately Tk. 10,000–12,000 in productive months and Tk. 5000–6000 in unproductive ones. All of them have experienced food deprivation at some point during the year. Finally, Tapan Roy, a college principal, indicates that most of his students are from poor or extremely poor families. Many of his students drop out of school to work for local crab hatcheries with salaries averaging from Tk. 6000–7000 per month. Also, many students work for 6 months earning an average of Tk. 40,000–50,000 in total, while they attend school for the other half.

The Gini coefficient for this population sample was equal to 28.46 (Fig. 4A), which indicates a lower inequality index compared to the Bangladesh's score of 32.4 in 2016 (World Bank 2020b). This score is the same as in 1988 for Bangladesh (ibid). However, this is not necessarily an optimistic value, as more than half of the population is below the poverty line. Although wealth is considerably evenly distributed, the results indicate that presently, the available wealth cannot create favorable economic conditions for most of the population.



(b)

Income range	percentage of population	Percentage of Income	Cumulative percentage of the population	Cumulative percentage of income
0 - 5000	16	8.56	21.6	8.6
5,000 – 10,000	49	32.17	62.2	40.7
10,000 – 15,000	15	20.09	79.1	60.8
15,000 – 20,000	13	20.76	92.2	81.6
20,000 – 25,000	3	6.14	95.3	87.7
25,000 – 30,000	1	2.85	96.5	90.6
>30000	3	9.43	100	100
GINI coefficient for responders	28.46			

Figure 4: The Lorenz curve (A) based on the cumulative percentage of the population (Y axis) and the cumulative percentage of the income (X axis) (B), along the Gini coefficient of the responders' population sample (Data source: 2017–2019 questionnaires).

From Fig. 5, the structure of more than half of the sampled dwellings (54%) is tin/wood/bamboo. The percentage of houses with semi-pacca building accounted for 20%, where roof was made of tin and wall was made of bamboo and tin. Only 16% of housing structures were cemented buildings (pucca) and 7% of housing structures were thatched, made of temporary materials such as straw. This shows that only 16% of houses can withstand a cyclone or be salvaged after a flood, as well as have a lower statistical mortality rate compared to other structures (Gazi 2019).

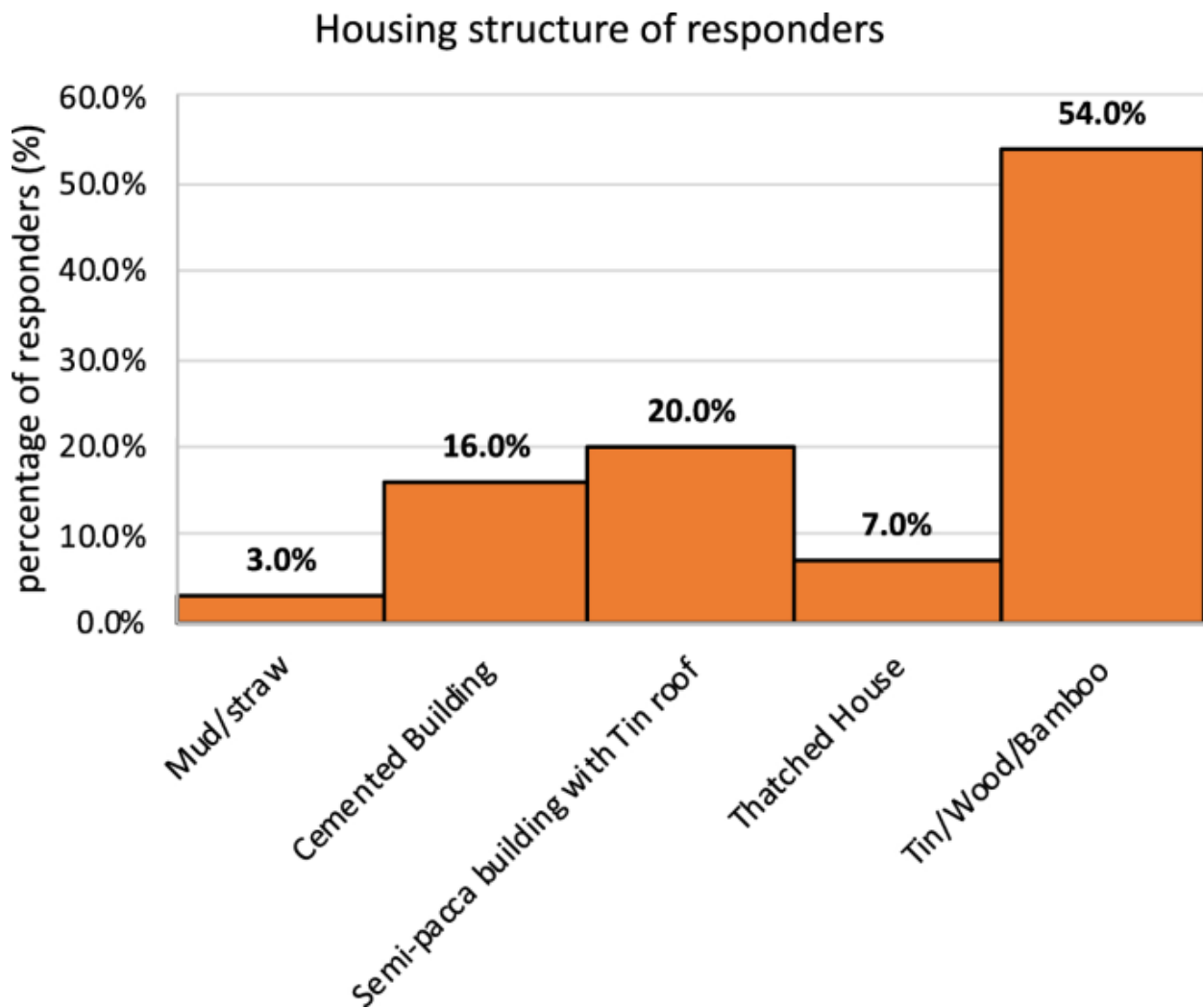


Figure 5: Housing structure of responders, where most of the population lives in structurally weak dwellings. (Data source: 2017–2019 questionnaires).

As seen in Table 2, the 32.2% of respondents indicated that their house had suffered damage from natural calamities in the last five years; 4.4% indicated that they were still living in damaged dwellings, and 24.7% or a quarter of responders suffered from notable damage. On the other hand,

more than half of all respondents (67.8%) declared that their house did not suffer from any damage within the last five years. This indicates that almost a third of the responders suffer from damage every 5 years, with significant damage for a quarter of responders. This cycle forces people to reinvest in dwelling maintenance within a few years, forcing them to go into debt (Roy and Sultana 2010; Biswas et al. 2019). Milon Gazi on the IDI also confirmed this pattern; during the rainy season and heavy storms, his mud and wood house gets flooded, and as a fisherman with a monthly income of approximately Tk. 3000, he is constantly in debt to repair it.

No	Yes	Yes with significant damage	Living in damaged houses
67.8%	3.1%	24.7%	4.4%

Table 2: Responders' answers to the question: Has your house suffered any damage due to natural disasters within the last 5 years? Almost a third responded affirmatively. (Data source: 2017–2019 questionnaires).

Climatic variation impacts

The results from Table 3 show that more than 98% of the responders are aware that the sea level has increased, and 97% of the responders are aware of the connection between rising sea level and climate change. Similarly, 94% of the responders indicate that global carbon emissions create social inequality in Bangladesh. Also, 92% of the responders believe that climate change is a threat to future generations and can change Bangladesh's coastline. Similarly, 91% of the responders indicate that climate change relates to capitalism, developed countries need to reduce CO2 emissions, and that climate education must be implemented at all levels of education. On the other hand, 87% of the responders indicated that they are able to have three meals a day. Also, 86% of the responders feel that climate change will influence existent social inequalities, and 85% of the responders believe that climate change creates poverty. Finally, 83% of the responders indicate that current economic activities pose a risk to the global climate system, sea level rise, and social inequality; as well as 75% of the responders have faced severe or massive disasters within the last 50 years. Overall, an average of 89% of the responders understand that anthropogenic greenhouse gases are linked to sea level rise and climate change (Biswas 2016) and then influence the creation of adverse conditions leading to poverty in Bangladesh.

Questions	Ye s	N o	Don't know
Do you think sea level has increased at all?	98	2	0
Are you aware of the connection between climate change and sea level rise?	97	3	0
Do you think that global carbon emissions create social inequality in Bangladesh?	94	6	0
Is climate change a threat for our future generation and could change the mapped coastline in Bangladesh?	92	5	3
Do you think climate change relates or is influenced by capitalism?	91	6	3
Do you think developed countries need to reduce CO2 emissions?	91	6	3
Is it necessary to add the topic about the consequence and bad effects of climate change in school, college, and university as well as community level?	91	9	0
Do you have three proper meals a day every day of the year?	87	13	0
Do you think that climate change will influence existent social justice inequalities?	86	14	0
Do you think climate change creates poverty?	85	13	2
Do you think economic activity is a risk for global climatic system, sea level change and social inequality?	83	17	0
Did you face any strong/massive disasters within the last 50 years?	75	18	7

Table 3: Responders' answers to a variety of questions relating to their perception on the link between anthropogenic greenhouse gases and climate change, sea level rise, and poverty in Bangladesh. (Data source: 2017–2019 questionnaires).

Half of responders noted that tropical cyclones linked to climate change, are the most significant factors in the rise of poverty based on Fig. 6. More than 47% of the total households mentioned that salinity in soil and water also leads to poverty (Borgomeo et al. 2018). More than 46% of respondents mentioned that rising sea levels create pressure on the embankment system of the study area, which increases the salinity level in soil and water through river and canal systems (Table 5.1). The respondents also mentioned that floods, regardless of the type, submerged agricultural land (Islam et al. 2015), disrupting the lives and livelihoods of the responders, leading to poverty and a high index of migration. Increased temperatures were also perceived by 42.8% of the respondents as a factor causing poverty. On the other hand, increased land degradation, desertification, and deforestation affected only 34.7% of the responders, while drought affected 31.3% of the responders.

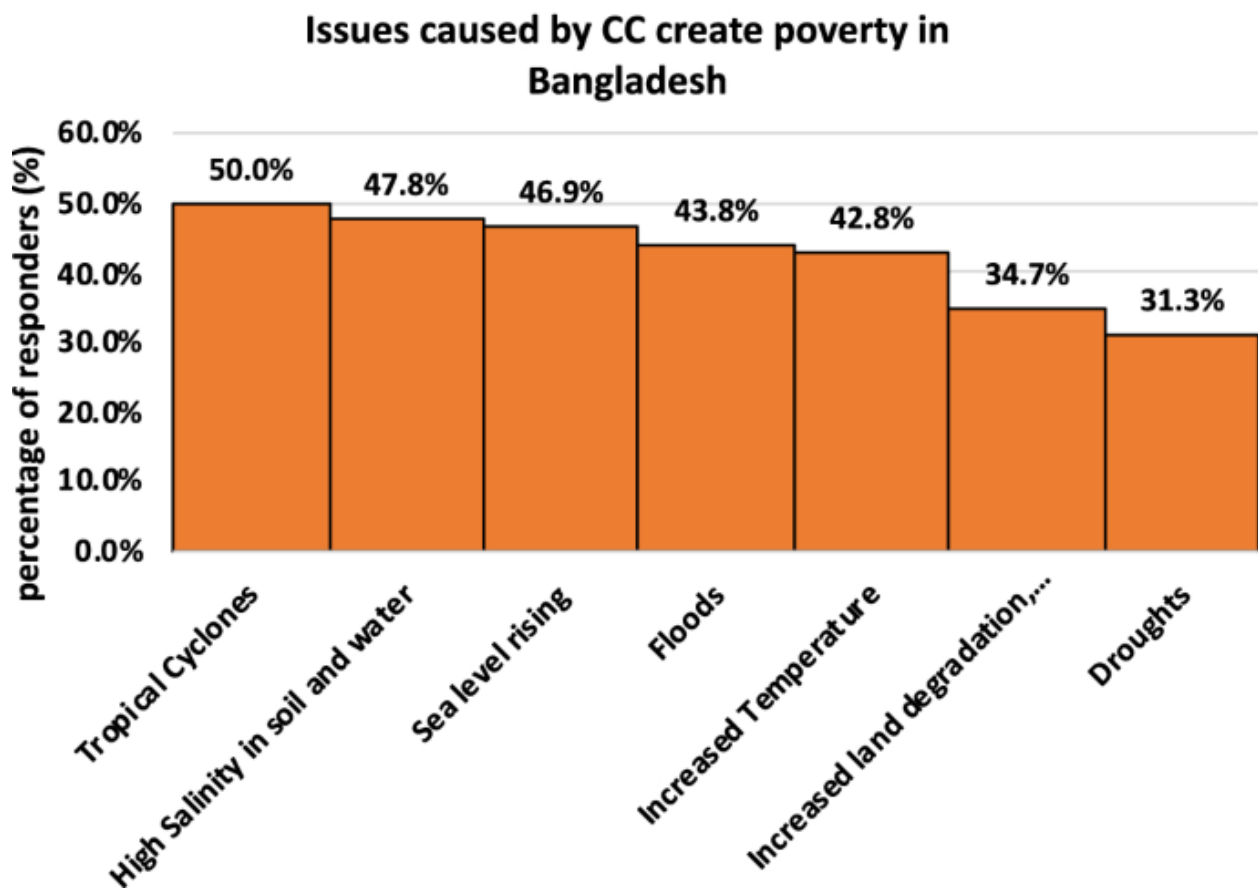


Figure 6: The perception amongst responders on the causes of poverty in Bangladesh related to climate change. This table includes multiple answers per individual. (Data source: 2017–2019 questionnaires).

Figure 7 represents the types of hazards caused by climate change and sea level rise that respondents face increasingly every year. Salt intrusion, cyclones, and flash floods are being reported as the three main types of hazards caused by climate change and sea level rise, by 48.44%, 44.69, and 43.44% of the responders, respectively. More than 48% of the responders mentioned that they face salinity intrusion as a hazard every year. Heavy storms and thunderstorms, erosion, tidal surge, and heavy rainfall are also latent concerns, with 39.69%, 39.06%, 37.5%, and 35.94% of the responders expressing their concerns. Loss of agriculture and biodiversity, droughts, and heat stress are the least concerns, with 33.44% and 30.94% of the responders.

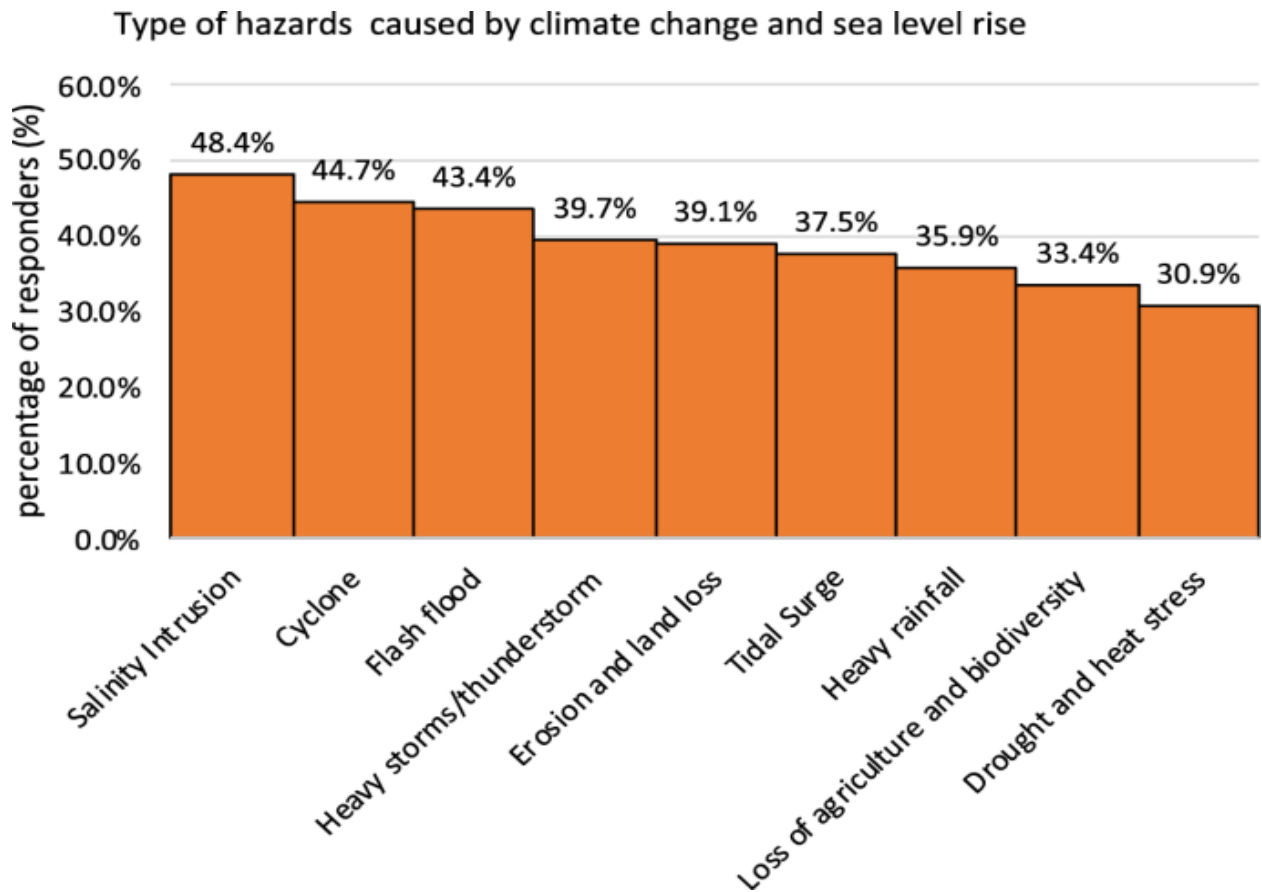


Figure 7: The perception among responders on the main hazards caused by climate change and sea level rise. Salinity intrusion, cyclones and flash floods are the main hazards. This graph includes multiple answers per individual. (Data source: 2017–2019 questionnaires).

The most frequent massive disaster within the last 50 years as seen in Fig. 8 was salinity intrusion, with 50% of responders reporting it. Flash floods, cyclones, and heavy rainfall were noted to be additional major concerns with 45.3%, 43.13%, and 40.63% of the responders, respectively. Heavy storms and thunderstorm, erosion, droughts and heat stress, and tidal surges are less of a concern for responders, as can be seen with 36.6%, 36.3%, 32.8%, and 31.3% of the responders, respectively. The three most popular responses from this table were very similar to those from Fig. 6, indicating salinity intrusion, floods (regardless of type), and cyclones as the natural disasters causing the most damage. Similarly, Nimai Mandal of Nurnagar Union in the IDI mentioned that if the salinity level in Nurnagar Union increased further, the farmers from the area would only be able to cultivate salt-tolerant varieties. However, past floods have created food shortage and caused the population in the area to be financially weak.

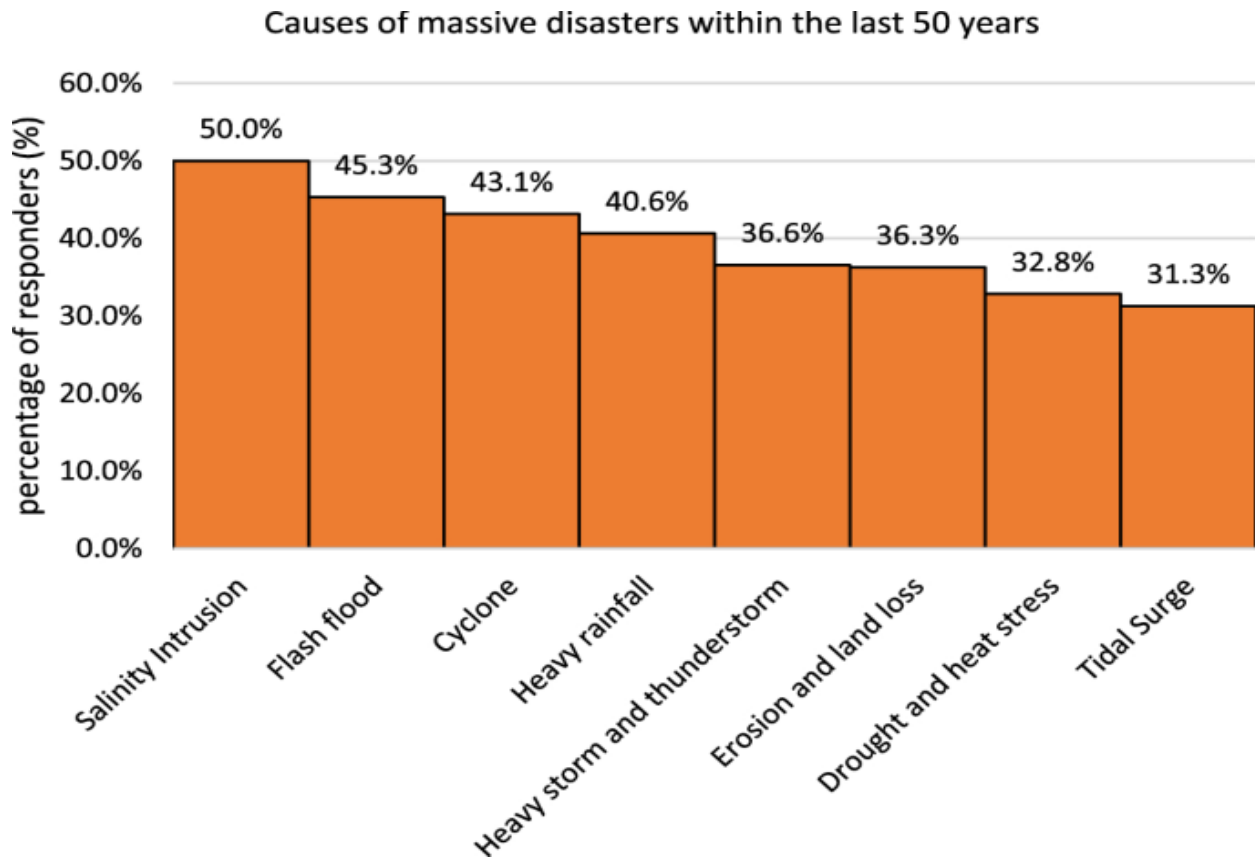


Figure 8: The perception among responders on massive disasters within the last 50 years. This table includes multiple answers per individual. Salinity intrusion, flash floods and cyclones are the main disasters in the last 50 years. This graph includes multiple answers per individual. (Data source: 2017–2019 questionnaires).

As per Fig. 9, more than half of the respondents (59.4%) have mentioned that the increase in CO₂ is responsible for shifting climatic patterns, while 25.9% of the respondents mentioned deforestation as the main reason. Further, continuous overall unsustainable lifestyles account was considered responsible for the shifting climatic patterns by only 12.2% of the respondents, while 2.5% of the respondents considered increasing harmful gases as one of the reasons. This indicates that more than half of the sampled population was aware of an existing connection between anthropogenic emissions and their role in increasing global temperatures, thus, affecting climatic patterns.

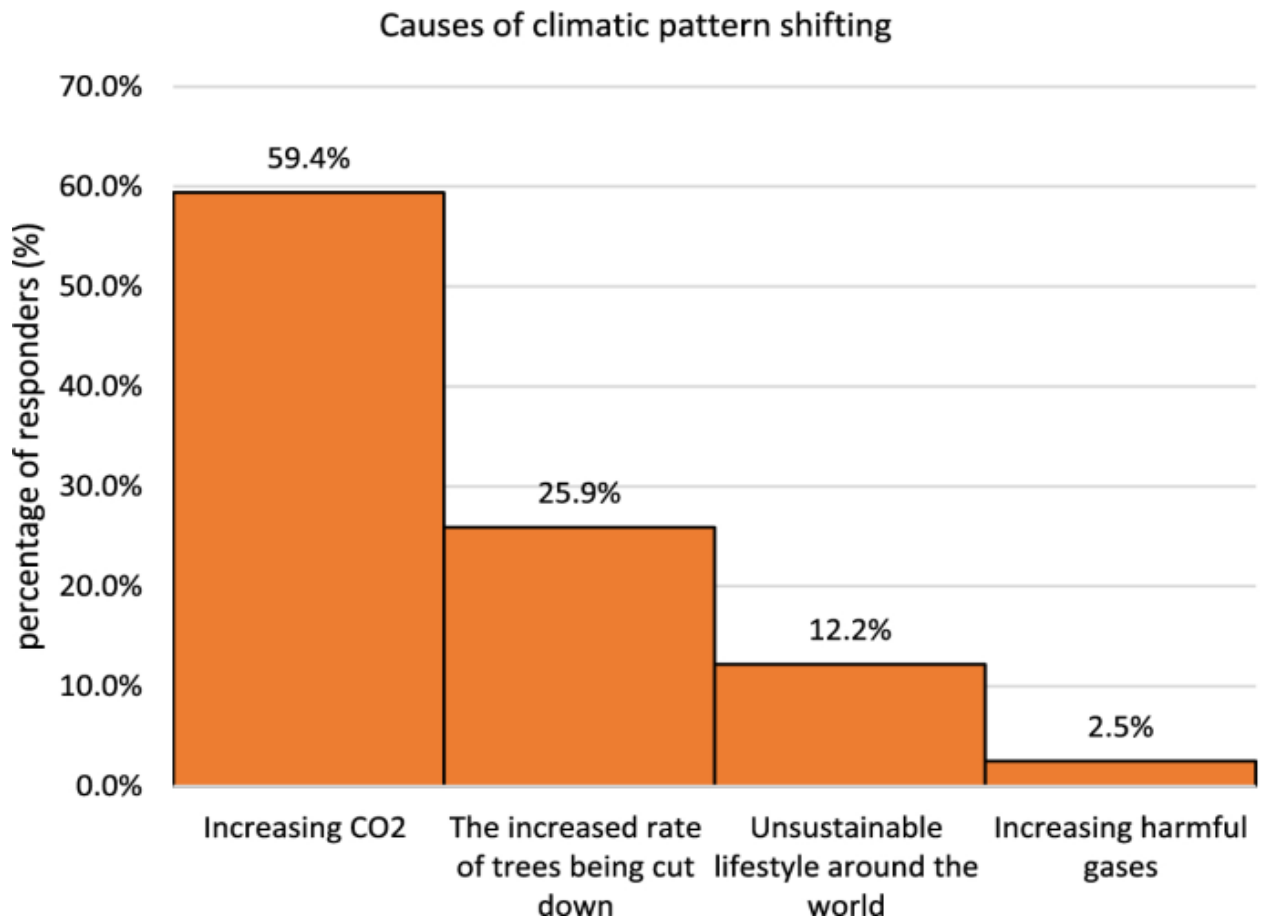


Figure 9: Respondents' perception of the main reasons for climate pattern shifts. This indicates that 85% of responders are aware of human-influenced climate change. (Data source: 2017–2019 questionnaires).

As per Fig. 10, 50% of the responders indicated that during their lifetime, sea level increased from 61 to 80 cm, while 25% of the responders indicated that it increased from 81 to 100 cm. Further, only 10% each indicated that it increased from 21 to 40 cm and from 41 to 60 cm. Finally, only 5% of the responders indicated that it increased from 1 to 20 cm. These results indicate a perception that sea level is rising at a rate higher than the average of 1 cm/year for Bangladesh. Further, considering that the average age for the responders was 40 years, the average sea level rise during the present average age of the population would be 40 cm. This indicates that the perception of sea level rise is twice as important as the actual values as people in this region are disproportionately affected by sea level change.

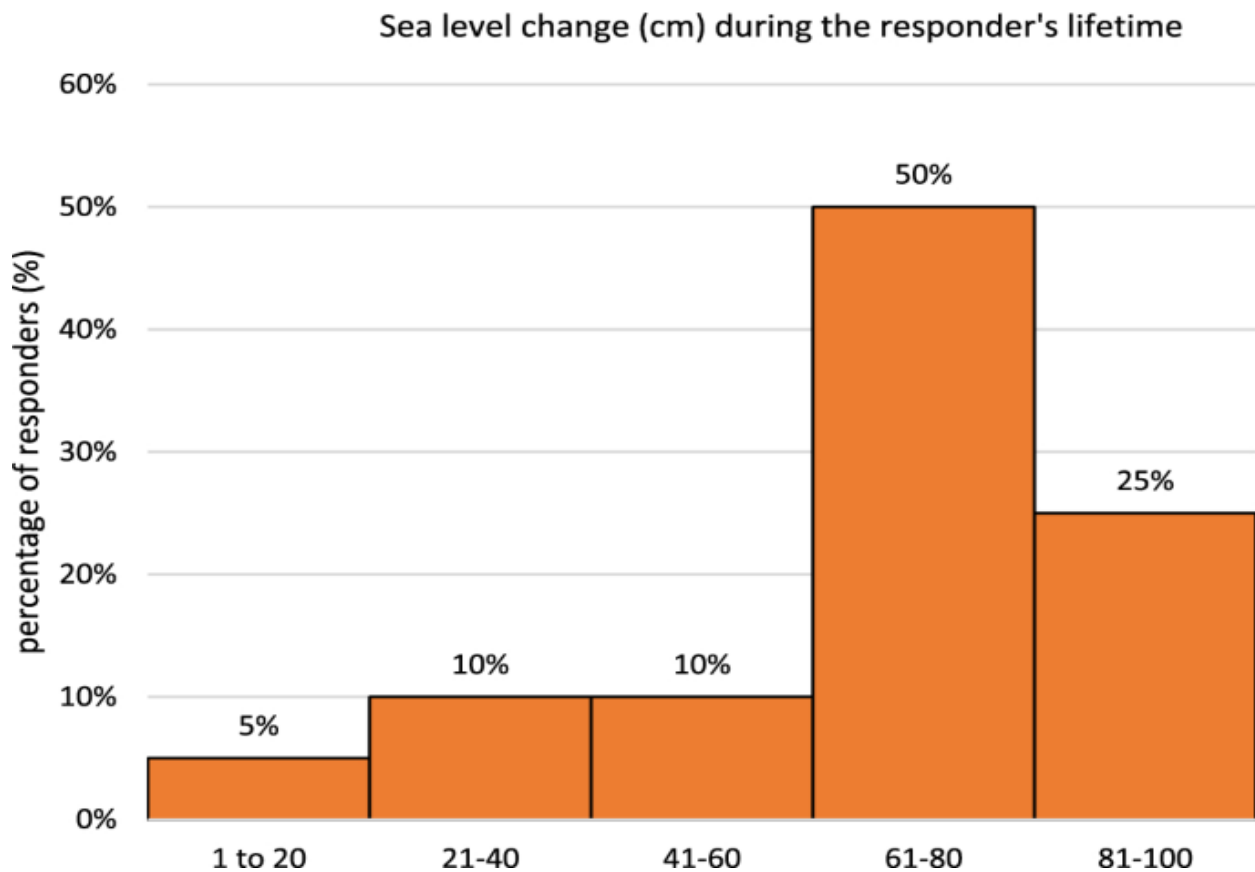


Figure 10: Perceived extent of sea level change over the lifetime of responders. 75% of the responders indicated that sea level change increased from 61 to 100 cm. (Data source: 2017–2019 questionnaires).

As per Fig. 11, more than half of the responders (51.2%) indicated that anthropogenic global warming is the main cause of sea level rise. This was followed by 16.3% of responders indicating that anthropogenic greenhouse gases (excluding CO₂) emitted from human activities cause sea level rise. Ocean currents, bio-thermostat, and albedo from cloud formation were perceived as reasons for sea level rise by 15.9%, 10.6%, and 2.5% of the respondents, respectively. Finally, planetary motion and solar variability accounted as reasons by 1.6% and 1.9% of the responses. This indicates that 67.5% of responders are aware of sea level rise being directly caused by anthropogenic emissions. This was corroborated in the workshops by the responses of the local priest, Father Luise, where he accounted the disappearance of South Talpatti Island due to the rising sea level into the Bay of Bengal in the late nineties, and the island of Lohachara, located at the mouth of the Hooghly River in India, gradually sinking in the 1970s. Similarly, Saidur Rahman, of Nurnagar Union, stated that global warming and climate change are causing polar glacial ice and Himalayan ice melt, increasing sea levels, and sinking several islands.

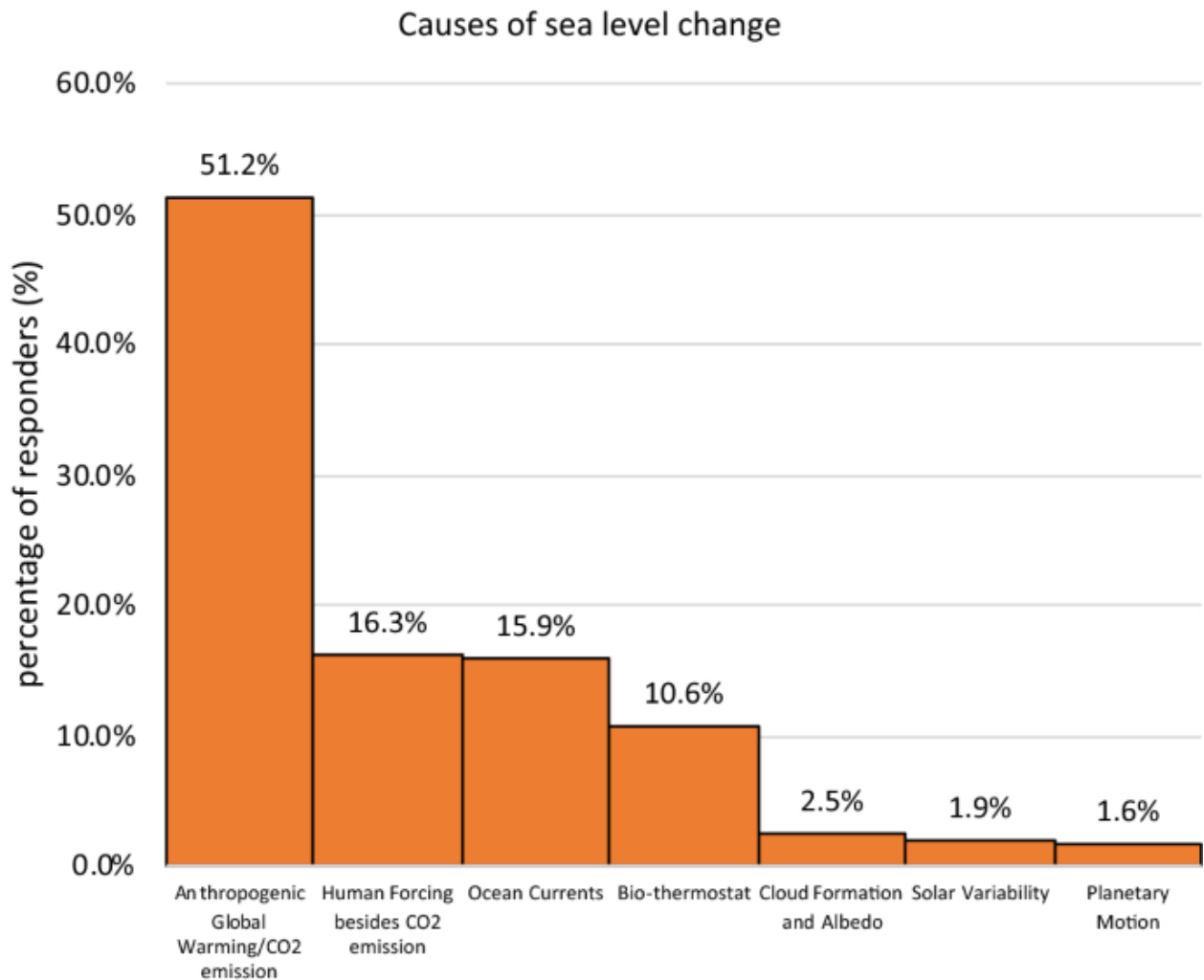


Figure 11: The perception among responders on the main causes of SLC. More than half are aware of the anthropogenic cause of global sea level change. (Data source: 2017–2019 questionnaires).

Most responders (93.1%) indicated frequent natural disasters as one of the main impacts of climate change and sea level rise, as per Fig. 12. This was followed with responders indicating the negative effects in agriculture, health hazards, and unemployment and poverty, with 75%, 65%, and 55% of the responses, respectively. Responders also noted that migration, damaged infrastructure and communication systems, and loss of land were impacts of climate change and sea level rise as per 50%, 46.9%, and 32.8% of the respondents, respectively. Finally, both high costs of natural disasters and loss of natural resources, as well as loss of biodiversity, were the least impacted according to responders, with 31.3% and 28.4% of the responses obtained, respectively. These three main factors were the most prevalent effects within these communities and the main drivers of poverty in the area (Adnan et al. 2020). Corroborating these results, Salma Begum from Burigoalini Union indicated in the IDI that she has invested Tk. 6500 on her house but is certain that it will get destroyed in the next hurricane. Similarly, Saddam Hussein of Ishripur Union said that his family invested Tk. 25,000 on their house, but it is very likely to get damaged from a big storm or from heavy rains. Like Salma and Saddam, most families undergo the same situation, where heavy rain, storms or floods can cause extensive damage to their houses.

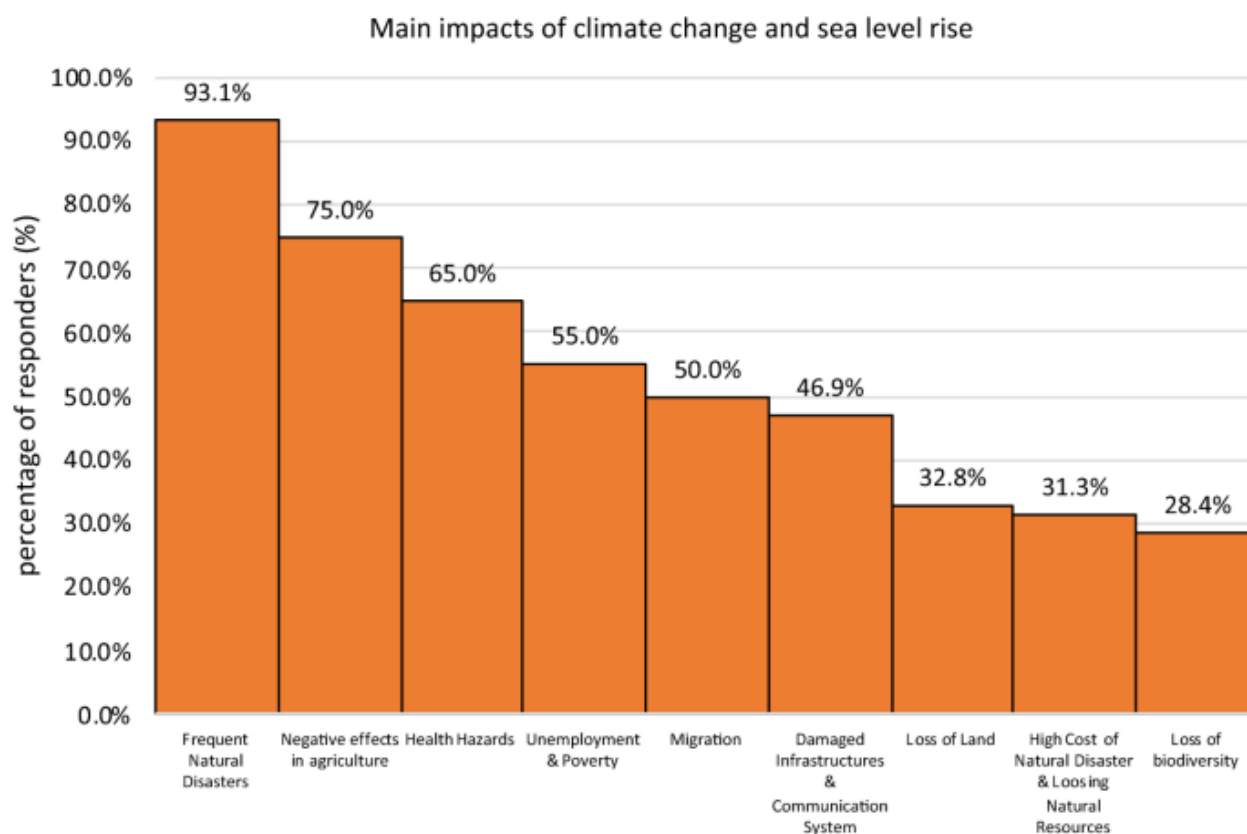


Figure 12: The perception among responders on the impacts of climate change and sea level rise. This table includes multiple answers per individual. (Data source: 2017–2019 questionnaires).

According to Fig. 13, the main reason that respondents cannot maintain a stable lifestyle is the lack of knowledge about climate-adapted livelihood, followed by damage to land due to salinity and social injustice, with 42.1%, 39.1%, and 37.5% responses, respectively. Further, lack of skills in maintaining a steady livelihood, lack of capital and access to service providers, and a lack of demand in markets were also perceived as problems by 36.9%, 29.7%, and 28.1% of the respondents. Finally, flash floods and waterlogging were the least of their concerns, receiving 25% and 24.4% of the responses, respectively. Saiful Sardar, from the village of Padmapukur, indicated in the workshops that constant flooding increased salinity on his land; his family is unable to meet minimum caloric demands, and they are subject to living in dwellings provided by the NGO BRAC.

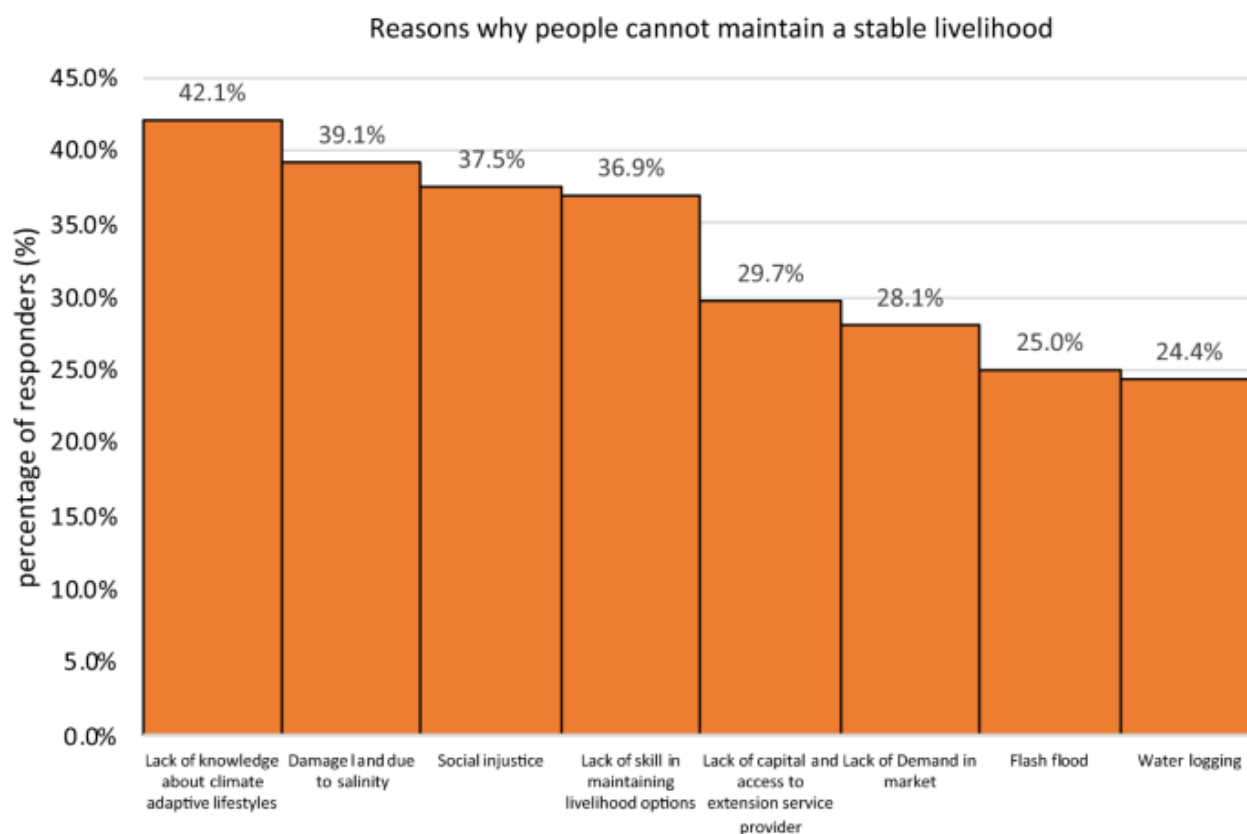


Figure 13: The perception among responders of the reasons why people cannot maintain a stable livelihood. This table includes multiple answers per individual. (Data source: 2017–2019 questionnaires).

Impacts considered more likely to create climate injustice on the coast of Bangladesh as per the percentages of responses for each impact are mainly salinity (65%), high economic costs of infrastructure damages caused by natural disasters (56%), loss of agriculture (55%), coastal erosion (53%), and monsoon flooding and waterlogging (51%). Food insecurity, increased heat stress, declining water levels, desertification, loss of natural resources, loss of human lives, and the emergence of climate poverty, received decreasing responses from 48.3% to 40.6%, as can be seen from Table 4. Finally, earthquakes, damaged infrastructure, climate refugees, loss of GDP, basic necessities and stable lifestyles, and the high probability of tsunamis were the least perceived impacts according to the responders, ranging between 37.5 and 30%. Mina of Dumuria in Gabura Union, mentioned in the (IDI) that her family is below the poverty line due to constant floods, as his dwelling is made of mud, and she is in constant debt in order to repair it. Along this, he has lost his main source of income as his land has been eroded by the river caused by embankment breaches. Achma Khatun of Gabura Union Mejbahar, from Padmapukur village, also indicates that Hurricane Aila (occurred in 2009) washed away their settlements, and now they have to rely on government housing, while they make their living by river-water fishing.

Issues that create climate injustice in the coast of Bangladesh	count	percentage of response
Salinity	208	65.0%
High economic cost of natural disasters & loosing natural resources	180	56.3%
Destroy agriculture & loss of agriculture land Loss of life	175	54.7%
Coastal erosion	169	52.8%
Monsoon flooding and water logging	164	51.3%
Food insecurity	155	48.3%
Increase heat stress	145	45.3%
Ground water level drop	144	45.0%
Desertification	140	43.8%
Loss of natural resources	132	41.2%
Loss of life	131	41.0%
Appearance of climatic poverty	130	40.6%
Earthquake damage	120	37.5%
Damaged Infrastructures	118	36.8%
Emergency of climate refugee	117	36.6%
Loss of GDP	108	33.8%
Loss of basic goods	102	31.9%
Loss of subsistence livelihood	98	30.6%
High probability of tsunami	96	30.0%
Frequent Natural Disasters	88	27.5%

Table 4: The perception among responders on the issues that create climate injustice on the coast of Bangladesh. This table includes multiple answers per individual. (Data source: 2017–2019 questionnaires).

People’s perspective for future adaptation

Table 5 shows preference by responders for adaptation and mitigation measures for poverty reduction with the promotion of provisioning basic services (13.4%), microfinance (12.2%), emergency shelters (11.6%), strengthening of coastal embankments (11.3%), and building awareness (10%) being the most popular. These were followed by promotion of environmentally friendly agriculture (9.4%), decrease in shrimp and crab cultivation (7.5%), promote asset bases (6.6%), and the promotion of early warning and prevention systems (6.3%). Finally, the promotion of safety-nets (5.0%), promotion of public infrastructure (4.4%), and not aware (2.5%) were all adaptation measures to < 10% of the responders. On individual accounts, Gazi of Nowbaki indicated in the workshops that although the rate of poverty reduction has slowed down, the government and public representatives have vastly improved the situation through microfinancing, education, and healthcare. On the other hand, Mokammel Haider of Kashimari Union stated that salt water has penetrated several nearby villages due to the lack of solid dams and drainage systems, and that most of the unions on the coast are under imminent threat of flood and riverbank erosion.

Adaptation measures	Percentage of Respondents
Promote provision of basic services (e.g. health and education)	13.4%
Micro Finance	12.2%
Multipurpose emergency shelters	11.6%
Strengthening coastal embankments	11.3%
Build awareness	10.0%
Promote environment friendly Agriculture	9.4%
Decrease shrimp and carve cultivation	7.5%
Promote asset bases (e.g. housing)	6.6%
Improving early warning and evacuation systems	6.3%
Promote safety-nets for those unable to pay for services	5.0%
Promote public infrastructure (e.g. piped water, sanitation, drainage, roads and footpaths)	4.4%
Don't know	2.5%

Table 5: *The perception among responders of the adaptation and mitigation measures to reduce poverty. (Data source: 2017–2019 questionnaires).*

The increasing sea surface temperatures in the SWCRB have promoted the increase of average magnitude and frequency of tropical storms and cyclones, increasing wind speed, and seawater flood range (Brammer 2016; Mondal et al. 2016). The increasing frequency of cyclones is reported and is especially apparent during the month of November on the coast of Bengal (Wahiduzzaman et al. 2021). As observed from the responses obtained, local communities are well-aware of this despite the effects of global warming not being apparent in everyday life. From the total responders, 93% understand that the increase in frequency and magnitude of these disasters are caused by climate change and sea level rise (Fig. 7), and more than 90% of the population is aware of the connection between sea level rise and climate change (Table 3), as also confirmed by Saidur Rahman, who elaborated on the causes of sea level rise.

It is estimated that climate change and sea level rise, with their associated effects, could directly affect one million people, forcing them below the poverty line or into extreme poverty (Lázár et al. 2020a, b). This will mainly involve people working in agriculture and fishing, further affecting millions more, and probably increasing the poverty rates among coastal communities in southwest Bangladesh (Siddiqui et al. 2020) Following this, the general perception among half of the responders is that sea level has risen twice the actual historically records, which indicates the stress of sea level rise locally (Fig. 10). Father Louise has attested to the disappearance of two islands in his lifetime. This indicates that the population is already suffering the consequences of sea level rise.

Following this, from 2000 to 2020, there have been eight major cyclones. Of these, Cyclone Sidr in 2007 affected over 37% of the cultivable seaside land due to massive storm surges (Mondal et al. 2015; Hossain and Mullick 2020; Mishra et al. 2021). This is evident from the responder's answers as half of the population indicated that cyclones are the main cause of poverty (Fig. 6) (Malak et

al. 2020), and the second most latent hazard by climate change (Fig. 7). Similarly, cyclonic activity was the third most frequent disaster within the last 50 years. Along the side effects of cyclonic activity, salinity intrusion was the most pressing issue among responders, even surpassing cyclones as the issue of utmost concern. Salinity intrusion was recognized as the most common disaster within the last 50 years (Fig. 8) (Amoako Johnson et al. 2016) and the main challenge arising from climate change and sea level rise (Fig. 7). It is also the second most pressing issue that creates poverty as well as the second factor preventing people from having a stable lifestyle (Fig. 13). Similarly, it is the main issue creating climate injustice (Table 4). The long-term negative effects of increasing soil salinity for agriculture and freshwater reservoirs compromise the subsidiary income of 37% of the population for several years after a cyclonic event (Bhuiyan and Dutta 2012).

Ahsan and Takeuchi (2015) recognized that several factors cause poor communities to be vulnerable to these natural disasters than wealthier ones, based solely on the division of classes. However, higher income dwellings have the capacity to invest in resilient infrastructure, as well as the ability to buy land in safer and more expensive locations (Wedawatta et al. 2016). These wealthier communities also have the resources to invest in natural disaster insurances and infrastructure to prevent damage to their assets (Ahsan and Takeuchi 2015). Unfortunately, only 8% of the respondents in our study were within this income range with the ability to meet the criteria for investing in a resilient lifestyle (Table 6).

Income pattern (84.83 BDT equals 1 USD in 2020)		Economic category of responders			
BDT (Bangladeshi Taka)	USD (US Dollars)	Upper class (%)	Middle class (%)	Poor (%)	Extremely poor (%)
0–5000	0–59	0	0	0	21.6
5000–10,000	59–118	0	0	40.6	0
10,000–15,000	118–177	0	16.9	0	0
15,000–20,000	177–236	0	13.1	0	0
20,000–25,000	236–295	0	3.1	0	0
25,000–30,000	295–354	0	1.2	0	0
> 30,000	> 354	3.4	0	0	0
Total	Total	3.4	34.4	40.6	21.6

Table 6 Economic income and socioeconomic status of responders divided into extremely poor, poor, middle class, and upper class (Data source: 2017–2019 questionnaires).

Immediate effects of natural disasters, such as loss of life, structural damage, as well as long-term impacts, such as reduction of income and lower standards of living, are all disproportionately higher in poor communities. This is due to substandard construction material, more vulnerability in income, and a lack of capital to invest in less natural disaster-prone activities (Ahsan and Takeuchi 2015; Khan et al. 2015; Rakib et al. 2019). Our results indicate that 84% of the respondents have houses made of materials likely to be destroyed in future cyclones (Fig. 5) and a third of the population suffered damage to their dwelling every 5 years (Table 2). Salma Begum and Saddam Hussein attested that despite constantly repairing their houses, they are unable to afford durable construction materials. Thus, several residents are forced to migrate to urban areas, as in the recent 10 years, natural disaster-related incidents have forced about half a million people to migrate from this SWCRB (Roy and Sultana 2010; Davis et al. 2018). This also reduces the economic activities for the communities, as earning members of the families migrate, workable land gets abandoned or monopolized, which subsequently reduces the social cohesion of these communities. Based on the results, despite having an overall low inequality index of 21.8% in Fig. 4, 62% of the population is

below the poverty line (Table 6). Similarly, Nimai Mandal indicated issues with food shortage arising from salinity in the past. This indicates that majority of our residents are highly vulnerable to the effects of natural disasters.

These issues that affect people under the poverty line disproportionately affect the population surveyed in this study. About 84% of the population is at a high risk of losing their dwellings and have a higher mortality rate due to non-resilient poor quality construction material (Ahsan and Takeuchi 2015; Islam et al. 2021). Further, fishing communities are especially vulnerable, as natural disasters have the potential to destroy their fishing infrastructure and equipment, which represents a third of the main income source and a fifth of subsidiary income source of responders (Table 1) (Das et al. 2015). Buli Rani and Yasin Ali, which earn a monthly wage below the poverty line, have very low means to recover from losing their equipment as they have faced food deprivation in the past. Massive reduction in rice production has been caused by the increase in saline soil and water-logged lands, which is one of the main crops harvested in this region (Kabir and Aftab 2017; Hill and Genoni 2019). Due to the increase in saline soil, the average income of poor farmers dropped by 44% after being affected by cyclone Aila of 2009 (Roy and Sultana 2010), which represents more than a third of the responders' subsidiary source of income (Table 1). In a more extreme case, agricultural lands have been reduced by half within 5 years in several areas in the SWCRB (Adnan et al. 2020).

These issues were studied by Adnan et al. (2020) where the researchers created a poverty trap, which is a feedback loop that impedes economically marginalized communities to invest in becoming increasingly resilient due to a lack of capital and an annual steady source of income. Especially after a calamity, besides the loss of investments in equipment and infrastructure, marginalized communities are forced to use their savings in reconstruction, survival, and buying necessities, making any opportunity to escape poverty almost impossible (World Bank 2018; Adnan et al. 2020). Our results indicate that more than half of the population believes that the high cost of infrastructure associated with natural disasters creates climate injustice (Table 4).

Policy implications

According to the results, the main issues affecting the livelihood and sources of income are cyclones, floods, and salinity. So, any strategy that will further increase the resilience of communities will have to mitigate these effects. The most direct way of reducing these is to create new coastal embankments as well as repairing and reinforcing existing ones. This will reduce the direct effects of cyclone-related damages, as well as both pluvial and fluvial floods, allowing marginalized communities to invest in increasingly resilient livelihoods and income sources (Adnan et al. 2019). Considering this, investing in coastal embankments would also have a long-lasting positive effect by mitigating floods in higher sea levels and more frequent and intense cyclonic events from present conditions. Huq et al. (1995) estimated that to have a minimum protection for a 1 m sea level rise, Bangladesh would have to upgrade 4800 km and build an additional 4000 km of embankments.

Based on the responses, a lack of knowledge on how to maintain an adaptive lifestyle is the reason people cannot maintain a stable livelihood (Fig. 13). Ha-Mim and Hossain (2020) reported that poor and vulnerable communities were found to have a better capacity than higher income homes to revert after disasters due to strong social networks and a higher adaptability by accepting a wider range of jobs as compared to wealthier communities. Thus, the introduction of scholar programs designed to teach communities on facing both immediate life-threatening risks and long-term effects of natural disasters, such as increasing soil productivity in saline conditions, installing emergency shelters, and guidelines on constructing stronger dwellings will create a well-prepared community in the face of future natural disasters.

Along this, the results indicate that with a system of microfinance and building awareness, vulnerable communities can invest in concrete dwellings or sheds for equipment; this involves a higher initial cost than rebuilding non-concrete material dwellings but will result in a long-term saving for the occupants as they will only have to invest in non-structural damages after a cyclone. Along this, microfinancing can be used by inhabitants to buy fishing or farming equipment lost to a cyclone or used to invest in new materials or training for changing to an occupation less vulnerable to natural disasters (Uddin et al. 2021).

After a disaster, it is common for low-income families to sell their plots of land to alleviate the initial costs. However, wealthier classes of the population buy these plots of land, further increasing the wealth gap (Roy and Sultana 2010; Mallick et al. 2017). Availability of microfinances will encourage local communities to invest in saline-resistant crop seeds rather than being forced to sell their land (Mondal et al. 2016; Islam et al. 2018). The introduction of saline-resistant crops complemented with training programs for locals on farming in saline conditions can represent a considerable relief after sea water intrusions and cyclones, which is the period with greatest economic stress (Faisal et al. 2021). A study conducted by Islam et al. (2018) indicated that 50% of the respondents were positive about the introduction of saline-resistant plants and distribution of these seeds within the population of the Shyamnagar Upazila. Along this, mean sea levels could reach as high as 1 m in 2100 (Majid 2020), vastly extending the area affected by salinity, as the sea line will be farther inland (Karsili et al. 2013). So, introducing saline-resistant crops will provide an extremely resilient solution for the subsequent decades.

Similarly, abandoned rice farms due to high saline conditions can be relatively easily and economically converted into gher ponds, as the required pond is already built and these species of shrimp thrive in brackish waters (Barai et al. 2019). However, aquaculture has several costs associated with fishing infrastructure and workforce (Adnan et al. 2020). Proper training and microfinancing for repurposing the pools and buying equipment as well as employing members of the community as labor force could represent a steady source of income for several families. Furthermore, this trend is already being implemented on a massive scale; Adnan et al. (2020) indicated that 1% of the agricultural land along the SWCRB is being converted into other land types, especially aquaculture. Based on the testimonies of Didarul Islam and Tapan Roy, shrimp farming is already a viable income source for women and students. However, these shrimp ghers promote the increase in salinity in aquifers and nearby freshwater bodies as well as the reduction in freshwater biodiversity, so these could be an option in highly degraded rice agricultural lands (Bahauddin and Bhuyan 2020).

This paper, thus, provides a better understanding of the issues that are perceived by responders to be the most damaging to their livelihoods and income sources, as well as the ones that will become more pressing in the future. Based on this, our study suggests highly focalized mitigation measures that specifically aim in reducing the vulnerability of these communities, increasing their resilience, and preparing them for a less hostile future considering the increased magnitude and frequency of natural disasters. Thus, this study serves as a starting point for the government and organizations to provide appropriate policies and programs to reduce the vulnerability of these communities. This study is highly relevant, as it points out the most damaging consequences for the livelihoods of these communities and some literature-backed solutions that can help them to increase their resilience.

Conclusions

In conclusion, 62% of the surveyed population is below the poverty line with a relatively low Gini inequality index of 28.5, and 84% have dwellings of non-disaster-resistant material. Community

income and livelihoods are heavily dependent on natural resources, such as agriculture, fishing, and gathering primary materials. Thus, cyclones, floods, and high salinity in freshwater and soil are the main issues affecting their livelihoods, income sources, and dwellings, affecting the population below the poverty line disproportionately. Considering this, policies should be directed to increase the resilience of communities or reduce the risk of natural disasters. These include building and readapting embankments for current conditions of natural calamities including cyclones, storm surges, flood, and their increased frequency and intensity due to climate change and sea level rise. Educational programs for emergency preparedness along microfinances can help communities gain access to climate-resilient building materials, labor equipment, and the introduction of salinity-resistant crops. Old rice farms, considering rice being the staple crop, can be refurbished to become shrimp ghers with financial aid in the form of microfinances. These policies also have the potential to reduce the wealth inequality by allowing communities to avoid poverty. Finally, this paper sheds a light on the perception of responders on issues related to natural disasters affecting them and possible policies to mitigate these effects; this can be a starting point to understand the priorities and necessities of population residing in the SWCRB.

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6. Exploring Gender and Climate Change Nexus, and Empowering Women in the South Western Coastal Region of Bangladesh for Adaptation and Mitigation

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Abstract

This study has been conducted to identify vulnerabilities and effects of climate change on women in 12 unions in Shyamnagar upazila in the Satkhira district in the Southwestern Coastal Region of Bangladesh (SWCRB). Climate vulnerability and gender inequality may increase due to climate change. Women may, thus, face specific conditions of vulnerability in society and daily livelihood. This paper focuses on investigating factors that influence women's vulnerability from climate change, their adaptations, and the importance of women empowerment to reduce their inequality in SWCRB. This study also emphasizes gender inequality caused by climate change, and looks at accommodations for women to reduce hostile influences of climate change. From the 9 unions in SWCRB, a total of 320 household respondents were randomly selected to complete a questionnaire. The results of the statistical analysis showed that most of the survey's perimeter has significant. Interviews, case studies, focus group discussions, workshops, and key informant interviews were also conducted from 12 unions, and it was found that climate change impacts men and women differently, with women being more vulnerable than men. Through case study this paper investigated the main factors influencing the vulnerability of women. In terms of empowerment women may also be well positioned to lead adaptation efforts alongside men, as this analysis represent that gender inequalities are leading by social norms. Women being more vulnerable both in short-term i.e., major natural disasters, cyclones, flood, and long-term i.e., sea level rise, salinity intrusion in water and soil, land erosion, droughts, climatic events, as they enhance gender inequalities. Further, gender inequality is seen in illiteracy, food shortages and poor health conditions, traditional norms, religious taboos, and patriarchy. Moreover, gender-based economic opportunities, women's mobility, and income are changing, while household authority relations and gender-based socio-economic, cultural, and institutional constraints remain. This study examines the increased vulnerability of women in SWCRB to climate change, which can be mitigated through women empowerment; female involvement with environmentally friendly stoves, rural electrification and renewable energy development, microfinancing, and nakshikantha. (Nakshikantha is a special type of sewing art that is made by creating designs with different types of colored threads on plain stitches). Lastly, women may also lead adaptation efforts alongside men, make decisions, and promote their participation.

Keywords: gender; climate change & vulnerability; inequality; women empowerment; adaptation; Southwestern coastal region of Bangladesh

Introduction

Most of Earth's coastal regions are threatened by climate change and sea level rise, natural calamities and meteorological turbulence originating from climate change [1]. On a superficial level, climate change does not seem to have an impact on gender elements. However, changing environmental conditions continue to alter the impact on women. Women, adolescent girls, and female children are the most abandoned during natural catastrophes [2,3] representing more than 75% of displaced people [4]. Even during hurricane Katrina that affected USA, the most affected people were typically females, in particular those with Afro-American ethnicity [5,6]. Because of shortage of health care privileges in times of disaster, women are vulnerable to reproductive and sexual health problems, in addition to prevalent sexual and domestic abuse [7]. This illustrates the logic that equal socio-economic rights can make recovery and in starvation assistance more effective in terms of public health service, food and water accessibility. Moreover, while complex relations between gender and climate change are still under review, previous studies of natural disasters can show climate change adaptation strategies [8,9]. Understanding the social implications of climate change can be illuminating though regretfully, as Kabeer [10] shows, the logic that makes predictions is complex and may not always lead to the desired results. Many inhabitants of developing nations like the South Western Coastal Region of Bangladesh (SWCRB) are already socially marginalized; dependent on State resources and with limited financial resources, their security tends to be progressively compromised by climate change [11]. Frequent natural hazards from climate change increases the women vulnerability. Further, women's social positions are based on social institutions, ethnicity, gender identity, and not on personal abilities [2,10]. Thus, gender characteristics and patriarchal norms serve as social barriers that make it difficult for women. This is because they lack power to make decisions, such as whether to take shelter during disasters. As such, vulnerability traits are based on physical, social, economic, and environmental aspects that increase individual and community susceptibilities to hazards [11]. Women are more vulnerable in poor countries, like Bangladesh, as they play multiple roles in the family (i.e., providing food, water, collect fuel, and care for their loved ones).

It is important to investigate the effect of gender to understand the issue of adaptation in vulnerable areas (SWCRB). In post-calamity, women in the SWCRB do not receive appropriate sustenance from family, society or non-governmental associations but they find ways to adapt [12]. Because of damaged dwellings and possessions, women must adapt and resort to adaptation measures to improve their livelihoods. It is recently widely accepted that the potential of adaptation is strongly linked to gender [13]. To better understand this connection of gender with climate vulnerability, it is essential to consider the socioeconomic roles of men and women within (rural) households in SWCRB. Recently, in response to the challenge of climate change, much attention has been paid to gender perspectives and the inclusion of women in disaster adaptation. It is generally believed that climate change shapes men and women in different ways, because inequalities in their roles and responsibilities in society, access to resources, and power relations that may seriously affect the ability of genders to respond to climate hazards [14–16]. In SWCRB, Women participate in different income-generating activities to help other poor women in the community to ameliorate poverty, aid them in achieving independence, and solving the problem of empowerment [15]. Therefore, to a significant extent of women who help to respond and adapt to the expected changes in climatic conditions. At this point, gender starts to play a defining role. Besides, the majority of Earth's coastal regions women are threatened by rising sea levels, natural calamities, and meteorological turbulence originating from climate change [16]. The area examined in this study is the Shyamnagar Upazila

region, adjacent to the Bay of Bengal. The Bay of Bengal has optimal conditions for the formation of tropical cyclones, with an average of 12 to 13 depressions, and 1 or 2 major cyclones affecting Bangladesh each year [17,18]. For example, cyclones Sidr and Aila and the latest cyclone Amphan, which occurred in May of 2020, devastated the SWCRB [19,20]. Moreover, the geophysical distinctiveness of the Bangladesh coast and the poor socioeconomic conditions of coastal residents contribute to the inhabitants' increased vulnerability to hurricanes and storms [21]. Most of the unions (Unions are the smallest rural administrative units, under Upazila level, and they can be taken analogously to counties in the western countries) in Shyamnagar Upazila are inhabited by people with low Income that are unable to maintain their houses in a sustainable manner. As a result, they have to face various dangers. Respondent -46, age 51, a resident of the Gabura Union (Unions are the smallest rural administrative units, under Upazila level, and they can be taken analogously to counties in the western countries), said: "I have built a house with an installment of (Bangladeshi Currency) (Bangladeshi taka is the currency of the People's Republic of Bangladesh) tk 5000 (\$45.04). If there is a big storm, there will be no house left." This paper highlights the most salient issues regarding climate change, what women are facing in the SWCRB, how to mitigate the uncontrollable effects of climate change and how to adapt to an unpredictable but inevitable future.

Additionally, there is focus on the interactions between natural climate systems, social norms, religious taboo, and dominant patriarchy system that have gender inequality implications in areas such as the SWCRB during the time of catastrophes. This study, thus, aims to identify people's perspectives on gender responses to disaster threats, women's vulnerability, adversities, and inequality. The development of adaptive capacity can contribute to the well-being of social and ecological systems, requiring radical transformation and changes in the mainstream of our society [22]. The dominant development perspective widely supports the truism that integrating gender analysis into development methods and practices will be beneficial in addressing climate change in the SWCRB. The government of Bangladesh and NGOs are concentrating on climate change and are implementing adaptation and mitigation steps to reduce the severity of environmental, economic and social impacts on women, such as the National Adaptation Program of Action (NAPA), Bangladesh Climate Change Strategy and Action Plan (BCCSAP) [23,24].

This paper is divided into five main sections, starting by outlining the process of incorporation of a gender perspective into developmental theory, leading up to the mainstream approach that is favored today and focusing in the vulnerabilities existing between gender, specially analyzing existing trends in literature on the gender and climate change nexus. It reflects on why women are particularly vulnerable to climate variability and change (short and long term) and also play a key role in adaptation, in the SWCRB. The broader social implications of women's vulnerability in rural areas, especially those generated by inequality, will also be addressed throughout the paper under the main perspectives raised from the 5th IPCC Assessment Report [22]. The second section presents the perceptions of local communities on women vulnerabilities and empowerment in the context of climate adaptation, bringing in critical stances with pressing policy implications. The third section reflects field survey analysis with social opinion regarding nexus of gender and climate change, the fourth section highlights four success cases of women empowerment with the potential to become contributors to adaptation in the SWCRB, And the final section that presents the discussion, comparison and conclusion.

The hypothesis is that climate exposure and events, as well as societal themes (i.e., increased illiteracy, food shortages, worsened health conditions, traditions, social systems and norms, patriarchy, and religious taboo), increase women's vulnerability and gender inequality. Thus, women

empowerment (in gender dimensions of climate change) improves climate induced vulnerability and gender inequality, as women serve as agents in SWCRB for climatic adaptation.

Literature Review

Vulnerability, Gender Dynamics of Climate Change

Gender dynamics is affected both material and non-material resources; it is likely that climate change will affect gender relations and gender equity. Developmental theory and practice aim to create and understand social change, alongside political and economic change [25]. Like all theories, developmental theory has revised and renewed itself, incorporating, refusing and re-assimilating criticism over time [25]. Part of its trajectory involved the inclusion of social analysis into research and practice, and gender equity [9]. Sen's [26] assertion that humans are actors for whom the maintenance of fundamental freedoms is an integral part of "what we have reason to preserve" questions and redirects the focus of what is to be sustained [26]. Amartya Sen [9] insists that people should be perceived as agents instead of as patients. People have the ability and capacity to act and value their surroundings are therefore should be given the capabilities to do so. Sen [9] states that prerequisites to enable people to become agents are the removal of unfreedoms, e.g., governmental oppression or starvation which curtails people's abilities. Capabilities in turn refer to the ability of people to achieve or to do what they value in life e.g., individual freedom to choose for themselves between certain alternatives. This in turn, assumes that there are certain prerequisites to make choices and also that there are particular alternatives to choose from. Capabilities can only be realized if, for example, there is enough food to choose from, i.e., if you want to eat or not to eat. Thus, under certain climatic circumstances such as in the event of a deprivation, women's potential capabilities may not be achieved [25]. Sen [9] further explains the concept of agency as a person who chooses to actively be an individual member of a society participating in social and political practices. Sen's capability-approach enables people to control their own life through individual and free choices. Powerlessness and inequality will limit a person's ability to choose freely. Empowerment can be acquired through availability of education or health care which in turn will enable people to access more alternatives and choices [9]. It is within this idea of mandate and expanding freedoms that we examine the logic of conventional gender analysis that has the potential to reduce gender inequity in SWCRB and tackle climate change through engaged and active participation of empowered women. This research is directed at utilizing gender insights to achieve sustainable development pathways. Amongst these, we highlight three implications of gender equitable analysis; (i) strengthening women's rights and socio-economic status to better cope with the effects of climate change, (ii) building resilience through women empowerment, and (iii) enhancing empowerment and income through women-friendly, low-carbon renewable energy for reducing climate effect. Moreover, it is necessary to prioritize micro-finances for improvement of social status for women.

Gender discrimination may be intrinsic in harsh background conditions (higher illiteracy rates, shortage of food and calories consumption and inferior health conditions), traditions, social systems and patriarchy are also responsible among other things. These obstacles handicap women more than men by increasing effective responses to foresee continuous environmental changes such as coastal erosion, flooding and soil salinity [27,28]. Strengthening women's rights and socio-economic status is to better deal with the effects of climate change. This suggests that there is a gendered vulnerability to climate change that largely ways in the favour of men [8,9,29–31]. The IPCC also recognizes that climate change plays a particular role in continuing gender inequality, such as in the SWCRB where men have larger access to land [22]. Existing gender inequality is highlighted as a result of weather

events and disasters related to climate, which increases the abyss of social, economic, and cultural rights perpetuating vulnerabilities [3,29].

The construction of economically poor women as victims denies their agency [10,30] and emphasizes vulnerability as an intrinsic problem [10]. Less than 20% of global lands are owned by women, and their high vulnerability can be checked in terms of labor force. In South Asia, for instance, women comprise approximately 70% of the agricultural labor force [22]. Rural women are dependent on natural resources to sustain themselves more than men because they perform majority of the agricultural work [8,31,32]. In Bangladesh, women’s participation in the agricultural workforce increased from 25% during 2002–2003 to more than 34% during 2005–2006 [32,33] and recently, women account for more than 50% of the agricultural workforce and the participation rate is much higher, compared to 30% in India and Pakistan though they are small marginal farmers. Women’s vulnerability through overwork may worsen under climate change scenarios due to negative impact on crops, leading to a new gender division within the SWCRB [22]. Projections of climate change impacts indicate that women’s vulnerability will manifest more intensively in terms of restricted access to natural resources (especially land and water), credit and markets, knowledge and information [33,34].

Table 1 shows how extreme weather can affect men and women in rural areas disproportionately, situation that can be observed both in the developed and underdevelopment nations. The following table, sourced from the IPCC AR5WGII report, summarizes vulnerable conditions faced by women in the countryside of India and Australia.

Table 1. Gender climate experiences. Source: IPCC, 2014:808.

Involvements	Male Farmers	Female Farmers
Rise in workload	Feeding livestock, drawing water(A)	Additional income by carrying out farm tasks (A)
	Increased migration for wages (I)	Collection of firewood, waging in neighboring villages (I)
Communal relations, remoteness, and misuse	Unable to migrate from farms, political powerlessness (A)	Increased interactions and responsibility of caregiving, negligence of health (A)
	Exploitation by contractors providing labor (I)	Disadvantage in accessing institutional support (I)
Physical and psychological toll	Increased stress, depression, suicidal tendency (A)	Indefinite support, increase in stress (A)
	Increased anxiety to escape indebtedness, domestic violence, suicidal tendency (I)	Increased pressure to provide for family, increase in domestic violence (I)

(A) Australia (ten-year drought, 2003–2012). based on Alston (2011); (I) India (climate variability and changing climatic trends), based on Lambrou and Nelson (2013).

In the context of climate change, it was observed in this research that in the SWCRB, women have less access to climate and disaster-related information compared to men. This includes emergency information and training programs to administrative processes at domestic and public levels to financial resources, including economic means to land ownership and to activities inside and outside the villages.

Capacities

All over the world, the ability of communities and individuals to deal with climate change involves a number of capacities [9]. The enlargement of women's social and economic freedoms, including their empowerment through involvement in decision making, is viewed as a means to formulate more effective response to climate change's effects, as well as contributing to social transformation through public discussion [9]. The impetus for socio-economically empowering women is strong because it expands their capabilities, entitlements, choices, and the overall effects [9,15]. Human security has been taken under risk in the context of climate change and preserving it plays an important role to protect life, as such as freedom and capacity to live worthily [22]. It's a challenge to keep such principles considering the weakness presented by the majority of institutions at national level to conduct effective adaptation efforts, risen human insecurity [3,9]. This sparks the logic that equal socio-economic rights can make recovery and response assistance more effective. Moreover, while the complex relations between gender and climate change are still being grappled with, previous studies of natural disasters can inform climate change adaptation strategies [8,9]. Understanding the social implications of climate change can be illuminating though regrettably, as Kabeer [10] shows, the logic which renders general and predictable that which is complex and particular may not always lead to expected outcomes. Many inhabitants of developing nations like SWCRB are already socially marginalized, state dependent of resource and with limited financial resources, therefore, their security tend to be progressively damaged due to climate change [22]. Though not relating to gender specifically, this is in line with Sen's [8,9] argument about famines. He states that hunger is caused by 'entitlement', ownership and command over enough food deprivation which relates to 'endowments', or ownership over productive resources (land and labor) as well as wealth. [8,9]. As it is stressed by Escobar [35], the economy is not only, or even principally, a material entity, but above all, it is a cultural production, a way of producing human subjects and social orders of a certain kind.

Climate shifts can affect areas that are considered profitable and cause people to lose their occupations, and droughts or floods can drive down the price of high value foods relative to food grains, which can have serious consequences for those who make a living from the sale of these foods [9]. If the SWCRB women have unequal chances to an alternative income, or lack land rights and lose their spouse, then it is likely that they will suffer most, as will economic development. Furthermore, small-scale women farmers often play a critical role in the food security of their communities. Gender equitable understanding of climate change impacts and related gendered risks/needs can contribute to the development of effective adaptation policies and lead to wide-ranging social impacts [36]. As climate change usually impacts livelihoods and income in the SWCRB for two main reasons: extreme events impacts on agriculture crops (SLR, riverbank erosion, floods, tropical storms and severe droughts) and loss of ecosystems on which coastal people depend [3], poverty and starvation tend to worsen with the increase of the price of food, restricted mobility, and discrimination [3].

Gender equitable understanding of climate change impacts and related gender risks and needs can contribute to the development of effective adaptation policies and lead to wide-ranging social impacts. Climate change impacts livelihoods and income in the SWCRB in significant ways. Sen [9] sees women are active agents of change, able to promote the required social transformation to alter the lives of women and men [36].

3. Adaptations and Women Empowerment

Adaptation is an important measure to reduce stress in developmental processes, especially in the SWCRB, where it can help promote and support sustainable development. Adaptation planning stimulates participatory social processes, including equity and legitimacy, and it can encourage women to think more clearly about broader sustainable development goals, options and pathways [22]. There is a great deal of confidence that public decision making for adaptation can be strengthened by understanding the participation of the people in the SWCRB [22]. In this sense, women empowerment is considered valuable in this research because it contributes to favorable environmental governance and builds climate resilience. As opposed to the previous focus on women's vulnerability, when it comes to adaptation, women are seen as powerful agents of change [37] endowed with indigenous knowledge of agriculture and water management, which also constitutes the SWCRB's [8] livelihoods and is intrinsic to effective adaptation and social change [9]. Women also wrap tubes with plastic to prevent saltwater infiltration and from time to time excavate clay openings to put in their jewelry and important documents underneath the soil. In addition, women also have distinctive culture and reflex actions before, during and after calamity phases. Currently, women's adversity groundwork methods have undergone change to a substantial level with knowledge obtained from cyclones Sidr, Aila, Bulbul, Foni and Amphan and calamity watchfulness guidance obtained from local stakeholders like Union Digester Management Committee.

The lack of financial resources (credit), physical resources (water and land), access to technologies and infrastructure (markets) are major factors inhibiting adaptation for farmers in Asia [3,22]. Albeit accessing such resources has become a barrier, knowledge is even more important because adaptation strategies involve dealing with uncertainty, and accurate information is crucial for perceive and decide how to adapt [22]. The fact that rural women are integral to food security yet make up a disproportionate number of those considered hungry [36] strengthens the case for eliminating gender specific barriers to livelihood adaptation in the face of climate change. Including women's voices in decisions on climate adaptation strategies makes sense because their livelihoods are different to those of men, as are their experiences, needs and perhaps perceptions of risks [8]. The World Bank Group illustrates the foundation of women's empowerment with projects where women have better dealt with drought risks through support for women's loans and savings groups, where women were given key roles [37]. The results show great success in facilitating income generation, saving assets, positively influencing food security and building social capital [36]. Yet, the term agent refers to acting on behalf of, rather than as, a voluntary and independent agent according to own values and objectives, envisioned by Sen [9]. Appropriation of the term 'agent' in instrumental form makes empowerment conditional and fragile; effective use of funds will strengthen the receiver's status while the opposite will produce additional indebtedness, a narrowing of choices and the loss of 'real' agency [9,36](Agency here refers to Sen's (1999) notion of an independent actor who works on the basis of personal values and objectives). This instrumental 'take' is most explicit in the Bolivian study [9] which bases the benefits of women's empowerment on their more efficient use of resources in innovative climate change adaptation strategies with their knowledge; women can develop adaptable methods for the vulnerable SWCRB. Besides [22], observed that in Bangladesh, women are required to be self-assured and use association expertise to improve recovery capacity. Similarly, males are required to be familiar with gender-specific characteristics of disasters to be socially prepared to deal with any disaster.

On the other hand, the term empowerment first appeared in gender and development debates during the late 80s and early 90s, [38, 39] and addressed the concern many feminists felt over global inequality. This global inequality would, according to the feminists inhibit women's ability to

develop. It was during the mid1990s that agencies began to adopt the concept of empowerment [38]. There are many different views of what the empowerment of women is. However, there are four aspects which are generally accepted in terms of defining the empowerment of women [39]. The first aspect is that the woman is powerless in various aspects of life. The second aspect is that women are not given empowerment, but they must claim it; “Canadian International Development Agency” (CIDA), 2012 [40], also emphasizes that outsiders can’t empower women. Aspect three is that empowerment is usually seen as the ability to make independent decisions. The fourth aspect is that empowerment of women is a process of development [39]. Institutions and agencies can support women through processes that increase their confidence and develop their self-reliance [40]. Development goals such as Climate Action can be seen as a sign of female empowerment, because these goals often give rise to empowerment [39].

Empowerment for Efficiency

A major motivation for the adoption of gender-sensitive analysis and socio-economic empowerment is to improve and enhance economic activity for women and their families [25]. Women empowerment does not appear to be supported by a desire for gender justice per se, but rather to make coping strategies more effective. Such measures can still have positive social effects although the instrumentalization of women empowerment may mask the visibility and possibility of constructive results [41–43]. Furthermore, there needs to be a critical analysis on how the local processes of empowerment and inequality are situated within the global economic and political arena.

Gender equality means that women and men are treated equally [25]. This implies that women and men have equal status and opportunity to contribute to social, economic, political, and cultural development [38,39]. Women empowerment can vary depending on factors like social class, ethnicity, and family position [39]. In many developing countries, religious and cultural values and upbringing have a profound influence on women’s roles in society [39]. In Bangladesh, mobility restrictions make women more vulnerable in their homes during disasters [3,22]. In addition, women take extra responsibilities before and after disasters, such as storing food and water and taking care of the children and the elderly [22]. A case in point, in 1991, Bangladesh was hit by a devastating cyclone and floods killed lots of people. Since men could move and communicate freely, they warned each other of the calamity. But a great number of women were not informed of the coming danger. The mortality rate for women was five times higher than that for men. There are two main reasons for the high mortality rate among women during the 1991 cyclone. Firstly, they waited for their male companions to migrate to a safer place. Secondly, in many Asian countries, along with Bangladesh, most women do not learn how to swim. Women have the responsibility to supply clean water for the whole family [31, 42].

Women Empowerment Rendered Technical

Tania Murray Li [43] has described a process which she calls ‘rendering technical’. In this process, an issue is formulated in technical terms, with specifiable limits and particular characteristics. It involves the definition of boundaries, rendering that within them visible, gathering information and devising techniques to mobilize the revealed forces and entities. The identification of a problem is intimately linked to the availability of a solution, according to Murray. A second dimension of rendering technical is that it simultaneously renders an issue nonpolitical. Experts who are working with development tend to focus more on the capacities of the poor than on the practices through which one social group impoverishes another, Murray Li argues [43]. Integrated approaches in development frequently face the issue of how to, or indeed if it is possible to, measure results for all parties

involved [10, 36, 39]. This is certainly the case when we consider the possibility of measuring empowerment.

Many feminist scholars believe the vagueness of the definition of women's empowerment to be an asset that makes it malleable to specific contexts and that empowerment is a process which eludes measurement [10,43]. Yet, for developmental organizations, the ability to measure and show quantifiable outcomes is intrinsic to the implementation and evaluation of policies [43]. This can be seen as part of the process of "rendering technical" [43]. Through defining a field of action which is intelligible, has specific limits and characteristics, experts create a boundary between them and their 'subjects', and can offer a solution within their repertoire. Regretfully, such delimitation in methodology and practice often results in ineffective programmes which miss the complex reality beyond that which they define. Integrating gender analysis into developmental methods and practices will be beneficial in addressing gender and climate change in the SWCRB.

Research Methodology & Study Area

Study Area

Shyamnagar Upazila (Upazila is the administrative tier under District level) (Satkhira District)(Bangladesh is divided into 8 geographical regions called Divisions, and these are separated into 64 Districts. The Districts are the first administrative level after Central Government) covers an area of 1968.24 square kilometers. It is a large uplift close to southwestern Bangladesh as can be seen in Figure 1. The border between Bangladesh and India, close to Sundarbans and the Bay of Bengal, has a total population of approximately 318,254 people, which equates to 46,500 households [44,45]. The annual average maximum temperature reaches 35.5 °C (Celsius)(95.9 °F) (Fahrenheit); the lowest temperature is 12.5 °C(Celsius) (54.5 °F) (Fahrenheit). The annual rainfall is 1710 mm (67 inches). Southwestern Bangladesh is highly exposed to various climatic factors, including temperature changes, erratic rainfall and sunlight, sea level rise, and cyclone events [46]. Climate change-induced sea level rise and cyclone events have led to an increase in natural disasters in coastal areas, which impacts the vulnerability of women [12].

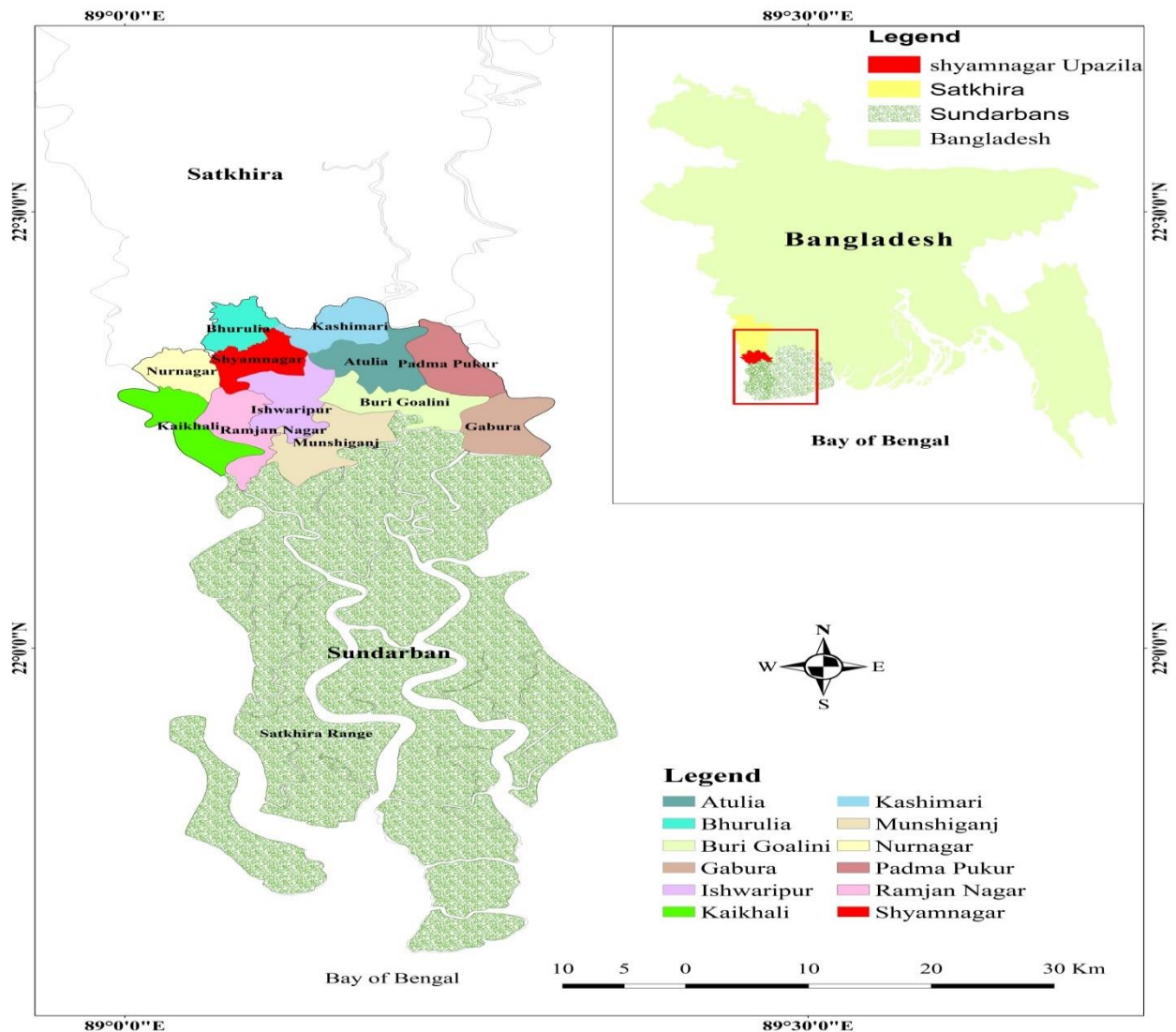


Figure 1. 12 Unions under Shyamnagar Upazila, adjacent to the Bay of Bengal.

4.2. Methodology

The data was collected in this research through qualitative and quantitative methods. Qualitative data collection techniques, such as focus group discussions (FGDs), case studies, questionnaires, workshops, in-depth interviews, and field inspections were used. The quantitative data collection technique included 320 household surveys. Both methods of data collection took place during various time frames between 2017 and 2019. Statistical Analysis was done by Cross tabulation, Chi-square test and symmetric measures were calculated by using SPSS software to determine the level of significance. The data obtained was sorted and reviewed using MS Excel-365 and SPSS (Statistical Package for Social Sciences, Version-25). QDA software is also used in the analysis process.

Before making a decision, different variables were verified and cross-checked, and then classified statistics were analyzed in terms of quality and quantity. Quantitative method indicators and questions were designed within the frame of Sen’s “Capability approach” [9], Kabeer’s “Resources, agency, achievements” [10] with “The Power of Relationships” [47] theories, Terry’s, “No climate justice without gender justice”[8], IPCC’s “Fifth Assessment Report “ [22], and the collected and analyzed

data were suitable to test the validity of the theories by Lama, and Wester's "Women as agents of change?" and Murray, L.T.'s "The will to improve" [43], in association with women empowerment. The study of the relation between gender, climate change, and other constituents (through Chi-square, Cramér's V interpretation and SPSS analyses) is a central element of the quantitative data analysis [48,49].

An observation guide was used to collect data during the case study, FGDs, KIIs, IDIs, and workshops. The data was recorded in field notes, audiotapes, and transcribed. The data analysis was consistent as it entailed two parts: First, reading the recorded field notes to reinforce hypotheses or themes developed during the data collection phase and to generate new hypotheses or themes [50,51]. This first step is referred to as initial coding or open coding [52,53]. The second part is to notice and systematically create records of patterns in the conversations and activities of people depicted in the notes or create coding frames. The initial coding of the collected data material guidelines for coding [52] was applied to ensure credibility, transferability, and dependability.

The theoretical and conceptual frameworks consisted of content analysis. This analysis method corresponds with the abductive approach of the research, as it is based on analytic codes and categories from existing theories and explanations relevant to the overarching research question [49, 50, 53]. In other words, in the directed content analysis, the researcher analyses the data from the predefined categories, e.g., climate change and gender, and the gender categories that emerge from the data itself [49]. Hence, the observation and interview guide serves as a data collection tool and an analytical tool, as it will be used to categorize the data material. It is challenging to understand the beliefs, norms, and values of local people on a primary level. However, for qualitative analysis to know the gender vulnerability and the status of female empowerment, it was necessary to obtain most of the cases from female respondents. In this research, a local female was included as a monitoring mediator (trained was done two days, on the 4th and 5th of October 2017, discussion was done how to collect data and describing meaning of each question) to include female respondents. This study exclusively focused on qualitative analysis on female vulnerability issues and concerns such as tiger widows (Tiger widow is a term used to refer to women who have lost their husbands to tiger attacks while working. Every village located near the forest has many widows trying to eke out a meager living after losing their husbands), sufferers from salinity, water crisis, and inequality. Women working in agriculture, small shopkeepers, honey cultivators and other occupations were also considered for in-depth interviews. Most of respondents name were not included in our research as we used Respondent/Participant-1, 2, 3, 4... or A, B, C ...X, Y and Z because of qualitative research ethics. A few names were used because she/he did not currently face social challenges, and his/her name was useful to reduce climate change challenges for the many people [49–53].

Household surveys were carried out through close-ended questionnaires to capture responses from respective respondents for capturing the nexus of climate change and gender [50] (Table 2).

In-depth interviews were conducted with selected respondents such as teachers, community leaders, farmers, non-governmental organization representatives, fishermen, farmers, honey collectors, and gender practitioners with guidelines prepared separately for each type of respondent specifically on climate shocks and vulnerability. These were conducted through field work, skype, messenger, telephonic interactions or interaction with respondents. The close-ended questionnaire consisted of household survey data collection from household heads together with interviews of family members (where permissible) (Table 2). During the close ended questionnaire surveys, interviews were focused on male and female respondents from each household. However, the women were generally due to religious taboo and traditional norms they are hesitant to give interviews with male researchers. To

realize such a comprehensive understanding of the relationship between gender and climate change, it is essential to characterize these notions from both scientific and SWCRB people perspectives. Moreover, women felt reluctant to express themselves in front of researchers. During this household research survey, 31% of the female respondents willingly responded to the close-ended questionnaires. A total of 320 household head surveys, 26 FGDs, case studies, observations, interviews, and several public discussions were conducted. Investigations were conducted between July 2017 and October 2019 in the Shyamnagar Upazila, SWCRB. The survey covered a total of 320 households from respective 9- union of the Shyamnagar sub-district. The respondent size was distributed proportionally depending on population size in the respective area using simple random sampling [49–53].

Table 2. Gender and climate change analysis questionnaire.

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- (1) Do you think the oldest, disabled, children, and women are most vulnerable at the time of disaster?
 (2) Do you think women are the most vulnerable due to climate shifting pattern?
 (3) If yes, what type of vulnerability do they usually face?
- (4) Is there climate change associated impact on a specific gender? (a) Physical and social settings of women (b) Link between climate change, livelihoods, etc. (c) Impact of climate change on women’s triple role (Reproductive, Productive, Community Management).
- (5) Do you think adaptation measures impact on men and women differently?
 (6) Is it possible to achieve women-friendly adaptation and mitigation in coastal region?
-

FGD: In this research, the locals got together to discuss on climate change, sea level rise, gender issues, vulnerability of women, empowerment, and were guided by a male and a female moderator. The group was called a focus group, and the discussions were tape-recorded, transcribed, and analyzed. We carefully evaluated and analyzed the interactions and discussions among the people [53]. The study organized 26 FGDs with different groups of pre-selected respondents of homogenous nature with semi-structured guideline and the use of participatory exercises.

Guidelines were prepared for each group of respondents to purposely draw out specific information related to the research objectives. Each FGD consisted of 8–12 participants including doctors, teachers, and stakeholders from government and non-government organizations, women, men, youth, elders, people with disabilities, and others. FGDs captured the data related to climate shocks and vulnerabilities, opportunities such as disaster- and climate-resilient practices (disaster risk reduction, climate change adaptation and mitigation)[49,50].

This research is a series-based analysis to assess climate change, sea level rise, the extent of impacts, vulnerability, and risk adaptation. The FGDs consisted primarily of mixed male and female respondents. Specifically, to identify vulnerability of women and the importance of female empowerment in the climate adaptation process in each union of the study area, there was an arrangement of the FGD session, solely consist of female participants. All other essential information was collected through face-to-face FGD sessions. Since patriarchy shapes women’s status to remain in obscurity, and discourage women from expressing their concerns in the presence of men, focus groups exclusively targeting women were very effective of Bangladesh. Gathering information through FGDs and informant interviews were conducted for females in the age range of 1947–2017 years. Considering the need to have participants with exposure to climate aspects and long-term trends, the focus group interactions focused on 8 to 10 individuals. To ensuring that research participants were aware of long-term scenarios, a minimum age-limit was set. The information

provided from rural inhabitants was important, as they had a limited academic background, and were more aware about the neighborhood [53].

Case studies: Case study is used for in-depth investigation. It is an ideal method that can run a holistic investigation [51]. Since case study spans its focus on an analytical domain in a comprehensive sense, such an approach is optimum for qualitative research within a short duration of a study. As life is not conducive in any aspect for these women, it is essential to understand how they could survive, and what their voice is in the SWCRB against the climate change debacle. They have limited alternatives to migrate elsewhere despite worsening circumstances. Thus, it is necessary to note if they will be able to adapt to the change. The case studies in our research were designed based on our research question [53]. For example, primarily, a list of women facing vulnerability due to climate change was generated, and their extent of vulnerability was discussed with the participants. If the participant was indeed vulnerable, an appointment was made, and the participant was briefed on the further design of the case study. Then the case study was analyzed and the interviewee was mentioned in the research [51]. They were briefed regarding the importance of our study topic during data collection and while concluding the study. They were also shown what was written and recorded during the case study, and their permission was obtained to use their responses in our research. Short cases and case studies on climate change and gender, gender vulnerability of coastal communities, social inequality, economic activities, climate justice, community-based adaptation, empowerment, food security, shrimp farming, drinking water, livelihood, adaptation etc. from the community were recorded. This research was facilitated with the knowledge of understanding the survival mechanism for vulnerability of women and their adaptation in the SWCRB.

Workshops: In this research, 9-meetings were organized with school, college students, and a mixed group of participants (local government officials, journalists, and representatives from non-governmental organizations). Workshop guidelines were prepared to sort out climate shocks and vulnerability, and benefit from their experience and knowledge [50,53].

Attempts to characterize people's perspectives on climate change in SWCRB have focused predominantly on observations of change. When attempting to characterize the relationship between gender and climate change it is common for SWCRB people to communicate the perceived influence of climate change on their: (i) Vulnerability, gender dynamics of climate change; (ii) how extreme weather can affect men and women in rural areas disproportionately; (iii) women's social and economic status; (iv) Social construction is that women are not able to deal with the effect of climate change but, when societies comes to adaptation question, women are seen as powerful agents of change in SWCRB; (v) In SWCRB, religious, individual movement from one place to another place, social values, and upbringing have a profound influence on women's roles in society (ex. during cyclones, women are more vulnerable); (vi) Types of vulnerability typically faced by women; (vii) Adaptation mechanism of women before, during, and after catastrophes; (viii) Differences in catastrophe adaptation measures between men and women; (ix) Women's capabilities in the SWCRB and challenges; (x) Empowerment are improving family and society. Because gender dynamics affect various aspects of SWCRB adaptation, it is difficult to isolate SWCRB people's perception of the relationship between gender and climate change alone. As such, it may not only be the process of climate change itself that characterizes socio-economic norms. It seems that it is the manifestation related to social norms that are enhancing social inequalities of women in SWCRB.

As a result, it may be interpreted that, to the perspectives and awareness based on this research field survey of, and experiences with, gender (and all related driving forces) a conceptual link between

climate change and gender inequalities may that a be identified. Participants were asked to describe what they thought would be key characteristics of climate from their perspectives (i.e., climate/environmental changes that they were starting to face). From the respondent key characteristics identified were climate change, sea level rise, cyclone, flood, and higher soil and water salinity in SWCRB.

During the interviews, FGDs, Case studies, workshops and questioner survey when we asked the questions to the respondents, we observed their eyes, body language and their conversation, we try to understand their motivation and information whether it is truthful or not. We also cross checked respondents answers with each and other (for the same questions) for reliability and validation of information [49–53].

4.3. Sample Size

Quantitative sample size determination:

For collecting primary data and information, the Shyamnagar sub-district under Satkhira district was chosen using purposive sampling as the most climate vulnerable area including the banks of Bay of Bengal. In the respective sub-districts, qualitative data and information were collected from 12 (100%) unions namely Gabura, Ramjan Nagar, Kaikhali, Atulia, Ishwaripur, Munshiganj, Kashimari, Nurnagar, Poddo pukur, Buri Goalini, Shyamnagar, and Bhurulia. Quantitative data were collected from different respondents from different places in 9 unions under respective sub-districts for this research focusing on social vulnerability.

A representative sampling approach was executed in this study. The sampling was undertaken by means of a non-probability sampling—a technique where the examination is permissible to opt individuals in accordance with a precise trait [49,52]. The targeted respondents were identified using probability sampling technique such as systematic, simple random, and stratified random sampling techniques to represent the target population with study coverage. Respondents were selected as per ratio of gender, age, and people with disabilities, ethnicity/minorities, and economic segregation status. An extra sampling method known as snow-ball sampling was also employed. Snow-ball sampling highlights the exploit of preliminary participants who assist in recommending other participants for this research [52]. For this study, communications was established with a local guide and a journalist for a local newspaper to locate potential individuals for interviews.

Table 3. The sample was considered at a 95% confidence level, with an accuracy rate or amount of admissible error margin of $\pm 5\%$ considering the exact beneficiary count and to sample the representative equally for Shyamnagar Upazila (Satkhira District) and distribute proportionately in accordance with population size. The following sampling approach and statistical formula has been applied for the sample design:

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

Where,

n = Sample size

N = Target population size

e = Admissible error in the estimate

p = Proportion of defectiveness or success for the indicator

$q = 1-p$

z = Standard normal variable at the given level of significance

Sample size distribution through stratified random sampling was as shown in Table 3.

Table 3. Detail of quantitative sample size distribution.

Type of respondents: Social and gender vulnerability	Unions: 09	N = Total population: 242392	e = Admissible error in the estimate: 5.5% admissible error margin	Sample size = n: 320	Female 98	Male 222	Youth 25.5%
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In this study, exclusive purposive sampling was employed to select the respondents. Gender: The gender of respondents is presented in Figure 2. Most respondents (69.4%) were male while 30.6% of the total respondents were female.

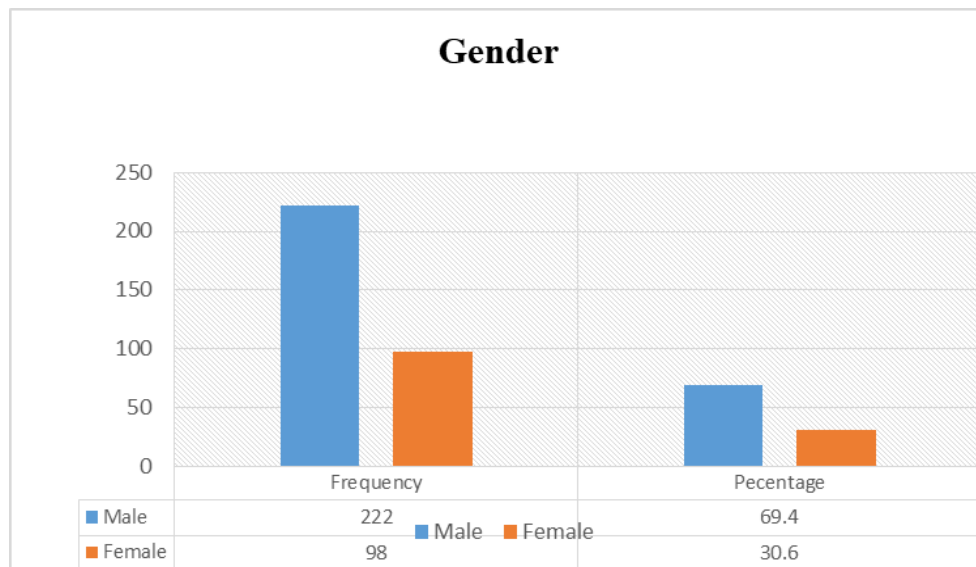


Figure 2. Gender of the Respondents; Source: Field Survey, 2017–2019.

In Bangladesh, women’s activities have traditionally been restricted. Even when they go out, Muslims generally abide by SWCRB by following the Muslim custom of wearing a veil and segregating women, and limiting their movements since they take care of their children. There is also an increased fear of sexual and physical abuse for women outside the home [54]. Still, social and religious barriers prevent them from leaving their homes. In this context, male respondents outnumber female respondents in this survey. It is clear that females are more vulnerable during disaster periods than males in the study area [54,55]. Females are less conscious as well as less concerned about the impact of climate change, rising sea level, pure drinking water and sanitation. They don’t even know how to cope with disaster or to mitigate their situation of vulnerability [55]. On that ground, this study included limited female respondents for collecting answer of the close ended questioner survey but we overcame this limitation through qualitative method like case studies, FGDs, workshops and interviews under 12 Unions

4.4. Respondents Occupation and Income

Key bases of earnings: Shyamnagar inhabitants have an extensive variety of professions, for example, day labor, farming employment, fish farming, crab farming, poultry farming, rickshaw-van pulling, auto bike-taxi driving, mechanics, fishing, grocery shopping, fishing [56]. There are individuals of

numerous occupations comprising cutting leaves, collecting honey, providing labor in shrimp farms, teaching, temporary labor, but maximum of the individuals of the Shyamnagar Upazila are engaged in fish farming. From the key basis of earning, maximum of the people of Shyamnagar make an income usual of tk 5000–10,000 (\$45.04–90.09) each month. Overall earning: Those who have a basis of incidental earning make around 10,000–12,000 tk (\$90.09–108.10) a month. In the instance of those who do not have incidental earning, it is 5000–6000 tk(\$45.04–54.05) with which the individuals of the locality devote half a day in starvation [56].

Field Survey Analysis and Results

This section presents the results of the questionnaire survey conducted from 2017 to 2019. It examines the perspectives and level of awareness of those impacted by climate change events. Furthermore, it presents the respondents thoughts and ideas regarding types of vulnerability, adaptation measures as well as cultural frameworks.

Many respondents (87%) believe that women, children, elderly, and disabled people are the most vulnerable to shifting climate patterns. A total of 12% of the respondents stated that they are not aware about the issue, which means that the respondents, especially women are not conscious about their vulnerability to climate change (Figure 3). Comparison of the mean values of the male and female respondent’s women, children, elderly, and disabled people are the most vulnerable to shifting climate patterns represents a significant value among them. The respondents also pointed out that gender inequality as well as gender differentiation is caused by climate shifting pattern, and women are more vulnerable than men to climate change due to their poverty, social and cultural norms and religious restrictions. One of respondent, B, age 43, from Ramjan Nagar union said that the lives of children, elderly people, women, and disabled become more vulnerable at the time of disaster because they cannot move easily or run fast. They cannot take shelter anywhere during this disastrous period, as they cannot say anything. The restricted movement of women makes them more vulnerable to the effects of climate change. Moreover, during disasters sanitation systems are disrupted as well as damaged. Under these circumstances, women feel insecure and ashamed to carry out their biological needs outside. Many elderly people have lost their memory, terrified by fear, and many of them have suffered strokes. Pregnant women are more affected by various diseases due to climate change. The locals have asked several times to build shelters nearby for the benefit of these women and elderly people but no action has been taken.

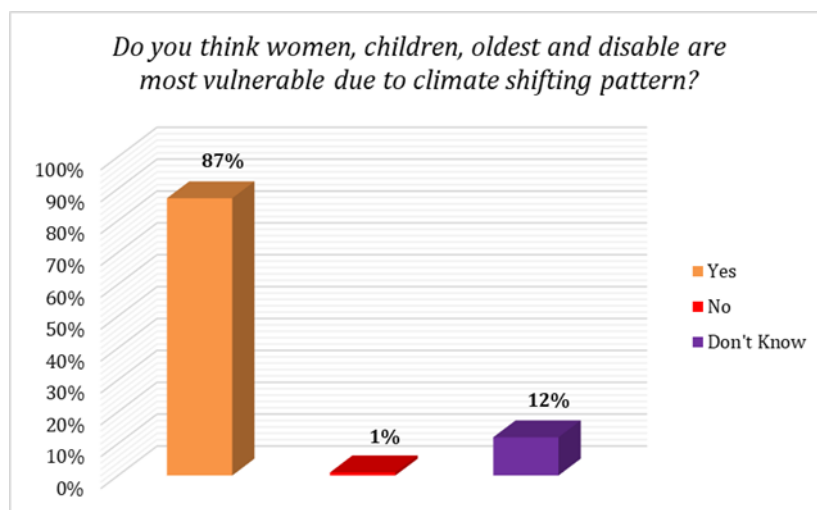


Figure 3. Vulnerability of population type to shifting climate patterns; Source: Field Survey, 2017–2019 [Whereas, yes (male 60.36%, female 26.64%); No (male 0.69%, female 0.31%); Don't know (male 8.32%, female 3.68%)].

A total of 12% of the respondents mentioned that they were not aware of it, which means the respondents, especially women are not aware about their vulnerability due to climate change. Gender equality means that women and men are treated equally [47,57] and that women and men have equal status and opportunity to contribute to social, economic, political, and cultural development. According to Kabeer [57], there is a distinction between men and women, because they are not treated the same. Many women, for example, receive lower wages for the same job in the context of the SWCRB [42,47]. Women empowerment can vary depending on factors like social class, ethnicity, and family position [41]. In many developing countries, religious and cultural values and upbringing have had a profound influence on women's role in society [29]. There is very high expectation in many developing countries that girls take on family responsibilities at a young age to be able to help around with domestic and other duties [11,25,37,57]. In countries such as Bangladesh, India and Indonesia, young girls have limited mobility and are not allowed to go far from the house as they are expected to perform domestic duties [22,54,57].

The Climate Change Cell of Bangladesh noted that women are further more exposed as they are often not allowed to partake in the community arena, and consequently, less likely to obtain decisive data for consideration of emergencies [58]. Furthermore, the majority of climate change, sea level rise, and adversity questions, planning, and agenda are not gender neutral [59,60]. As women do not have enough opportunities to earn income, they are dependent on men's choices and interests. Participant-47, age-19, mentioned that the women of the Gabura union in the SWCRB are more vulnerable to health risk because in such areas, they have to travel a long distance to collect water and such hard work is detrimental to their health. The women of the SWCRB suffer more than women of any other area of Bangladesh because this region is prone to natural disasters, and clean water is rare.

According to Table 4, 43.75% of the total respondents stated without hesitation that women face shortage of food and clean water. Approximately 55% of the respondents stated that the distance between the cyclone shelter and their home is far. The respondents pointed out that during climatic hazards, they become nervous and worried because the weather forecasting and warning system of the study area do not work well and they do not receive updates on climate hazards. Moreover, the respondents especially women, children, and disabled people cannot connect with local institutions due to poor road condition and communication systems. A total of 20% of the respondents have mentioned that they feel helpless. Women's specific physiological needs add additional challenges to their already existing vulnerability in terms of climatic conditions in the SWCRB. Approximately 25% of the total respondents pointed out that there are limited high areas in the coastal area. As a result, during flood or cyclone, water enters the homes and the inhabitants suffer from various problems.

Approximately 27.5% to 35% of the total respondents respectively mentioned that women living in the study area face a very dangerous situation due to their physical weakness during the disaster. In addition, many of the women do not know how to swim as they have never tried to learn swimming because of religious and cultural norms (Table 4). As a result, they are not able to cope with hazards. Long-term climate change effects like Sea level rise, droughts or flooding are likely to affect women more negatively than men in situations where their means, capacities, and opportunities are unequal [58–61].

Table 4. Types of vulnerability typically faced by women

Types of Vulnerability	Respondents	Percentage of Responses	Male (222)	Female (98)
Women that don't know how to swim	112	35%	24.28%	10.72%
Water and food issues	140	43.75%	30.35%	13.40%
Cyclone shelter is far from home	176	55%	38.16%	16.84%
Lack of high places to build homes	80	25%	17.34%	7.66%
Physical weakness	88	27.5%	19.09%	8.42%
Helplessness	64	20%	13.89%	6.13%
Nervousness & Fear	96	30%	20.81%	9.19%

Multiple Responses: N = 320; Source: Field Survey, 2017–2019.

According to Table 5, more than 43.75% of the total respondents have mentioned that women are affected differently by physical and social setting for women/health issues. A total of 35% and 38.1% of the total respondents respectively registered that women's economic condition are adversely affected by the worsening effects of climate change. A total of 46% of the respondents admitted that women are not sufficiently involved in decision-making or in planning climate change adaptation or mitigation strategies. This traditional thought restricts to flourish women's decision-making power (Table 5). According to total respondents 40.6% in SWCRB women's undertake triple role in the family and society (Reproductive, Productive, and Community Management). Women's reproductive roles include the physical and connected to the labor of the household such as maternal duties and care and maintenance of household chores. The productive role of women relates to agricultural production, informal production, household production and livelihood. Women's community management roles include caregiving and unpaid work, and water collection, health care, natural resource management, etc. In Bangladesh, mobility restrictions make women more vulnerable in their houses during floods [3]. The case of the cyclone is a prime example of the dramatic gender disparities during floods [22]. Other differences may be exacerbated during extreme events of cyclone, drought or flooding because women take on extra responsibilities before and after disasters, like storing food and water and taking care of the children and the elderly [22]. Inadequacy of shelter capacity during and after climate events affects every sector e.g., human trafficking. From the total respondents 27.5 % have mentioned that women are affected differently in connecting to Inadequacy of shelter capacity (Table 5).

One of the participant-48, age-38, said that food and water are the main concerns of women in the SWCRB, for those of whom the partners have migrated because of climate change. Food is vital in people's everyday lives. Women are part of the food supply chain from the beginning, as gatherers of seeds, leaves and eggs; growing plants in gardens and raising animals for family and income; cooking, and collecting fuel [61]. However, although women contribute to half of the world's food production, they face more obstacles than men to reach resources such as land, credit, and agricultural inputs and services [60,62].

Table 5. The impacts of climate change on gender in particular.

Impacts	Respondents	Percentage of Responses	Male (222)	Female (98)
Physical and social setting for women/health issues	140	43.75%	30.35%	13.40%

Women's triple role (Reproductive, Productive, Community Management)	130	40.6%	28.16%	12.43%
Women's economic livelihood/poverty	112	35%	24.28%	10.72%
After hazards, income and occupation challenges for women	122	38.1%	26.43%	11.67%
Inadequacy of shelter capacity	88	27.5%	19.07%	8.42%
Women's participation in decision making	150	46.9%	32.54%	14.36%

Multiple Responses: N = 320; Source: Field Survey, 2017–19.

In coastal region, most of the women mainly depend on natural resources for earning money as well as managing their livelihoods. The respondents said that women living in the study area earn money through performing agro based activities (like transplanting, harvesting crops, boiling and drying cereals), collecting fish & prawns in the river, raising hens and goats. The findings of the study indicated that different natural disasters contribute to the reduction of the source of income, especially those of women. During disaster periods, women cannot find agro-based jobs because natural disasters damage crop production. Moreover, natural disasters hamper the reproductive capacity of fish and prawns. Additionally, women are unable to travel or move to another location to look for work because of their social attributes and religious restrictions, whereas men can easily migrate to another region to earn a living without facing any social or religious restrictions.

The following (Table 6) shows the operating framework of women namely, culture and conditions, during and after extreme climate events.

Table 6. Culture and condition induced tackling mechanism of women before, during, and after catastrophes.

Circumstances	Culture Triggered Manners	Condition-Induced Approach	Informer-Respondents of 12 Unions from SWCRB
Before calamity	Women usually overlook the cyclone indicator or continue to be oblivious about it.	Cautiously judge every cyclone sign	Respondents 1 Respondent 2 Burigoalini union
	Male individuals are not concerned to bring along women to cyclone-safe haven because of insecurity and lack of space to themselves within the atmosphere.	Get themselves ready to set off for cyclone-safe homes with other family members	Respondents 3, Respondent 4 Munshiganj union
	Because of insufficient or no facts available, they have slight/no alternative to communicate with the neighbors about the imminent calamity.	Share and communicate with the people in the community about the imminent catastrophe	Respondents 5 Respondent 6 Gaura union
	Attempt to bond and take care of their children and elderly family members collectively.	Maintain their children in close proximity, along with ailing and elderly family members	Respondents 7 Respondent 8 Ramjan Nagar
	Release livestock within the domestic setting	Look for secure positions, such as dam and cyclone sanctuaries for livestock.	Respondents 9 Respondent 10 Koikhali
	Attempt to salvage jewelry and important documents.	Strive for their greatest level to guard their possessions to a considerable extent.	Respondents 11 Respondent 12 Nurnagar
Circumstances throughout catastrophe	To follow their male partner	Caregiving responsibilities may save lives	Respondents 13 Respondent 14 Bhurulia
	Be present with teenager girls at house and periodically go to a cyclone protection center with men in the family	They cautiously regard every cyclone indicator and prepare themselves with family members to	

		take refuge at protection in the cyclone safe haven	
After calamity	Women's work in agriculture is often seen as an extension of their family responsibilities.	Ensuring the safety of food, water, and fuel is the main concern	Respondents 15 Respondent 16Kashimari
	Assist male members in tasks inside the house	Assist male members in resettling undertaking; doing work out of home for bringing in ready money, for example, in farming ground, ready money for labor vocation and so on.	Respondents 17 Respondent 18Atulia
	Fixing fishing nets	Relating them in gathering of fish fingerlings, fish processing and drying undertaking.	Respondents 19 Respondent 20Shyamnagar
	Fetch water from pond within proximity and tube well	Arrange secure drinking and potable water from distant source.	Respondents 21 Respondent 22 Ishwaripur
	Put aside money and other belongings for the coming days.	Strive to get more cash from farmhouse vegetable farming, betel leaf farming and tree plantation in farmstead and roadside	Respondents 23 Respondent 24 Padma Pukur

Source: FGD, Interview, workshops, women from 12 unions in 2017–19 (Skye, Messenger, 2020–2021).

According to the World Bank Group's report, women's lesser involvement in shaping of policies that affect flow of finances, or reduced access to assets, services, and voice [37] make them more vulnerable to climate change. In the context of climate change in the SWCRB, gender analysis promotes an understanding of the ways that men and women are differently impacted by climate related hazards and the adoption of adaptation strategies. In Bangladesh, gender inequality prevails in various social, economic, and political institutions. Natural disasters and climate play an important role here, and women suffer more than men from gender disparity. All the important elements of life such as income, property, access to credit, decision-making and source of food are controlled by men in the Bangladeshi society. Women's movement is limited and restricted and so they can hardly access information and natural resources. In the same way, they are not authorized to run monetary events [62, 63]. However, when women were involved in the community enlistment and participation with the local disaster management before the 2007 cyclone, deaths decreased substantially [37].

The following figure shows how adaptation measures affect men and women differently. When respondents were asked if they think that adaptation measures affect men and women differently, 80% responded positively. This means that gender inequality is a factor in preparing adaptation and mitigation measures (Figure 4). Comparison of the mean values of the male and female respondent's adaptation measures affect men and a woman differently represents a significant value among them. Introducing adaptation measures that include women will not only empower them and enhance their role in society, but it will also help women to learn and understand climate challenges and ways to cope with extreme events.

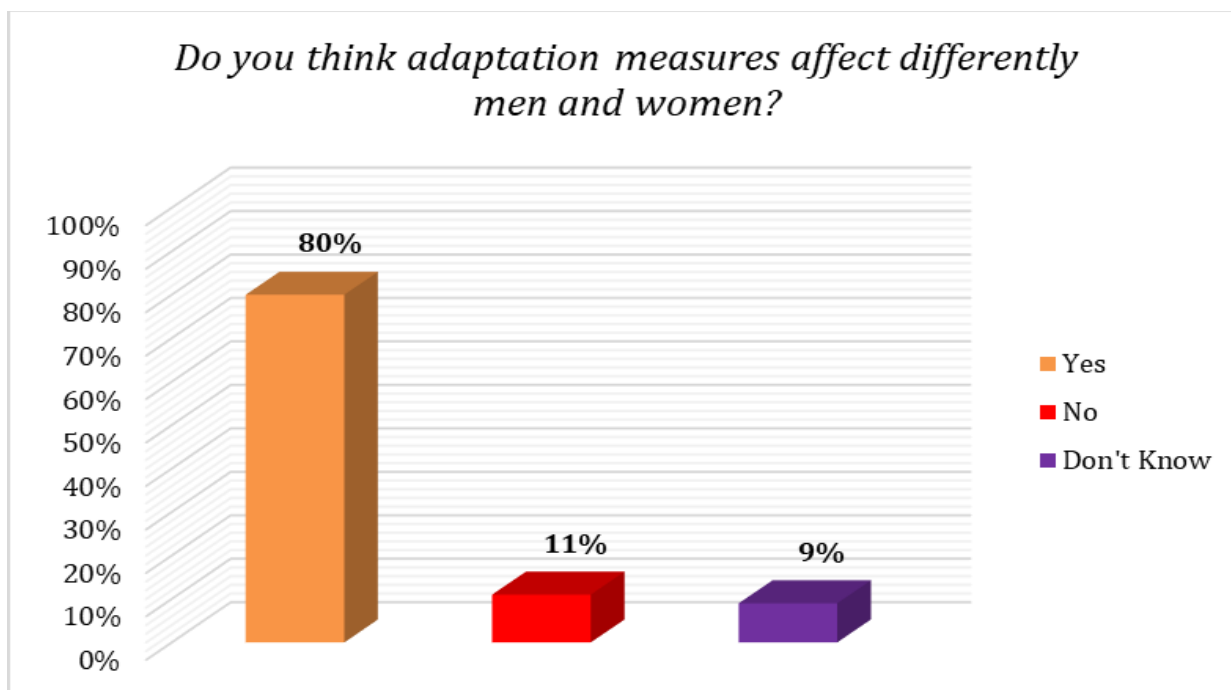


Figure 4. Affects of adaptation measures on men and women; Source: Field Survey, 2017–2019. [Whereas, Yes (male 55.5%, female 24.5%); No (male 7.63%, female 33.7%); don't know (male 6.24%, female 2.76%).

It has been reported in IPCC [22] that in Bangladesh, women are required to be self-assured and use association expertise to improve recovery capacity. Similarly, males are required to be familiar with gender-specific characteristics of disasters to be socially prepared to deal with any disaster (Table 7).

Table 7. represents women-centered adaptation measures in the SWCRB.

Adaptation Measures	Respondents	Percentage of Responses	Male (222)	Female (98)
Female empowerment through employment with land rights	150	46.9%	32.54%	14.36%
Women friendly agriculture	64	20%	13.88%	6.13%
Female education and building awareness	120	37.5%	26.02%	11.48%
Micro-finance	160	50%	34.68%	15.31%
Policy formation regarding gender equality	50	15.6%	10.82%	4.78%
Ensuring women's participation in idea development	92	28.8%	19.98%	8.82%
Organization of stakeholders with equal access and involvement of women	138	43.1%	29.90%	13.19%
Integrate climate change information in academic curriculum	52	16.3%	11.31%	4.99%

Multiple responses: N = 320; Source: Field Survey, 2017–2019.

Women in SWCRBs are certainly the most vulnerable to the impacts of climate change, and adaptation is a process that builds and enhances their resilience. How women in SWCRB are particularly vulnerable to the impacts of climate change, and what adaptation processes occur in SWCRB by which women can avoid harm from climate change impacts (Table 8).

Table 8. Women’s vulnerability and recovery capacities in the SWCRB.

SWCRB Women Vulnerability	Women-Focused Adaptation Capacity	Name of Union
Livelihood	By women/stakeholders	Women participant/informer name
Losing farmstead land and structure	Several women received help from government and non-government organizations while some were reconstructed by their selves with family members	Respondents 25 Gabura
Damage of farming yield	Obtained credit and instruction from non-government organizations for farming of season-based vegetables and substitute agricultural work	Respondents 26 Gabura
Shortcoming in essential needs like schooling, wellbeing, secure intake of water, refuge, sanitation, power supply, and communicative privilege	Government and non-government organizations make fundamental facilities available where women are dynamically involved	Respondents 27 Burigoalini
Uncertain sources of income	Probing for more varied origin of living instead of conventional ones	Respondents 28 Burigoalini
Deficiency in right of entry to and power over production like land, farm contribution, animal resource, and assets	Received credit from non-government organizations for agricultural purpose, farm animals rearing and purchasing fishing boat and farming tools	Respondents 29 Munshiganj
Reliance on money lending sources, usurious sources	Involved with uphill struggle comprising outer periphery of home for repayment of the borrowed cash timely	Respondents 30 Padma Pukur
Sharp or continual food scarcity	Farm animals rising, sowing seeds of fruit trees, season-based vegetable farming, and substitute agricultural undertaking	Respondents 31 Ramjan Nagar
Soaring death rate, undernourishment and illness	Seek advice from with the neighborhood medical doctors, herbal practitioner and visit neighborhood clinic	Respondents 32 Kaikhali
Overexploitation of natural reserves	Quit misuse of natural reserves if earning making encouragement is provided augmented by women’s economic involvement by means of self-employment	Respondents 33 Nurnagar
Escalating household violent behavior and neighborhood clash because of mental trauma	Through self-employment to decrease the mental pressure triggered from adversity	Respondents 34 Bhurulia
At Society/organization level	Through women participation	Women participant/informer name
Fragile family/relationship configuration owing to losing male adult in family unit	Improved local job openings for the women learned and working women making better contribution to reduce these troubles	Respondents 35 Shyamnagar
Shortcoming in guidance, enterprise, managerial composition to resolve troubles or disagreement	Majority of the girls are presently attending school, optimistically they will experience lesser troubles	Respondents 36 Ishwaripur
Disproportionate involvement of women in society interaction	Learning and job opening of women can diminish these gaps, consequently, decrease hostility towards women	Respondents 37 Atulia
Unfairness and deficiency of admission to political practices	Learning, job opening and creation of women group can diminish the social misery Calamity awareness instruction and schooling can organize women better against calamity	Respondents 38 Kashimari
Social pestering	Instruction on calamity can develop the understanding on reasons and cost of it	Respondents 39 Munshiganj

	Alertness and calamity supervision-associated instruction develop understanding about perils and costs	
Unpleasant inferior situation in the society	Gender-responsive planning and homework for early caution or reaction to a calamity can decrease fair allocation of crisis relief easy, avail protection situation in refuge houses better, and advance alleviation	Respondents 40 Munshiganj
Attitude related issues	Women take it as a challenge	Women participant/informer name
Negative outlook towards transformation and no combating fortitude	Improved local job openings for the educated women and working women making better contribution to reduce these troubles	Respondents 41 Padma Pukur
Negative viewpoint/bigotry	Majority of the girls are at present attending school; optimistically they will experience lesser troubles	Respondents 42 Atulia
Ignorance about perils and cost	Learning and job opening of women can diminish these gaps, consequently, decrease hostility towards women	Respondents 43 Bhurulia
Reliance on outside endorsement	Learning, job opening and creation of women group can diminish the social misery. Calamity awareness instruction and schooling can organize women better against calamity	Respondents 44 Ramjan Nagar
Dispensing attitude, recuperation competence	Instruction on calamity can develop the understanding on reasons and cost of it. Relating themselves in diverse off-farm and on-farm earning creation actions	Respondents 45 Nurnagar

Source: Interview; workshops; FGD 2017–2019 ((Skye, Messenger, 2020–2021).

Case Studies

Climate-Induced Challenges

Participant-49, age-50, of Padma Pukur union informs us that she barely maintains her family by putting entrapment on river. She also informs she has been affected during different natural catastrophes. Her house got destroyed due to the assault of hurricane Fani in 2019. Their health vulnerability is increasing due to food shortage. They cannot create and maintain gardens due to salinity. Potable water crisis is at its peak now. Various types of waterborne illnesses are surfacing due to saline water use. Pure water is becoming scarce. Fish are also dying due to salinity. A number of concerns emerge because of salinity. Participant-50, age-45 from Kashimari union is surviving within such hundreds of obstacles. Existing gender inequality is highlighted as a result of weather events and disasters related to climate, which increases the abyss of social, economic, and cultural rights perpetuating vulnerabilities. Though increasing attention is given to this topic in developed countries, it is still widely discussed in the context of developing countries, in particular with regard to ocean-related risks and sea level rise [63]. For instance, the recent surveys focusing on the southern coastal Bangladesh show that women attach less importance than men to climate and disaster-related information (both emergency information and training programs), to administrative processes at domestic and public levels, to financial resources including economic means such as micro-credit, to the ownership of land and to activity inside and outside the villages [53].

Participant-51, age-60, mentions that they are dying without water or money. They cannot afford to go to Nowabecki every day to fetch water due to their poverty. They desperately request for the water supply facility. The widow from Borkupot village informed us further that since the only son R, and her daughter-in-law ‘S’ went for day-labor job, she, along with her grandchild ‘M’, went to Atlia

Union Porishod area to fetch water but as the water was not supplied to the pipe connected to a source 2 km away, they returned empty handed. Participant-52, age-60, a peer of Participant-51, following the latter, informed us that she has to stay with the foster son since her husband is paralyzed. Since her daughter-in-law is ill, in a five-member family, she had to go to fetch water at noon and had to walk for an hour but could not obtain water. She would borrow water from the preserved rainwater of her neighbor to meet the demand for the noon; she would return the favor in the afternoon or evening. People from the villages of Napitkhali, Chandnimukha, Talbaria of Upazila have not water in proximity to their home; however, they would have to walk miles to fetch potable water. They claimed that even the day laborers have to buy water after cyclone Aila hit the waterbodies in the neighborhood rendering it saline. The water crisis worsened daily, the housewives informed that it is possible to survive without food but not without water. Without having the capability to buy water from the vendors, they are going through excruciating sufferings for days.

Participant-53, age-52, from Atlia village, and Participant-54, age 47, from Chandipur village, claimed that apart from themselves, in order to provide water to the domestic cattle, they have to cross 2–6.0 km approximately four times per day. The pond water is not potable, and hence, they have to fetch water for cooking from outside. All the inhabitants of Shyamnagar Upazila are in desperate need for potable water despite being in proximity of water. In the coming summer days, the situation is assumed to worsen. Participant-55, age 28, of Manikkhali said, “I was not married in 2009. I was studying. The sky was normal on Saturday night. Then, on Sunday evening, the weather got worse. The signal (The Bangladesh Meteorological Department (BMD or Met) uses 11 warning signals during cyclones to warn people, and these signals are announced based on the intensity of the cyclone and the wind speed measurement mode) was No. 8 in the morning, No. 6 in the afternoon, No. 10 in the evening.

The storm started with the sound of breaking trees. It was like a horrible scene beyond imagination.” She added, “I was swept away in the waters of the cyclone Aila, and never imagined that I would survive the onslaught of floodwaters.” With the water, the house was washed away, chickens, goats, cows all died, and we became destitute. It struck the coastal area at 11 a.m. on Monday, 25 May 2009, flooding vast coastal areas. It had been raining heavily since morning, darkness all around; most of the abadas (embankments) were broken. Waves rose from river and descended on the land. The river looked like it was going to overflow. Then the floods came. The water was like poisonous water. There was no way to calculate the number of lives lost during that time. It doesn’t matter how many things I had in my house that day. Everything including our family dreams was washed away in the flood waters. We had no money to build a new house. We lost everything in this disaster. Crops are not like before. There is no more fresh water in the pond. The plants died. This water would have killed cows and goats and we would get infected with various diseases and still now”.

In 2009, the cyclone “Aila” hit the Southern part of Satkhira during the day and those who had mud houses died after being pressing away by the mud. If it hit at night, the amount of damage would increase. Then, the cyclone centers were not near from the remote area for stay there. Some people went to the cyclone center during the cyclone Aila but most of the people interviewed did not. Participant–56, age-54, said that cyclone center authority usually separates family members from their families, and same family member have to worried for others family members, for that cause people did not went to Cyclone Center e.g., the inhabitants who is living near of the Lakshikhali Cyclone Center, in Gabura Union.

One of Catholic Father stated that there is no equality among Muslims and Hindus. There is a caste system among Hindus. Until the caste system is eradicated, there will be inequality in society. The idea of equality does not exist in the Indian subcontinent, the poet Nazrul spoke of communism. When it comes to equality, people will say that social inequality will always persist because in hand five fingers are not same. For example, during catastrophe periods, Hindus or Muslims, Mosques or temples are not open to everybody because of religious differences, those places are well-built and are safe places to take shelter during a cyclone. In SWCRB look down on the rich people, who do not want to give shelter the poor in their homes during the catastrophe.

Participant-57, age-46 a resident of 9 No Sora in Gabura Union, said: ‘We have suffered a lot due to the breach of the dam. The house is ruined. Houses have been destroyed as well as crops due to the demolition of embankments. There is no income at this time. The water was contaminated due to saltwater infiltration into the pond and has become unsafe for consumption. Poultry food has been wasted. The vegetables in the field are spoiled, plants are dead. You have to build a house with a loan. In the coming days, if we build big embankments, are provided with drinking water and financial assistance, our misery will be lessened’.

Participant-58, age-45, said, “I have no land. I live on government khas land (Government land). I used to sell firewood in the past. There are 6 people in my family, 2 have income. Earlier, my occupations were fishermen and collecting/cutting firewood from the forest. I used to catch fish or gather firewood from the Sundarbans by boat. We had to go deep into the forest to cut. I am poor. I didn’t have permission to go to the Sundarbans Forest, but I went there anyways. When I collected 40 kg of firewood for cooking, market price was 130 tk (US \$1.5). Now firewood cutting is totally forbidden by the government in this region and market price is 200 tk (US \$3). Previously, when I collected firewood for cooking, I used to cut Bain, Garan, Sundari, Keora, Golpata trees. The government has stopped going into the forest because of river erosion and deforestation. Thanks to the Sundarbans Forest, she saves us from North-wester (Kalavaishakhi) storms, tornadoes, cyclones, and floods. I convert my occupation as a small egg business woman because of uncertain climatic pattern, and don’t have my own shop. I go to Burigoalini bazar to buy whole sell price eggs, at 11 tk per egg. I buy 1200 to 1400 eggs per day. I earn 3000 to 4000 tk (US \$35 to 45) per month. While my family’s finances are generally good now, before this small business, I used to spend my days in trouble. Yet the present is better than my past.

Participant-59, age-48, a small trader. I have a grocery store. I don’t have a husband. The government gave me a house made of brick I couldn’t run a shop because my husband died. I have tried to run on our business even though the capital is low and have succeeded today with government and private financial help. NGO Caritas helped with 18,000 tk (\$205). At present I am able to educate boys and girls through my small entrepreneurship. From the river collect young fish then I sell it to local market. I am playing a role in meeting the family food needs and conserving the environment by cultivating vegetables organically in homestead. Through my income involvement in family decision-making processes and social status has increased.

5.2. Climate-Induced Health Problems

The area has seen a rapid increase in illness due to polluted water and water-borne diseases in the last six months. The sea level has risen due to climate change, resulting in a rise in water level in the river, eventually leading to flooding and inundation of the coastal areas. Due to this, salinity level in the water of ponds, canals, lakes rise, and the water gets polluted. Participant-60, age-30, of ward no. 9 of Gabura union informed us about this issue. She also said that after Aila, pathogens have increased due

to water and soil level salinity; diarrhea, jaundice, cholera, abscesses, sore in different parts of the body. Participant-61, 41, from Dumuria Village of Gabura Union tells us that there is a sharp rise in the number of illnesses due to climate change. Due to unfavorable weather conditions, children are suffering from pneumonia, measles, pox, clod, fever, and other illnesses. Pregnant women are suffering from anemia, lack of nutritional balance, headache, vomiting, and other problems. Waterborne illnesses such as diarrhea are on the increase. Skin problem, like soreness, abscess, and intensity of allergy is increasing. Participant-62, age 43, of the same Union informs us that she and her daughter had been suffering from different types of skin problems since the last few weeks.

Participant-63, age-38, from union Jelakhali, Munshigonj, is a doctor by profession. She informs that teenage girl's aged 12–16 years suffer from white inflammation. As high as 80% of the problems are due to lack of nutrition—iron, calcium deficiency. Women suffer from depression due to irregular menstruation. Anemia, headache, fever occur frequently. Allergy incidents increase due to saline water intrusion as exposure to saline water causes soreness, scabies, eczema, and other skin problems. It also leads to disability infertility among women. Under aged girls prematurely deliver at the age of 13–15 years. Many early marriages are as a result of extreme poverty here, which causes problems in conception. Cases of high and low blood pressure become frequent, weight loss occurs, and anemia becomes pervasive. Many people suffer from soreness, scabies, and allergy problems due to the polluted water in the locality. Diarrhea, dysentery, acidity, iron, calcium, mineral, protein problems are also common. Even after six months of child delivery, this deficiency is not recovered through regular intake of supplementary vitamins. Saline water also leads to loss and greying of hair, for which men are the prominent sufferers. Girls experience menstruation at an early age—even at 10 years of age, when they study at class IV–V, girls gradually become physically weak. Several women suffer from breast tumors, which turn to breast cancer eventually. Among the 40-year-old women, breast pain is a common complaint. Women start lactating even without bearing children. Several children are malnourished. Women aged 25–35 years suffer from anemia; their hands and feet become numb. Homeopathic and ayurvedic medicines are used to combat such problems, which help to some extent. Besides, some people fight against gastric inflammation by consuming energy drinks. Availability of fish to supplement calcium in the body is limited. Consequently, the children born are mentally retarded. Infants do not get enough breast milk from their mothers due to poor availability of nutritious vegetables. Thus, the people believe that if food scarcity is met, most of the problems will be resolved.

Participant-64, age 37, from ward no. 9 of Gabura union tells us that climate change is triggering flooding, eventually creating pressure on river water leading to the damage of houses. Every year they have to raise the soil level in their house courtyard. The saline water mixes with the river water and makes the latter saline. Eventually, the coastal croplands experience salinity, and cultivable lands do not produce much crop. The weather has undergone drastic change; storms, floods are occurring frequently. The water level is swollen and causing siltation on the river, eventually causing flooding. For these reasons, there is an indirect or direct impact on the health of the inhabitants of the Shyamnagar Upazila.

The cyclone Aila took the father-in-law of Participant-64, age 56, besides her losing five ducks, six hens, 14 goats. Her house also got damaged. After Aila, contrary to her expectation, she did not receive any help. However, Participant-65, age-51, her next-door neighbor, got a tin-built house. She built her own house, and she had to make use of pond water for cooking and river water for bathing. Participant-66, age-57, saw her house being destroyed due to Aila in addition to ducks and hens. She had to take shelter on the roof of the house during the storm for 2–3 h. She did not have the time to go

to the cyclone centers. She also said that vulnerability to climate change effects has different implications for both men and women, and its response efforts to natural disasters can compound existing gender inequalities. In addition, some of the issues she stated are incidences of women being raped in disaster shelters or losing their homes and means of earning a living and still 98% lands are owned by males. Two sons, had heart attack on the aftermath of cyclone Aila.

Participant-67, age-49, makes a living from farming although she does not own land. She said that because of the salinity of the water, and lack of self-awareness, women are easily affected by a variety of water-borne diseases, such as skin problems, itching, scabies, sores, worms.

6.3. Climate Change Driven Tiger Widows

Crop productivity has been declining in SWCRB due to climatic shocks like cyclones, sea level rise, salinity caused by long-term commercial shrimp farming for that cause the livelihoods of people who reside near the Sundarbans, the world's largest mangrove forest, depend mostly on the forest because of the availability of a variety of resources both from the forest. Their economic dependence on forests has led to many deaths from tiger attacks, an event that has long plagued people here.

In the villages attached the Sundarbans, women who lost their husbands to tiger attacks are known as tiger widows. Due to prejudice, these women are considered to bring bad luck and misfortune to their husbands. They have to live in one house. There are 1165 such women in the Shyamnagar upazila. Due to the employment crisis in the coastal areas, the only earning member of the family depends on the Sundarbans as an alternative occupation. Increased salinity is destroying the agricultural system of the coastal region and saltwater shrimp farming reduced human employment. Thousands of agricultural workers became unemployed. Since people depend on the Sundarbans as an alternative occupation, they are being attacked by tigers. The asceticism of their wives begins when they enter the Sundarbans. Their hair cannot be combed or tied back, they cannot talk loudly, or walk in front of strangers, or fry dried salt. The lives of such women are trapped in a world of unjustified rules. If unfortunately, a husband loses his life in a tiger attack, the tiger widow is blamed and named indecently. They also need permission to attend social events such as birthdays and weddings. Many are also evicted from their own homes. Most of the tiger widows have left their husband's house, and their father's house or khas (government land) place is their last resort. In these difficult times, natural calamities such as cyclone Aila, Bulbul, Foni, Amphan have left their mark in the coastal region. In the struggle to survive, many people have lost their small slum houses.

Expressing her opinion that widows are still active in their husband's profession in the Sundarbans, one of, a tiger widow Participant-68, said "I have not received any compensation for the last 20 years. She used to make a living by fishing in the forest. She said he was tired of throwing nets in the Sundarbans and was resting under a tree. At that moment, the tiger came and jumped on her. She jumped into the trap to save his life and screamed. Sailors came to the rescue. There are still big scars on her head, back and hands. Since the attack, she has lost many of her abilities. Her head hurts a lot. Officially, she got a special place as settlement, where we stay." Participant-68's family currently survives by begging and through human donations.

Participant-69, is another tiger widow from Sora No. 9 of Gabura union. When her husband went fishing in the forest and was killed by a tiger, she was three months pregnant. Her child now goes into the forest for earning a livelihood. She has been married for two years. She has a scarcely spaced house on government khas land, which she was not able to fence. Yet, she claims that she is fine.

Participant-70, another tiger widow, from Nakipur Malopara, got married at a very young age in the Munshiganj union. Lost her husband, which indicated the beginning of a life of extreme misery.

Society continues to place a heavy burden of stigma on her. This cursed life lasted for several years. Now, she is happily married again to her husband's younger brother. A few years later, she had two more sons and daughters. But this happiness did not last for long. Once again, the tiger attacked her second husband to which he perished. This time she suffered from extreme harassment, humiliation and misery. She has been stuck in the house for years and occasionally even considered suicide; however, she did not act on the thought due to her religious belief that suicide is a great sin.

Importance of Empowering Women in the SWCRB

This section explores specific case studies of women's empowerment in response to climate change in the SWCRB. Based on this research, empowering rural women is an important measure for adapting and mitigating to climate change. Through the case studies, it was revealed that the local women possess unique level of resilience, in terms of climate change, women may also be well positioned to lead adaptation efforts alongside men, and it is important to include women in decision-making and their participation.

Environmentally-Friendly Stoves

Bangladesh lacks a modern energy infrastructure for a large portion of its population. Eco-friendly stoves provide an innovative energy alternative in addition to reducing the workload of women and reducing deforestation in the region. Moyna Rani, age-55, of Shyamnagar was awarded the Best Jayita Award for her development of eco-friendly stoves. She used her knowledge of technology to respond to the energy crisis and reduce the impact of climate change, global warming, harmful carbon emissions and aided in the protection of women and children's health. She has produced these stoves in the coastal regions of Shyamnagar, Kaliganj, Asashuni, Debhata, Satkhira Sadar, and Koyra Upazilas of divisional Khulna district for approximately 7000 families and more than 50 hotels for the past 15 years. She has also trained countless local women in the construction and use of eco-friendly hand stoves (Source: field work: 2019).

As Bangladesh has not yet afforded modern energy for large parts of its population, more than 60% of the total population still heavily relies on fuel wood, dung, and crop residues for their cooking needs, the eco-friendly stove help to reduce the deforestation, and drudgery of SWCRB women. As a positive outcome from the initiative, eco-friendly stove provides a direct benefit, especially to rural women, as a result of the reduction of the workload moreover reduce deforestation. Going further on women benefits, ecofriendly stove enables to save approximately 1 h 30 min time per day per family. This saved time can be used for childcare, income generating activities, education, recreation and other social works.

The use of energy-efficient stoves could help reduce unwanted emissions and improve the climatic situation, especially since the stoves reduce the amount of biomass while needed its reducing cooking time and increase their distribution by reducing costs and allowing access to cleaner, safer, faster, and cheaper energy [64,65]. Other than energy proficient stoves, it is particularly important for SWCRB because in the remote area did not have access to electricity, like Gabura Union power created by private renewable energy source. At the end of the day, energy-efficient stoves that allow women and man to be more efficient while reducing their workload.

Electrification of the SWCRB and Women Empowerment

An example of rural women's empowerment and social inclusion in Bangladesh is a program run by the World Bank, in partnership with the national government (Bangladesh Bank's Non-Bank Financial Institution (NBFI) in January 1998 to bridge the gap in medium to large development funds, playing an important role in Bangladesh's large-scale infrastructure and renewable energy projects.) and grant donors (US Agency for International Development (USAID), and multi-donor trust fund Global Partnership for Output Based Aid (GPOBA), named Rural Electrification and Renewable Energy Development (RERED). Partners of solar projects aim to train women as solar technicians and improve their social status and enhance sustainable energy sources [66,67]. An example of women's involvement in low-carbon emissions development paths such as solar power is that of F age 47 owns a tea stand and a small restaurant in East Buri Goalini. She makes stoles with her husband and serves local snacks to her customers. In the restaurant, two white light bulbs are suspended, which are powered by electric energy generated by solar panels. She bought the solar home system (SHS) for 20,000 TK (approximately US\$ 181). Participant-71, age-47, stated, "I can now keep my small restaurant open even at night. My business is booming, and the increase in income makes my family much more comfortable".

Participant-72 stated that "The SHS is an alternative solution to meet the needs of home lighting. (Source: field work: 2019). The use of SHS units can provide a convenient and sustainable way to obtain high-quality, clean, and environmentally-friendly energy services Furthermore, operating SHS services in coastal villages can bring positive socio-economic benefits, including high-quality home lighting, extended education hours, and increase women's health awareness through TV programs and income-generating opportunities." Although access to these resources has become a barrier, knowledge is even more important because adaptation strategies involve dealing with uncertainty, and accurate information is crucial [36].

The fact that rural women are a key component to food security while representing a disproportionate number of those considered hungry [55], reinforces the case for eliminating gender-specific barriers to livelihood adaptation to climate change. Including women's opinions in decisions on climate adaptation strategies makes sense because their livelihoods are different to those of men, as are their experiences, needs, and perhaps perceptions of risks [8,68]. Women can thus acquire knowledge, broaden decision-making, and generate economic independence, which is crucial in terms of climate change adaptation in the SWCRB [68].

Participant-73, age 28, Participant-74, age 31, of Dumuria in the Gabura union, and Participant-75, 28, from Sora No. 9, Gabura union, Participant-76, 30, from Padmapukur Union, Ward-1 said that they use solar power as well as a few families close to home. She mentioned that empowerment of women is growing in the coastal areas of Bangladesh. In addition to daily work, they also maintain income-generating activities at home and make money to meet their personal needs. In addition, the SHS is an alternative solution to meet the needs of home lighting. The use of SHS units can provide a convenient and sustainable way to obtain high-quality, clean and environmentally friendly energy services. In addition, operating SHS services in coastal villages can bring positive socio-economic benefits, including high-quality home lighting, extended education hours, and increased women's health awareness through television programs and income-generating opportunities.

Figure 5, taken from IPCC's AR5WGII report, shows positive results in terms of food security through women's education. Women's empowerment, mainly at local levels due to cultural change will improve livelihoods, and in addition, bring extra benefits [22].

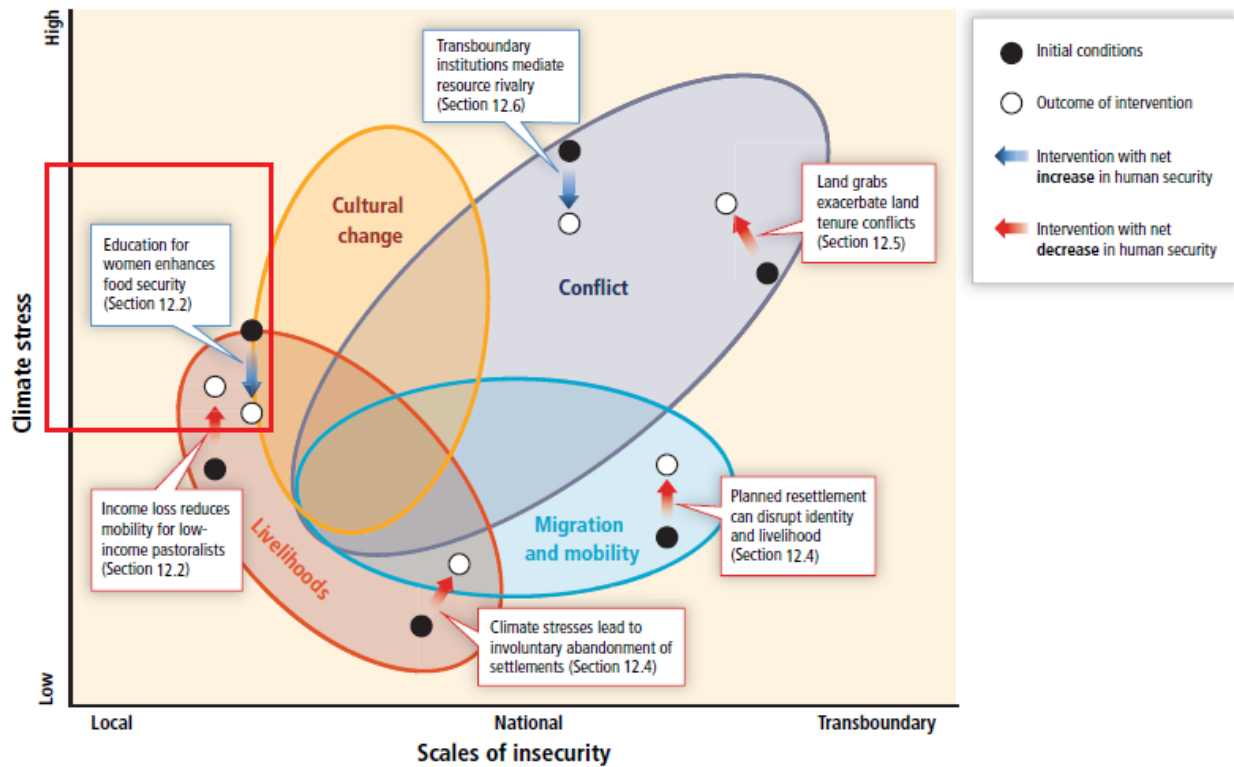


Figure 5. Women’s education strengthens livelihoods and promotes cultural changes [22].

In terms of dealing with adaptation to climate events, interventions and strategies can reduce risks to human security, mainly by providing women income alternatives in agriculture and education [22].

Nakshikantha

Chandrika Banerjee has always had a passion for helping women. In 1993, she started a small sewing business in her home with six other women to help alleviate the poverty of women in Satkhira, a coastal town near the Sundarbans. Her business expanded into an organization involving many more women. Hundreds of stories of rural women’s happiness, sorrow and suffering are woven in each Nakshi kantha (Bangladeshi “Nakshi Kantha” is the most popular traditional handicraft in the world. “Nakshi Kantha”, a type of embroidered quilt, is a centuries-old Bengali art tradition of the Bengal region, notable in Bangladesh. It usually uses this product to cover itself and protect itself from the cold at the beginning of winter. Especially rural women make their art and enhance all the traditional activities when they make a handicraft item) (a type of embroidered quilt), so she named her organization Nakshikantha. Thousands of women have become self-sufficient by working on more than 30 projects within her organization. One of her projects is to dig freshwater ponds in the saline area adjacent to the Sundarbans and help in the construction of farms with training on growing vegetables, raising cattle, goats, sheep, ducks, and chicken and constructing biogas plants and fish farms with their feces.

To date, Nakshikantha has built 60 tanks to conserve fresh water, provided 350 women with tailoring training and thousands more women and men with computer literacy. Other projects that assist in self-sufficiency include green forestry, training of farmers, and education of underprivileged children, construction of rural sanitation, granting of interest-free loans, production of organic and

vermicomposting manure. The majority of respondents in the research area believe that her efforts are very successful. This organization has shown that men, women, and children can work together to build a Bangladesh free from hunger and poverty (Source: field work: 2019).

The people of Satkhira think that her efforts are very successful. Besides running the household, they also educate the boys and girls. Many have become self-sufficient by raising goats, sheep and chickens. Disabled Participant-77 started a business with a small loan from her organization. Widow Purnima Rani Pal learned how to sow with a sewing machine.

Sen [8] states that hunger is caused by entitlement, ownership and command over enough food deprivation which relates to endowments or ownership over productive resources (land and labor) as well as wealth [36]. Climate shifts can affect areas that are considered profitable and cause people to lose their occupations, and droughts or floods can drive down the price of high value foods relative to food grains, which can have serious consequences for those who make a living from the sale of these foods [25,47]. If the women in SWCRB have unequal chances to an alternative income, or lack land rights and lose their spouse, then it is likely that they will suffer the most, as will economic development. Furthermore, as McMahon and Johra [34] pointed out those small-scale women farmers often play a critical role in the food security of their communities.

Gender-equitable understanding of climate change impacts and related gendered risks/needs can contribute to the development of effective adaptation policies and lead to wide-ranging social impacts. As climate change usually impacts livelihoods and income in the SWCRB for two main reasons: extreme events impact on agriculture crops (sea level rise, riverbank erosion, floods, tropical storms, and severe droughts) and loss of ecosystems on which coastal people depend [3,25], poverty and starvation tend to worsen with the increase in the price of food, restricted mobility, and discrimination [57].

Micro-Finance

Micro-finance is a form of low interest lending which can enable women to start livestock farming, homestead gardening, tailoring or any other home business. It is a solution that could reduce economic inequalities between men and women and increase women's economic independence. Micro-finance plays an important role when it comes to the maintenance of economic growth and poverty reduction. Micro-loans enable women to educate them-selves and gain their own income, which promotes their empowerment [69–72]. Micro-loans can, for example, be utilized by a group of women planning joint projects, where they share all purchases and profits. Micro-loans empower women and create independent income, ensuring their independence from men, and they can have repercussions in other areas such as the political sphere in the form of voting and participation in protests [70]. Bolivia is an example of a country where women have been able to improve their economic situation through micro-loans provided by UNDP (United Nations Development Programme) [71,72]. With micro-loans, women have been able to increase their income more than 53%, reducing their poverty, allowing women to buy tools to create jewelry, craft leather or weave, produce handmade pastries, cheese, yogurt, ice cream, honey and soda or raise pigs, chickens, and hens.

Participant-77, said, “I have been working as a tailor for almost 16 years. Although I don't have a shop, I started a business at home. I had a machine. Since Aila, several disasters left us destitute. Sometimes, houses were washed away by river erosion. The NGO BRAC helped us by paying tk 16,000 (\$145) for the purchase of the shop. However, we have to reimburse in installments. I earn

more money during worship or ceremonies. I have trained six people, each women paid me tk 4000 (\$36). Through this micro loan now I'm self-sufficient.

8. Discussion and Comparison

As opposed to the previous focus on women's vulnerability, when it comes to adaptation, women are seen as powerful agents of change [36] (Table 6,8). Developmental theory is a specific concept in this regard that involves the inclusion of social analysis into research and practice [9], and much later, gender equity [25,73,74]. As described by Carothers and Gramont [73] with respect to politics mainstreaming, conflict over gender mainstreaming arises because it can mask feminist goals of challenging power structures and distort the essence of empowerment once again in favor of economic goals and maintaining gender differences.

Decreasing the gender gap is not just about increased education and access to employment but also on the values attributed to girls and women in family and society. In societies of extreme patriarchy, boys are often favored over girls [68,73]. Sen believes there is a positive correlation between women empowerment and employment, because job opportunities outside the home will provide women with independent salary [74]. Women empowerment through employment can in turn influence decisions regarding climate adaptation, improving social status of women in society (Table 6,8). Women are active agents of change, able to promote the required social transformation in order to alter the lives of women and men (Table 6, 8). Above the case of environmentally friendly stoves, electrification of the SWCRB and women empowerment, nakshikantha, micro-finance, are mentionable example women can have a greater influence in the distribution of income in the household moreover women get empowered, through education or employment. Furthermore, women's education is directly linked to their children's, especially by reducing the gender bias. In addition, mothers are concerned about the well-being of their children. Improving the mother's position can have an impact on child mortality. In this discussion part, we are referring back to field surveyed (Figures 3 and 4 and Tables 1,4–6), from the statistical analysis, to see whether it is significant or not according to the respondents answer.

Chi-square interpretation: According to the total respondent $n = 0.05$ (95% confidence level) indicates that the p -value less than or more than 0.05 (95% confidence level), that indicates the variables are not independent of each other and there is a statistically significant relationship between the categorical variables.

Cramér's V interpretation:
Estimated Values, Interpretation of Association
0.00–0.10, Negligible
0.10–0.20, Weak
0.20–0.40, Moderate
0.40–0.60, Relatively Strong
0.60–0.80, Strong
0.80–1.00, Very Strong

Statistical analysis shows that the Pearson Chi-square value is 0.994. Since this value is much higher than our chosen significance level $n = 0.05$ (95% confidence level) it can be said that the result is non-significant and according to Cramér's V value, there is no significant association between male and female respondents opinion. Whether, the women, children, the elderly and the disabled are most vulnerable to climate change (Table 9). (Calculation, see the supplementary Material Section).

Table 9. refer back to Figure 3. Gender * Vulnerability to_ women, children, the elderly and the disabled are most vulnerable to climate change -Cross tabulation.

Yes (87%)		No (1%)		Don't Know (12%)		Pearson Chi-Square	Cramér's V
Male	Female	Male	Female	Male	Female		
60.36%	26.64%	0.69%	0.31%	8.00%	3.00%	0.994	0.006

Statistical analysis shows that the Pearson Chi-square value is 0.001. Since this value is less than our chosen significance level $n = 0.05$ (95% confidence level) it can be said that the result is significant and according to Cramér's V value, there is strong association between sample size frequency and respondents opinion whether, the adaptation measures affect men and women differently (Table 10). (Calculation, see the Supplementary Material Section).

Table 10. refer back to Figure 3. Frequency * Vulnerability to_ women, children, the elderly and the disabled are most vulnerable to climate change- Cross tabulation.

Frequency	Pearson Chi-Square	Cramér's V
Yes (87%) No (1%) Don't know (12%)	0.001	1.00

Since the p -value is less than our chosen significance level of $n = 0.05$ (95% confidence level), we can reject the null hypothesis and conclude that there is a significant association between this adaptation measure and gender except for the two variables. Policy formulation related to gender equality and integration of climate change information into academic curricula showed different results than other variables. For these two variables, the Pearson chi square value is greater than our chosen significance level $n = 0.05$ (95% confidence level), so our null hypothesis is accepted and we can explain that there is no significant relationship between these two variables (policy regarding gender equality structure and integrating climate change information into academic curricula) and gender (Table 11). (Calculation, see the Supplementary Material Section).

Table 11. refer back to Table 4. types of vulnerability typically faced by women.

Adaptation Measures	Male (222)	Female (98)	Pearson Chi-Square	Cramér's V
Female empowerment through employment with land rights	32.54%	14.36%	0.001	0.189
Women friendly agriculture	13.88%	6.13%	0.043	0.113
Female education and building awareness	26.02%	11.48%	0.003	0.167
Micro-finance	34.68%	15.31%	0.001	0.197
Policy formation regarding gender equality	10.82%	4.78%	0.101	0.092
Ensuring women's participation in idea development	19.98%	8.82%	0.018	0.132
Organization of stakeholders with equal access and involvement of women	29.90%	13.19%	0.002	0.176
Integrate climate change information in academic curriculum	11.31%	4.99%	0.081	0.097

At our chosen significance level $n = 0.05$ (95% confidence level) the null hypothesis is rejected in all the variables and we can conclude that there is a significant association between this type of vulnerability and gender. In other words, there is evidence that vulnerability type and gender are

related. For the variable (cyclone shelter is far from home) the statistical test is highly significant compared to others. This means variable (cyclone shelter is far from home) and gender have a strong correlation (Table 12). (Calculation, see the Supplementary Material Section).

Table 12. Refer back to Table 5. the impacts of climate change on gender in particular.

Types of Vulnerability	Male (222)	Female (98)	Pearson Chi-Square	Cramér's V
Women that don't know how to swim	24.28%	10.72%	0.007	0.150
Water and food issues	30.35%	13.40%	0.001	0.180
Cyclone shelter is far from home	38.16%	16.84%	0.001	0.207
Lack of high places to build homes	17.34%	7.66%	0.035	0.118
Physical weakness	19.09%	8.42%	0.015	0.137
Helplessness	13.89%	6.13%	0.043	0.113
Nervousness & Fear	20.81%	9.19%	0.012	0.141

Statistical analysis shows that the Pearson Chi-square value is 0.992. Since this value is much higher than 0.05 it can be said that the result is non-significant and according to Cramér's V value, there is no significant relationship between male and female respondents opinion whether, adaptation measures affect males and females differently (Table 13). (Calculation, see the Supplementary Material Section).

Table 13. refer back to Figure 4. Gender adaptation_measures_affect_differently_men_and_women Crosstabulation.

Yes (80%)		No (11%)		Don't Know (9%)		Pearson Chi-Square	Cramér's V
Male	Female	Male	Female	Male	Female		
55.5%	24.5%	7.63%	3.37%	6.24%	2.76%	0.992	0.007

Statistical analysis shows that the Pearson Chi-square value is 0.001. Since this value is less than our chosen significance level $n = 0.05$ (95% confidence level) it can be said that the result is significant and according to Cramér's V value, there is strong association between sample size frequency and respondents opinion whether the adaptation measures affect men and women differently (Table 14). (Calculation, see the Supplementary Material Section).

Table 14. refer back to Figure 4. Frequency adaptation_measures_affect_differently_men_and_women Crosstabulation.

	Frequency	Pearson Chi-Square	Cramér's V
Yes (80%)	No (11%) Don't know (9%)	0.001	1.00

By applying statistical analysis tool (chi-square test) we tried to find out if there is any relationship between effect and gender. Since the n-values are less than our chosen significance level $n = 0.05$ (95% confidence level), we can reject the null hypothesis and conclude that there is a significant association between effect and gender. The statistical test for variable (women's participation in decision-making) is highly significant as compared to others. It has a strong correlation with meaning variable (women's participation in decision-making) and gender (Table 15). (Calculation, see the Supplementary Material Section).

Table 15. refer back to Table 7. represents women-centered adaptation measures in the SWCRB.

Impacts	Male (222)	Female (98)	Pearson Chi-Square	Cramér's V
Physical and social setting of women/health issues	30.35%	13.40%	0.001	0.180
Women's triple role (Reproductive, Productive, Community Management)	28.16%	12.43%	0.002	0.176
Women's economic livelihood/poverty	24.28%	10.72%	0.007	0.150
After hazards, income and occupation challenges for women	26.43%	11.67%	0.002	0.171
Inadequacy of shelter capacity	19.07%	8.42%	0.015	0.137
Women's participation in decision making	32.54%	14.36%	0.001	0.189

Moreover, according to interviewed respondents from SWCRB, women are the biggest victims of natural disasters caused by climate change (Table 1, 9-15). Due to the impact of natural disasters, most of the time, the male members of the family will work in different parts of the country to earn money for survival. As a result, all the responsibilities of a parentless family fall on women. Most of the time, women cannot communicate regularly with their husbands who are out looking for work. As a result, their family ties eventually weaken. Moreover, many men cannot send money on time to support household expenses. Because of this, the woman at home has to work hard to take care of the family. Again, many widows have no one to turn to for help. The responsibility of a woman is not limited to managing the family, but earning money for the livelihood of other members of the family including her children. As a result, women's livelihood is increasingly threatened (Table 4-5, 7, 9-15). After many efforts by feminists to highlight the relevance of gender equity in political dialogue on climate change, today, gender dimension analysis on climate change is widely included in policy documents of development institutions. Supported by qualitative and quantitative data from the SWCRB indicating the gender-specific vulnerability to climate change and the capacity to adapt to it [9,37], this research is directed at utilizing gender insights to achieve sustainable development pathways (Tables 6 and 8).

The ability of women in SWCRB to cope with climate change involves a number of means. The expansion of women's social and economic freedom, including their empowerment through involvement in decision making, is viewed as a means to an effective response to the effects of climate change, as well as contribution to social transformation through public discussions [9]. The impetus for socio-economically empowering women is strong because it expands their capabilities, entitlements, and choices, and the effects will be felt by all. As per the results of this study, proper adaptation and mitigation measures are required to reduce vulnerability that respondents, especially women, face during disaster periods and, abolish gender inequality (Tables 1, 4-5, 7). The adaptation measures affect both genders differently as observed in this study.

Furthermore, according to respondents' interviews, workshops, and FGDs of the local population of SWCRB, women vary from their male partners in the preparation of strategies. Considering possible nuisances during the catastrophe, women are accustomed to creating moveable stoves, stack firewood,

amass dry provisions, namely Chira, Muri, and Khoi (derived from paddy), molasses and biscuits, essential medicines, save money wherever possible, place Chhikas (jute derived bag that can hang from wall or ceiling) so that utensils can be suspended above the floor throughout the deluge. They also plant various trees and plants such as banana (Musaceae) and pink morning glory (Ipomoea carnea) around their dwelling as a step-in disaster risk reduction strategy (Tables 6 and 8). Besides, few women survive through engagement with various sectors in SWCRB.

Moreover, gender dimension analysis on climate change is widely included in policy documents of development institutions. National Adaptation Program of Action (NAPA) is an important catalyst for activating climate change and adaptation policies in Bangladesh, and thus, consideration must be given to the main systems that ensure gender inclusion in widely implemented transformational programs [75,76]. Through NAPA, the UNFCCC believes that men and women play different roles in obtaining livelihoods. The Adaptation Fund supports provably gender-sensitive activities and checks subsidy proposals to ensure they support participation cycles and observations in projects/programs that disaggregate clearly marked information by gender [24,77]. In Bangladesh, climate change adaptation is integrated into broad multisector strategic development and poverty reduction policies. Therefore, the Sixth Five-Year Plan, Annual Development Plan (2011–2015) and Poverty Reduction Strategy Paper (PRSP) (2005) were explored to assess gender responsiveness. Bangladesh prepared the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) (2010), National Environment Policy (1992), National Disaster Management Plan 2010–2015 (2010), Health Policy (2011), National Women’s Development Policy (2011) and Bangladesh National Maternal Health Strategy (2001) [24,78].

Also, the strategies have a very explicit tendency towards floods, with generally little spotlight on miniature level preparation at villages or Upazilas (sub-locale) [63]. Ultimately, BCCSAP and NAPAs show reflexivity for reconciliation with other sectoral strategies. The BCCSAP and NAPAs are center around areas like agribusiness, water (metropolitan and industry), foundation, lodging, wellbeing, food security, disasters, and energy, stressing the part of reflexivity with other sectoral approaches [76,77]. For this, they have included transformation for the yearly advancement plans (sixth and seventh long term plans) for making vigorous and target-based interlinkages between areas. Furthermore, Bangladesh has considered the environmental change gender activity plan, specifying out the interlinkages between gender viewpoints, and environment-impacted areas considering these referenced approach drives reflexivity is supposed to expand soon [24,77,78].

But it is not be found that the environmental change and segregated gender impacts are not perceived. Strategy targets connected with climate change and gender are by and large resolved as fundamentally unrelated issues; existing arrangements do not consider gender explicit functional exercises. The main approach that incorporates gender-based contemplations for climate adaptation is the Poverty Reduction Strategy Paper (2005), but functional exercises under this arrangement have not yet satisfied these targets [76–78]. Environmental change approaches by and large perceive women as vulnerable, yet functional reactions are not established. In arrangements connected with gender and conceptive wellbeing, the effect of climate change is not considered, except for the National Women Development Policy, which momentarily advances women’s part in ecological administration and the significance of guaranteeing offices for and the security of pregnant women in case of catastrophic events [76].

The National Forest Policy (1994) states that women will be encouraged to take an interest in residence and farm gardening, and participatory afforestation programs; nevertheless, it does not give

explicit instructions to accomplish the expressed objective or put forth other gender explicit objectives (e.g., decision-making related to forests and forest resources) [78]. In approaches connected with gender and conceptive wellbeing, the effect of environmental change is not considered aside from the National Women Development Policy 2011 [6,24,78].

Despite the fact that women are involved in adaptation discourse, gender explicit contemplations are evidently not advanced. Multi-sectoral reactions and coordinated efforts to address environmental change, and approaches connected with catastrophe preparedness and reaction, jobs and medical services might consider the combination of gender issues into needs [23,24,75,78]. Besides, the speculation of women is another significant gap in both national and international policy papers. The current approaches frequently highlight women as being casualties of climate change and disregard their efforts as dynamic supporters of adaptation procedures in changing natural realities.

Globally, the ability of communities and individuals to cope with climate change involves a number of means [3,9,22]. The expansion of women's social and economic freedom, including their empowerment through involvement in decision making, is viewed as a means to more effective response to the effects of climate change, as well as contributing to social transformation through public discussions [8–10,25,43,57,68,74]. The impetus for socio-economically empowering women is strong because it expands their capabilities, entitlements and choices and the effects will be felt by all [36,57,60]. Human security has been jeopardized in the context of climate change and its preservation plays an important role in protecting life. It is a challenge to maintain these principles, given the difficulty for the majority of institutions at the national level to carry out effective adaptation efforts [3,25,26,34].

9. Conclusions

The results of this study indicate that women are most affected by climate change and natural disasters. Conditions, such as lack of water and food, distance from home to cyclone shelter, absence of Women's participation in decision making, unfavorable physical and social settings for women, women's triple role in the family, poverty, limited resources, and loss of homes make women vulnerable in this region. Even in such unfavorable conditions, women are capable of working with agriculture and water collection, which contributes to the SWCRB people's livelihoods [9], and is an intrinsic to effective adaptation and social improvement [9]. The inclusion of gender analysis in development policies on climate change has the potential to have far-reaching positive effects in mitigating and adapting to climate change, as well as contributing to gender-equity. The arguments in favor of empowering women as part of this process are persuasive in the sense that the 'odds' often sway in the favor of men and puts the role of adapting to climate change on women. Definitions of empowerment matter when it comes to policy and practice, and that there is still much work to be done in finding adequacy between competing agendas. Measurement and 'rendering technical' [43] are salient issues here. To implement climate friendly, women policies at the local level from governmental agents (i.e., NAPA, PRSP, and BCCSAP) there must be more focus and prioritization. While national policy makers need to weigh out the benefits, costs, and potential losses of new initiatives, they face failure in achieving meaningful or wanted results through this process. Deep and flexible analysis and a long term dedication to deciphering processes of inequality and empowerment are of the utmost importance in meeting the interests of feminists and development practitioners alike. Yet without situating the local processes of inequality within the 'larger forces' and discourses that cause inequality, it is questionable how much transformation can occur because women have not received their land rights. Regretfully, equality and reducing women's vulnerability may not be in

everyone's interests. Based on the field surveys, case studies, FGDs, workshops, and interviews findings show that empowerment initiatives in the SWCRB have already had a positive impact on women's role in the community, one that is recognized by its members. Thus, the outline of adaptation and mitigation measures has proven that the gender gap can be reduced, and vulnerability levels can be successfully addressed. Empowered women will strengthen the society, and the economy will be enhanced which helps SWCRB to reduce climatic effects. Further, women involvement in Bangladesh shows us that the challenge of climate change adaptation and mitigation is possible through female empowerment.

The existing adaptation measures have already proven their positive impact on the local community, and both genders recognized the promising outcomes. Climate change will worsen the current situation. Sen [9] argues that the expansion of women's social and economic freedoms, including their empowerment through involvement in decision making, is viewed as a more effective response to the impacts of climate change, as well as contributing to social transformation through public discussions. If every member of society becomes aware of the challenges they face and receives proper education and support, the local population will be strengthened against the threats and will have the opportunity to develop towards a brighter future. Women of coastal areas of Bangladesh suffer the most in disasters. Government and some local and international non-governmental organizations attempt to reduce the vulnerability of people in coastal areas. It is recognized that customized policies, planning, and good governance can also reduce hazards and increase the socio-economic situation by different micro-credit schemes through mutual collaborations. In this regard, the following recommendations can be provided for mitigating and reducing suffering of the coastal people: 1. Women should be prioritized in all policies, planning, and programs related to disaster management. 2. It is essential to modernize the meteorological and hydrological networks for forecasting and warning systems. 3. Emergency response systems and supporting livelihood strategies should be optimized based on local conditions, especially for women and children. Finally, this article proposes that, in order to reduce female vulnerability in SWCRB, women as stakeholders and agents of change must be encouraged and integrated into mitigation measures and adaptation plans.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Tables S1–S100 are cited in the supplementary materials file.

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7. Climate justice for the southwestern coastal region of Bangladesh

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Abstract

Climate change is considered a moral, ethical and social issue, which makes it different from other developmental issues. The foremost instance of lack of justice regarding climate change is that the worst impacted areas are the ones with the lowest contribution to greenhouse gas emissions, such as the southwestern coastal region of Bangladesh (SWCRB). Climate change is principally triggered by the presence and eventual spread of industrialization. This study employed the mixed method, combining qualitative and quantitative methods of data collection and analysis for development of a framework for climate justice. Data and information were obtained from both primary and secondary sources. In primary sources, quantitative data were collected from climate vulnerable community households using a structured close ended questionnaire and interactive sessions such as focus group discussions, in-depth interviews, key informant interviews, workshops, and case studies. This study explored the perceptions of people in the SWCRB, currently experiencing devastating effects of climate change and sea level rise including extreme natural disasters, seasonal changes, flooding, salinization, riverbank erosion, and waterlogging. These climate-induced changes are causing loss of housing, livelihoods, and land to the natives, in addition to a lack of access to proper nutrition, potable water, and healthcare thus exacerbating social injustice. A capability-based approach to climate justice is introduced in this paper, which allows for residents of this region to prepare and rebuild their own communities and create adaptive mechanisms based on their specific capabilities. This approach requires compensation (funding) from the global community, in addition to organizational connection between local people and other stakeholders. The people in the SWCRB are increasingly opting for community-based disaster management and inclusion in policy making. Persistent issues faced by these communities require sustainable development of embankments and infrastructure, as well as affordable and sustainable access to potable water. Industrialized nations should provide this compensation for climate change, in addition to acting promptly to reduce greenhouse gas emissions and opt for renewable energy to avoid worst-case scenario. Lastly, involuntarily displaced climate refugees must be provided rights, compensation, and relocation assistance.

Keywords: Climate Change; Climate justice; Capability-based approach; Carbon dioxide Emissions; Risk Assessment and Disaster Management; Southwestern Coastal Region of Bangladesh

Introduction

Greenhouse gases (GHGs) such as methane and carbon dioxide are naturally present in the Earth's atmosphere; however, their concentrations have been anthropogenically increased through burning of coal and natural gas, increasing animal husbandry, and deforestation. Since pre-industrial times, humans have contributed to 2,500 billion tons of CO₂ emissions, which exceeds the average natural

levels in the past 650,000 years (IPCC, 2013, 2021; Chancel, 2021). Additionally, 10 nations have contributed to ~69% of the global GHG emissions and 20 nations have generated ~82% of the global CO₂ by 1990 to 2019 (Crippa et al., 2020; Olivier and Peters, 2020; Ritchie et al., 2020). The increase in GHGs after the industrial revolution is responsible for increased average global temperature, ocean acidification, contributing to melting of polar ice caps and rising sea level, causing climatic variability (Garcia-Soto et al., 2021). Although the 50 least developed countries contribute to <1% of global emissions (IPCC, 2013; Liu et al., 2019), climate change disproportionately affects the developing countries and especially the marginalized populations.

Besides, Bangladesh a low-lying South Asian country is highly susceptible to the adverse impact of global climate change particularly to sea level rise due to its unique geographical settings and poor socio-economic conditions of the vulnerable communities. Scientific projections showed that sea level rise ranged from 0.53 to 0.97 m in 37 coastal stations at the Bay of Bengal for the year of 2100, where the predicted global sea level rise is 0.09–0.88 m (Haque A. et al., 2019). World Bank assessed that 1.5 to 1.54 million people would be affected by 2070 by sea level rise of 1 m causing permanent relocation of 13 million people. Therefore, this study investigated the potential impacts of SLR in Bangladesh along with the climate justice. Bangladesh comprises of 19 coastal districts (among 12 districts exposed to the sea and lower estuaries) consisting of 710 km coastline, which makes the country one of the most disaster-prone and climate vulnerable countries in the world (ibid). The coastal area is ~1.5–11.8 m above the mean sea level. The estuarine islands constantly change shape and position due to river erosion and new alluvial deposition. These areas are subject to flooding in the monsoon season and waterlogging in parts of the basin areas in the dry season (Feist et al., 2021). Scholars have analyzed risks of climate change and sea level rise (CCSLR) in Bangladesh from different perspectives like human security risk (Rashid and Altaf, 2020), adaptation, and mitigation (Islam M. A. et al., 2020), the involvement of local institutions (non-governmental organizations (NGOs), civil society organizations (CSOs) and community-based organizations (CBOs) (Rahman, 2019; Prabhakar and Shaw, 2021); however, limited studies discussed the issue of CCSLR vulnerabilities and climate justice in the coastline of Bangladesh.

Due to the large population density, reliance on natural resources, geography, and socioeconomic status, Bangladesh is considered the second country most vulnerable to the effects of climate change but in the context of CO₂ emissions in 2020 was 108.504 megatons; ranking Bangladesh is the 148 out of 181 countries for contribution to global CO₂ emissions (URL-1; Eckstein et al., 2019). The coastal zone of Bangladesh was assaulted by a razing cyclone in 1970, in which more than 300,000 lives perished (Eskander and Barbier, 2022). Subsequently, the nation suffered from another food crisis in 1974 causing the demise of 27,000 lives (Currey, 1979). In 1991, cyclones affected almost 100,000 lives. The consequences of climate change are causing the nation to be impacted in an extreme intensity, placing the inhabitants in a sorry state with compromised ability to adapt to the situation. This vicious cycle of repression, catastrophe and paucity is preventing the advancement in Bangladesh. Predictions reveal that within 2050, one in 45 individuals globally (Brown, 2008; Davis et al., 2018) and one in seven individuals in Bangladesh will lose shelter due to climate change (Ahmed et al., 2019).

People of the southwestern coastal region of Bangladesh (SWCRB) are already trying to adapt to the effects of CCSLR, such as saltwater intrusion, agricultural loss, and high intensity cyclones. The most vulnerable people are the most susceptible to the effects of climate change, such as people inhabiting areas with compromised security, poor financial conditions, limited awareness of human rights, areas at a geographical disadvantage, and those that contributed the least to climate change (Didar-Ul Islam et al., 2015; Dasgupta et al., 2017; Khanam et al., 2022). Environmental disasters caused by climate

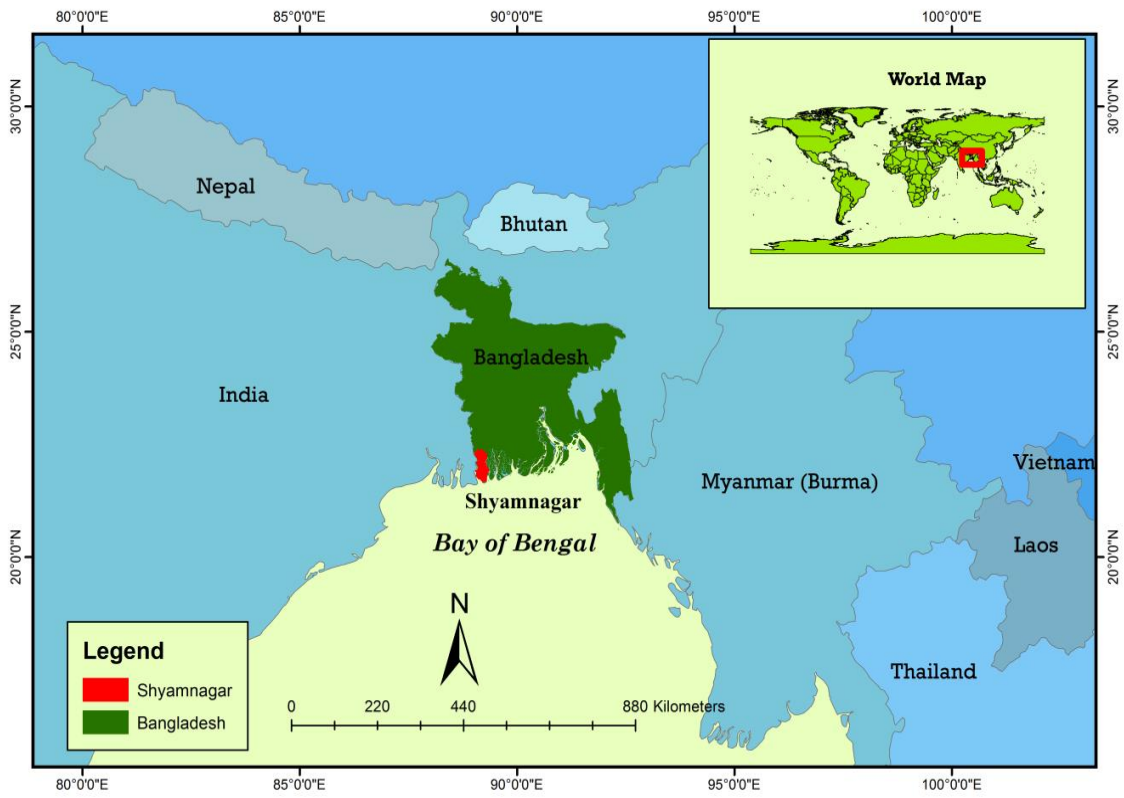
change cause stress on these developing countries and lead to social and economic stresses including lack of access to clean water, food, employment, and loss of homes and farms (Alam et al., 2020).

Climate justice is a complex issue involving social, economic, and political aspects. Due to the social inequities presented by climate change, current political debates on policy frequently focus on climate justice at the regional and global level; however, specific focus is currently needed to the environmental policy priorities of people in impoverished and lower-emitting nations (Byrne et al., 2002; Dryzek et al., 2011; Adel, 2020). Additionally, a core topic of climate justice is that of the causative nations assuming liability for creating and then confronting CCCLR by legitimately restoring the developing countries and/or providing refuge for involuntary climate refugees (Dryzek et al., 2011; Ahsan, 2019). Although the government of Bangladesh (GoB) and NGOs provide some relief to the SWCRB after disasters occur, more assistance is required to create resilient communities, and each phase of the planning and implementation processes must include matters of equity and justice (Hossain, 2020). Many challenges arise as implemented measures that are intended to combat injustice are not always equitable and may even harm the groups of people they are meant to uplift.

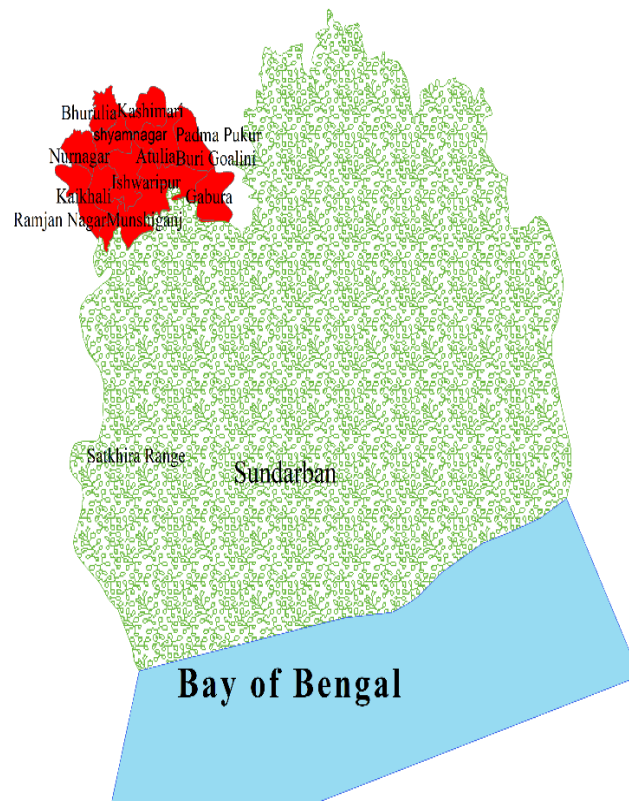
Study area

The considered zone encompasses Shyamnagar Upazila (sub district) of Satkhira locality within the southwestern coastal region of Bangladesh (Figure 1). Shyamnagar is situated between 21°36' and 22°24' N latitude and 89°00' and 89°19' E longitude, which is exceptionally near to a mangrove forest and the Bay of Bengal. The region was regarded as vulnerable to CCCLR due to its geographical setting (the foremost southwestern portion and its conical form) and topographical aspects (largely flat regions). The mean sea level extended from 1 to 5 m from the years (Didar-Ul Islam et al., 2015; Rezaie et al., 2019). This region was secured by the Ganges floodplain, which was for the most part formed by sedimentation (Rashid et al., 2019). The overall population of the Upazila was 313,781 in the year 2010 (Abedin et al., 2019). The Sundarbans, along the Shyamnagar, are sections of the planet's biggest delta created by the GBM rivers (Whitehead et al., 2015). The Ganges and Brahmaputra rivers originate from different basins in the Himalayas and converge in the Bengal Basin of Bangladesh, where they form one of the largest deltas in the world. Delta sediments form a shallow area that extends about 200 km south from the coastline, i.e., GBM rivers (Kuehl et al., 2005; Masood et al., 2015; Whitehead et al., 2015). The Shyamnagar sub-area is near a mangrove forest and the Bay of Bengal and is vulnerable to climate change and SLR due to its low-lying topography. This region was formed by sedimentation of the Ganges floodplain and has a moderate population density. The mean height above sea level (MASL) ranges from 1 to 5 m, with 45% of the study area having a high chance of inundation from a 1 m storm surge (ibid). High Mountain Asia (HMA) adjoining the Tibetan Plateau feeds the fluvial system of the Indus, Ganges, Yangtze, Irrawaddy, and Mekong with seasonal glacial melt (Azam et al., 2018; Wester et al., 2019). The HMA acts as a freshwater reservoir, crucial to ecology, cultivation, and hydropower, as well as being essential to more than a billion people (Masood et al., 2015; Pratap et al., 2015). The retreat of glaciers will cause a series of effects as these provide a steady source of water to South Asia where the population is dense. Political and social issues will arise with the increasing scarcity of water and flash floods (Harrison et al., 2018). Along with this, ice in the Himalaya vicinity alone would raise sea level by 1.5 meters (Pratap et al., 2015; Maurer, 2020). However, considerable breaches in understanding the dynamics and linked climate triggers in HMA exist (Azam et al., 2018). Around 36% of landscape ice will undergo the melting process by 2100 even if states fulfill the determined 2015 climate accord goal to limit heat release increase to 1.5 C (Wester et al., 2019).

Shyamnagar in World Map



(a)



(b)

FIGURE 1. (A) Bangladesh and Shyamnagar in World Map; (B) Study area

Methodology

This study uses the perception of people in the SWCRB to develop a framework for climate justice as defined by the people themselves. Quantitative data was obtained from this region between 2017 to 2019 with a set of questions used for quantitative analysis, which was also involved with a disaster risk assessment and qualitative data was obtained from 2017-2021 such as case studies, focus group discussions and workshop which is done by field work as well as due to Covid-19 through skype, messenger, over telephone. The capability-based approach to climate justice was then applied to this data as a specific productive pathway for realizing the concerns of susceptibility and consequence, which aids in effectively conceptualizing the precise adaptive methods to climate change. Such an approach to climate change could be utilized as a normative rule for climate policies and is a comprehensive solid benchmark to quantify improvement. The normative theories of climate justice are the main basis behind these frameworks that can ground global climate policies. The crucial point is that how those can be made relevant to the real-life scenario and requirement of adaptation.

The geographical region selected for this study was SWCRB, an area extremely vulnerable to the detrimental consequences of climate change and socioeconomic progression obstacles. In FGD, case studies, and participating individuals' scrutiny, we employed open and close ended instructive queries “what,” “how,” and “why” ones. Such queries are connected with the epistemic hypothetical building block of information utilizing social and technical means rooted within ethnography (Flyvbjerg,

2001; Yin and Davis, 2007). With real life issues in what are conversed by social science research as constructing context of trusting clarification (Flyvbjerg, 2001).

Qualitative method

To conduct the study, both primary and secondary data were accumulated. Key informant interviews (KIIs), (Edwards and Holland, 2013) case study (Johansson, 2007; Hennink, 2013) workshops, and 26 focus group discussions were organized at Shyamnagar Upazila, which included the members from local neighborhood, and the innovators during the field visit. Case study allows qualitative analyses of data and helps to explore the real-life scenario regarding the vulnerability of people in the SWCRB; at the same time, it explains the complexities of real life to the face of climate change.

In workshops, seven meetings were organized with school students, college students, and a mix of participants (local government officials, journalists, NGOs) with the purpose to benefit from their knowledge and experience regarding climate change. In focus group discussions, open discussions usually of 60–90 min (Hennink, 2013) on climate change, sea level rise, and climate justice are encouraged and are guided by a moderator. The group is called a focus group as well as the discussions are tape-recorded, transcribed and analyzed. The focus group discussion and the meetings were held at a convenient place like school, youth club, community organization where the concerned respondents were able to discuss issues and express their idea and concerns independently. The recorder was used by the author for writing the discussion, at the same time we took their consent to record the discussion and explained them to purpose of the research. They were well informed that the participation is completely voluntary and they also had the right to refuse to answer any questions, if needed. The participating members of the community established a respectful appreciation by providing their valuable contribution for this research. All members were encouraged to talk freely and ask questions at any time during the session and each participant's consent were recorded using predetermined format. Then, with the consent of the participants, climate change, climate justice checklist was used demonstrating other benefits. This driven a guided discussion helps that one single respondent cannot dominate the discussion and everyone gets an opportunity to contribute in the discussion session to develop the exposure factor of climate change for the climate justice issues. The respondents of the focus group discussion, IDI, KII were, UP Representatives, women respondents, local school teacher, male and female farmers, member of civil society, doctor, member UDMC, member WDMC, poet, NGO practitioners, journalist etc.

A detailed close ended questionnaire all-inclusive of economic, social and environmental aspect of the current justice protocol was used for data collection. Along with literature review and initial desk study, a broad range of Participatory Rural Appraisal tools were used, which included detailed interviews of the key informants. Numerous communities meeting with multi-stakeholders were conducted at all the unions under the scope of the study, where stakeholders were asked to present status of climate change. Following participatory approach, Bryman (2016), Jull et al. (2017) the hazard risk in the exposed SWCRB were identified through 387 respondents voting. We ensured the collection of comprehensive idea and qualitative information from all types of participants including under-privileged and vulnerable communities, government, and non-government actors. Some of the key research findings we got in our research from the FGD, IDI, KII, PRA, Works shop which is provoked climate justice, which is given below.

Quantitative method

Quantitative analysis was performed via a field survey in 2017 and 2019 for 320 households to obtain 95% confidence level ($p < 0.05$). The household survey was carried out through close-ended structured questionnaires to capture the response of respective respondents for capturing risk and

hazard, social vulnerability. In the present study, a representative sampling approach was undertaken. The following sampling approach and statistical formula were applied for the sample design:

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

Were,

n = Sample size

N = Targeted Population size

e = Admissible error in the estimate

p = Proportion of defectiveness or success for the indicator

q = 1-p

z = Standard normal variable at the given level of significance

For ensuring representative sample size from each Union equal proportion of sample size was selected. The details of the quantitative sample size distribution have been provided in SI Table 1. Respondents reported their perceptions of CCSLR by responding “yes,” “no,” or “I do not know.”

TABLE 1. The detail of quantitative sample size distribution.

Type of respondents	Union coverage	N	n	Female numbers	Male numbers	Percentage of youth
Hazard analysis	12	318,254	387	189	198	35.5%
Social vulnerability, adaptation and Justice analysis	09	242,392	320	98	222	25.5%

Climate justice theory

Despite the political debate, the people who are directly impacted with continuous consequences of climate change (increasing warmth, rising sea levels, and intense weather conditions) must immediately develop adaptive mechanisms (IPCC, 2013, 2021; Hoogendoorn and Fitchett, 2018). The core topic of climate justice debates is the fundamental evenhandedness of the climate conformity, meaning those industrialized nations who created the problem undoubtedly suffer less than developing countries, and must bear the responsibility of this injustice. Strategies based on this concept support an original polluter payment standard, which places the load evenly on heavily industrialized countries (Byrne et al., 2002; Dryzek et al., 2011; Schlosberg, 2012; Pellow, 2017). The rule of equity must be applied to the measures used by humans to adapt to increasing consequences of climate change (Schlosberg, 2012).

Several approaches exist in climate justice theory, two of which include the allocation- or rights-based approach and the capability-based approach. The allocation- or rights-based pathway to climate justice highlights fundamental human rights, rights for advancement, and environmental rights. Caney (2010) asserts that all inhabitants have a moral justification not to endure climate impacts that weaken their fundamental concern and debates that climate change breaches human rights to life, wellbeing, and survival (Caney, 2010). Vanderheiden (2008) reformulates the right to advancement as an ethical justification to have the fundamental environment in which human progress is a possibility, which necessitates a more stable climate. Following Shue (1999),

Vanderheiden argues that developed nations are obligated not only to not deter underdeveloped nations from development but also to compensate the full charge of their own actions (Shue, 1999; Vanderheiden, 2008). This rights-based approach to climate fairness has two significant drawbacks: (1) this approach overlooks other significant notions of justice, such as social and political appreciation, and necessities (that the capability-based approach encompasses), and (2) it articulates ethical urging for global strategy to avoid or diminish climate change and its diverse rights outcome (Sen, 1999; Lafontaine and Sipowo, 2013).

The recognition-based approach to climate justice is problematic as non-recognition, mis-recognition, or mal-recognition of inhabitants, population groups, and situations cause unfair treatment. Discrimination triggered by organizational control and coercion could be the center of this unfair allocation (Dryzek et al., 2011; Young, 2011; Schlosberg, 2012). Identification of the problem itself is the main drawback that causes unfairness and poor distribution (Young, 2011; Fraser, 2014). Specifically, cultural supremacy, non-appreciation, and lack of respect are exclusively included (Fraser, 2014). Simply realizing unfair allocation and dearth of appreciation is not enough for justice. Aside from denial, other issues that cause destruction are abuse, lack of attention, and undervaluing people or their neighborhoods (Honneth, 1996). For example, the Alliance of Small Island States (AOSIS) presented their fears of being inundated by sea level rise in 1991, but the UN Framework Convention on Climate Change (UNFCCC) failed to acknowledge this. Acknowledgment of loss and damage was denied by developed nations until 2007 when it was discussed at the COP 13 (Conference of the Parties) but did not gain true momentum until COP 16 in 2010 (Shamsuddoha et al., 2018; Toussaint, 2021). Therefore, this denial by developed nations caused a lack of action for nearly two decades.

Additionally, recognition of the connection between the environment and cultural distinctiveness to a group is heavily missing or overlooked in the UNFCCC, even with the Convention on Biological Diversity and the Universal Declaration on the Rights of Indigenous Peoples. It is a matter of frustration for many indigenous social workers and organizational entities that in contemporary strategic discussions on climate change, none of the cultures, practices, or ecosystems that create belongingness to groups of indigenous people is documented or appreciated (Dryzek et al., 2011; Raftopoulos and Short, 2019). According to Fraser (2014), the downfall of recognition is that it is often used to attain authority over those who are already being discriminated, ridiculed, or ignored.

Contrarily, a capability-based approach acknowledges different social and political circumstances and allows for differences in regional susceptibilities and fundamental necessities of humans in different places (Holland, 2008). The logic in this regard is that a capability-based pathway to justice can aid in addressing a host of worries caused by climate change, such as allocation of susceptibility, fundamental privileges, and acknowledgment of individuals, localities, and their correlation. Sen (1999) and Nussbaum (2006) believe the focus of justice should move toward people's ability to develop free and dynamic lives designed by them. To have the communal platform of self-esteem and honor is the main essence of a capability-based relationship.

The two key methods of broadening the capability-based approach are either developing a visible policy of recognizing the ecological reinforcement of human abilities that already exist or proposing a broader view of capabilities. Holland (2008) proclaims that a viable environment is a “meta-capability” and it eventually enables all others. Mainly, when our focal point moves from the concepts of preventing and mitigating to the practical nuances of adaptive mechanisms, impacts to natural earth must be central to a capabilities-dependent pathway to climate justice (Holland, 2008; Dryzek et al., 2011; Schlosberg, 2012). This direct approach to climate justice offers a

portrayal of climate justice that admits and includes the human engagement in the non-human domain. Therefore, the gap between the concrete theory of climate justice and real-world adjustment strategy is addressed by the capabilities approach. According to Sen and others, to obtain the exact environmental capable limits similar to their previous generation is the right of the upcoming generations of human race (Sen, 1999; Anand and Sen, 2000).

Firstly, most recognized pathway to climate justice has two vital limitations, in the manner of failing to exploit two significant improvements in latest justice theory: firstly, the familiarity of social and political misrecognition as the vital causal state of the misdistribution of goods and threats (Schlosberg, 2012; Fraser, 2014) and secondly, the influence exerting pathway, which focuses on the precise series of fundamental necessity and capacity–recognition that human race needs to work on (Dryzek et al., 2011). These two options aid us understanding the aspects of politics, society, and culture, along with the physical ones, that give rise to and help to flourish susceptibility. Besides, the huge portion of the present propositions on climate justice are based on frameworks of preventing or mitigating, or on the allocation of the expenses of adapting to climate.

Second, adoption of a capability-based pathway to climate change justice links the void between the perfect as well as conceptual viewpoint of climate justice theory on the one end and the actuality of policy-formulation for adapting on the other. A capability-based pathway can place social and political acknowledgment of particular and regional susceptibility and the consequence of climate change on the fundamental requirements of human beings in different circumstances and with various situation. This pathway is based on how much capable we acknowledge the society and politics of particular and regional susceptibilities and the impacts of climate change on the fundamental necessities of human race in different places and under various circumstances (Holland, 2008, 2012). Holland also developed a competence approach in environmental and climate justice, although there are major differences between our efforts: Holland's work focuses more specifically on the environment as a tool support system to meet human needs, while current's work addresses broader concepts related to climate justice, the role of recognition and its application to communities and non-human areas. The capabilities approach makes an offer of a specific productive pathway of realizing the concerns of susceptibility and consequence, and thus aid us effectively to conceptualize precisely what adaptive method to climate change would be consisted of. Such an approach to climate change could be utilized as a normative rule for climate policies and makes an offer of comprehensive solid benchmark by which to fathom improvement.

The two key methods of broadening the approach of capabilities to include a range of risks and weaknesses resulting from climate change are either developing a visible policy of recognizing the ecological reinforcement of human abilities that already exists or proposing a broader wing of capabilities approach to the natural world. Here, first and foremost the focus will be on the first one, however, the most debatable concept of fairness to nature based on capabilities will be laid a hand on in brief (Thompson and Bendik-Keymer, 2012). The important thing is in both ways the capabilities approach recommends a method of encompassing the actual human dependency and their interest in the affected natural world by our actions. Democratic partaking in and manipulation over one's very own surroundings are vital for the realization of a capability-based pathway to justice and are an invariable requirement in climate justice actions (Anand and Sen, 2000). Local community members can be associated in dialogue about neighborhood susceptibility, as realized via a range of parties involved. Community members are required for complete engagement in both the mapping of their own susceptibilities and the planning of adaptive strategies. Such inclusive approach fulfills both acknowledgment and ability to participate (Dryzek et al., 2011; Heltberg and Bonch-Osmolovskiy, 2011; IPCC, 2013). Policy-making bodies can utilize the abilities data obtained from climate

researchers, health organizations, emergency administration organizations, agricultural and parallel bodies, and other stakeholders to recognize mechanisms effectively, and then place very exact modifications to the tangible environment, which will influence the ability of those environments to maintain a particular human skill range (Heltberg and Bonch-Osmolovskiy, 2011). Additionally, threats and problems tend to accumulate, and there must be acknowledgment that people who are vulnerable to losing abilities are likely to undergo the loss of others, and authorities must work to disintegrate such accumulation (Chuang and Peterson, 2016).

In the immediate past tendency of premise of justice, the most important outlines for climate justice have been observed not to be connected completely. In regard of improving our realization regarding the concern of weaknesses, fundamental necessities and rights and human thriving, this kind of involvement is essential. Discrimination triggered by the organizational control as well as coercion could be the determiner of unfair allocation which now is a major focus. According to Young (2011), Schlosberg (2012) the need of identification facilitates distributive biasness where cultural and political discrimination encourage weaknesses and economic discrimination.

At the national level, Bangladesh Climate Change Strategy and Action Plan (BCCSAP) was arranged in 2008 to emphasis on the long term and midterm objectives of the prior National Adaptation Programme of Action (NAPA) of 2005 (Bhuiyan, 2015). The amended BCCSAP 2009 record (Islam et al., 2009) predicts that countless individuals will be forced to relocate, particularly from coastal zones, due to diminishing income and farming efficiency and furthermore gauges that 6–8 million individuals could be dislodged by 2050. Furthermore, slums in large urban areas have been alluded to as a profoundly conceivable objective for the individuals who migrate. Confronted with the peculiarity of fast, impromptu urbanization in Bangladesh, this represents an approaching issue (Islam et al., 2009). However, in spite of the affirmation of critical movement because of climate change, clear strategy rules for such migrators have not been tended to in NAPA or the BCCSAP, and there are no rules for the public and local governments to confront the drawn out friendly and monetary outcomes of climate change. This approach gaps and the absence of comprehension of climate movement and its complex metropolitan effects are the vital restrictions of the local level current reaction to climate change and to ensuring social justice.

Global agreements and absence of climate justice

Overwhelming proof exists that we are reaching the upper limit to our capacity to emit GHGs without severe consequences (Ritchie et al., 2020). To stabilize GHG emissions in the atmosphere at a level that stops disastrous climate change necessitates an assessed 40% to 70% decrease in anthropogenic GHGs by 2050 from 2010 levels to deter CO₂ from exceeding 450 ppm by 2100, and reaching worldwide zero emissions since 2100 (Meinshausen et al., 2020). It has been argued that global warming has happened in the past and is thus not a concern; however, in the past, climate change occurred over thousands of years, allowing for flora and fauna to adapt. Currently, global warming is occurring in hundreds of years and is decreasing biodiversity on the planet and endangering human lives.

An argument is going to be put forward in regards to how climate change is prioritized without any political commitment which creates climate injustice. Many agreements and accords such as the Kyoto Protocol 1997, Copenhagen Protocol 2009, and the Paris Agreement, 2015 (Dessler and Parson, 2019) were of considerable importance. The United Nations Framework Convention on Climate Change summit that took place in Copenhagen protocol 2009 was considered one of the greatest moments in world politics although certain states could not come to a conclusive agreement after hours of negotiations. Therefore, this meeting in Copenhagen was viewed as a failure as there was no official agreement. The Kyoto Protocol, adopted in 1997, was first forced into action in 2005

with its legally binding treaty addressing climate change. The requirement of the Kyoto protocol was for developed countries to reduce carbon emissions on an average of 5% where a monitoring committee was put in to place to witness its progress. However, this treaty remained ineffective against developing countries that were major contributors of carbon in the atmosphere such as India and China (Aichele and Felbermayr, 2013).

The Paris Agreement became active in November 2016, with a target to not surpass a mean global temperature increase of 2°C, with an aspirational target of 1.5°C above pre-industrial levels (Zahar, 2020). A total of 160 participants, including the USA and China, who were responsible for generating ~40% of global carbon emissions and signatories of the Paris Agreement, became active in November 2016 (Hardoon et al., 2016). Under the agreement, a Climate Fund was also established to support projects that empowered vulnerable nations to help them adjust to the consequences of climate change by setting up a requirement for industrialized nations to provide compensation to the nations impacted by climate change (Sovacool et al., 2017). To achieve this goal, CO₂ emissions from coal, oil, and natural gas must be limited to 36 gigatons; however, many researchers estimate that global carbon emissions will likely reach 41 gigatons in the next 20 years, which stresses the importance of prompt actions (The Economist, 2019).

Global agreements face extreme challenges due to the complicated relationship between politics and climate justice (Beauregard et al., 2021). For example, the Paris Agreement goal of 2°C was agreed to, although, this temperature increase is likely to immerse the coastal areas of Bangladesh, which is already undergoing life-altering effects of sea level rise (Lyster, 2017). Additionally, political issues have hindered this agreement as the USA discontinued its cooperation in the Paris Agreement in 2020, and then re-entered in 2021 accompanying the change in their presidency.

Additionally, this act by the USA to pull out of the climate accord is an example of privilege, which allows for people to deny or ignore climate change, and to even be immune to some of the effects (Mahaseth and Pandey, 2021). This also points to the general unfairness of climate change and the “denialism” mindset that is prevalent in developed nations; Klean highlights those ideologies in capitalism often create a materialistic and consumer-focused extractive mindset that perpetuates inequality. Additionally, Klean discusses the need to move away from this extractive mindset of humans having power-over nature, to a stewardship-focused mindset, which is already common in indigenous populations (Klein, 2015). Experts suggest that the Paris Agreement cannot create an impact strong enough to keep the average temperatures decrease from 1.5 °C, giving rise to devastating consequences such as floods and heat waves (Kim et al., 2020).

The Montreal Protocol (2016) addressed substances that harmed the ozone layer (Bergeson, 2017), with the Kigali Amendment with a focus on the gradual reduction of HFCs (Chen et al., 2021). In 2019, the developed countries started their reduction phase. Most developing nations are to freeze HFC consumption by the year 2024 and 2028 for some. By the year 2036, all developed nations are required to phase down the usage of HFC by 86%. Developing countries have to follow this same pathway by 2,047 (Roberts, 2017). Theoretically, both Kigali Amendment and the Paris Agreements are positive changes toward tackling climate change. However, in since there are no legal bindings, Paris Agreement has a stance of political encouragement with no accountability (Karlsson-Vinkhuyzen et al., 2018). A more effective and stronger enforcement of the agreement can help tackle climate change. Significant advances have been made in Glasgow to reduce greenhouse emissions, although financial support is required to help the vulnerable countries (Jacobs, 2021).

In 2021, a climate conference which was hosted by the UN, also known as the COP26, commitments were renewed by many governments. However, experts and activists believe that none of these renewed agreements is good enough to tackle the consequences of climate change that are the fast

approaching (Arora and Mishra, 2021). A more effective and stronger enforcement of the agreement can help tackle climate change. Significant advances have been made in Glasgow to reduce greenhouse emissions, although financial support is required to help the vulnerable countries (Jacobs, 2021).

The United Nations state that meeting the objectives of the Sustainable Development Agenda for 2030 will require promoting policies that strengthen resilience to the risks of sea level rise responding to issues of poverty, social exclusion, and climate injustice (Aleksandrova, 2020). The differential impact of sea level rise on coastal populations in SWCRB can be better understood through disaster risk assessment and through social categories such as income or wealth, ethnicity, gender, life cycle, schooling, class, territory, or geography (Sultana, 2022), which in turn are expressive of the multidimensionality of climate injustice.

Effects of CCSR in the SWCRB

In the SWCRB, the well-known effects of extreme weather events and sea level rise reflect asymmetries in the dynamics of regional development as well as issues of social justice (Mason and Rigg, 2019) effecting different dimensions of society, at social, cultural, and political levels (Adger et al., 2013). Extreme events have profound effects on agriculture, riverbank erosion, salinity, loss of natural ecosystems, gender vulnerability, poverty, migration, food security, fisheries, safe water resources, and public health factors that influence human development (Lázár et al., 2020); thus, leading to social injustices that are especially acute in the SWCRB.

The residents mentioned several cases of social injustice as an indirect impact of climate change. An infant was delivered by a housewife, an inhabitant of the locality of Machkhola Jhutipara of the upazila, with the aid of local residents in a van outside the Shatkhira Sadar Hospital as no physician was available at the time. The mother of the housewife, Participant-101 informed that her daughter X was refused admission at two hospitals due to fear of SARS-CoV-2 infection (Covid-19). This caused enormous sufferings to the baby as well as the mother. This is the usual scenario where the patients are being deprived of services by doctors due to the pandemic. This is the reason that general patients are refusing avail the medical facilities at hospitals. In most cases, village doctors and pharmacies are provided prescriptions to the rural patients. Many patients are dying without having any medical services.

Furthermore, a discussion of underprivileged groups of people (i.e., elderly, women, people with disabilities) within these regions is important. Gender is also an unaddressed area directly intersecting with other social areas. For example, the natural resources that women in rural areas of developing countries depend on for their livelihoods, such as water, agriculture, and forest products, make them particularly vulnerable to changes in supply and access patterns. It is widely expected that climate change will adversely affect all these aspects of women's lives (Peras et al., 2021). In addition to rural areas, poverty and sociocultural norms also lead to greater vulnerability of women (Table 2). For example, religious taboos often restrict women from going out. If women live in housing that cannot withstand environmental hazards, their restricted activities will make them more vulnerable, e.g., after the hurricane and flood hit Bangladesh in 1991, the death rate of women was almost five times that of men. As in many other Asian countries, women have never learned to swim due to religious orthodoxy and cultural norms, thus reducing their chances of survival in natural disasters (IPCC, 2013; Fakhruddin and Rahman, 2015).

TABLE 2. Widows living in the Gabura, Munshiganj, and Burigoalini Unions after their husband's death (NGO, 2009).

Location	Gabura Union	Munshiganj Union	Burigoalini Union
Husband's house	180	46	39
She took refuge in her father's house	60	42	24
Lives in khas or government land	20	20	8
Lives on someone else's land	31	10	7
Total	291	118	78

Participant-102 mentioned that witnesses the women to be unevenly impacted by severe climatic actions, irregular cyclones. Additionally, gender customs may likewise limit women from acclimatizing to climate jeopardies. Due to unlike familiarities, viewpoints, and social capital, male and female livings and adjustment approaches are also probable to be dissimilar (Reggers, 2019). Apart from the differential admittance to possessions, the capability to determine income variation chances impacts the adjustable capacity of men and women (Partey et al., 2020). In the scenario of Bangladesh, particular gender disparities and biasness exacerbate women's susceptibility to climate extremities (Reggers, 2019). Furthermore, gender variances in Bangladesh are decidedly exhibited in the acceptance to and the possession of all the living resources in all-purpose, and predominantly, to the possession of land. On average, women's authority over livelihood possessions is lesser, and consequently, the bearing of climate jeopardies on their living is assumed to be of high with men (Aryal et al., 2020). Women are at the lowest of the power setting and have the least supremacy, freedoms, and possessions; consequently, much of volume to risks and shocks differently exists. Because of their socio-economic and social transformations, women, get exposed to perils and bitter surprises in a different way; for instance, ferocity, early matrimonial boding, and absence of reproductive health care throughout and afterward catastrophes offer jeopardies for female groups throughout the calamities, Climate justice and gender equity are inseparably connected (Corcoran-Nantes and Roy, 2018). Climate justice emphasizes on the requirements of the most sidelined clusters who depend on natural possessions for their survival and incomes. Women dependent on agricultural activity progressively encounter the difficulties of having to adjust to their yield approaches in the milieu of climate change and natural reserve exhaustion. It's continuously altering, what (harvests and woods) flourishes where, which livestock and fish will be practicable, sea level rise and acid accumulation in oceans, whether water provisions can be continued, vector borne illnesses like malarial, dengue, and plant pests migrating into newly-warmer areas (Reggers, 2019; Aryal et al., 2020). These would have a sluggish effect than the intense weather incidents, and necessitate long period adjustment reactions. Without scrutinizing the gender components of these climate change effects, and without involvement and guidance of women, adjustment endeavors for these sluggish influences hold the danger of being insufficient. It's fairly obvious that women and girls are understated in evolving climate arrangements across all stages and segments, from national to communal phase arrangement, in the public segment, climate economics, or clean energy (Corcoran-Nantes and Roy, 2018). Presently, the Ministry of Environment, Forest and Climate Change is bringing itself up-to-date with the ccGAP, with backing from UN Women, expecting to put the plan into accomplishment. Critical moves have restricted the ability to standard orientation into strategies and activities, absence of interest in gender-responsive activities, and exceptionally restricted admittance to women associations and in decision-making (Haider, 2022). The adjustment strategies and tactics recognize the part of gender, but extenuation discourse rarely mentions gender facets. Momentous segments for climate change adjustment, such as farming, water reserves, or forestry plans and approaches do not provide importance to gender impartiality. Absence of looking after

approaches or assessment outline and pointers merely prolongs gender insensitivity of the climate change adjustment and moderation undertakings (Haider, 2022).

During the precious era, Bangladesh has been exposed to the advent of periodic floods, powerful cyclones, water logging, salinity interference, and riverbank corrosion as the climatic push factors that have compelled highly unprotected and susceptible coastal societies to drift specifically from the southwestern region (Table 3) (Mishra et al., 2021). The effects of cyclone Ampan, which made landfall in the Sundarbans, a world heritage site, near the Munshiganj Union in May 2020, provides a vivid picture of the struggles faced by this area. Cyclones are often accompanied by excessive rain, high winds, and flooding, which causes riverbank erosion and embankment collapse in many areas of this region. This erosion is a huge issue in the area as many villages live on chars, or islands within the river, which can be easily eroded by flooding, leaving many residents homeless and landless (Mishra et al., 2021; Rafa et al., 2021).

TABLE 3. Ranking of hazard risk observed in the 12 Unions of the Shyamnagar Upazila during the disaster risk assessment e.g., the effects of such amplified hazards upon the SWCRB exemplify the concept of climate injustice (Holden, 2018) (Source: Field Survey, 2017–2019).

Union	Types of Hazards														Total Respondent
	Cyclone		Salinity		Waterlogging		Riverbank Erosion		Flood		Thunderstorm		Drought		
	Respondent vote	Ranking	Respondent vote	Ranking	Respondent vote	Ranking	Respondent vote	Ranking	Respondent vote	Ranking	Respondent vote	Ranking	Respondent vote	Ranking	
Atulia Union	102	1	70	2	49	4	67	3	56	4			43	6	387
Bhurulia Union	90	3	121	1	97	2					43	4	36	5	387
Burigoalini Union	94	1	91	2	55	3	53	4	48	5			46	6	387
Gabura Union	92	3	101	2	58	4	105	1			31	5			387
Ishwaripur Union	74	4	81	3	82	2			93	1			57	5	387
Kaikhali Union	93	2	103	1			66	4	71	3			54	5	387
Kashimari Union	96	2	109	1	73	3	57	4	52	5					387
Munshiganj Union	85	3	93	2	52	4	102	1			29	5	26	6	387
Nurnagar Union	77	3	112	1	91	2	52	5	55	4					387
Padmapukur Union	81	3	98	2	43	5	103	1	51	4	11	6			387
Ramjannagar Union	83	3	106	1	84	2	51	5	63	4					387
Shyamnagar Union	87	2	82	3	93	1	43	5			47	4	35	6	387

Due to sea level rise, which pushes the coast further inland and creates salinity intrusion, freshwater is often obtained by collecting rainwater in ponds, or via groundwater tube wells; however, both sources often become saline during natural disasters, and some suffer from arsenic contamination (Table 3). Additional issues that occurred during Ampan included lack of electricity, improper garbage management, lack of access to healthcare, and halted employment. After several days without relief, NGOs provided one pitcher of water per family and the GoB provided 20 kg of rice per survivor (Key informant, 2017–2021). This assistance was helpful, but the amount of water provided by NGOs was insufficient for a family's needs; additionally, these people lost agricultural land and infrastructure (such as homes, schools, roads), for which they were not compensated. Many people become climate refugees and were involuntarily forced to migrate to larger cities, such as Dhaka, in search of housing

and livelihood (McDonnell, 2019). Although most people did not die in Amphan, most people became homeless. This is an example of the social and economic losses caused by these devastating cyclones and other natural disasters.

Extreme weather events and natural disasters are particularly harmful to the rural poor areas in the SWCRB, as there is heavy economic reliance on natural resources. CCSR is causing soil and water salinization, changing rainfall pattern, and increased extreme events (such as flooding, drought, and natural disasters), which puts great stress on resource-based livelihoods (Mallick et al., 2017). Agriculture used to be the dominant livelihood, but people here are already adapting to these difficulties by growing rice and other vegetables. However, even using salt-tolerant varieties of rice and crops, agriculture is still facing great challenges in this area, including the sheer destruction of cropland during extreme events and death of plants from salinization of water and soil. People here gain alternate livelihoods, such as fishing, shrimp farming, or beekeeping (Islam S. et al., 2020) whereas shrimp farming turn into local context climate injustice.

In the areas near the coast of Bangladesh, the alteration of farming lands for marketable shrimp aquaculture has appeared as a crucial tactic pushed by donors and development agencies for climate change adjustment. This alteration transmutes the risks of increasing coastal susceptibility and increasing soil salinity into a prospect for market progress and export-led advancement. Consequently, suggestions for shrimp aquaculture as climate change adjustment illustrate a comprehensive image for technical resolutions to the social and ecological catastrophe of climate change confronting this area (Figure 2) (Kais and Islam, 2019). Nevertheless, the alteration of farming land for shrimp cultivation precedes the drive toward climate change adjustment: between 1980 and 2014, the land being utilized for shrimp aquaculture in this area extended over ten-fold (Abdullah et al., 2017). Shrimp aquaculture has itself been caught up in the prevalent dislodgment of many of the most helpless members of countryside communities in the coastal region, while transporting economic profits to the least susceptible (Deb and Haque, 2017). In this perspective, shrimp aquaculture thus provides a momentous instance of how this kind of a social scrutiny might advocate differing tactics to appreciating the science of and reaction to global ecological change (Castree et al., 2014; Kais and Islam, 2019).

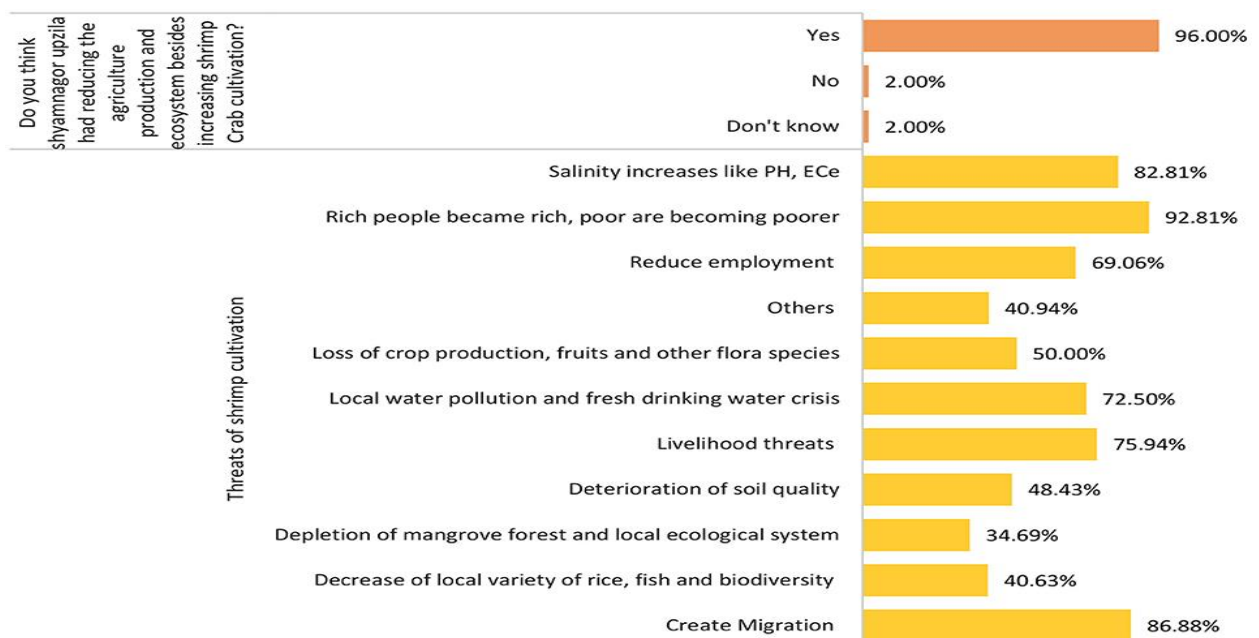


FIGURE 2. Figure represents that the threats of shrimp cultivation to the coastal area of Bangladesh. Multiple Response: $N = 320$ (Source: Field Survey, 2017–2019).

Within the existence of insufficient resources and a range of goals, adaptation strategy options contain a trade-off between numerous strategy goals (Kabir et al., 2020). Although the trade-offs between tactics are focused on moderation and adjustment have been much argued, modifications among tactics to assessing what determines for fruitful adjustment, and for whom, have been less deliberated (Adams et al., 2020). Similarly prominent as discussions over who will recompense for adjustment (and in what way) (Ciplet et al., 2013) are queries of how these capitals are expended, and the types of social alterations that they may involve.

Shrimp cultivation in the area around coast of Bangladesh is a significant illustration of this type of adjustment options with disputed conclusions. Similar to numerous other sectors met with sea-level rise, SWCRB is endangered by increasing soil salinity and the wearing of land and shielding dams (Sovacool et al., 2017). Though climate change is not the sole reason of such alterations, the consequences and combatting techniques are related. Among countless choices for dealing with these worries are to adapt lands that have archaeologically been utilized to nurture rice farming and other crops into huge ponds for raising shrimp, which is handled and exported mainly to Europe and the United States (Ahmed et al., 2010; Afroz and Alam, 2013).

Nevertheless, the profits of marketable shrimp production are not for share amid all affiliates of these groups correspondingly. The greater part of proceeds is received by a tiny proportion of large segment of landholders who remain absent, and by urban-based processing unit proprietors (Deb and Haque, 2017). The salination of farming soils through the imposition of saline water employed in shrimp ponds has its own ecological significances and makes conciliations with the richness of the soil for continuing and imminent agricultural undertaking (Hasan et al., 2020). Furthermore, the awfully low volume of employment essential for shrimp production compared to rice farming pushes for a labor leftover that has the consequences of dislocation from agricultural livings, driving numerous landless laborers and previous sharecroppers to migrate to cities in pursuit of employment (Barai et al., 2019). New hiring created by the growing shrimp industry is restricted, and chiefly grounded in processing workshops situated in urban expanses. In this way, considerable rural populations become expatriate from their birthplaces in the non-appearance of substitute rural livings. Despite the fact that profits may be the derivative of more affluent inhabitants and the state balance-of-trade, the underprivileged (those who are greatest susceptible to environmental transformation in the initial phase), agonize unreasonably (Belton, 2016). As a consequence, there is substantial hostility to shrimp aquaculture among social drive groups and other local inhabitants, who view it as a hazard to their welfare and their sustained inhabitation of this locality (Belton, 2016).

The dispute over commercial shrimp farming in Bangladesh pitches two standpoints on its application as a climate change adjustment approach into plain respite. One standpoint suggest that it is a perfect adaptation tactic, signifying that social paybacks ensues from GDP progress through the extension of export markets, rotating the ecological jeopardies of sea-level rise and salination into a prospect (Sovacool and Linnér, 2016). The other perspective, which emphasizes the prevalent negative social and ecological influences of shrimp farming, proposes that the extension of shrimp aquaculture should not be viewed as an operative adaptation approach because of its unreasonably undesirable influences among the most underprivileged members of coastal groups. The scenario of shrimp aquaculture stresses the pathways in which considerations of climate change, reactions to it, and likely prospects in the context of it, are determined by sociocultural relations of supremacy (Barnes and Dove, 2015). The imminent phase of Bangladesh's coastal section and its inhabitants will be dictated not only by climate change, but also by climate change adjustment. The bearings of these interferences are reliant

on their understanding to power disparities. Where technical adjustment approaches disregard investigation of such disparities, they put into jeopardy of exacerbating them. The worth of conceivable adaptation tactics should be measured relative to exactly this apprehension: their influence on prevailing socioeconomic discrepancies, and profits to the underprivileged and most helpless. These contending adjustment frames exemplify the crucial predicaments at the core of climate justice. How do authority and evenhandedness dictate the capability to adjust along with the capacity to regulate what the upcoming time should appear like? The normativity of climate change adjustment suggests that an operative adjustment should aid some individuals. Nevertheless, even as some may be advantageous from specific adaptation tactics, all resolutions will be unproductive resolutions for some individuals. Discussions about climate change have the requirement to focus on these inconsistencies straightaway, or contain the hazard of prolonging disparities which have led to so many susceptible to the effects of climate change in the initial phase. When it boils down to climate justice, from the coast of Bangladesh to center of Manhattan and beyond (Wachsmuth et al., 2016), adjustment procedures which do not first and primarily deal with authority and justice are fragment of the problematic aspect, not the answer.

However, these alternate livelihoods are still resource-based and are in danger from the effects of CCSR. For example, due to the loss of flora from natural disasters, bees have lost their habitat in the Sundarbans, and honey production has drastically decreased. Participant-103, aged 51 works for a private honey conservation company and reported that between April and May 2019, 602 kg of honey was collected, which reduced to 265 kg during the same timeframe in 2020. Participant-104, a honey trader aged 48, said that he sent beekeepers to the Sundarbans to harvest honey from loan and the amount of honey the present year was very low compared to that of last year. Participant-105 aged 39 said that the forest plants were destroyed due to the Bulbul storm. That is why honey is scarce as bees cannot find a place to build their hives. Talking to local Sundarbans researcher Participant-106 aged 40 about the shortage of honey in the Sundarbans, he said that bees are not able to collect honey from flowers as the vegetation in the Sundarbans has been destroyed due to natural calamities and bulbul storms.

Many believe that this reduction in honey by ~44% from the previous year is largely due to hurricane Bulbul, which occurred in November 2019. Participant-107 mentioned that Bulbul damaged 48,000 unfinished houses in Satkhira. Of these, 16,000 houses were completely destroyed; 30,000 houses were partially damaged. In addition, 5,017 fish farms and 15,000 hectares of transplanted aman paddy were completely damaged, and 10,000 hectares of transplanted aman paddy were partially damaged in the cyclone. Two thousand hectares of land including vegetables, betel, mustard and other crops were damaged. According to the office of the District Relief and Rehabilitation Officer, most of the Upazilas including Gabura, Padmapukur, Burigoalini, Munshiganj, Ramjannagar and Kashimari in Pratapnagar, Anulia, Khajra and Shriula areas of Asashuni Upazila, most of houses were damaged. Fish farms and crop fields in these areas were damaged, and thousands of trees were uprooted (Haque M. et al., 2019).

In addition to providing livelihoods (such as beekeeping, firewood, pulp, fishing) the Sundarbans Forest also sequesters carbon, reduces the ambient temperature, provides habitat to many species including threatened and endangered species, supports biodiversity, reduces river erosion, and ameliorates the effects of extreme storms (Dasgupta et al., 2017). The Sundarbans are the largest global contiguous mangrove forests, span ~10,200 km² in India and Bangladesh, and rely on a brackish water environment (Dasgupta et al., 2017). Although this forest provides numerous benefits to humans, animals, and its natural ability to combat the effects of climate change, deforestation continues and makes this area further vulnerable to CCSR.

Shyamnagar is one of the notable towns in the Sundarbans. Most of the people of 12 unions of this Upazila depend on the natural resources of the Sundarbans. These unions are extremely poor, and 80% of the families, such as the Bawali, Mouali and fishermen in the Sundarbans, depend on the Sundarbans for their livelihood. Many members of these families have been attacked or killed by tigers and crocodiles. As of June 2009, a joint survey of leaders and union councils collected data on 326 tiger attacks in the Gabura Union, of which only 38 people survived. There are thousands of affected families in the entire Sundarbans. The native people are subject to belief that a man married to a particular woman is susceptible to death. It is from this belief that after a man is attacked by a tiger; the family begins to mentally and physically torture the widow. Additionally, many widows are victims of bullying and hatred by their own family, and are often blamed for their husband's death.

Table 2 shows that many widowed women from the three Unions in Bangladesh must seek refuge in their paternal house, in khas or government land, or on someone else's land to survive.

From the above case that gender inequality in local level affect to control over both material and non-material resources; it is because climate change is affecting gender relations in the context of local climate injustice.

Perception of people in the SWCRB

This study provides results of data collected during 2017 and 2019 in the 12 Unions in the Shyamnagar Upazila. Data was collected by talking to local communities to determine their perception of the effects of CCSR in their areas. This data was presented as disaster risk assessment, case studies, focus group discussion, interviews, workshop discussion, and a quantitative analysis.

Results

Disaster risk assessment

To understand the risk of vulnerability in this study, a disaster risk assessment was completed in the 12 Unions of the Shyamnagar Upazila. Data was gathered by traveling to different areas in the concerned wards and discussing hazards and risks with the locals. So, the nature of jeopardy taking place in SWCRB because of climate change which we recognize through 387 response providers given their opinion below figure demonstrates that chief hazard mechanisms in SWCRB that also enhancing local climate injustice. The top six hazards and disaster risks, as determined by the assessment, are provided in Table 3 and include cyclone, salinity, waterlogging, riverbank erosion, thunderstorm, and drought. Different hazards prevail based on the location of each Union. Cyclone was the hazard reported most often. Salinity occurred as the most frequent #1 hazard, followed by riverbank erosion and flood.

Case studies

Participant-108 (aged 30), from the Tatinakhali Union in Burigoalini (ward no. 8), stated that developing countries like Bangladesh have suffered the most from the effects of CCSR. The developed countries and people of the northern hemisphere are responsible for this, and the underdeveloped countries must be compensated.

Participant-109 (aged 52), who lives in the Chaulia village (ward 8, Nurnagar union, Chaulia mouza) with a monthly income of ~25,000 tk (270\$) has a shrimp enclosure on 10 acres and paddy on 4–5 acres of land. Drinking water issues are widespread in this area, and he collects rainwater for 2 months, and pays 1 tk per liter to collect 900 liters of water per month from Haripur, located 7 km

away. The result of a broken dam caused to lose his land due to river erosion, and he did not receive monetary compensation for his loss.

Father Luise is a Catholic, whose religious leader, Pope Francis, declared a global “climate emergency” in 2015 (Harvey and Ambrose, 2019). Father Luise stated that many NGOs talk about climate change, but do not help with human rights, especially for the indigenous people of this area. He stated that he does not have much faith in the work of NGOs. He relocated 20 families of the Mundas from Datina Khali as the water level in the canal had increased, and the village was nearly submerged in the tidal waters. Soon, the Gabura and Padmapukur Upazilas will be submerged, which were submerged at the time of cyclone Ayla in 2009. However, he stated the NGOs do not typically discuss this rise in sea level.

Father Luise believes that the stakeholders must prioritize the lives of the people in these areas, and prepare proper areas for them to migrate. He stated that climate change cannot be prevented or controlled, especially in the southern portion of Bangladesh, which is expected to be submerged by sea level rise. International regions such as Venice, Italy, Jakarta, Indonesia are also experiencing sea level rise. He believes that the responsibility for climate change should be globalized, e.g., the presidential decision in Malta is that new cars will be electric, and petrol will be avoided.

Participant-110, aged 45 stated that the lives of children, the elderly, women, and the disabled become worse during natural disasters. Many of these population suffer from decreased or slowed mobility, which causes issues for taking refuge. Elderly persons are terrified and lose their memory or have a stroke. Additionally, livelihoods have changed and many resort to cutting down trees in the Sundarbans. The deforestation causing loss of animals and birds has been acknowledged. He stated that climate change has upset the balance of life in the region. He expects climate justice at the local and foreign levels, as well as increased cooperation in times of danger or disaster. By doing so, he believes that the quality of life of people in this area would be improved.

Participant-111, a resident of Ward 4 of the Kalbari village, has several domesticated animals including one goat and three ducks. Diseases such as dysentery, allergies, and diarrhea are common in the area. Rainwater is stored as drinking water for 3 months, and during the remainder of the year, pond or river water is used; however, river or pond water often has high salinity, which causes disease and skin irritation (boils and rashes) in children. According to the general community opinion, salt water is essential for shrimp farming, but potable water must be available for drinking and cooking. Siltation in the river, combined with storms and sea level rise, leads to high water levels in the river. Due to the lack of cultivable land, the people here earn money by catching fish in the river to sell at the local market. An instance of the difficulty in this area can be seen in Figure 3, depicting two brothers and their mother, after a recent storm, who did not have access to food for days and took refuge on a high embankment without sleep due to lack of a proper shelter.



FIGURE 3. Photograph of a UNICEF worker speaking to two brothers, waiting to swim with their mother (who is swimming in the background). Photo courtesy by Masum Billah.

Participant-112, 113, 114 and 115 informed that there was acute paucity of potable water due to salinity. They tend to collect rainwater for 2–3 months during the year; for the rest of the year, they try to collect water from ponds and find themselves in a precarious situation due to salinity in the river water during the dry season. During the majority of time in dry season, the tube wells fail to provide water, the surface and subsurface soil is devoid of water. There is no source of potable water even below 1,200 ft since the sea level is higher here and the salinity increase has penetrated deep into the soil. This is why the inhabitants have to endure such chronic water dearth.

It was learned from the National Household and Agricultural Survey that a reverse osmosis. Plant has been used for desalination of water salty water in ward number 4 of Burogoalini. Among the 688 families in the ward, 400 families had cards, which enabled them to obtain water at 33 paisa (local cent have lower value against the US cent) per liter. However, for the ones without cards, it was 50 paisa per liter. Nevertheless, 10–15% of families continued to purchase water at 50 paisa per liter. From the group discussion it was learnt that despite having 2,300 people from 688 families, only 100 people could fetch water regularly. The rest collected water from the pond sand filter set up by NGO and the Government, and those living in the remote areas fetched water from places as far as 5–9 kms away through pond sand filters. As a jar of water of 25 liters sold at 35 taka (1tk = 1 cent), which was beyond the reach of the common people; besides, during the dry spell, potable water became scarce.

Former UP Member Participant-116 informed that the situation was the same in Chandipur, Golakhali—near Sundarbans coast, Henchi and hundreds of villages in the coastal region. This acute water scarcity was due to the drying up of the waterbodies in the neighborhood before the summer set in and also for rapid consumption of water collected during the monsoon. Apart from that, the salinity intrusion in the coastal Region also worsened the water shortage problem. Participant-117, from Chandipur and Participant-118, informed that they were surrounded by saline water everywhere, and they had to literally struggle to avail a small amount of water. The Upalzilla Assistant Engineer Participant-119, informed that 70% of the inhabitants of the region consumed this saline water. Being a saline-prone area, during the summer, the water level subsided, leading to acute shortage of water. However, an initiative was provided to meet the demand of water for the whole year for the local people through preservation of rainwater to be supplied to the government tanks.

Participant-120, from ward no. 8 of Chailiya Village, informs that they have to buy water for one paisa per liter from 6 km away. They have to purchase 30 liters water every day; however, this facility is not available throughout the year despite having to pay for it. As there is no option for storing rainwater, potable water and not having sufficient hand pumps in the village, 3,000 families from the village are undergoing severe water crisis and very soon this condition would worsen.

Participant-121 (aged 55) lives in Sora No. 9, where there has been much damage due a broken river dam and states that embankments and riverbank erosion are extremely dangerous in his area. The embankments are hardly wide enough for vehicles to travel and erosion from the river erodes the

roads. During times of natural disaster, embankment collapse is inevitable. The destruction from this damage has caused house collapse, decrease in or disappearance of fish populations in ponds, destroyed agricultural land, and perished farm animals.

Focus group discussion, workshop discussions, and interviews

Out of the 19 coastal districts, the area most at risk to the effects of CCSR in the SWCRB is Shyamnagar in the Satkhira district. River erosion is more pronounced in coastal areas, creating higher vulnerability. Due to sea line regression, salinity intrusion into the river and groundwater creates drinking water issues, compromises the health of trees, and causes loss of employment. Many people of this area have been working in brick kilns in childhood, which is an example of the cultural changes caused by CCSR. Almost 99% of people in this area consider that global climate change is due to anthropogenic activities. Previously, people of this area cultivated fish, but this is more difficult now as freshwater fish cannot live in saline water. In this area, people still grow freshwater paddy crop. Also, those who live next to the Sundarbans can make a living, and the forest protects animals and humans from natural disasters. The forest also provides wood (for fuel), honey, and other essentials.

People here raise a red flag to alert others of high wind and swelling of water in the river. Most people have no buildings and must seek shelter during storms. If people can afford it, they keep dry food. During Hurricane Aila (2009), a respondent hid in his home, and stated “everything floated away” from heavy rains and flooding. Luckily, Aila occurred during the day, otherwise fewer would have survived. Aila killed 330 people, 6,208 people went missing and more than one million people became homeless.

After Aila, respondents stated that they traveled by boat, did not eat for 3 days, lived in poverty for 22 days, did not have wood for cooking, and some drank river water due to lack of potable water. People of this region suffer from diseases caused by drinking unclean river water or saltwater. Consuming saltwater causes widespread kidney problems for people of this area, and the average life expectancy of people has decreased to 50 or 60 years. Following natural disasters, some of the poor obtained grants for partial housing, and many of the wealthy were protected as they were less vulnerable to risks; however, the middle class could not work and were ineligible or had lack of access to receive grants.

Respondents stated that disasters like Aila are easily dealt with and are worse than historical disasters. For example, in the 1988 natural disaster, a respondents' house collapsed, and they were able to rebuild and had food from their vegetable garden; however, during Aila everything washed away, people had no access to food for 2 days, drank river water, and could not work for a month. The NGOs and GoB provided food and water after 2 days to the affected people.

The hurricane and the water retreated, leaving stench and diseases from fish rot, garbage, and loss of human life. Respondents stated that using the restroom was restricted after Aila because of the flooding, and they were forced to openly defecate. People of this region acknowledge their poverty as sometimes 5–6 families live together to survive.

Participant-122 and 123 stated that his daughter-in-law was pregnant during hurricane Aila. Difficulties arose due to lack of access to a doctor or clinic; she drank salt water and developed preeclampsia, anemia, blindness, and skin sores. Due to improper access to water, food, and healthcare, the pregnant mother and her child perished.

Participant-124 of the Atulia Union and Participant-125, of Chandipur village stated that they travel for ~2 to 3 km four times a day to get drinking water for themselves and the animals (cows and ducks). As the saltwater of the pond is not suitable for long-term use, rainwater is harvested for cooking. People not just in this area, but from the entire Shyamnagar Upazila are in dire need of food.

Participant-126, (aged 60) and her husband with disabilities live in the family of their adopted son. When her daughter-in-law was ill, she walked for an hour to obtain water. She had to borrow rainwater from the neighbor for her family of five, which had to be repaid by collecting water in the afternoon and evening.

Participant-127 (aged 28) of the Gabura Union said that she fetches water from the pond for food and drinking and stores it for 3 months. Moreover, she uses it to harvest and conserve the rainwater. After the rains, she collects water from a nearby pond and uses it in the following months. Participant-128 stated that she collected water for 2 months during the monsoon season; however, much of this water had to be discarded due to the presence of insects in the water.

Everyone participating in the group discussion informed that they suffered from shortage of water for cooking purpose. They had to undergo enormous struggle to collect water throughout the year. As a result, they have to feel the heat of the effort. Participant-129, a teacher from Kuptot village, informed that they fulfilled their requirement by purchasing a 40-liter drum for 50 taka. Participant-130 and Participant-131, two women from Durgabati village, informed that their husbands try to make their ends meet through day labor, although they still had to buy water for cooking purpose due to a lack of source of potable water. Water scarcity surfaced for 200 families due to increase in salinity in ward number 4 of Nurnagar Union resulting in Kultoli, Manikpur, Syed Alipur, Dormujkhali of wards number 5, 7, 8, and 9 not having stable levels of salinity, along with not having potable water sources no filtering system in the ponds, with no facilities for reformation or preservation.

Participant-132, from Romjannogor Union, claimed that the coastal belt was being attacked frequently by different natural catastrophes due to climate change. Due to the occurrence of cyclone Aila, the embankment got broken resulting in 3,000 ponds getting salinity intrusion leading to the damage of cooking water source ponds, culminating in acute scarcity of water for domestic use. Participant-133, from number 5 Kaikhlai Union, informed that due to WAPDA not being good, farming saline water fish in an unplanned way, not maintaining natural water sources, not digging normal water ponds, not having filter reformation and preservation, not facilitating rainwater harvest, not having desalinization option, 5,479 families from East Koikhali, Sayedkhali, Shoikhali, West Koikhlai, Kathamari, Astakhali, Ghoshalpur, Purakhali, Noikathi, Ghagramari, Mendinagar, Shibchandrapur, Nidya, Jadabpur village were undergoing severe water crisis.

Gabura is located on an island surrounded by the Kolpetuya River; hence, saline water is a concern here. There is a tube-well in this neighborhood, which is drilled to 600–1,200 ft below the ground surface. Even at this depth, the water is saline and is contaminated by arsenic. This water is used for food, cooking, and bathing. The abundant saline water causes issues in afforestation the resulting tree quality. The absence of vegetation further leads to increased erosion and no sequestration sources for CO₂. Additionally, the GoB has stopped people in this area from entering the Sundarbans, due to the destruction of trees and animals. Some people were using poison to kill animals and birds. The abundance of deer, tiger, and birds in this area has decreased. Many people from different areas of the Upazila, including Napitkhali, Chandnimukha, and Talbaria, must begin walking for miles as soon as they wake up to fetch enough water to survive. The overseers demanded that the day laborers pay for drinking water as the water bodies became salty during hurricane Aila. Participant-134, said that they are struggling to obtain drinking water as they cannot afford to buy water sold by ferry. Participant-135 and 136, said the drinking water crisis continued to intensify each day after Aila, as people cannot survive without drinking water. Participant-137, of Ramjannagar stated that cyclones have substantially changed the way of life and employment in coastal areas. Due to salt water, various types of water borne diseases, such as eczema, diarrhea, dysentery, stomachache, fever, itching, uterine problems and kidney problems, are prevalent. Most of our people here suffer from high blood pressure due to consumption of saltwater. Additionally, it appears that boys and girls are reaching

puberty at a younger age (age 7 vs. ages 12–15), and many children are born early (6–7 vs. 9 months of gestation).

Quantitative analysis

The 96% of the respondents have mentioned that the inhabitants living in the coastal area have been started to cultivate Shrimp aquaculture instead of traditional crop varieties from 1980. More than 92.8% of the respondents have claimed that rich people became the rich and poor people becoming poor. The 86.88% of the respondents have mentioned that as a result of Shrimp cultivation factors poor people in the SWCRB turn into the migration. The 75.94 % mentioned that the livelihood pattern of respondents is hampered by shrimp farming. The 72.50 respondent mentioned that local water is being polluted, water quality is being hampered and fresh drinking water crisis is being created because of only shrimp cultivation. In shrimp cultivation, the salinity preserves in the soil and surface water for a long time due to the addition of extra salt to the logged water resulting in hampered both soil and water quality. This shrimp farming initiates salinity which is seriously making the study area vulnerable to unsafe drinking water. Water borne diseases and fresh drinking water crisis are obvious effects of salinity as well as shrimp farming. In addition, 48.43% of the total respondents have informed that soil quality is being deteriorated because of shrimp cultivation. The respondents have also mentioned that saline water is put into land for starting shrimp cultivation and this saline water holds for a long period in soil which changes soil chemistry, decreases soil fertility. About half of the respondents have highlighted that shrimp cultivation has an adverse impact on the agriculture, crop production, tree plantation and other flora species. Salt stress reduces the rice production and tress. Shrimp cultivation in one land makes the surrounding lands saline due to intrusion. As a result, the farmers have no alternative choice instead of shrimp farming. Moreover. Women living in the study are cannot continue their homestead gardening where they cultivate different types of seasonal vegetables due to saline intrusion. As a result, loss of vegetable production is leading to food shortage or the scarcity of foods which contains large number of vitamins, minerals, proteins and carbohydrate. Moreover 40, 69, and 34.69% of the respondents respectively have informe that cultivation of local variety of rice and fish is decreased and ecological system and mangrove forest are also depleted because of adding more salt in water during shrimp farming. The respondents have also registered that saline resistant crop are being practiced at small range instead of local variety of crops to ensure food security resulting in demolished local variety of crops. The saline water used for shrimp cultivation which runs into ponds, canals and rivers making the water of those water bodies saline which adversely affects aquatic species and its biodiversity. Even, the ecological system of local area and mangrove forest is getting damaged with degradation of soil quality due to saline intrusion caused by sea level rise and shrimp farming.

It is also apparent that people of this area (91%) believe that climate change relates to capitalism (Table 4). Additionally, 92% of people (Table 4) consider climate change a threat for future generations. The locals have also mentioned that economic development directly or indirectly affects the environment by expanding industrial works, increasing the use of motor vehicles, and deforestation rather than planting. Alternatively, 5% of the respondents are not conscious about the environment; 91% of people agree that CO₂ emissions cause global warming, and most emissions are produced by industries in developed countries. People here believe that developed countries need to reduce CO₂ emissions and focus on environmental issues. Additionally, 94.1% of people in this area are aware of the climate injustice to developing countries. Climate change and sea level rise have adverse impact on economic development, environment, social issues, and livelihood patterns of the people who live in Bangladesh, especially in the coastal regions. These risks, hazards, and increased vulnerability are more intense for indigenous communities and marginalized groups, which 84.1% of people of this area agree with (Table 4). For example, lives of the Munda indigenous people and others marginalized populations are quite different than other regions. The livelihood of these people depends on the Sunderban mangrove forests. These communities are not well recognized with

politicians or other social stakeholders. Under extreme circumstances, they always struggle with the impacts of climate change. Thus, an inequality is formed between the mainstream people who get facilities to boost up their living capacity and those marginalized people who are deprived from the facilities which they need more. The Munda indigenous people house and others infrastructures are not durable fighting against natural calamities, and these peoples are not well recognized by the society and politicians. As a result, the governmental or other non-governmental donations are not distributed among the needy people.

TABLE 4. Responses to various questions from quantitative analysis.

#	Question	Yes	No	I do not know
1	Do you think that CC will influence the existent social justice issues and inequalities, and climate injustice?	85.6%	14.4%	
2	Do you think CC relates to capitalism?	91.0%	6.0%	3.0%
3	Do you think being climate victims is a threat for future generations and for the changing map of the country?	92.0%	5.0%	3.0%
4	If yes (above), Do you think developed countries need to reduce their CO ₂ emissions?	91.0%	6.0%	3.0%
5	Based on your lifetime where you are faced/live with several climatic anthropogenically-caused disasters, do you think this represents justice for coastal Bangladesh and others who are facing same problem all around the world?	3.1%	94.1%	2.8%
6	Do you think coastal indigenous communities and marginalized persons are more vulnerable than others to CCSR	84.1%	13.8%	2.2%

Source: Field survey 2017–2019.

Responses obtained for question 1 showed that 85.6% of people believed that existent social justice will cause issues related to climate change. In coastal regions, the human capacity, financial conditions, infrastructure quality, and social status varied by location (Table 4). Therefore, inequality was formed between the mainstream residents with access to facilities to better their standards of living and those marginalized that are in dire need of facilities but are deprived from the same. It is worth noting that the majority of the respondents felt that the disasters faced by them were unjustified and that the developed nations need to be accountable for the direct/indirect impacts of climate change. This is a very important observation which builds on the concept of climate justice at both global and local level.

When we asked the respondents- Is your land of SWCRB protected by embankment, most of the respondents (86%) have mentioned that no their land is not protected by embankment. Only 14% perceived that the land is protected by embankment but the embankment is not able to protect severe flood and causing the loss of land and house, lack of food and pure drinking water etc. According respondents answer that Figure represents that the erosion level of river bank is due to sea level rise (Figure 4). More than half of the respondents (59%) have perceived that high level of erosion is occurred due to sea level rise. Over 63% of the total respondents have mentioned that the river erosion takes away not only the homestead land but also agricultural land. Moreover, 55% of the total respondents have perceived that the impact of river erosion on agriculture is massive. Again 40.6% of the total respondents have claimed that the river erosion has a great impact on socio-economic condition. the livelihood of the people of the study area mostly depends on day labor, fishing and agriculture. The income source of the people of the study area being changed significantly during pre- and post-erosion periods (Figure 4). Additionally, the respondents have difficulty to find a job and

often turn out to be poverty and hunger. In this way, the socio-economic condition of the study area is being deteriorated gradually.

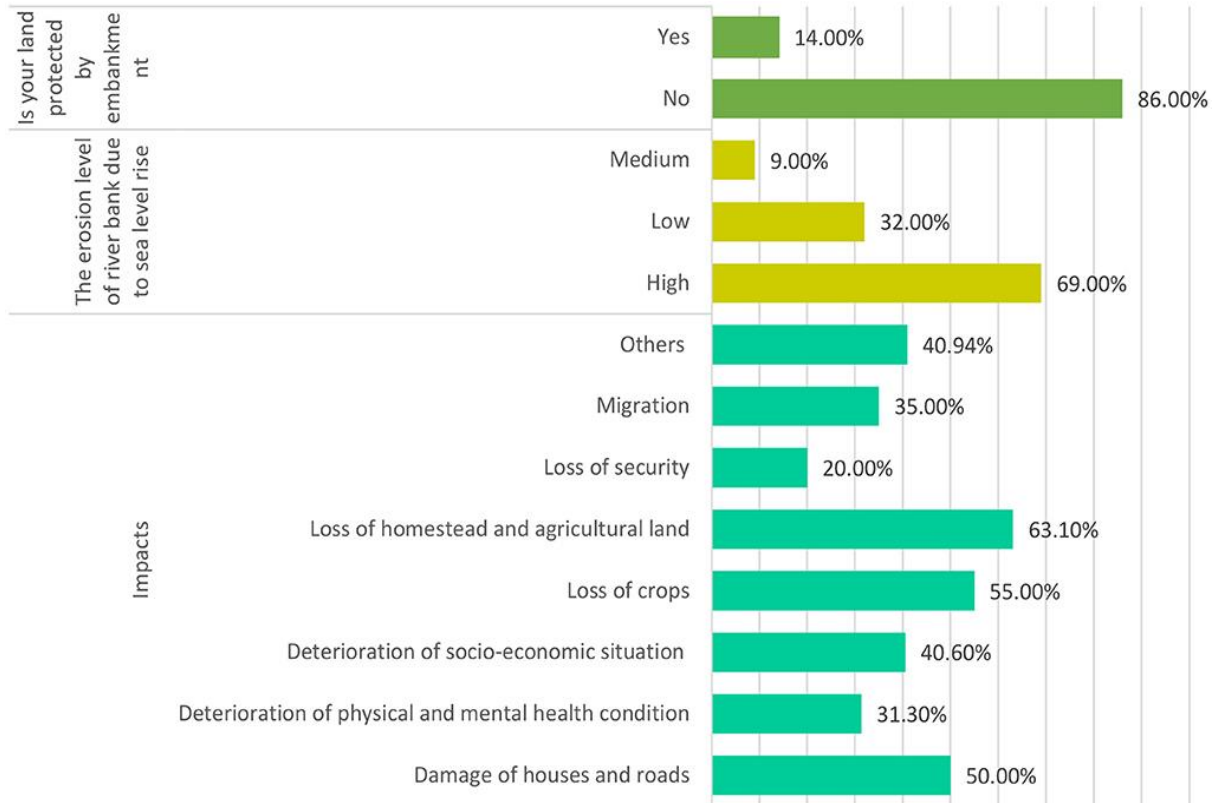


FIGURE 4. The negative impacts of river erosion. Multiple response: $N = 320$ (Source: Field Survey, 2017–2019).

Figure 5 represents the respondents' replies about the specific impact of sea level rise, which creates climate injustice in the SWCRB. The most frequent responses were salinity (65.0%), high economic cost of natural disasters and lost resources (56.3%), destroyed agriculture and loss of agricultural land (54.7%), coastal erosion (52.8%), monsoon flooding and water logging (51.4%), and food insecurity (48.3%).

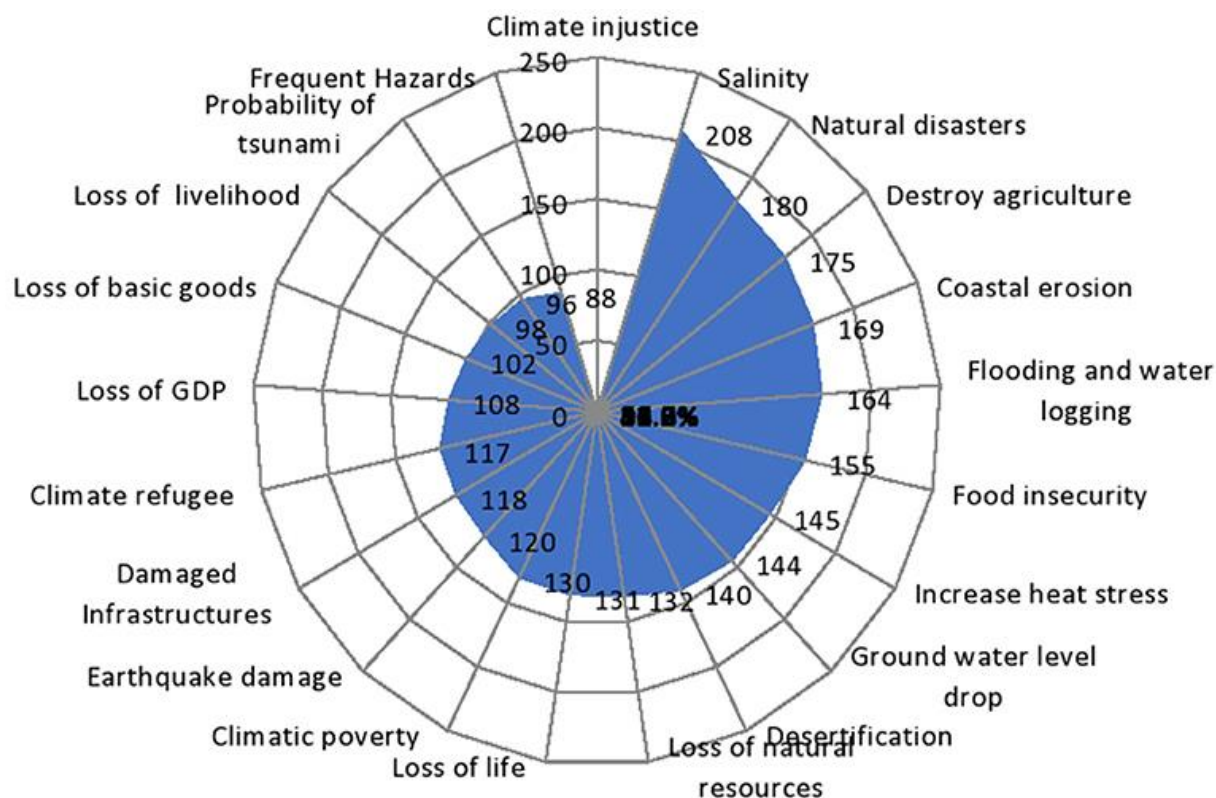


FIGURE 5. Issues that create climate injustice in the SWCRB multiple response responses: $N = 320$; Source: Field survey 2017–2019.

Discussion

This section summarizes some of the main recently formulated pathways about climate change justice with the view to clarify the contrasting aspects between the allocation-based and rights-based debate as a point to consider and the recommendation from this study for an appreciation and capabilities-based approach of perception about the subject on the opposite extreme (Agarwal et al., 2002). As discussed by (Thomas and Twyman, 2005), natural resource-dependent nations are typically more vulnerable to the effects of climate change and usually have a low adaptive capacity to deal with changes. The advocates of historical duties claim that those with more susceptibility in the third world will be greatly impacted by climate change in their eternal struggle to survive than their counterparts in the first world. From agricultural-supported livelihoods to those supported by resources in the Sundarbans (wood, pulp, honey, etc.), it is apparent that Bangladesh is an area highly dependent upon natural resources, with the locals having little access to those resources. The changes in livelihood (shift away from agriculture as the main livelihood and increase in shrimp cultivation) shows that the people here have already implemented adaptive strategies to the negative effects of CCSR. Other examples include using floating gardens in flooded areas, combined aquaculture-agriculture techniques (e.g., fish and rice), and planting either salt-tolerant crops or rice with variable maturity times (Hossain et al., 2018). These coastal people are less in a state of adaptation and need compensation and reconstruction

It is apparent that a large-scale global effort is needed to reduce global emissions to zero, and likely requires a legally binding agreement (Collomb, 2014). The Paris Agreement and Global Climate Emergency declaration are helpful, but not sufficient. It is clear with the slow movement to action and, at times, downright refusal of the science behind climate change that developed countries must

adopt a new mindset to the urgent need to decrease emissions for all living beings and the environment to survive and thrive (Table 4) (Collomb, 2014). The commitments set by the COP26 will not be fast enough to prevent disastrous events from taking place in the more vulnerable communities that already face major catastrophic climate crisis (Wilson et al., 2020). Even though there were significant advances made in Glasgow to reduce greenhouse emissions, people argue that the financial support that is required to help the vulnerable countries were the reason why the negotiation broke down in the final hours (Jacobs, 2021). Frank Bainimarama who is the prime minister of Fiji stated that the decisions that were made on the UNFCCC, the Kyoto Protocol and Paris Agreements, the Glasgow targets now become bruised and battered but not dead (Morgan, 2021). The only way out for the loss and damage which is now of top priority in the list of agenda in political terms, is to eventually deliver it. Developing nations and small island nations have debated for 2 weeks to commit toward phasing out of using fossil fuels, financial commitments for damage and loss which occurred due to the devastating harm that took place from climate change, mitigation and adaptation (Hunter et al., 2021). While meeting these goals were held by promises of draft decisions, delegates were accepting of the decision to phase down while being in the spirit of compromising (Jacobs, 2021). Antonio Guterres who is the secretary-general of the United Nations stated that the summit was unable to meet the goals that were set such as reducing carbon emissions, eliminating fossil fuel subsidies. However he further pledged a \$100 billion toward developing countries to tackle the adversities that are brought by climate change (Broom, 2021). Alok Sharma who is the COP president also expressed his frustrations toward the changes that he faced in relation phase out coal situation and almost became tearful expressing the process of how the whole thing unfolded (Hayes, 2021). Besides, four issues have been pointed out by Bangladesh to tackle global warming and climate change. In the past seven years, Bangladesh doubled its expense toward climate related issues and are now in preparation for the National Adaptation Plan [(CVF (Climate Vulnerable Forum), 2021)]. Back in 2009, the “Bangladesh Climate Change Trust Fund” was created to provide funds toward climate related issues. Updated Nationally Determined Concentrations were also submitted. By the year 2041, it is aimed to have 40% of the energy sourced from renewable sources (Das et al., 2018). Coal based plans with foreign investments of \$12 billion were scrapped by the country in an attempt to tackle climate change (Moazzem, 2019). A “Mujib Climate Prosperity Plan” will be implemented for resilience to prosperity from vulnerability (Mujib Climate Prosperity Plan Decade 2030, 2021). Other initiatives include knowledge gathered about adaptation and best practices and proposing a climate emergency pack,

Therefore, the primary focus and mindset should reduce emissions; alternative aspects of science such as carbon sequestration are also important, but it does not address the primary issue of continued large-quantity emissions release by developed countries. The halting of these emissions and conversion of all countries (developed and developing) to renewable energies (solar, wind and hydropower) is vital (Quaschnig, 2019). This must be supported by the global government and private industries. Additionally, global policies and agreements must be cross-checked and held accountable to ensure that they are facilitating this switch to renewables and vastly cutting emissions (United Nations Geneva, 2020). For example, carbon offset allows for companies to reduce emissions by funding emissions reductions in a different location usually through the purchase of carbon credits (Henderson et al., 2020); this caveat could allow emitters to continue with their typical business without largely reducing their emissions. The largest driver of CCSLR is anthropogenic emissions, and reducing these to zero needs to be a main global focus and goal. Exploitative policies that are not actually helpful in this regard must be avoided (IPCC, 2018). Additionally, the carbon exchange is not accounting for the fact that a unit of carbon to the individual in a placid environment will make

available a dissimilar stage of fundamental necessity than to the individual in a rougher setting (Gulluscio et al., 2020).

A substitute pathway for climate justice is on average fairness argument, or carbon egalitarianism (Williges et al., 2022). Instead of focusing on previous bindings for emissions, such a line of action looks for giving everybody the same share of the capacity of the atmospheric sink. Scheme made on the basis of the equity principle would demand a technical accord on the entire quantity of greenhouse gas emitting limit to be permissible; that total would be distributed with the whole global populace, and the consequence would be an equivalent emissions quantity for every individual on the globe (Singer, 2004). Moreover, Peter Singer has prescribed a cap-and-trade approach, in which nations with soaring release could purchase allowances from those with lesser release. In spirit, such a method would lead to both lesser release in general and a way to compensate countries that exploit lesser per head quota.

In addition to strict emissions decrease, consumers in developing countries must consume less. Many companies now are “green-washing” their products to convince consumers that their products are sustainable, when, these companies are often just re-branding the same ideas (de Jong et al., 2020). Consumers in developed nations often feel they are making an environmentally conscious choice by purchasing items with select words such as green, sustainable, cage-free, while, these people just need to consume sustainably. Global initiatives have also adopted this mindset such as “climate-smart agriculture,” which was pushed heavily in 2010 and claimed to support sustainability, resilience, and reducing GHG emissions; However, the lack of organization, safeguards, clarity, or accountability caused 350 organizations to deny adapting climate-smart agriculture (Zhongming et al., 2013). Additionally, many companies such as Monsanto (Agrochemical Corporation) backed this idea, which supported the use of pesticides (Bonny, 2017). It is important to be aware of this widespread re-branding to ensure that global initiatives actually facilitate sustainability in an equitable and just way and contain detailed explanations and procedures to implement and conduct sustainability.

A global-scale effort to provide compensation to the communities at risk of CCCLR in tropical and sub-tropical coastal areas in developing countries is necessary. As discussed above, the Paris Agreement includes a Climate Fund meant to help vulnerable countries deal with the effects of extreme natural disasters (Scandurra et al., 2020). This is needed on a large scale, and proper organization and implementation of funds to certain regions is needed with greater urgency and organization. Providing the financial assistance to these areas is greatly necessary, as these people already know their biggest challenges and require funding and assistance to overcome their specific challenges (Sforna, 2019). Additional funding will likely be necessary to strengthen vulnerable communities; providing these countries with this compensation creates justice and allows the affected countries to tackle the issues in their own way and how they think is most beneficial. This approach is different to previous attempts by developed countries to provide assistance as it resembles a take-over and does not consult the local communities before implementing their idea of priority for these regions.

Compensation also comes in the form of a funding mechanism to climate refugees. One of the large unknowns is, where will the climate refugees go? Some argue that countries like the USA and China, who had a large responsibility in creating the problem (contributing to a combined 40% of the total carbon emissions) must accept climate refugees [IOM (International Organization for Migration), 2008; Ahmed, 2017; Qayyum, 2021]. However, migration on a large scale from developing to developed countries is unlikely based on historical events and cultural differences (McLeman, 2018; Warner, 2018). Therefore, there is a need for legally binding international recognition and

protection for these people. This would not only help in the case of migration to a different country, but also migration and compensation for those within the same country. Participant-138 mentioned that as climate refugees are involuntarily displaced, they are not currently recognized by the stakeholders and do not have any protections or rights. This causes increased suffering, and those who do migrate often continue to struggle for livelihood, food security, and housing.

The global conversation must acknowledge that sea level rise is creating very real and devastating impacts to people all over the globe at this moment, and in some cases, has been an issue since the 1990s or before (Klein, 2015; IPCC, 2021). Additionally, sea level rise is likely to continue regardless of reduced emissions, which means that many areas of coastal Bangladesh will be submerged due to anthropogenic ally-caused climate change (Table 3).

As suggested by the Case Study on Father Luise, local people are often wary of assistance by NGOs, and there is a perception that these organizations do not discuss the issue of rising water and the subsequent creation of climate refugees. By recognizing the undoubted fact that sea level rise will displace many more people, communities in the SWCRB may begin to build trust for NGOs. Additional trust-building could be found in inclusion of local people in the process and decisions made by these organizations. The funding mechanism for this could, again, be on the international as well as regional level to reduce vulnerability and support sustainable development.

One other principal pathway to climate justice highlights the rights issue fundamental human rights, rights for advancement, and more exact environment related rights and the distinguished responsibilities and bindings that emanate from them (Gonzalez, 2015). The novelty here is that this mode is susceptible to the environmental state essential for growth and operation while preserving that all human beings with these rights also have the load, obligation, and liability related with defending the rights of other stakeholders (Calzadilla, 2018). One of the critically remarkable facets of the rights-based approach is that they cross the boundary of the concept of climate justice assumed on equity solely to one stressed on the environmental and advancement situation that individual members, community members, and authorities feel the necessity to make a survival, progress, and remain functional (Toussaint and Martinez Blanco, 2020). For the cause of climate justice to include the individual civil liberties framework to cover this kind of essential needs is visibly attuned in regards of capabilities pathway that has been suggested here, however, these ideas of climate fairness concerning rights has two significant drawbacks. The same way it was recognized at the beginning, they overlook other significant notions of justice, to be specific, those focusing on social as well as political appreciation and the more subtle and detailed notion of necessities that capability-based pathway encompasses (Figure 6).

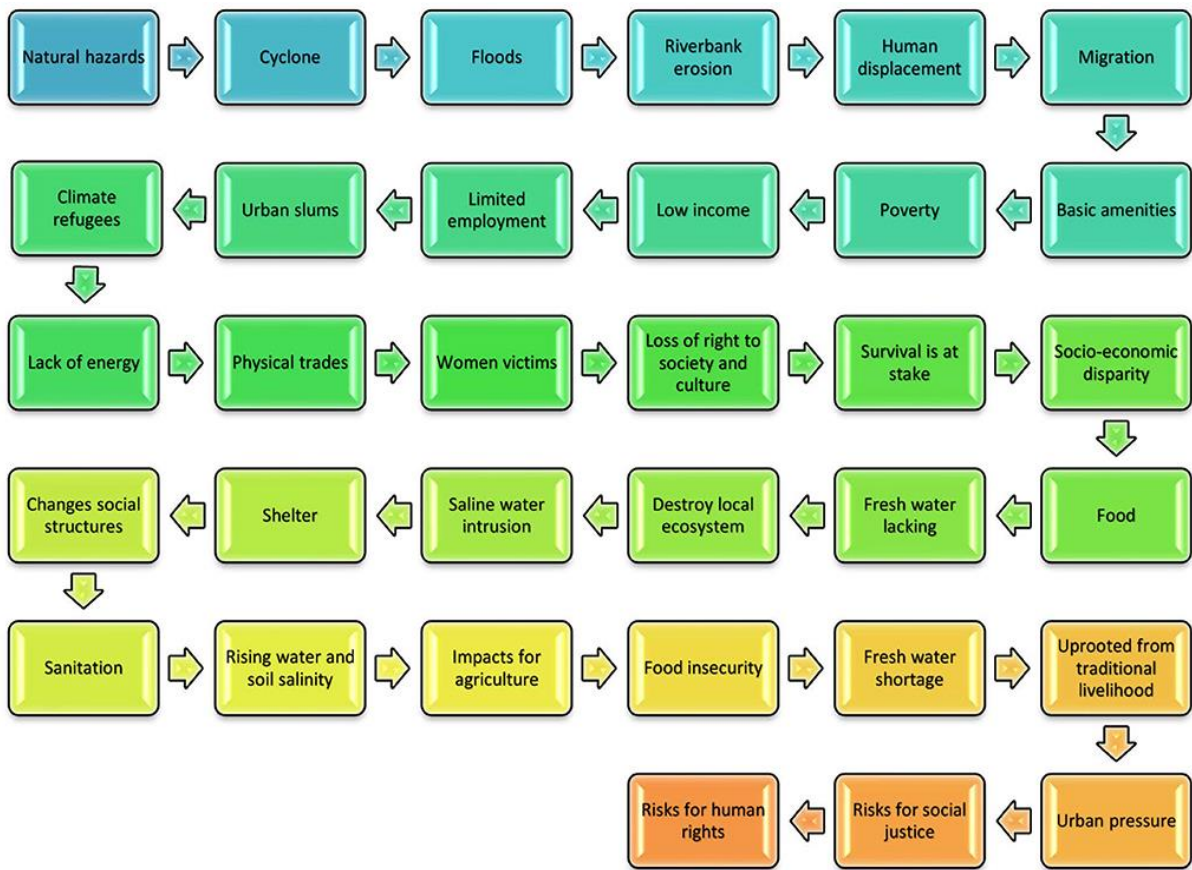


FIGURE 6. Figure shows key findings of climate justice through the respondent's viewpoint (Source: FGD, IDI, KII, PRA, Workshops, 2017–2019).

Sustainable development is necessary to create resilient populations in the SWCRB. As shown in Figures 3, 7, 8 people of this area are demanding sustainable embankments instead of relief. The ability for people to reduce flooding conditions and riverbank erosion would create an immense impact on the multitude of issues relating to salinization, human displacement, loss of homes and land, and other challenges (Table 3, Figures 4, 5). As identified through this study, often it is the voluntary efforts of community members themselves who volunteer their time to rebuild local dams and embankments. Additionally, corruption hinders proper dam construction by local districts, and it is almost inevitable for these structures to fail. In addition to embankments, sustainable infrastructure, such as roads, schools, homes, and healthcare facilities, is also necessary. It appears that homes in the rural areas of SWCRB are often built using mud and thatch; providing these people with the tools to build their infrastructure with more resilient materials such as brick and concrete would help immensely and reduce the amount of suffering after natural disasters. The funding allocation described above could help with this. Additionally, local and regional communication and organization of government, NGOs, stakeholders, and citizens is necessary to gaining properly constructed embankments that are capable of withstanding extreme events.



FIGURE 7. A young man standing waist deep in water with broken embankment behind him from river erosion, with the placard “We want sustainable embankments, not relief” (Khorbor, 2020).



FIGURE 8. Climate strike near Padmapukur Union Chhota Chandipur Beri Dam on June 5, 2020 (Kantho, 2020).

A news article published in *Drishtipat* on June 5, 2020 spoke of the youth climate protest in the Padmapukur Union of the Shyamnagar Upazila for climate justice and to protect the Sundarbans. This protest was part of the Fridays for the Future movement sparked worldwide by Greta Thunberg and in response to the destruction from cyclone Amphan (2020). Amphan hit Bangladesh on Wednesday evening, May 20, 2020 in Satkhira district. Cyclone Amphan entered Bangladesh mainly through the Sundarbans adjacent to Munshiganj, the southernmost locality of Shyamnagar in Satkhira (Figure 5) (Islam et al., 2021; Rafa et al., 2021). One of respondent mentioned that through skype- the four most affected Upazilas of Satkhira were Shyamnagar, Asashuni, Kaliganj, and Sadar of Satkhira. Out of these four Upazilas, the most affected was Shyamnagar Upazila. Gabura, Padmapukur, Kashimari, Burigoalini and Ramjannagar unions were inundated due to the cyclone Amphan. A few thousand fish enclosed. Hundreds of houses, power lines, and trees were destroyed. Thousands of people in five unions were without water. The storm caused extensive damage to power lines in Shyamnagar Upazila. A total of 40 electric poles, including 19 of 33 cable lines, were damaged in the storm. As a

result, the entire Upazila was without electricity. Burigoalini, Munshiganj, Kalbari, South Porakarla, East Porakarla, North Porakarla, East Durgabhai, West Durgabai, North Durgabai, Madia Arpangashia, Ampan storm flood-affected people were the worst hit. The locality was flooded with salt water for 1 week while being surrounded by garbage (Table 3, Figures 4, 5).

Participant-139, mentioned that at that time, there was a great crisis for fresh water all over the western coast of the country. The biggest problem in our coastal areas was the problem of drinking water. Due to the stagnant water in the storm, all the fresh water ponds and tube wells were submerged in water. The water in the tube well was salty and contaminated by arsenic. There was already a shortage of potable water in several areas, and the erosion of cyclone Ampan made the erosion situation even more complicated. Some of the residents collected water by renting a local Van for 7 to 8 miles. Most of the people were poor with no scope for employment or availability of food. The residents were looking forward to water aid distributed by NGOs or other voluntary organizations. These NGOs provide water to each family in a water jar/pitcher, which was not enough to meet the needs of a single family. The government availed 20 kg of rice per head and also provided food to the flood-affected people. As a result of the collapse of the river bank, our valuable agricultural land, houses, roads, educational institutions and markets were lost. Social and economic life was severely damaged. Excess water from the floods hit the banks of the rivers, causing severe erosion of the river banks during the floods (Table 3, Figures 4, 5).

Fifty protesters attended the climate strike near the Chandipur Beri Dam, which was organized by Youthnet with help from the Action Aid Bangladesh; they called for construction of sustainable dams in public partnership, immediate rehabilitation while maintaining human dignity, and quick preparation for the next cyclone, while accounting for the coronavirus pandemic (Figure 8). The Satkhira District Coordinator of Youthnet, SM Shahin Alam, explained negative impacts of the climate crisis on livelihoods of coastal people. The combined global pandemic and climate crisis are straining the Sundarbans, creating climate refugees, and causing loss of housing, human life, and crops. It is apparent that these people are calling for participation in the decision-making steps on adapting to and preparing for CCSR.

The Padmapukur Union Chairman, Participant-140, expressed the importance of listening to the local people for the solution to the destruction after cyclone Amphan, including the public, agricultural farmers, fish farmers, teachers, and local political and NGO representatives in the area-based coordination committee in all government activities in the affected areas. This included marginalized groups such as youth, women, and persons with disabilities. Protesters called for dam repair to be organized by local people via public hearings, establishment of a Climate Commission and Coastal Development Board, and increase in the national budget allocation for the areas affected by the climate crisis. Additionally, to deal with the social distancing, there is a need for increased shelters and personal protective equipment for health care workers to work safely. There is a clear emphasis expressed here on community-based disaster management. Based on historic event, natural disasters (hurricanes, cyclones, and other extreme storms) are highly likely to occur in the summer and fall months in this region, and communities here want rapid preparedness for these inevitable events (Table 3).

As determined by the disaster risk assessment, these communities are often facing similar issues, but not at the same level. For example, all areas are influenced by cyclones and salinity, but flooding or river erosion may be viewed as the highest hazard in some areas.

SWCRB is susceptible to shifting pattern in climate effect in its coastal regions and more specifically in its more densely concentrated population spread in the low-lying deltaic vicinity, which faces a

looming danger with sea level increase conspicuously. The sufficiency of the legal adaptable mechanism in SWCRB to react to such climate susceptibility is evaluated with the result indicating limitation in appreciating the community stakes ensuing from the climate and sea level increase uncertain situations. A more thorough pathway for ensuring justice in the social domain requires helping government to react to the effects from such concerns and to their implicated susceptible segments. The country can have a better adaptation legal approach to deal with climate change consequences and raise the association of local inhabitants in climatic pattern adapting decisive action. Financial allocation is a must to help policy making body to include adapting mechanism deciding endeavor and this could expedite social fairness consequences for susceptible SWCRB community members. The Bangladesh Climate Change Strategy and Action Plan (Ministry of Environment and Forest, 2012), strategy arrangements highlight procedures intended at dealing with dissimilar physiographic sections inside the country, counting and with importance on the coastal zone. The effects of climate change on livelihoods and means of poor farmers are also dealt with, but stress on steps to lessen negative effects on women, specifically, are deliberated merely in comparatively rudimentary customs, with inadequate tangible recommendations for approaches in which strategies can be allied to provide backing for underprivileged groups, along with women rights, the option to decide in society and household, women land access, women's right to exercise them (Aryal et al., 2020). Our investigation outcomes offer additional perceptions that could be from NAPA, for instance, be taken into account in the devising of Bangladesh's Thirty 30-year plan for 2022–2052 which offers thorough direction for climate justice questions to sustain national growth. It is specifically critical for indigenous inhabitants and island regions, such as SWCRB, which are losing cultural identity and environmental balance to integrate recognition and capabilities in their adaptation strategies (Table 4). It is claimed by Figueroa (2011) that the initial environmental justice effort for such group of people is the acknowledgment of their environmental uniqueness and custom, instead of personal level acknowledgment. But the local or island communities are not only marked as susceptible communities; many neighborhoods and benefactor factions of those communities are also recognizing what climate change would bring for different facets of community operation from areas of public wellbeing, the losing of specific regional economic initiatives, to community indulgence explicit by relocation and asylum seekers' distribution, to risks to fundamental survival due to sea level rise or havoc created by stormy weather (Figueroa, 2011). The authorities must take initiatives to extend the probabilities of recognition and capabilities to communities to make aware the people against those looming risks and worrying issues.

This also supports the idea of community-based management as each area has its own unique challenges to overcome. The GoB must be instrumental in prioritizing the lives of these people, facilitating access to necessities (fresh water, food, livelihood, infrastructure, and healthcare), and creating a resilient community. It is known that several times, external assistance intended for certain a marginalized population does not benefit those intended; we can reduce this harm by compensating these people to allow them to create their own resilient communities through their own framework of sustainability. Climate change impacts diverse geographical zones and groups in a different way. As the most underprivileged countries and the most susceptible individuals within those nations, like women, girls, and gender diverse clusters agonize the maximum, and despite contributing the minimum to the climate predicament, climate justice is turning out to be a crying call for the developing nations (Table 2). Just saying climate justice is not enough; the underprivileged nations, and individuals should be aided by those who have played a role most to climate change.

Conclusion

With the industrial revolution, developed countries began utilizing resources such as coal, natural gas, and to build their economies and boost profit. The consequence of this emissions release of GHGs into the atmosphere was unintended warming of the temperature at the global level due to the greenhouse effect. Science has long supported this understanding, but the conversion of this understanding into true policy change and large-scale emission reduction has not occurred. Global agreements to reduce emissions are insufficient and must be ramped-up to reduce emissions to zero to not surpass a 2°C warming of the atmosphere; this is the anticipated point when warming will continue due to natural earth feedback loops. The SWCRB is unjustly affected by CCSLR via extreme events, coastline recession, and increased salinity, which have affected all aspects of these people's lives including livelihood, infrastructure, food security, freshwater access, and healthcare. This climate injustice ensures that those countries that contributed least to global warming are likely to be impacted the most. Recently, Intergovernmental Panel on Climate Change (IPCC) has declared the crucial cause of global warming, climate change, and sea-level rise is the release of carbon dioxide (CO₂) and Bangladesh may face a shortage of freshwater due to the continuous melting of glaciers. This may lead people to use underground water resources to meet both their agricultural-industrial and domestic needs. Thus, it is important to reduce CO₂ release to ensure climate justice at the global or national level. The frequency and scale of extreme climatic events like cyclone, and storm surge causing deluge, have increased due to climate change. Ignorance in polders flow regulation at the upstream barrage, shrimp cultivation development, expansion of farming water supply, and extreme removal of groundwater may result in increased salinization and decaying freshwater quality. Polders in coastal regions are not secured which becomes the greatest risk of SLR in the SWCRB. Besides, the coastal people become conscious of their rights despite their little educational background and often request to the stakeholders to build embankments. Thus, climate justice can be ensured by the nation's government and the NGO's financial capacity both globally and nationally.

The southwestern coastal areas of Bangladesh, often experience extreme climatic events like cyclones associated with storm surges causing saline water intrusion. This soil and water salinity causes alteration in natural and anthropogenic processes which possess a threat to freshwater availability, health, agriculture, food security, etc. Due to salinization, the farmers are now more interested in converting agricultural land to shrimp cultivation. This may be economically beneficial for them but hampers the total agriculture farming, and destroy soil and water quality and the ecosystem in the long run. Also, shrimp cultivation needs low manpower compared to agricultural purposes resulting in a labor leftover which drives the agricultural living landless laborers to migrate to the cities for employment. There are two viewpoints proposed despite the disagreement regarding commercial shrimp farming in Bangladesh, as climate change adjustment approach into plain respite. The first one recommended it as an ideal adaptation strategy that ensues the rising of GDP through the expansion of export markets and minimizes the ecological damages caused by sea-level rise and salinization. The second viewpoint emphasized the negative social and ecological perspective of shrimp farming and proposed to consider the shrimp aquaculture extension as a non-operative adaptation approach because of its fondness among the underprivileged coastal people. Sociocultural relations of supremacy are considered to be the determiner that influences the scenario of the shrimp aquaculture stresses leads to the pathways of climate change, reactions to it, and likely prospects in the context of it. Recently health risks are increasing day by day due to anthropogenic climate change and are the greatest challenge for Bangladesh. Besides, medical assistance is a fundamental right as good health condition ensures the quality of human resources obtaining economic growth and social equality as well as national development. Furthermore, gender discrimination often seems prominent in climate change issues, SLR and adversity questions, planning, and agendas. Especially, when women receive

lands inherently from their family or relatives, most of the time those lands are ceased from them as the relationship ends. Climate shifting patterns create gender inequality and women are more vulnerable to it due to their economic, social, and cultural norms and religious restrictions. Eventually, these climate changes have enormous influences on damaging agricultural land, decreasing yield, drinking water scarcity, food shortage, shrimp farming damage, amplified life risk, unemployment, migration, etc. According to the National Adaptation Program Action (NAPA), 2005 and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP), 2009 in the development of two national strategies on climate change adaptation, Bangladesh has taken a lead among low- and middle-income countries. But again it is neglected in both the national and SWCRB's policy on justice and action for climate change.

This study mentioned that SWCRB has been considered one of the successful pioneers in the national context of climate change adaptation to protect people but it is not possible without reducing global carbon emissions and global political commitment to achieve climatic justice. The world politicians so far couldn't come up with an effective solution for Climate Justice even through the Kyoto Protocol 1997, the Copenhagen protocol (2009), the Paris Agreement (2015), Montreal Protocol (2016), and COP26. Mohammad Adow, the director of Nairobi-based think tank Power Shift Africa stated, that there is nothing to show for all the work the developing countries have done so far, and the damages and the loss suffered are nothing more than a political agenda. He also stated that it is the only last option to be delivered eventually (Newell and Adow, 2021). They are also hopeful that sustainable development and more meaningful support could be achieved for the vulnerable communities in the coming year to deal with the irreversible impacts of climate change from those who denied taking any responsibility (Broom, 2021). COP president, Alok Sharma expressed disappointment toward the whole coal situation and almost to tears describing the entire process (Hayes, 2021).

This paper supports climate justice theory for a capability-based approach rather than a rights-based approach, due to the inherent discrimination in recognition. The capability-based pathway can assist in addressing many of the matters like sharing weaknesses, identifying the individuals, areas and the link between them and many of the fundamental rights being at danger caused by the climate change is the dispute here. On top of this, such steps can put an ease to the adjustment of confined inconsistencies in the outcomes and the understandings of the climate change and to the way how it responds, if it is necessary. The capabilities approach allows for the people of the SWCRB to facilitate and manage their own issues in their own way, while being compensated in the form of funding from developed nations. The focus here is on community-based disaster management, which includes local people in the conversation along with NGOs, government, and others involved. These people must be provided funding so they can prepare for the inevitable natural disasters while being safe from the added impacts of the COVID-19 pandemic.

An inclusive approach fulfills both acknowledgment and ability of residents to participate. The factor in this regard is to be more receptive in realizing discrepancies of perils and outcome, and to encompass those impacted via climate change in the realizing and preference of susceptibilities and the building up of adaptive strategies in reaction. This all-encompassing susceptibility mapping can be utilized both to demonstrate the precise exterior climatic and environmental prerequisites that warn fundamental competencies and to formulate strategies that tackle those susceptibilities. A capability-based pathway, in this case, provides a technique of examining the unique necessities of communities, of guiding adaptive strategy toward maintaining or reformulating the particular abilities within hazardous scope from climate change, and of fathoming the accomplishment, or not, of employed adaptive strategies. Both the rights-based and capability-based theories include a wide range of issues related to justice in their potential capability pathway counting equity in distribution, acknowledgment

in the societal level and involvement of public. The climate justice theory for a rights-based approach can be considered as a future scope of this study and will be investigated subsequently.

Data availability statement

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding author.

Ethics statement

Ethical review and approval were not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent was obtained from the individual(s) and minor(s)' legal guardian/next of kin for the publication of any potentially identifiable images or data included in this article.

Author contributions

Conceptualization, methodology, software, formal analysis, investigation, resources, data curation, writing original draft preparation, and visualization: MA. Validation: MA and CG. Review and editing: MA, CG, and JG. Supervision: CG and JG. Both authors read and approved the final version of the manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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8. Discussion: factors of vulnerability for the SWCRB

In synthesis, this thesis followed a structure based on one overarching research question, branched into three other sub-questions. These questions were then addressed through field data collection, employing an interdisciplinary approach based on both quantitative and qualitative methodologies (MMR). This chapter provides an integrated discussion of the papers published during my doctoral research on SLR vulnerability in the Southwestern Coastal Region of Bangladesh (SWCRB), addressing how they have contributed to fulfill the objectives and respond to the research questions raised at the beginning of the research, as well as demonstrating what have been their key contributions to improve academic knowledge on these research topics.

At the micro level, each paper addresses a specific research question (see table below). The aims of the research papers are derived from the research questions in the same way that data analysis is derived from the research objectives. This meta-analysis will be the subject of the current discussion chapter. During the PhD research, six papers were published in peer-review journals, besides two peer-reviewed book chapters. This integrated discussion of the research findings considers the four papers included as chapters in this thesis (chapters 4 to 7) and begins by offering an account of risk, vulnerability, impact, inequality, adaptation and justice. The following figure illustrates the key concepts addressed by this doctoral research.

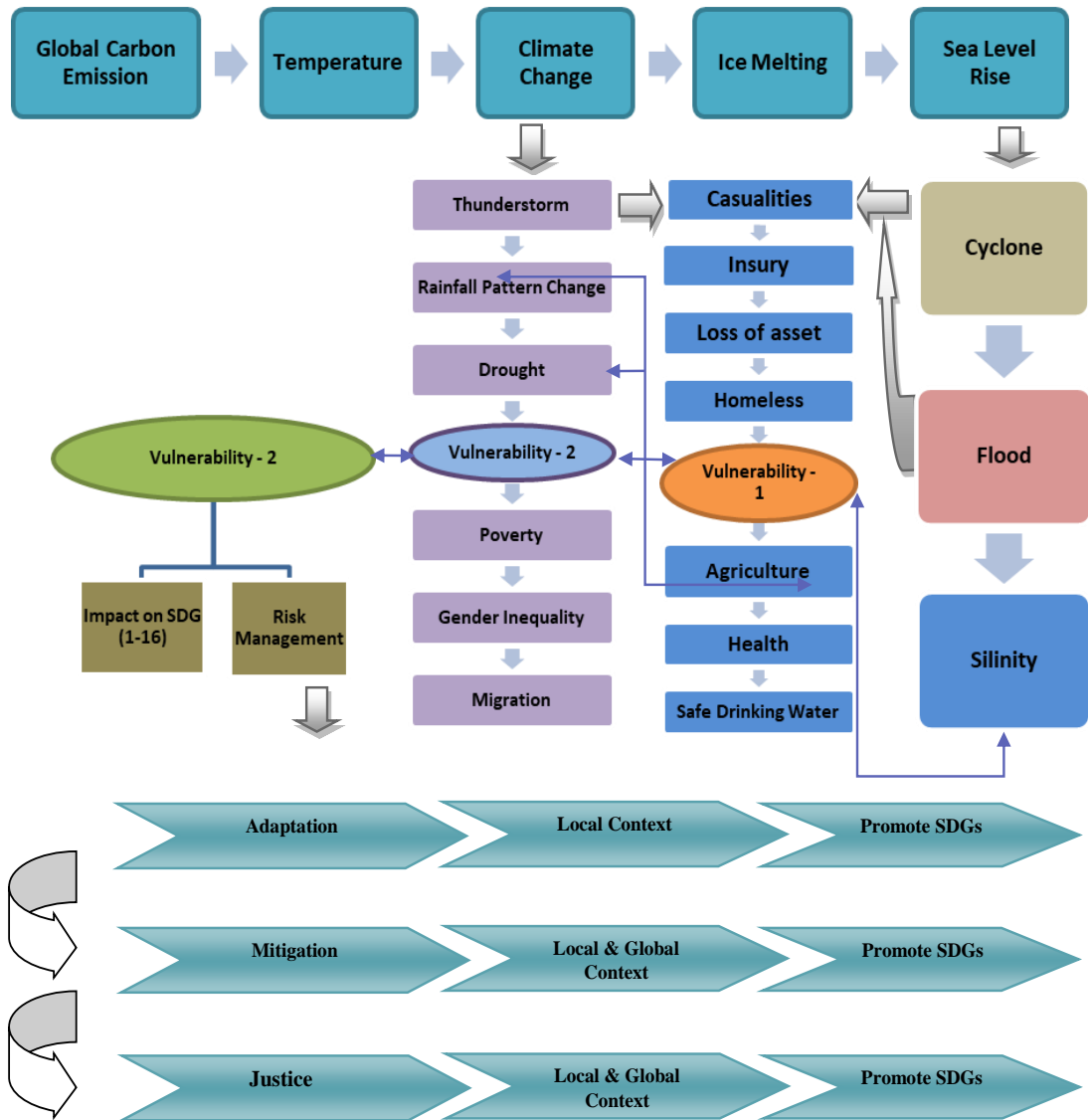


Figure 11: total research findings

The papers’ topics focus on the impacts of climate change (on health, gender, migration, sea level rise, salinity intrusion, natural disasters, and agriculture) and climate justice, adaptation, and vulnerability.

The following table summarizes how each of the papers integrated as chapter results (chapters 4 to 7) has contributed to respond to the research sub-questions, highlighting its main conclusions in relation to the key concepts of the thesis.

Research questions	Papers	Climate change impacts	Social vulnerability	Climate justice	Adaptation practices & strategies
SQ1 – Which are the dynamics and principal impacts of SLR on the SWCRB?	Dynamics and causes of SLR in the SWCRB at Global, regional and Local levels	Global warming , El Nino, La Niña's , Ice melting , Extreme sea levels, Storm Surges: Tropical cyclones (TCs), Extratropical cyclones (ETCs) Thunderstorm , Wind, Waves, Sea surface temperature (SST), Flood Salinity Ocean acidity. Erosion.	Shortage of fresh water, Land subsidence Loss Agriculture Groundwater Salinity, Submergence, Damage, Saltwater intrusion, Wetland loss (and change), Coastal infrastructure damage, Flood defense failure, Increased coral bleaching and mortality, Poleward species migration, Increased algal blooms, Altered water quality , Altered nutrient supply, Increased seawater pH, Ec, Ocean acidification Loss of coastal ecosystem, Loss of biodiversity ,Loss of economic livelihood, Casualties Migration	Reduce Global greenhouse gas emissions	Observed sea level global, regional and local, Improved atmospheric observations. Emerging information on coastal changes in SSTs, Emerging information on freshwater input, Construction of Sea wall.
SQ2 - Which socioeconomic issues and factors most critically influence vulnerability to climate change driven disasters and SLR in SWCRB?	Climate change driven natural disasters and influence on poverty in SWCRB	All above Social Inequality	Loss of house Loss of agriculture Loss of biodiversity Land loss Deforestation Frequent natural disaster , Health hazards Unemployment Migration Damage infrastructure and communication system Loss of Natural Resources Loss of GDP, Food insecurity Loss of life	Sea level rise , Salinity , Frequent Natural disasters, High economic cost of natural disasters, Lack of support, Poverty, Social injustice	Promote probation of Basic needs , Micro finance, Strengthening coastal embankments, multipurpose emergency shelters, Environment friendly agriculture, Ban shrimp farming, protect their assets, Promote early warning and evacuation systems, Promote safety

			Social inequality and wealth inequality reduce job opportunities		net for poor, Improve public infrastructures
SQ2 - Which socioeconomic issues and factors most critically influence vulnerability to climate change driven disasters and SLR in SWCRB?	Exploring gender ad climate change nexus, and empowering women in SWCRB for adaptation and mitigation	All above , Traditional norms, Unavailability of basic need, Religious taboo, Social Inequality, Cyclone shelter is far from home, Lack of high places to build homes, Physical weakness, Helplessness, Nervousness & Fear, .	Gender inequality, Women socially marginalized, Lack land rights, Lack of financial resources (credit), Lack of physical resources (water and land), Women’s extra responsibilities ,Absence of women decision making, Social construction, Water and food issues, Women health issues, Women’s triple role, Reduce women’s economic livelihood, Increase poverty, Income and occupation challenges, Inadequacy of shelter capacity, Rise in workload, Political powerlessness, Collection of firewood, Collection of water, Negligence of health, Increase in stress , Domestic violence, Women empowerment rendered technical, Adaptation measures affect men and women differently, Increase tiger widows.	Climate change and sea level rise, Frequent Natural disasters, Salinity , Traditional norms , Women Security , Gender inequality , Local climate adaptation plan policies not woment friendly , Absence of effective woman governance, Ideology against the women , Absence of reproductive health care, Low volume of employment, Sociocultural relations of supremacy.	Women Empowerment, Cautiously judge every cyclone sign, -safe homes, Share and communicate imminent catastrophe Maintain children in close proximity, Safety net to ailing and elderly , Look for secure positions, Build sanctuaries for livestock, Save lives, Ensuring the safety of food, water, and fuel , Arrange secure drinking and potable water , Female empowerment through employment with land rights, Women friendly agriculture, Female education and building awareness, Micro-finance, Policy formation regarding gender equality,
SQ3 – How do local communities perceive the climate justice	Climate Justice for the Southwestern Coastal Region of Bangladesh	All above, Geographical location, , Negative impacts on basic livelihood,	Basic amenities Poverty Destroyed agriculture & loss of agriculture land , Food insecurity ,	Risks for social justice, Risks for human rights, Harsh economic, and political	Reduce carbon emissions, Committed global governance,

<p>problem and what are their principal local-based adaptation responses?</p>		<p>1970 cyclone 300,000 lives perished, In 1991, cyclones affected almost 100,000 lives.,</p>	<p>Low income Limited employment Human displacement , Migration to Urban slums, Climate refugees Lack of energy Physical trades Women victims Loss of right to society and culture Survival is at stake Socio-economic disparity Saline water intrusion Lack of access to clean water, Shelter, Loss of natural ecosystems, Gender vulnerability and inequality, Food insecurity, Loss of fisheries, Public health factors, Changes social structures , Sanitation Rising water and soil salinity, Uprooted from traditional livelihood Urban pressure , social and economic stresses , Loss of homes and farms, Loss of life, Damaged Infrastructure, Appearance of climatic poverty, Loss of gross domestic product, Loss of natural resources, Desertification.</p>	<p>aspects, Breaches human rights to life, Disparaging wellbeing, and survival, Absence of global agreements, Capitalist ideologies , Inequality, Issues of poverty, Social exclusion, Women have less power , Un-freedoms. ,</p>	<p>Committed local governance , Women friendly adaptation, Reduce shrimp farming Improve human capacity, Ensure human rights, recognition- , Promote agriculture livelihood, Improve infrastructure, Ensure food security, freshwater access, and healthcare, Build embankments, Promote adaptation, Build people own capabilities,</p>
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The paper “Dynamics and Causes of Sea Level Rise in the Coastal Region of Southwest Bangladesh at Global, Regional, and Local Levels” (chapter 4 of this thesis) compared historical and projected sea level change trends for the coast of Bangladesh, the Bay of Bengal, and globally.

Averages were calculated using satellite altimeters, and tide and river gauges. The coast of Bangladesh presents the highest amount of sea level rise, which is a direct consequence of both natural and anthropogenic events, related to subsidence in the deltaic environment, along with higher rates of glacial melt water from the Himalayas, resulting in sea level rise in the Ganges Delta.

Tide gauges (TG) records are crucial for assessing coastal SLR changes because they measure regional sea level, which has been the accepted way to estimate coastal sea level increases (Pugh and Woodworth, 2014). In this context, the main objective of this study was to examine the rates of sea level rise in the SWCRB and compare them to the rates of SLR at the regional and global levels. Ten deltaic gauge stations are used in the study, along with three coastal tidal gauges. Few studies have previously been conducted on the SLR in the Bay of Bengal. The majority of these studies use a single measurement method, such as tidal gauge analysis or satellite analysis. This research, however, used a combination of tidal gauges, satellite altimetry data, and the CMIP5 model. More importantly, earlier studies did not take into account the SLR measurements of river deltas.

Degradation factors occur faster in local areas than in larger areas, and the loose material in the delta is easily compacted, resulting in slow land subsidence and an increase in RSLR of 3.37 mm/year. Since Bangladesh depends heavily on the Sundarbans from a biological, environmental, geological, and economic standpoint, its submergence under specific SLR conditions will have disastrous effects. Melting glaciers have created a shortage of fresh water in the area, forcing people to obtain water from underground sources for domestic, agricultural and industrial use. Excessive surface water withdrawal will worsen land degradation. Land subsidence and uplift can explain the SLR in the river deltas of the study area, as land subsidence contributes to sea level rise in Bangladesh (Brown, and Nicholls, 2015; IPCC, 2022).

Floods, eroding coastlines, elevated storm frequency and intensity, saltwater intrusion, and ecosystem changes all exacerbate the effects of SLR in the SWCRB. In addition, the area receives freshwater from the northern Himalayan glaciers. The salinity of freshwater used for agriculture and drinking can grow as a result of sea level rise since saltwater can increasingly access coastal groundwater sources (Ashrafuzzaman et al, 2022). As a result of glaciers and ice caps melting due to rising temperatures, more water is entering the oceans. In High Mountain Asia (HMA), which includes the entire mountain range bordering the Tibetan Plateau, glaciers also contribute to regional water riches in a number of regions and serve as a hydrological cushion (Bhattacharya, et al., 2021). Greater sea level rise in the Gulf of Bengal is a result of shrinking Himalayan glaciers. The Ganges Brahmaputra Meghna (GBM) delta region of Bangladesh, home to the highest human density in the world, is particularly vulnerable to the effects of climate change and anthropogenic activities (Unnikrishnan, et al., 2015).

In the southwest coastal region, area vulnerable to cyclones, drought, riverbank erosion, and water logging; where the soil and water are salty at certain times of the year; and where living circumstances are difficult, poverty is primarily a serious issue. In order to better understand how poor

households on Bangladesh's southwest coast perceive the connections between poverty levels, changes in natural resources, and natural disasters brought on by climate change, sea level rise, and global warming, the paper “Climate change driven natural disasters and influence on poverty in the Southwestern Coastal Region of Bangladesh (SWCRB)” examined poor households in these communities. This research examined the local poverty rate, as well as wealth distribution, by developing the Gini inequality index. This study's primary goal was to give in-depth information on the most important issues that had an impact on the livelihoods and sources of income of marginalized people in the SWRCB.

This study also analyzed the perception and effect of the local population on the issues that increase poverty, especially those caused or influenced by natural disasters, climate change, and sea level rise, and the means of adaptation, and adaptation measures taken by the respondents. Adaptation measures are improved and discussed for policy makers to reduce the vulnerability of these communities. Lastly, this study discussed possible solutions for the most pressing issues to create resilient communities and establish effective policies to reduce the vulnerability of SWCRB communities.

From this study, we found that SWCRB population largely depends on natural resources for income. However, the SWCRB is one of the most prone areas for natural disasters due to its location and low topography, where floods, freshwater salinity, and droughts are common, as well as challenges from climate change and sea level rise. This study findings shows that a link between poverty and natural disasters (exacerbated by climate change, sea level rise, and global warming) in Shyamnagar Upazila communities, located on the southwest coast of Bangladesh. A total of 320 households were surveyed for their observations through quantitative questionnaires, and qualitative in-depth interviews, FGD, case studies, and group workshops. Findings of this study show that the most popular main occupation of the respondents is fishing, at 33.1%, and second as subsidiary occupation with 36.9% based on Table 1 (Ashrafuzzaman, 2022). Day labor is the second most popular occupation, at 22.2% and fourth most popular subsidiary occupation, at 10.9%. Only 15% of total households have agriculture as main occupation, which is third place, and 36.9% of total households have agriculture as subsidiary occupation, the most popular option of subsidiary occupation (Table 1) (ibid). Although wealth is considerably evenly distributed, the results indicate that presently, the available wealth cannot create favorable economic conditions for most of the population. Our results also contrast to a very similar study carried out by Islam et al. (2019), where 35% of the responders worked in agriculture and only 17% in the fishing industry.

Respondents stated that the implications of climate change and sea level rise included migration, destroyed infrastructure and communication systems, and the loss of land. Responders concluded that the primary effects were the high expenses associated with natural disasters as well as the depletion of natural resources and loss of biodiversity. These three key elements were the most pervasive influences on these communities and the primary causes of poverty. (Lack of knowledge about

livelihoods that are climate-adapted is the largest barrier to respondents' ability to sustain a steady way of life, followed by salt damage to the soil and social injustice. The respondents also identified a lack of finance, a lack of access to service providers, a lack of market demand, and a lack of skills in maintaining a consistent income as issues. This suggests that the impacts of sea level change for local residents are disproportionate.

The study findings indicate that the main factors that are thought to be more likely to cause climate injustice on Bangladesh's coast are salinity, high economic costs of infrastructure damages brought on by natural disasters, loss of agriculture, coastal erosion, monsoon flooding, waterlogging, food insecurity, increased heat stress, declining water levels, desertification, loss of natural resources, human fatalities, and the emergence of climate poverty. A respondent 201, age- 61, from Gabura Union mentioned in the IDI that their house is made of mud and due to constant flooding, his family is below the poverty line. She is also constantly in debt to fix the house. Furthermore, due to embankment breaches that caused the river to erode his land, he has lost his primary source of income. Respondent 202, age 54 of Gabura Union, and Respondent 203, age -48 from Padmapukur Union, also claim that Hurricane Aila (which occurred in 2009) wiped away their communities, forcing them wiped out their community, after that they are rely on government accommodation, now they earn a living by fishing in river water.

Previous studies found a strong and negative relationship between socioeconomic patterns and vulnerability to natural disasters; low income increases vulnerability, since they are not equipped to deal with stress issues (Ha-Min and Hossain, 2020). Bangladesh is highly vulnerable to climate variability and change. Population is at risk of losing property, crops production and life. However, despite the socioeconomic impacts, the coastal areas in Southwestern Bangladesh are not resilient to climate-induced disasters even though the entire countries are not protected (Ahmed 2019; Bianchi and Malki 2021). As a result, any change in the dynamics of the ecosystem is likely to have an immediate impact on people's ability to support themselves (Roy and Sultana, 2010), and the region's economic stability is vulnerable to natural disasters (Lazar et al., 2020).The findings of this study demonstrate that respondents prefer certain adaptation and mitigation strategies for reducing poverty, with the most popular strategies being the promotion of basic services, microfinance, emergency shelters, reinforcement of coastal embankments, and raising public awareness. The promotion of environmentally friendly agriculture, a decline in the farming of shrimp and crab, the development of asset bases, and the advancement of early warning and prevention systems came after these. Finally, it is critical to support public infrastructure and safety nets, which are signs of efforts taken for SWCRB residents' adaptation.

The data indicate that building new coastal embankments, as well as repairing and strengthening existing ones, is the most direct method of adaptation supported by the local community. A community will be better prepared for future natural catastrophes if emergency shelters are installed, soil productivity in salty conditions is increased, and building standards for stronger homes are

developed. Thus, locals can utilize microfinance to purchase farming or fishing equipment that was destroyed by a cyclone or to invest in new supplies or training for switching to a profession that is less susceptible to natural catastrophes. When microfinance is accessible, local populations will be encouraged to spend money on saline-resistant crop seeds rather than being compelled to sell their land (Ashrafuzzaman, 2022). So, this study offers a clearer knowledge of the issues that respondents believe would have the most negative effects on their sources of income and livelihood, as well as those that will become more urgent in the future.

Given the substantial correlation between socioeconomic patterns and vulnerability, the contribution of this PhD study is crucial because it will allow policymakers to better understand the major social and economic problems in SWRCB, and therefore suggest measures to reduce vulnerability and improve resilience at local level. Also, looking at the Sustainable Development Goals (SDGs), this research helps to understand how regional poverty is caused by climate change, which is generating interest in the regional development debate.

Locals in the SWRCB are impacted by climate change in a variety of ways, which are intimately related to the region's persistent poverty and inequities (Sen, 1999). When it comes to vulnerability studies, this form of disparity is seen as a crucial first step in identifying the uneven social structures that have an impact on pastoral and biologically predisposed vulnerable groups (Islam et al., 2020). The productions of sufficient food, as well as the implementation of practical adaptations and preventative measures, are all significantly hampered by inequality. The poor and disadvantaged are unable to manage daily threats and deal with both climate-related and non-climate impacts because of inequality (Tschakert et al. 2013). This study examines adaptation strategies in rural life using a variety of variables, including age, class, and income (Hallegatte and Rozenberg, 2017). According to the many conclusions of this study, climate change makes poverty worse and has a significant impact on the livelihood of Bangladeshis living along the southwest coast, which obscures the pursuit of sustainable development goals.

We hope, this research on policy dimension from local people's development perspective was reduced all aspects of poverty and inequality by 2030, providing the GOB and Stakeholders follow it properly. Thus, it will contribute to policy frameworks, nationally and regionally, based on pro-poor and gender-sensitive strategies.

To help mitigate the negative effects of climate change, the paper "Exploring Gender and Climate Change Nexus, and Empowering Women in the Southwestern Coastal Region of Bangladesh for Adaptation and Mitigation" (published in journal 'Climate', chapter 6 of the thesis) focused on gender inequality induced by it and examined accommodations for women. A total of 320 households were randomly chosen to complete a survey from among the 9 unions in SWCRB. The statistical analysis findings demonstrated that the majority of the survey's perimeter is significant. It was discovered through interviews, case studies, focus groups, workshops, and key informant interviews that climate change affects men and women differently, with women being more vulnerable than males. This

paper examines the key elements affecting women's vulnerability through a case study. Women are equally qualified to lead adaptation efforts with men in terms of empowerment, as this analysis shows that gender differences are mostly caused by social norms. Due to the fact that they exacerbate gender inequalities, women are more susceptible to long-term (sea level rise, saline intrusion in water and soil, land erosion, droughts, and climatic events) as well as short-term (major natural disasters, cyclones, and floods, hazards). Moreover, patriarchy, conventional norms, religious taboos, food shortages, poor health, and illiteracy are all manifestations of gender inequality. However, while household's authority relationships and gender-based socio-economic, cultural, and institutional barriers persist, gender-based economic opportunities, women's mobility, and income are changing. This study explores how women's empowerment, including female involvement in eco-friendly stoves, rural electrification and renewable energy development, microfinance, and nakshi kantha, can reduce women's heightened vulnerability to climate change in the SWRCB. Nakshi Kantha is a unique form of stitching art that is formed by tracing patterns onto plain stitches using various colored threads. Women may make decisions, work with men to lead adaptation efforts, and encourage involvement. As a result, it will support regional and national policy frameworks that focus on pro-poor and gender-sensitive tactics.

The incorporation of a gender perspective represented a significant change in development scholarship (Jonsson et al, 2012; Sen, 2001). According to Sen's capacity approach (Sen, 2001), the removal of unfreedoms is critical to have the ability and capacity to act and enable people to be agents. Taking account of this, under certain climatic events, impacts, like impoverishment, women's potential capabilities may not be achieved. In this sense, empowerment is very important to enable people to have access to more choices and alternatives. Women are active agents of change, able to promote the required social transformation to alter the lives of women and men and play an important role in the potential of adaptation to climate change (Lama and Webster, 2019).

One of the most urgent challenges of our day is the connection between gender inequality and climate change. Natural disasters frequently occur in Bangladesh's coastal regions, making women particularly vulnerable. Yet, little is known about how gender differences are impacted by climate change. In order to comprehend women's empowerment, climatic danger, damage, cultural practices, modifications, and recovery from natural disasters, this study was conducted in the southern coastal regions of Bangladesh. When a disaster strikes, women face different difficulties than men. For example, they may experience problems with their income, be denied access to supplies, experience sexual annoyance, or have fewer opportunities to participate in household decision-making. Contrarily, adversity can also bring about constructive effects that contribute to women's transformative role yet are frequently underappreciated. To investigate how SWRCB climate vulnerability, mitigation, and adaptation measures assist in achieving Sustainable Development Goal (SDG) 5 (gender equality), this research takes a gender perspective. This study examined both quantitative and qualitative data using FDG, case studies, key informant interviews, and IDI in the

SWRCB to better understand women's vulnerability and increase women's empowerment. According to research, women in the SWRCB are becoming more gender-focused in their climate actions, which has a beneficial effect on gender equality and improves gender balance in climate change.

Impacts of climate change are projected to have an especially severe impact on women's access to credit, markets, education, and information, as well as to natural resources (particularly land and water). Despite the fact that the developmental theory analyzes This shows that women are more vulnerable to climate change than men are, generally speaking (Sen, 1999; IPCC, 2007; Terry, 2009). In the SWRCB, where men have easier access to land, for example, the IPCC acknowledges that climate change has a special role in the persistence of gender inequality (IPCC, 2014). Climate change-related weather events and disasters, which widen the gap between social, economic, and cultural rights and sustain vulnerabilities (Terry, 2009), bring attention to the gender inequality that already exists. According to a majority of respondents (87%), the most vulnerable groups to the changing patterns of climate change include women, children, the elderly, and those with disabilities. The study's findings demonstrate that women are more susceptible to climate change than men are because of their poverty, social and cultural standards, and religious limitations. Hence, advancing women's rights and raising their socioeconomic standing are tools for reducing gender disparity.

According to earlier research, women in many poor nations were more susceptible to the effects of climate change and dealt with its effects differently (Sen, 1999; Terry, 2009). Women were the most neglected and vulnerable to reproductive and sexual health issues due to the lack of healthcare, which were some factors noted during catastrophic events (Nishat and Rahman, 2019). Gender features and patriarchal norms were shown to be significant social impediments for them in the majority of cases (Kabeer, 1999). The effects of climate change, such as an increase in disasters, also exacerbate gender inequality and make women more vulnerable (Sen, 1999; IPCC, 2014). In order to comprehend the issue of adaptation in vulnerable areas, it is crucial to look into the impact of gender (SWRCB).

Women are crucial agents for climate change adaptation in the SWRCB, and it is crucial to strengthen their rights and socioeconomic status in order to empower them and develop resilience, according to this research, which took into account the significant roles that women play in the adaptation process, gender disparities in vulnerability to climate change, and complex relationships between gender and climate change. In this sense, the goals of this research were to investigate the main causes of women's vulnerability to climate change and their crucial role in adaptation, how the local communities perceived these vulnerabilities and empowerment, and what the general consensus was regarding the relationship between climate change and gender. Research involved four cases of women's empowerment and field work to address these topics.

Improving and enhancing economic activity for women and their families is a primary driver of the implementation of gender-sensitive analysis and socio-economic empowerment (Jönsson, et al., 2012). The motivation for women's empowerment does not seem to be a desire for gender justice in

and of itself, but rather to improve coping mechanisms. Even if women's empowerment is used as a tool for social advancement, however, women's empowerment instruments may mask the visibility and potential of constructive outcomes (Li, 2007; Fielding-Miller, et al., 2020). A critical examination of the local processes of inequality and empowerment in the context of the world's political and economic system is also necessary.

Tania Murray Li (2007) has described a process which she calls 'rendering technical'. In this process, an issue is formulated in technical terms, with specifiable limits and particular characteristics. It involves the definition of boundaries, rendering that within them visible, gathering information and devising techniques to mobilize the revealed forces and entities. Rendering technical is the term Tania Murray Li (2007) uses to describe a process. Through this procedure, a problem is expressed in technical terms, complete with boundaries and distinctive qualities. It entails defining limits, making what lies within them visible, gathering data, and developing strategies to activate the forces and entities revealed. Murray contends that the presence of a solution is directly related to the identification of a problem. The absence of women's land rights and earnings as technical "issues" amenable to the technical "development" intervention in our study is an example of this second aspect of the rendering technique, which concurrently renders an issue nonpolitical.

Findings indicated that women in the SWRCB were more susceptible to the effects of climate change and they dealt with them in different ways. Notwithstanding these disparities, they were strong forces for adaptation and change. It was discovered that reinforcing the values placed on women in the family and society is crucial in the process of removing restrictions to improve women's capacities. According to study instances, women could be empowered by using eco-friendly stoves, participating in solar projects for SWRCB electrification, starting a small sewing business called Nakshi Kantha, receiving microloans, and educating her children to combat gender bias.

Sen's capability approach was supported by this study, which also highlighted the value of empowering women to be effective change and adaptation agents. People should be viewed as agents rather than patients, according to Amartya Sen (2001). Individuals should be provided the tools they need to act and value their surroundings because they have these capacities. The eradication of unfreedoms, such as local customary norms, patriarchal oppression, or poverty, which limit women's talents, is a requirement for enabling people to become agents, according to Sen (2001). Our examination of gender equity has three implications, which we have emphasized. In order to better manage the effects of climate change, women's rights must be strengthened, as well as their socioeconomic standing. Additionally, resilience must be built through women's empowerment, and income must be increased through women-friendly, low-carbon renewable energy sources. In addition, microfinance must be given priority in order to raise the social standing of women. A greater understanding of the intricate connections between gender and climate was also made possible by the research.

Chapter 4 of this thesis includes another paper published during the doctoral research, “Climate justice for the southwestern coastal region of Bangladesh” (published in *Frontiers in Climate*). Climate justice is a framework that shows the intersection between the experiences of social inequality, climate change, sea level rise and structural violence. Climate justice has grown in public debate and grassroots campaigning over the past decade, especially increasingly making connections between human rights, unequal development and climate change. Often presented as a question of human rights, often discussed in a capability-based approach, climate justice debates often focus on the distributional impacts of climate change – pointing out that these impacts disproportionately burden the poorest and least disadvantaged.

Because the region’s most severely harmed by climate change typically the least developed countries are the ones that contribute the least to greenhouse gas emissions, this inequity is evident. Bangladesh is regarded as the second-most vulnerable nation to the effects of climate change, although it is also one of the nations with the lowest CO₂ emissions (Eckstein et al, 2019). Past studies have examined the dangers of climate change and sea level rise (CCSLR) in Bangladesh from several angles (such as adaptation and human security risk) (Rashid and Altaf, 2020; Islam et al., 2020). Few studies, however, have examined the connection between climate justice and CCSLR vulnerability along Bangladesh's coastline (Rashid and Altaf, 2020; Islam et al, 2020). Environmental policy priority are required for individuals living in impoverished and lower-emitting nations, notwithstanding the current political discussions on policy focusing on climate justice at the global and regional levels (Ahsan, 2019). It is critical to concentrate on local vulnerability given the uncertainty surrounding international climate justice policies.

As a low-lying deltaic coastal Bangladesh, environmental changes are likely to have a multifaceted negative impact on the wellbeing and livelihoods of the local population by exposing the vast coastal populations to multiple hazards with increased severity and frequency. According to Gain and Giupponi (2014) and Mirza (1998), the Ganges delta's upstream rerouting and decline in the flow of clean water reveal that deltas are extraordinarily common active coastal systems connected to both land-based fluvial and coastal ocean advancement. The world's biggest deltaic population is concentrated in Bangladesh's Ganges-Brahmaputra-Meghna (GBM) delta, which is particularly vulnerable to the effects of climatic change and human activity ((Paszowski, et al., 2021). This study investigated how residents of the SWRCB saw the disastrous effects of climate change and sea level rise, which include extreme natural disasters, seasonal shifts, flooding, salinization, riverbank erosion, and waterlogging. As a result of these climate-related changes, the coastal people are losing their homes, means of support, and land, as well as their access to healthy food, clean water, and medical treatment, aggravating social inequity.

Some of the key research findings we got in our research from the FGD, IDI, KII, PRA and workshops reveal how risks, hazards and increased vulnerability are more intense for indigenous communities and marginalized groups. For example, the lives of the Munda indigenous people and

other marginalized populations are quite different from other regions. The livelihood of these people depends on the Sunderban mangrove forests. These communities are not well recognized with politicians or other social stakeholders. Under extreme circumstances, they always struggle with the impacts of climate change. Thus, inequality is formed between the mainstream people who get facilities to boost up their living capacity and those marginalized people who are deprived from the facilities which they need more. The Munda indigenous people's house and other infrastructures are not durable fighting against natural calamities, and these peoples are not well recognized by the society and politicians. As a result, the governmental or other non-governmental donations are not distributed among the needy people.

A disaster risk assessment using PRA was done in the 12 unions of the Shyamnagar Upazila in order to comprehend the danger of vulnerability in this study. According to the evaluation, the top six hazards and disaster risks are listed in this study and include cyclones, salinity, floods, waterlogging, riverbank erosion, thunderstorms, and drought. Depending on where each union is located, different dangers exist. The most often mentioned dangers were cyclones. Salinity was the most frequent danger, then riverbank erosion, and finally floods. The SWCRB's experiences with such elevated risks serve as a prime example of the concept of climate injustice (Holden, 2018).

In coastal regions, the human capacity, financial conditions, infrastructure quality, and social status varied by location. Therefore, inequality was formed between the mainstream residents with access to facilities to better their standards of living and those marginalized that are in dire need of facilities but are deprived from the same. It is worth noting that the majority of the respondents felt that the disasters faced by them were unjustified and that the developed nations and local system are accountable for the direct/indirect impacts of climate change. This is a very important observation which builds on the concept of climate justice at both global and local level.

People in the SWRCB have contributed the least to climate change and are therefore most vulnerable to its impacts due to factors like lack of security, precarious financial situations, a lack of knowledge of human rights, and geographical sensitivity (Dasgupta et al., 2017). Concerning social, economic, and political facets, climate justice is a complicated subject. Given the social injustices brought about by climate change, current political policy discussions frequently center on climate justice at the regional and global levels; however, special focus is currently required on the environmental policy priorities of people in underdeveloped and low-emitting countries (Adel, 2020). According to Thomas and Twyman's 2005 discussion, countries that depend heavily on natural resources are normally more susceptible to the effects of climate change and typically have a limited capacity to adapt to changes. The move away from agriculture as the primary source of income and the development of shrimp farming demonstrate that the local population has already begun to put adaptive measures against CCCLR's harmful impacts in place. Additional examples consist of planting rice with different maturation dates or salt-tolerant crops, rainwater gathering, using floating gardens in floodplains, fish and rice aquaculture techniques, and pond sand filters (Hossain et al.

2018). They require reparations and reconstruction since they are less adaptable than other coastal populations.

The complex link between politics and climate justice makes global agreements extremely difficult to implement (Beauregard et al., 2021). Bangladesh does not establish specific strategy rules for climate refugees in the NAPA or the BCCSAP at the national level. Many states repeated their promises during the COP, or Conference on Climate Change, which is organized by the UN. Experts and campaigners, however, contend that none of these renewed agreements is sufficient to address the climate change effects that are rapidly arriving (Arora and Mishra, 2021). To combat climate change, the agreement should be more strictly enforced. Although financial support is needed to assist the disadvantaged countries, and recently significant progress has been made in Glasgow to reduce greenhouse emissions (Jacobs, 2021).

This study also offered a capability-based approach to climate justice that enables locals to plan and reconstruct their own communities as well as develop adaptive strategies based on their unique skills. This strategy calls for remuneration (funding) from the international community as well as organizational ties between locals and other stakeholders. People in the SWRCB are choosing to participate in policy making and manage disasters on a local level. These communities need to develop their infrastructure and embankments sustainably, and they also need to have access to drinkable water at reasonable prices. In addition to taking immediate action to reduce greenhouse gas emissions and choosing renewable energy to avert the worst-case scenario, industrialized nations should offer this compensation for climate change. Finally, rights, compensation, and relocation aid must be given to forcibly displaced climate refugees. Politicians are currently debating climate justice on a global and regional scale, but those who live in underdeveloped and low-emitting countries need environmental policy priority (Ahsan, 2019). It could be noted that SWCRB has been regarded as one of the leading innovators in the national context of climate change adaptation to safeguard people, but it is not feasible without lowering global carbon emissions and a global political commitment to achieve climate justice.

Four significant, interrelated components make up the main assertion of climate injustice. First, there is a significant gap in who is causally responsible for greenhouse gas (GHG) emissions that are a result of climate change. It is impossible to avoid discussing historical responsibility for climate change in discussions about climate justice (Agarwal, et al., 2017). This is especially true given its connections to other aspects of climate injustice.

Because of the unequal distribution of climate consequences and preexisting patterns of privilege and marginalization, the second and third dimensions of climate injustice are indissolubly intertwined (Tschakert et al. 2013). Due to their limited ability to adapt, low-income and socially and economically marginalized populations, those with chronic illnesses or social isolation, the elderly and young, and vulnerable populations will be disproportionately impacted by climate change (Baker 2012). These changes occur both domestically and internationally.

The concept of the fourth justice dimension arises from the recognition that the causes and impacts of climate change are not limited to specific locations or timeframes but extend across boundaries. This dimension encompasses the social, temporal, and spatial barriers that separate those who contribute to climate change and those who bear the brunt of its consequences. It highlights the challenges faced in making decisions and assigning responsibilities in the face of these barriers. The fourth justice dimension brings attention to the complex dynamics that emerge when emissions and their effects create distances, both physical and social, between those who benefit from certain activities and those who suffer the most from climate change. It underscores the inherent difficulties in addressing these issues and achieving justice. One aspect of the fourth justice dimension is the presence of actors who reside within a jurisdictional boundary but are not directly accountable to the authorities. This highlights the challenge of holding those responsible for emissions accountable when they operate outside the jurisdictional framework. Similarly, individuals within a jurisdiction who are affected by climate change but are not recognized as influential decision-makers or analysts face exclusion from the decision-making processes. The fourth justice dimension poses a threat to procedural justice, which emphasizes fair and inclusive processes in addressing climate change. The exclusion of the most vulnerable individuals from jurisdiction-specific trials undermines the principles of procedural justice, as they are deprived of their voice and agency in shaping decisions that directly impact their lives. Recognizing and addressing the fourth justice dimension is crucial for achieving meaningful climate justice. It calls for inclusive and participatory approaches that consider the diverse perspectives and experiences of those affected by climate change, irrespective of their social, temporal, or spatial positions. By acknowledging and addressing these barriers, we can strive for more equitable and effective climate action.

9. Conclusions and recommendations

Bangladesh is one of the most disaster prone and climate vulnerable countries in the world. It has unique geographical patterns (low elevated) that produce specific climate change impacts of sea level rise. Based on tide gauges, satellite altimeters and CMIP5 Model show that SLR projections where the regional trend is higher than the global average and average river gauge trends are higher than global and regional trends. According to the results of this study, the coastal tide gauges records from 1993 to 2019 along with the projected trend until 2100, SLR Hiron Point, Char Changa, and Cox's Bazar had greater trends than regional and global averages. This study proved that local variability differed greatly from both regional and global localities, with five river delta stations showing much greater SLR rates than global and regional values, with two coastal gauges projecting a change of more than 1000 mm from 2020 to 2100 magnitude. Similarly, invariant, and even decreasing trends were recorded.

SWCRB is at special risk because of its low elevation, the confluence of three major rivers and the reduction of upstream freshwater supply. In the Southwestern coastal territory the dominance of sea level rise is perceived through 1) provoking deluge, flooding and storm surge impacts in low-lying coastal borders and land subsidence 2) ongoing coastal deterioration 3) impacts on coastal ecosystems like saltmarsh, mangroves and coral reefs, 4) saline water intrusion into exterior and underground waters and 5) alterations on residue accumulation down the river courses. Every part of the eleven specious deltas of Asia is defenseless to the impacts of climate change and sea level rise, and saline water intrusion into the freshwater supply has been noted. Climate change is likely to worsen these phenomena.

Furthermore, this study refers to the chemical element analysis where the findings show that in high salinity conditions more than 95% of the samples which were having ECe dS/m values greater than 8 dS/m across all sample areas. It also has a major impact on agricultural production as only some salt-tolerant crops can produce satisfactory yields in these areas. The results showed that most of the samples exceeded the permissible limits of salinity in the sampling area, especially in river water (>30 dS/m). Continued use of saline water is a major threat to human health and agriculture. The analysis showed that more than 83% of soil and 41% of water samples have medium and high salinity (>0.3% salt) and this indicates very unacceptable for soil fertility and safe drinking water standards; And in 82% and 96% of samples sodium and chloride levels in water were unacceptable for safe drinking and agriculture. The results of the river salinity analysis show a pattern of spikes or increases in both salinity and chloride at the Kalaroa, Benarpota and Elarchar stations of the Bangladesh Water Development Board that affect every aspect of human livelihood. This research calculated the areas affected by different seawater surges, three different storm surge heights were used, 1.5, 5.25, and 9 m as the minimum, mean and maximum surge height. Results show that one large storm surge is predicted, covering 12 percent of the region every five years on the coast, and one

third per 20 years. More than half of the Shyamnagar Upazila, on the other hand, is affected every 5 years and almost entirely every 20 years. Furthermore, a Digital Assessment Model (DEM) was used to estimate storm surges by inducing salinity in the respective affected areas. Potential scenarios of storm surges of 1 to 9 m height may affect 1% to 33% of the country and 6% to 97% of Shyamnagar upazila and may affect 1 to 38% of the country and 9% to 93% of Shyamnagar upazila area in 2100. However, the estimated storm surge associated with the cyclone will increase further and may make Shyamnagar Upazila district unsuitable for agriculture and permanent settlement. Climate change will increase the harmful geochemical consequences of salinity as a result of sea level rise and saline water pollution in the near future.

Approximately 70% of the coastal areas globally are predicted to undergo remarkable sea level rise, and this is applicable to the coastal areas of Bangladesh. The coastlines of Bangladesh are critically impacted by climate change in the coming decades. The rise in the air and ocean temperatures drives sea level rise and more frequent cyclones, representing a looming danger for livelihoods, local ecosystems, species and human lives. Due to imbalances in rainfall and temperature patterns, hydro-meteorological calamities are turning out to be occurring more often in Bangladesh, e.g., tidal increases, flooding, cyclones, sea level surging, coastland and river margins erosion, suffering from clean surface water supply, saline water concentration increase, long heat waves resulting in loss of crops, heat severity and rainfall triggered landslides, and sudden occurrence of flooding. The climate triggered severe weather occurrences and linked calamities are creating difficulties, like land soil deterioration, reduction of crop harvests, threatening agricultural sustainability and food security, water carrying illnesses, endangered sources of income, gender discrimination, compromise in human wellbeing, human displacement and migration, social instability, joblessness, impoverished status, eventually inducing social clashes. Besides, due to frequent climatic disasters, most people who are dependent on the Sundarbans forests for their livelihoods, such as fishermen or honey collectors, have been forced to switch their professions.

Longer-term consequences encompass loss of marshlands and environmental changes due to sea level rise and salinity, deterioration of beaches and less robust cliffs, and saltwater intrusion into groundwater. Due to climate change scenarios, water accessibility and sea level cause salinity issues in SWCRB are increasing health issues, e.g., water sources related to waterborne diseases, and the relationship with heat waves can exacerbate health problems related to high blood pressure, leading to cardiovascular diseases. Vulnerable population groups in the SWCRB, such as the elderly, women, and young children ultimately bear the greatest burden of health risk, in great part due to lack of safe drinking water. Future deterioration of water quality raises concerns about health risks.

The findings of this thesis show that SWCRB is greatly vulnerable to driven climate change impacts like SLR, which affect the quantity and quality of water and lead to the use of unimproved sources that cause increase in water-borne diseases. Increased salinity in water is related to important health issues like hypertension and pre-eclampsia, skin diseases, respiratory infection and diarrhea

diseases, as well as transmission of mosquito-borne diseases. Research results also show that the most used water sources are rainwater harvest, pond, hand pump, river and supply water, and at the same time these sources are related with the highest number of waterborne diseases. Most people admit that available drinking water does not meet their household needs, and they also perceive that sea levels have risen during their lifetime. The connection between drinking water saltiness and related to health issues in SWCRB which Results reveal that safe drinking water is affected by climate variability and change. Local people mentioned that it is difficult to access protected drinking water, and they perceive that health care options in this region do not cover the number of health issues cases, and through this study it was found that half of people were affected with the health problems during their lifetime, due to unsafe drinking water. Women and children are the most vulnerable to this salinity related waterborne diseases. Pregnant women suffer from different diseases related to high blood pressure, urinary tract infection, malnutrition, anemia, eclampsia, cardiovascular diseases and so on. During and after effect of the disaster which causes cough or cold, diarrhea, pneumonia, malaria, and other diseases among children. Women and children have specific nutritional needs; they tend to suffer more due to nutritional deficiencies. Therefore, a high vulnerability was identified, and it is worsening with climate change. These results reinforce inequities between the core and the periphery, demonstrating that low CO₂ emitters have a higher vulnerability to climate change impacts.

The studies included in this doctoral research found a strong and negative relationship between socioeconomic patterns and vulnerability to natural disasters. Low income increases vulnerability and reduces capacity to deal with stress issues. Despite the socioeconomic impacts, the coastal areas in Southwestern Bangladesh are not resilient to climate-induced disasters. It has also been found that most of the respondents of the surveyed households live in predominantly rural communities and depend on fishing and agriculture, and more than half are living below poverty. Through the analysis of the Gini coefficient, this study found that there is an enormous increase in wealth and income inequality which creates poverty and injustice. 62% of the surveyed population is below the poverty line with a relatively low Gini inequality index of 28.5, and 84% have dwellings of non-disaster-resistant material. The wealth inequality of the study area in the SWCRB is high compared to national levels. Communities' income and livelihoods are heavily dependent on natural resources, such as agriculture, fishing and gathering primary materials. Also, they are unable to withstand disasters due to poor infrastructure, historically have higher mortality rates during disasters, and little economic means to prepare for disasters and invest in safety measures. The increase of salinity has decreased the income generated by agriculture, worsening poverty and forcing communities to adopt brackish water shrimp farming as an alternative. Moreover, this study demonstrates the vulnerability of women to climate change in the Southwestern coastal areas of Bangladesh. Women generally have limited assets, low-productivity livelihood options, such as small-scale agriculture, vegetable gardening around the home, poultry and animal husbandry, and small businesses, otherwise day labor of shrimp farming and agriculture land. The responsibility of a woman is not limited to managing the

family but also earning money for the livelihood of other members of the family, including her children. Climatic events affect their food security, access to drinking water, sanitation and health. Women's strong reliance on the environment makes them very vulnerable to disasters.

From this study it is imaginable that all responsibility for climate vulnerability is global carbon emissions. It's not true. Evidence is that local ideology, practice, rules and local hegemony, such as the vulnerability of women in SWCRB, is caused by economic, environmental and sociocultural factors. As demonstrated in this research, the various concepts along the gender and climate change nexus carry different meanings, and consequently lead to different ways of framing the problems and solutions in this area. A woman's right to join the decision-making process is commonly what gives a woman power at the local level. Social norms and traditional rules have undermined women's status in the SWCRB and rather disempowered them. The aspect of adaptation is linked with the concept of empowerment as something which will bring a woman power and respect. This is further framed within IPCC's, Sen's, Kabeer's, Terry's and Li's concept of women's vulnerability, agents, capabilities, gender equity, freedoms, adaptation, power structures, empowerment for efficiency, women empowerment is a rendered technical. Looking into how men face adversity and deal with the loss of women may be just as illuminating as understanding what women experience. Generalisations about women and their perceived vulnerability or virtuousness with regards to climate change are at risk of rendering gender inequality invisible and oversimplified.

Climate adaptation policy has not had optimal effects on women empowerment earlier because it did not adequately consider cultural, social and political structures and inequalities in human society. Earlier the adaptation process was not concerned with how and in what way women actually achieve power. Importantly, the restrictions of empowerment rights on a local level were derived from patriarchal norms and social norms discourses. Such tasks which often derive from and are decided by religious taboo in developed nations because of a lack of education. Though the women's physical security context religious rule gives some advantages, in developing countries national rules and regulations are fragile. Additionally, rules are imposed on women in developing nations, due to ignorance or neglect of economic and land rights. The current religious tendency within the local level is to favor the notion of "women as mothers" and that "our religion grants women much respect", and to frame the women in terms of 'respect' rather than 'rights'. These tendencies can be described as a process of rendering the issues in question technical and nonpolitical. The identification of a problem is intimately linked to the availability of a solution, according to Tanya Li. Empowerment is not a static concept; it is highly context based and culturally and socially varies from one society to another. The reason why some women act differently concerning adaptation and empowerment is dependent on the cultural context they act within.

Local communities also recognize that climate change and sea level rise have an anthropogenic origin, with very devastating effects, which are not only global but also regional and local. Farmers who account for a lesser influence on climate change are facing its multidimensional effects. In

SWCRB agriculture is one of the segments most vulnerable to climate change. It is not only a function of climate change characteristics, but involves other factors like cultural and socioeconomic patterns, its sensitivity, and its adaptive capacity. Some complex climatic and non-climatic indicators are the link with vulnerability of agriculture to climate change. One of the most important climate change impacts on agriculture in SWCRB is salinity intrusion caused by SLR, results show that capitalist farmers convert agricultural land to shrimp cultivation as it is the high profitable and that is impact on poor marginalized people. Rising sea levels, combined with rising salinity due to the cumulative effect of all upstream meanders, have also profoundly affected the quality of soil and the nation's groundwater. Farmers are at the forefront of climate change impacts, with changes of weather patterns currently affecting their crops and their livelihoods.

Through the study findings it was found that migration is a multi-causal event; besides climate as an important driver, it is generally compounded by social, economic, political, and other different variables, which lead to a push and pull factor migration in the SWCRB. By 2050, one in 45 individuals globally and one in seven individuals in Bangladesh will lose shelter due to climate change. It raises important concerns to governments and policy makers around the world, since millions of people cannot migrate legally and there are no international laws to protect them. This research has contributed to filling some gaps in the human rights-based framework in what concerns climate change driven migration. The human rights-based approach provides a conceptual and practical framework to protect human rights during and after climatic events. However, there is a lack of an international framework for people who migrate due to the negative impacts of climate change. A key finding of this research is the link between migration patterns in the SWCRB, climate change and climate injustices.

However, adaptation plays a critical role in reducing vulnerability to climate change. It is the process to adjust to actual or expected climate extremes and their impacts, while taking advantage of potential new opportunities. This process requires some transformations and there are some important features influencing these adaptation changes (IPCC, 2022).

This research considers local adaptation mainly as a safeguard against risk, hazards, and vulnerability through qualitative and quantitative analysis. Important adaptation strategies and practices in the SWCRB, like early warning systems, adaptation on agriculture, fish farming, and structural adaptation, adaptive alternatives in relation to adverse situations, saline tolerant agriculture, rainwater harvesting, secured drinking water adaptation, homestead plinth raising, homestead gardening, salt-tolerant fish farming, heightening pond boundaries, structural adaptation and increasing community resilience. In addition, there are adaptation initiatives of the population that are assumed by diverse organizations, like modernization of the drinking water filter, and construction of embankments. They repair or build a raised, strong pond wall to protect saline water and use netting to protect crabs from heavy rainfall and inundation, which is really tough and stressful sometimes. Rapid flooding and heavy rain pose some challenges in maintaining a favorable environment for this

system. These results contribute to reinforce the concept of adaptation in the literature review. Nevertheless, eight climate change adaptation practices were found in the SWCRB: agility, interchange, allocation, sharing, variation, magnification, novelty, and revival. Further, local adaptation provides life and moderate scale livelihood protection during disasters in recent years. Even key components of indigenous or local adaptation techniques and knowledge practices (ITKPs) have taken importance for the SWCRB communities. As an adaptation strategy, they now fish in the river, farm shrimp, catch crabs, run small businesses and collect wood from the forest; they also sell clothes in the village. But in general, these communities are constantly struggling with poverty. Poverty in these communities is reinforced and prolonged by environmental and climatic issues. Similarly, based on projected climate changes and sea level rise, measures, such as natural disaster prevention education, access to safer construction material, and the introduction of salinity resistant crops will greatly help to achieve sustainable development goals of poverty eradication, water supply, safe coastal cities, food security, healthy living and sustainable economic growth, and will help protect terrestrial ecosystems and biodiversity.

Conversely, women are important agents for climate change adaptation. According to Sen's capability approach, it is critical to remove un-freedoms to have the ability and capacity to act as agents (Sen, 2001). Therefore, women empowerment is very important to enable them access to more choices and alternatives. Study cases show that they can get empowerment through active participation in different activities (e.g., environmentally friendly stoves, being partners of solar projects on electrification, small sewing businesses that encourage women to become self-sufficient, microfinance, and reducing gender bias through her children's education). These findings strengthen theories and approaches like Sen's capacity approach and demonstrate the critical role of women for adaptation and the importance of their empowerment. Also, these results contribute to understanding better the complex relations between gender and climate change. According to a survey question based on people's expected agriculture adaptation in this research to test the multinomial logistic regression, statistical significance indicates that the full model represents a significant improvement in fit over the null model, whereas the deviance chi-square does indicate a good fit.

Nonetheless, global climate governance still faces some challenges, besides the United Nations and bilateral donor agencies are the main actors providing services of adaptation. There are debates about local and global aid effectiveness, and these affect the agriculture, health, poverty, and gender issues directly. As an important component of global and local governance support, all climatic vulnerability aid should consider not only the technical ways but also the economic and cultural context of different countries and take politically smart methods which understand local realities. Lack of gender equality, increased poverty and wealth inequality, declining agriculture, lack of health care services and access to safe drinking water are not only a global burden, but are also due to a lack of national initiatives for environmental justice at the local level. Climate change impacts are entirely linked to challenging issues of reducing carbon emissions and local policy.

SWCRB communities are marginalized people who are deprived from their fundamental rights. So, they always struggle to develop their capacity for coping with natural disasters which are consequences of climate change. In regard to improving local settings regarding the concern of weaknesses, fundamental necessities and rights and human thriving, this kind of involvement is essential. People in SWCRB have implemented a number of adaptation strategies to CCSLR impacts; however, it is not possible to reach this process without a political commitment to achieve climatic justice. Protecting the SWCRB region would require a uniform carbon budget of 1.5 °C. The global problem of climate justice has faced ever-increasing debate, both among scientists and policymakers. Despite increased attention, the impact of global warming on justice at different levels remains uncertain.

Referring back to the concept, this research, and development process has rendered it difficult for capability adequacy to be achieved seeing that climate change somehow relies on inequality. This aligns with Sen's (1999) notion of capabilities: the ability to achieve the life which marginalized people want that is undermining all aspects of life, and inequality is such paucity which provokes challenge at several levels, and powerlessness and inequality limit a person's ability to choose freely. Indicators of access to resources, achievements or evidence of agency can only have meaning if they look at the array of possibilities in which people are located (Kabeer 1999). There is a need to pay attention to the gaps between what policy makers think and the complex realities on the ground. Even if policy makers are not intent on eradicating equality and justice as a standalone goal, misunderstanding will lead to unwanted and inefficient outcomes of policies. This is an issue that is even more pressing with regards to climate change since we are dealing with a situation in which the scale and speed of changes are intense and which will have known and unknown repercussions.

This research highlighted the allocation or rights-based approaches for climate justice such as fundamental human rights, rights for advancement, ethical justification, and environmental rights. Through the capability approach it acknowledges different social and political circumstances. People in SWCRB are conscious of their rights and they often request embankment building. Results also reveal that SWCRB is considered one successful pioneer in the national context of climate change adaptation; however, a global political commitment for reducing carbon emissions is needed to achieve climate justice.

As temperature rises, extreme weather events are becoming more frequent and severe. Climate change and sea level rise have created many challenges that hamper ordinary life in the SWCRB, resulting in low incomes and inequality. Rising sea levels can affect three times more people by 2050 than earlier assumed. Additionally, 300 million people living in the coastal areas of China, Bangladesh, Vietnam, and Indonesia will be recurrently flooded which leads to climate refugee and effecting human rights and justice. Such disparities of contributions and impacts have led to climate justice demands and movements. Within this above context the growing concerns about the equitable sharing of climate change burdens and benefits, climate justice approach movements are at the center

of global agendas and discussions, with the climate change driven sector increasingly threatened by anthropogenic climate change. Ensuring climate justice is essential to protect the rights of vulnerable people and communities.

9.1. Contribution for policymaking

The set of research papers focus on the SWCRB area and explore diverse topics related to SLR, like local SLR rates, salinity intrusion, health impacts, agriculture, vulnerability, adaptation, migration, and climate justice. Measurements of sea level rise through tidal and satellite altimetry data, image and the CMIP5 model are rare in the context of the Bay of Bengal. Additionally, earlier research in academic oceanography has not considered river deltas for SLR measure. Therefore, this research brings an important contribution for better understanding local coastal area SLR rates patterns, which helps to reinforce the dynamics of RSLR which is fundamental to enhance SLR projections models. It helps the policy maker decide what type of initiative needs to be taken on a global and local level. Through this research we came to know detailed and accurate effects of soil and water salinity on crops, fish, and livestock, especially in the agricultural and health sector. It helps to know stakeholders' perceptions on levels of salinity, which will be important for existing and future adaptation processes. Salinity research provides important information on impacts on soils and a better understanding of the interrelationships between water and soil. It is filling gaps in the understanding of salinity impacts on soils and water, since the research considers the links between water and soil, these results are more comprehensive in the context of understanding the compound impacts on local livelihoods. This information is critical to propose policies toward a decrease in vulnerability. Women and Children were the most vulnerable to climate related health problems, during and after disasters, due to high salinity. This study also provides evidence to support the link between respondents' challenges related to climate change and its impact on human health. The SWCRB predominantly in rural locations, that are identified as specialist doctor shortage areas. For example, where there are no pediatrician's, gynecologists or other health-related specialists as well as lack of safe drinking water facilities.

Moreover, the high vulnerability of the populations health revealed in the study results strengthens the need for initiatives to mitigate these impacts. These initiatives, along with global health governance are critical for the adaptation of the population to these climate change impacts. Additionally, In terms of rural areas improving public health infrastructures to access safe water, the study results strengthen the need for initiatives to mitigate these impacts. Thus, it is important to address the challenges and to perform coordinated initiatives by policy makers, stakeholders, government and non-government agencies.

Based on the research findings, it is critical to mitigate climate driven poverty effects through the performance of strategies to increase resilience in the communities, such as microfinance and

educational programs, and to create new coastal embankments as well as repairing and reinforcing existing ones. Increasing soil productivity in saline conditions, installing emergency shelters, and guidelines on constructing stronger dwellings will create a well-prepared community in the face of future natural disasters. Abandoned rice farms due to high saline conditions can be relatively easily and economically converted into gher ponds. Thus, this study serves as a starting point for the government and organisations to provide appropriate policies and programs to reduce the vulnerability of these communities. Moreover, in empowering women it is crucial to understand the relationship between women's status in relation to climate change. Moreover, it is necessary to prioritise social circumstances such as Intersectionality, Women Empowerment Rendered Technical, social norms, taboo, and social stigma for improvement of social status for women. It reinforces the importance of women empowerment to become powerful agents of change. Furthermore, there needs be critical analysis of how the local processes of empowerment and inequality are situated within the global economic and political arena. Through this research, it was revealed that local women are capable of unique levels of resilience to future climate change.

Even though climate justice is a critical issue for SWCRB, clear strategy rules for such marginalized people have not been tended to in plans such as the NAPA or the BCCSAP. The rules depend on the regional institution, thus avoiding concentrating on inequality, poverty and other climatic issues related to governmental affairs (Li, 2007). Furthermore, NGOs' or local adaptation plans are not viable, as climate stress triggers occur throughout the year. Nevertheless, specific focus is currently needed to the environmental policy priorities of people in impoverished and lower-emitting nations. This is reinforcing the notion of a climate change injustice because Bangladesh is one of the countries that contributed least to global warming, but yet is among those most affected. Besides, the livelihoods of these people depend on the natural resource-based Sundarbans mangrove forest. Consequently, based on field observations in the Southwestern Coastal Region of Bangladesh (SWCRB), it is evident that this region requires extended, effective, and viable strategies for sustainable development.

Conversely, this research was capable of highlighting the allocation or rights-based approaches for climate justice such as fundamental human rights, rights for advancement, ethical justification, and environmental rights. It identified local climatic problems and introduced a capability-based approach, which allows people to prepare and rebuild communities and create adaptive mechanisms based on their own capabilities, which is reducing climate injustice. People in the SWCRB have the communal platform of self-esteem and honour the main essence of a capability-based relationship, are conscious of their rights and often request embankment building. Results also reveal that SWCRB is considered one successful pioneer in the national context of climate change adaptation; however, reducing carbon emissions and global political commitment is needed to achieve climate justice. Besides, water and soil salinity problems in the SWCRB should not be thought of as natural crises, but as a result of poor governance and management practices which is seeing in this research as a

dominant hegemonic rule from local capitalist and India. Environmental justice can be read as a form of environmental nationalism. Environmental governance is the means by which some countries regulate and act on their own goals and priorities in relation to the management of the natural world (such as Farakka Barrage on rivers). An Environmental Justice (EJ) lens can be re-framed to theorize the scale of strength and vulnerability in Bangladesh, the geographical location of its downstream position and dependence on superior and extra-powerful countries like India as well as global CO2 emissions. Thus, EJ is also effective in highlighting losses and uneven distribution of policies. Thus, the existing political order acts as a fundamental barrier to social and environmental justice. In the Farakka Barrage and global carbon emissions dispute, there is a common shape of environmental injustice in which the less powerful nations are ruined by influential nations, and India benefits from control of the Ganges. The underlying principle of river intervention projects such as the Farakka Barrage is understood through the hegemonic story of domination to water scarcity, which complicates important features of existential inadequacy.

On the other hand, before analysis the adaptation this research analyzed the “Risk = Hazard x Vulnerability” was proposed by climate and disaster exponents. The detailed information about adaptation strategies and practices found in the research is useful for governmental and non-governmental organizations to perform initiatives for the mitigation of impacts to climate change. Due to climate change, sea level rise, frequent natural disaster, loss of land, loss of agriculture production, poverty and gender imbalance which provokes a push and pull migration in the SWCRB, as part of climate change impacts. People in SWCRB are migrating permanently or temporarily for two main reasons: to protect their life and to secure a livelihood because of damages to crops and houses. The two reasons are related to climate change driven natural disasters. Migration is also attributed to socioeconomic reasons like employment opportunities, social insecurity, and health risks. Climate change driven migration combines with others socio-economic factors then pushed to people migrate. It is critical to have a deep knowledge of current climate change and migration related policies for understanding why such policies may cause inequalities instead of mitigating them. The findings about socioeconomic reasons contribute to a more comprehensive understanding of important factors associated with climate change driven migration and help the human-rights framework to fill legal political gaps.

9.2. Proposals for future research

It is important to explore more the climatic and non-climatic factors associated with the high SLR and their relationships. This would reinforce the understanding of RSLR and then would strengthen the knowledge of SLR rates, enhancing the future scenarios. It is essential to constantly observe the warming of the oceans as well as the Earth's average surface air temperature as they could affect more than half of the Bangladeshi population if not maintained below 2 °C. Throughout the 21st century, various climate-related drivers, including La Niña, El Niño, Himalayan glaciers, storms, tropical cyclones (TCs), extratropical cyclones (ETCs), winds, waves, sea surface temperature (SST), freshwater input, ocean acidification, and physical/chemical impacts, have had significant global and local impacts. Therefore, this study suggests investigating the impacts of all the aforementioned drivers for future research.

This research also proposes to diagnose the effects of salinity on the human body and to test local crop varieties and plants that are more tolerant to salinity. It is important to continue the research focusing on the long-term effects of saltwater intrusions. Here a more in-depth analysis of the relationships between water, soil and salinity impacts is needed as well as potential changes of economic activities (for example changes from shrimp cultivation to agriculture). Moreover, considering the lack of comprehensive soil and water research through laboratory testing since 2009, it is strongly advisable to collect 2000 soil and water samples from the entire coastal area for thorough testing. This extensive sampling approach will provide a comprehensive and detailed understanding of the current soil and water conditions. By obtaining a large number of samples, researchers can obtain a more accurate representation of the overall environmental status in terms of soil and water quality.

This research proposes further study on the issues of human health links with climatic events around the world's coastal region. Also heat stress in the urban region is much higher, it is necessary to undertake more research to close the knowledge gap of health and heat stress. Finally, this research prioritized the impacts of water salinity on coastal areas, but in urban areas there are other types of water related diseases, and further research on urban areas waters impacts on human health and their safe drinking water status would also be highly appreciated. Further academic research is needed to help local populations out of poverty, due to new threats from climate change, and food insecurity. Although poverty is a ubiquitous characteristic of the developing economies, this research highlights the key issues such as health, education, standard of living, availability of basic needs, food security, safe drinking water accessibility, freedom, safety and security, employment, gender equality, land rights, and corruption, which also deserved further investigation in future studies on poverty. It is important to research more on the principal socioeconomic factors associated to vulnerability to future natural disaster occurrences, to know the associations with each natural disaster impact. It is true that significant funding has been allocated to developing countries through global governance schemes to address climate change impacts and support sustainable development. These financial resources aim

to assist countries in implementing mitigation and adaptation measures, as well as promoting sustainable practices and building resilience against climate change. However, it is crucial to ensure effective utilization and accountability for these funds. Transparency and monitoring mechanisms are essential to track the allocation and utilization of financial resources and assess their impact on poverty reduction and sustainable development. By evaluating where the funding has been directed and the outcomes achieved, we can identify gaps, challenges, and successes in its implementation. Future research can play a vital role in examining the effectiveness of climate finance in developing countries. This research can focus on assessing whether the allocated funds have been utilized efficiently and effectively, whether they have reached the intended beneficiaries, and whether they have contributed to poverty alleviation and sustainable development outcomes. Such studies can provide insights into the areas where improvements are needed, help identify best practices, and inform future policy and decision-making processes. Additionally, research can also explore the social, economic, and institutional factors that influence the utilization and impact of climate finance in different contexts. Understanding the barriers and enablers to effective resource allocation and implementation can contribute to the design of more targeted and impactful interventions. By ensuring that climate finance is properly used, with a focus on poverty reduction and sustainable development, we can enhance the prospects of achieving long-term poverty alleviation and sustainable outcomes in the face of climate change.

It would be also useful to perform similar studies in other coastal regions of the global and local level, to promote the importance of women's role in adaptation, and reduce the gap of women empowerment. Social norms have influenced women's response to disasters. Food insecurity, land rights, women's education status, poverty, unemployment, social stigma of tiger widows and its effects on women's livelihoods can also be further considered in future research. Women based short-term and long-term adaptation can contribute to ensure social equality and justice, so this research proposes to study the barriers to women empowerment and adaptation. This research proposes a Climate Risk Vulnerability Assessment (CRVA) for the local and global coastal areas who are most vulnerable to the impacts of climate change on agriculture. Additionally, it is very important to study how local non-climatic factors are linked with climate change. Also climate change impacts most of the time come from neighboring countries. In this context further research is proposed to study Himalayan glaciers melting status and its impacts on regional level, as well as giving high importance to research on identifying the knowledge gap on river system governance at local and global levels.

Performing similar studies in other underprivileged coastal regions of the world is indeed important to enhance the policy framework surrounding climate justice. Research that incorporates the perspectives of global leaders contributes to a comprehensive understanding of the political landscape and helps identify areas where further action and policy development are needed to promote justice and equity in the face of climate change. The insights gained from such research can inform

policy decisions, advocacy efforts, and international cooperation, ultimately leading to more effective climate justice outcomes. It is important to compare diverse adaptation strategies from different vulnerable areas of the world, to find common patterns and important differences. This would help international organizations to improve the global knowledge of adaptation, to find spatial differences and then enhance the activities for mitigation. Mangroves can be the basis for nature-based solutions to tackle climate change around the globe, as we have shown by evidence from the Bangladesh Sundarbans. Basically, mangrove are alternatives in contrast to the traditional embankment setting, for example, dams, seawalls, and reservoirs which include concrete infrastructures and are in many cases just small fixes for issues like flooding, and water scarcity, and quality or soil disintegration. More suitably, the International Union for Conservation of Nature (IUCN) says nature-based solutions include activities to protect, sustainably manage, and restore natural or modified ecosystems that address social difficulties effectively and adaptively, all the while giving human well-being and biodiversity benefits (D'Souza et al., 2017). Further research can take place in the context of adaptation, by analyzing the role of multiple stakeholders in local adaptation processes and thus uncovering gaps in policy and funding. Local NGOs receive significant financial aid from global governance institutions and programs, but local people are not happy about their support. More studies are needed in diverse vulnerable areas to achieve a comprehensive understanding of these multiple factors.

The adaptation and mitigation techniques derived from this study can play a crucial role in informing policymakers and shaping future policies. It is important for future research to explore and identify additional policies that can complement and enhance these existing techniques. Some potential areas for policy development could include:

Integration of Early Warning Systems: Future research could focus on improving and expanding early warning systems for coastal regions, ensuring timely and effective dissemination of climate-related information to vulnerable communities.

Occupational Transitions and Skill Development: Research could explore strategies to facilitate occupational changes and skill development for communities affected by climate change, enabling them to adapt to new economic opportunities and livelihood options.

Financial Management for Healthcare: Future studies could delve into the development of financial mechanisms and policies that specifically address the healthcare needs of vulnerable populations in coastal areas, ensuring access to affordable and quality healthcare services.

Enhanced Migration Policies: Research could examine the potential role of migration as an adaptation strategy and assess the effectiveness of policies that support planned and sustainable migration for individuals and communities facing climate-related challenges. **Microcredit and Alternative Adaptation:** Future research could explore the effectiveness and scalability of microcredit programs as a means of supporting alternative adaptation measures for vulnerable coastal communities, such as livelihood diversification and small-scale infrastructure development.

Strengthening Infrastructure: Studies could focus on enhancing the resilience of infrastructure in coastal regions, including the construction and retrofitting of schools with cyclone shelters, granaries, cow sheds, embankments, and multipurpose cyclone shelters. Research could assess the effectiveness and feasibility of such measures in reducing climate risks and protecting communities.

Community-Based Adaptation and Behavior: Future research could delve into the mainstreaming of community-based adaptation approaches, understanding local adaptation behaviors and dynamics, and identifying strategies for fostering community resilience and self-reliance in the face of climate change.

Institutional Adaptation: Research could explore institutional adaptation, including policy frameworks, governance structures, and decision-making processes that support effective adaptation actions at various levels.

Access to Basic Services: Future studies could address the provision of essential services in coastal areas, such as access to pure drinking water, healthcare facilities, agricultural equipment, and organic fertilizers. This can contribute to improved living conditions and resilience of vulnerable communities.

Public Participation and Awareness: Research could focus on fostering public anticipation and participation in climate adaptation measures, ensuring that communities are actively engaged in decision-making processes and adjustment mechanisms. By addressing these areas in future research; policymakers can gain valuable insights and recommendations for developing comprehensive and context-specific policies that support effective adaptation and mitigation in underprivileged coastal regions.

In terms of carbon emission justice, it is important to assess and adjust nature-based solutions to ensure that they do not have harmful impacts at the local level. This requires careful consideration of the social, economic, and environmental implications of adaptation techniques. Future research can focus on evaluating the effectiveness and fairness of different adaptation strategies, taking into accounts their local impacts and potential trade-offs. In summary, for climate justice research, it is important to focus on both the recognition or rights-based approach and the capability-based approach, consider global agreements, address all aspects of coastal livelihood vulnerability, and ensure the adjustment of nature-based solutions for carbon emission justice at the local level. Both the recognition or rights-based approach and the capability-based approach are important for climate justice research at the global and local levels. These approaches emphasize the need to consider the rights, needs, and capabilities of vulnerable communities in the face of climate change impacts. The recognition or rights-based approach focuses on recognizing and protecting the rights of individuals and communities affected by climate change. This includes ensuring access to basic human rights such as the right to life, health, food, water, and shelter. Future research can explore how these rights are impacted by climate change and how they can be upheld through policy and legal frameworks.

The capability-based approach looks at the ability of individuals and communities to adapt to and cope with climate change impacts. It emphasizes enhancing the capabilities and capacities of vulnerable groups to effectively respond to climate-related challenges. Future research can examine the specific capabilities that are needed in coastal regions, such as access to education, skills development, resources, and social support networks, in order to build resilience and enhance adaptive capacities. In terms of climate justice, it is important to highlight global agreements and frameworks that promote equitable and just responses to climate change. These include agreements such as the Paris Agreement, which aim to address the impacts of climate change and promote climate justice through international cooperation and support. To ensure climate justice, it is crucial to consider all aspects of coastal livelihood vulnerability. This includes factors such as poverty, gender inequality, migration patterns, agriculture loss, health impacts, and limitations in accessing safe drinking water. Future research can investigate the interconnections between these factors and climate change and explore strategies to address them in a just and equitable manner.

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Supplementary material (annexes)

Paper: Climate change and human health linkages in the context of globalization: and overview from global to southwestern coastal region of Bangladesh

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RESEARCH QUESTION: What are the impacts of climate change on human health in the swcrb under a globalization context, and what are the principal challenges in dealing with these impacts?

There is evidence that climate change affects human health (WHO, 2012; IPCC, 2014), and that under a context of globalization, the events that take place in one place can produce impacts in other parts of the world (Jonsson et al., 2012) increasing the inequality between core and periphery. According to the hegemony theory of Gramsci, dominant groups raised with the consent of subordinated groups convinced of a common interest (Gramsci, 1971; Hobsbawm, 2011; Arrighi and Silver, 1999). This dominant and subordinated group's relationship could be transported to the unequal emissions of CO₂, where most of them come from core countries (Bast, 2010).

During the last decades there have been important changes in the patterns of carbon emissions due to location changes of industries from the core to the periphery, migrating the pollution to the periphery (Wallerstein 2004). According to the world system theory, the inequalities between core and periphery (high technology and goods production versus raw material supplier and cheap labor) are a key feature for the economic exchange network (Wallerstein, 2004). These inequalities produce important disparities in income distribution, creating poverty in many developing countries, and increasing vulnerability to different diseases (Terry, 2008).

One important contribution of this paper was a linear graph showing CO₂ emissions by developed countries (core), less developed countries (LDC, periphery), and BASIC (new industrialized countries: Brazil, India, China, and South Africa) for the period 1960-2014, using global CO₂ historical data from the World Bank. This graph allowed to better visualize the enormous differences of emissions in developed countries compared to LDC. Based on the context of globalization and world system theory, and results from previous studies about the impacts of climate change on Asia and South Asia waterborne diseases, this research performed a case study in a rural region of SWCRB with issues to water access. The principal objective of this Research was to identify water sources related to waterborne diseases, and the relationship with climate change. There were three specific objectives related to the questioners performed to the households in the study area. Results showed that vulnerability was identified in the three objectives and that it is worsening with climate change.

Access to water, health, and climate change are the study's most significant findings for SWCRB households. Every single respondent is a rural resident of SWCRB who struggles to get access to water for their homes due to the area's poverty and isolation. Bangladesh, one of the world's most populous and disaster-prone nations, is rated among the LDC group and experiences such realities on a regular basis (WFP, 2017). Availability of water for health purposes and its quality is one of the biggest challenges and the major issues that climate change poses for health, this research has already indicated. In order to do this, the basic goal was to determine which water sources were linked to

waterborne illnesses and how climate change would affect them. It uses closed-ended questions, which are presented graphically to appear objective.

The main drinking water sources, and water availability meeting their needs; it was found that rainwater harvesting and ponds were the most used water sources, and that most of the respondents admitted that drinking water did not meet their household needs, showing a vulnerability to meet their water basic needs. It was to find relationships between the water source and waterborne diseases; it was found that the people using rainwater harvesting and ponds as water sources have the highest number of waterborne diseases (e.g. dysentery, diarrhea, skin disease). Research explores the perception of people about sea level rise during their lifetime; most of the respondents perceived a sea level rise.

According to climate change scenarios, more frequent events of waterborne diseases are expected in Asia for the future (IPCC, 2014), which will increase the diseases vectors. If resilience actions are not taken, health problems in population can surpass the capacity of public health services (ADB, 2011). In Bangladesh and other countries of South Asia, snow melting from Himalaya is critical for water accessibility to population. Melting processes from warmer temperatures would affect water accessibility and salinity, which can affect the waterborne sources for human use and the increase of health issues (Sadik et al, 2018).

Key findings of this study show that given this comparison of safe drinking water and human health as indicators of health, the SWCRB has unique challenges related to the indirect and direct impacts of climate change on the human health of vulnerable populations. Many of the health issues addressed in this study are related to chemical pollutant exposure as an indirect result of climate change impacts, including rising temperatures and water quality and quantity concerns.

The divergence of interests in terms of sharing responsibilities was identified as one of the important challenges to increase mitigation initiatives in the region, since developed and developing countries have different basic needs, and different CO₂ emissions per capita, the impacts on human health found in this research reinforced the globalization perspective, with a least CO₂ emitter area showed higher impacts and vulnerability . Global health governance was other important challenge found in the area, since it is considered one of the most important adaptation tools to address climate change.

Inaccessible to safe drinking water and lack of health care facilities and services is not only a global burden, but also a lack of local national initiatives for environmental justice; there are additional disparities in access to the quality of healthy food sources, which is often, vary by rurality, ethnicity, and socioeconomic status. SWCRB communities face greater stress regarding health consequences, this pressure is likely place an additional burden on low-income, minority and who live in remote areas and communities unable to access safe and affordable safe drinking water options, which indirectly shows climate injustice.

The divergence of interests in terms of sharing responsibilities was identified as one of the important challenges to increase mitigation initiatives in the region, ;since developed and developing countries have different basic needs ,and different CO₂ emissions per capita, the impacts on human health found in this research reinforced the globalization perspective, with a least CO₂ emitter area showed higher impacts and vulnerability . Global health governance was other important challenge

found in the area, since it is considered one of the most important adaptation tools to address climate change.

This research reinforced the need to take actions to mitigate health impacts of climate change. This involves addressing the challenges and to perform coordinated initiatives by policy makers, stakeholders, and government and non-government agencies.

Paper: Current and Future Salinity Intrusion in the South-Western Coastal Region of Bangladesh

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https://www.frontierspartnerships.org/articles/10.3389/sjss.2022.10017/full?fbclid=IwAR0dQcY7SCMluhgQ8jGN5_6Ffsij0lb5QRrm9sdleffN8pjlWtBhZY9G3EY

Research Question: What are the impacts of salinity intrusions on the quality of water and soils in SWCRB?

Salinity in soil and water is a global phenomenon that occurs in a variety of geographical regions divided by varying climatic conditions. Because of the lack of groundwater and rainfall, even low semi-arid and arid settings are more affected and present extremely confronting impediments to the spatial and temporal dissemination of soil salinity. This is particularly throughout during dry spells because of beneath the shortage of ground water and rainfall (Bannari, and Al-Ali, 2020).

Chapter two of the discussions stems from an interest in understanding how Bangladesh is particularly vulnerable to saltwater intrusion as a result of climate change-driven SLR, given that the country has a large area of low elevation near the coast and is often subject to salinity from tropical storms. The salinization of the water and soil caused by these seawater intrusions has an impact on local residents' means of subsistence. Due to seawater intrusions and groundwater depletion (groundwater mining), there is a long-term salinization issue in SWCRB. This examination was conducted to test salinity levels at the Buri Goalini, Munshigonj, and Gabura unions in the Satkhira District's Shyamnagar Upazila.

In line with the general tendency, soil potassium levels rise as salinity rises. This is consistent with the research of Alam et al. 2017, which showed that salinity will increase the presence of various ions in the soil, some of which are outside the purview of the study. This means that if salinity increases because water surges are increasing, potassium levels will also increase, causing more harm to agricultural areas (Rasel et al., 2013). Since water and soil salinity are negatively correlated, this indicates that salts accumulated and concentrated in dry soils due to evaporation may dissolve with future monsoons.(Sharma et al., 2013).

From the study two soil samples and eight water samples, all from ponds, had pH levels exceeding 8.5. The pH of this water makes it unsafe to drink and could be harmful to human health (Kumar and Puri 2012). Because of the corrosive environment it produces for metal pipes, the amount of dissolved metals in drinking water rises. The average pH of Bangladeshi tap water is somewhat alkaline, according to Akter et al., (2016), (pH of 7.4). Although our analysis produced significantly more severe consequences, alkalinity exceeded levels recommended for human consumption. The precipitation of phosphorus in solution under alkaline conditions can be attributed to the inability of organic matter to fix phosphate in soils with high organic matter concentrations, where soil organic matter content is high (Weil and Brady, 2017; Alam et al., 2017). If saltwater intrusion occurs more frequently on agricultural land, alkalinity is predicted to increase, which will reduce the amount of P that plants can absorb.

Research analysis shows that agricultural land is disproportionately depleted of P compared to other land uses, as this element acts as plant fertilizer. On the other hand, shrimp enclosures had the highest concentration of phosphorus, which could be attributed to residual phosphorus from fertilizers

and shrimp meal (Tan 2005). Research illustrates how Bangladeshi territory can be profoundly affected by flooding at low water levels. The water mass is exchanged between reservoirs as a result of the hydraulic dynamics of the river system, which also has a significant impact on surface and groundwater (Alam et al., 2017). According to research findings, saline water incursions are channeled by river and channel systems. According to this, salinity will likely be far more prevalent than originally anticipated.

In this way, when the soil and water salinity rise, difficulties arise within the coastal ecological environment, impacting agricultural production, lowering food security, and worsening the water deficit by drastically lowering the quality of freshwater. In these coastal upazila, changes to the freshwater-seawater interface already have a negative impact on people. As storm frequency grows and sea level rises, soil and water salinization tends to be more pronounced in the SWCRB. Salinization adversely affects human health, decreases the agricultural productivity of arable land, and prevents crop development.

Studies on the impact of cyclones and storm water surges in the Shyamnagar Upazila district of SWCRB have been conducted in the past (Shaibur et al., 2019). They discovered that the region's freshwater resources were impacted by saltwater intrusions. There was evidence available regarding the effects of salinity on soils and the long-term reaction to saltwater intrusions. Most of soil and water characteristics were discovered to have salinity values that were greater than recommended. It was discovered that extremely saline soils with high levels of organic matter and low phosphate concentrations can cause a decrease in agricultural productivity. One of the most noticeable effects of climate change in the SWCRB right now is increased salinity. The agricultural sector's reliance on the climate puts future food security at jeopardy; agricultural output is unmistakably correlated with changes in soil and water salinity. Regions close to beaches are also vulnerable to the effects of climate change and suffer large losses due to the salt brought on by sea level rise. The response to this salinity has shown that the right to life and other human rights of SWCRB residents are at risk.

This paper provided important information of impacts of salinity in soils and water in SWCRB, filling gaps in the knowledge of soils salinity impacts. The research approach considering the link between water and soil produced a more comprehensive understanding of the dynamics of saltwater intrusions effects. This information is critical to propose policies toward a decrease in vulnerability.

Paper: Local context of climate change adaptation in the southwestern coastal regions of Bangladesh

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Research Question: What are the local adaptation strategies and practices towards potential sea level rise in SWCRB?

–This paper analyzed that disaster events are related to extreme consequences of climatic risk exposure including vulnerability. The simplest to the most sophisticated, the perception of risk may be permanently influenced by different levels of climate change events and local people are impacted by these events. Adaptation and resilience has become the most important concept in the local context of SWCRB to refer to the challenges to deal with disaster management, which is replacing the concept of vulnerability. In this study adaptation refers to the ability of a local people's livelihood change to respond to the climatic hazard, however, this research shows local people adaptation choice when trying to identify the adaptation and resilience of a local context. Also this research adopted risk, vulnerability, response to the local context climatic adaptation and highlights the adaptation procedures which is assumed as both factors of reform and reactions to alteration in the native setting. The most vulnerable areas of natural hazards are located in poor regions of the world such as South Western Coastal Region of Bangladesh, therefore, to know the local context adaptation and resilience at community level is fundamental to reduce victims from natural disasters. From the total research paper analysis it could be mentioned here that in terms of SWCRB social economic development local adaptations have not ensured a strong background like reducing inequality and climate justice.

The IPCC (2022) defines it as the process to adjust to actual or expected climate and its impacts, seeking to reduce the negative impact of climate change, while taking advantage of potential new opportunities. This concept became important in the past two decades since mitigation of Greenhouse gases (GHGs) has received significant attention from policymakers and scientists. Due to the influence of climate change on the entire world, policy and study in this area have expanded recently (Arezki et al. 2018). Because of the diversity of the climate change impacts, several adaptations have been created and used by communities, researchers, and policymakers due to the heterogeneity of climate change impacts (Kihila, 2018; Amin, et al., 2021). These modifications lessen the effects of climate events (such as drought, salinity, floods, and sea level rise) or increase possibilities to mitigate the negative effects of climate change (Afjal et al., 2012; Dubey, et al., 2017). Hence, adaptation is essential in lowering vulnerability to climate change. This process needs certain alterations, and there are some significant factors that are affecting these adaptation changes. Many types of adaptation exist, including proactive versus reactive, spontaneous versus planned, and gradual versus transformational (IPCC, 2022).

The SWRCB has years of collective learning through experiential observation and the results of practical participation in daily life, which serve as the primary sources of key components of local context adaptation (Reid et al. 2014). Local adaptation approaches are transmitted through the generations. The indigenous climate change adaptation techniques in this study are the structural measures (earth embankments for saltwater protection built by the local community, rainwater harvesting, etc), and the non-structural measures (adequate fishing scheduling by fishermen, changes in farming practices, and diversifying alternative livelihoods) are knowledge practices of climate

change adaptation that are adopted by the local community (Barua and Rahman 2017; Kihila 2018). The primary distinction between indigenous and contemporary adaptations and knowledge practices is the nature of the approaches. The community uses indigenous adaptation strategies and knowledge, like duck rearing, since they are useful (Kihila 2018).

A multifaceted technique that revolves around eight essential processes of broad-scale human adaptation was presented in light of the active and intricate adjustment qualities found in the SWRCB population. These procedures included movement, trade, distribution, sharing, variation, reinforcement, novelty, and revival (Workshops, 2017–2019). Each approach has a specific and individual motivational foundation. The following flexible approaches draw on local context, learning opportunities, and organizing at various scales from the most basic households in SWRCB (Table 1). Consequently, it is necessary to consider adaptation processes as both modifiers of the native configuration and its responses to change.

Table 1: Local adaptation and behavior in reaction to climate change in societies of SWCRB

Adaptation Practice	Narrative	Illustration
Mobility	Periodic movement or perpetual relocation to evade peril or in quest of better conditions	Seasonal, temporary and permanent migration
Interchange	The movement of material and symbolic goods and services between people.	Handover of customary information across to generations, e.g., house construction. Providing information for land uses, e.g., farmstead gardening and mangrove plantation (UDMC) (WDMC)
Allocating	Managing the spread or ingesting of limited or acute assets among the people	Recovery relief from Government and NGO.
Sharing	Spreading or involving of new livelihood options across social clusters.	Allocation of new scientific information and expertise, homestead gardening, duck rearing, planting trees, pigeon rearing, Local knowledge concerning climate change adaptation
Variation	Diversifying food, earnings production tactics, and specialty to augment livings.	Modifying agricultural excellence and profession, such as shrimp agriculture and women entrepreneurship. saline endurable rice.
Strengthening	Growing the obtainability of assets by increasing their harvest	Individual yields in winter and saline endurable vegetables in.
Novelty	New, scheme that arises to deal with a definite necessity.	Biofuel for culinary need, and renewable energy practice,
Revival	Systematized reconfiguration of dogmas and performances to decrease strain and generate a more pleasing culture.	Utilizing conventional information, association, and skills. Embankment project 1960- 1980, 'Sorjan method agriculture; National Adaptation Plan of Action (NAPA) and the Bangladesh Climate Change Strategies and Action Plan (BCCSAP)

Through qualitative methods such as FGD, workshops, interview and case study we are describing the various adaptations that have been developed and adopted by local people, due to the heterogeneity of climate change impacts which was shown above in table 2. These adaptations reduce the effects of climate events (e.g., Sea level rise, cyclone, salinity, floods, drought), or extend opportunities to offset negative impacts of climate change.

According to this study, local modifications are used by people to reduce the danger to their livelihood and to their financial security. During disasters, a lot of local indigenous knowledge and methods are employed to safeguard resources and secure livelihoods. In coastal Bangladesh, local adaptation is crucial, and practical climate adaptation strategies are required given the socioeconomic

and livelihood conditions there. In order to reduce vulnerability, local adaptation focuses on economic gains, agricultural and non-agricultural sectors, as well as livelihood activities (Alam et al., 2017). Pests, unpredictable rainfall, and the destruction of cropland are uncertainties that highlight the necessity for local adaptation to climatic occurrences (Ayers et al., 2014). Although it is not possible to mention all local-based adaptations in this study, the NAPA projects "Livelihood Adaptation to Climate Variability and Change in Drought-prone Areas of Bangladesh" and "The Reducing Vulnerability to Climate Change (RVCC) Project" demonstrate that general local adaptation to climate change has been documented in Bangladesh (MoEF, 2009; MoEF, 2015; Mehzabin and Mondal, 2021).

Important adaptation strategies and practices were found in the region, like early warning systems, saline tolerant agriculture, rainwater harvesting, secured drinking water adaptation, raising homestead and plinth, salt-tolerant fish farming, heightening pond boundaries, structural adaptation and increasing community resilience. In this study the perils are evaluated through the qualitative and quantitative method, and we observed that people of the SWCRB through numerous plans, activities, approaches, and strategies to reduce the consequences of risks, the costs of perils and vulnerability, have taken countless efforts. The adaptation approaches include early warning systems, saline tolerant agriculture, rainwater harvesting, secured drinking water adaptation, raising homestead and plinth, salt-tolerant fish farming, heightening pond boundaries, structural adaptation and increasing community resilience. Adaptive substitutes are implemented in connection with opposing circumstances, structural adaptation in domestic settings and public domain. Adaptation initiatives comprise modernizing the drinking water filter, construction of dams, and community people engagement during the catastrophe for the construction of embankments.

A range of adaptation initiatives are undertaken by diverse governmental organizations and NGOs with the aid of state and global organizations like respondents have acknowledged, e.g., distribution of drinking water facilitated by NGOs. Throughout the calamity, the government, disaster management committee, volunteer organizations, the defense force, and local people aid in the evacuation of individuals to shelters which is also a commendable adaptation tactic in the local setting. In addition, there are adaptation initiatives of population that are assumed by diverse organization, like modernization of the drinking water filter, construction of dams, and construction of embankments.

Bangladesh continues to place high priority on local adaptation to climate change. Additionally, the need for local-scale estimates of livelihoods and local adaptation benefits in the context of local climate change has been ignored in policy, despite calls for locally focused climate change adaptation, which this study describes as an internal or local climate injustice (Younus, 2017). NAPA's primary goal was to build capacity and awareness to build environment-specific adaptive knowledge, including indigenous knowledge on how to adapt to future climate variability. Although specific adaptation strategies have received more attention than the small-scale adaptation (Amin et al., 2021).

Adaptation is inevitable to deal with the impacts of climate change but adaptation determinations are hindered in many ways. Restrictions and obstacles to adaptation hamper people's capability to recognize, evaluate and cope with risks in a way that has not led to their safety. Constraints are hurdles that are in some logic widespread, while hurdles are fluctuating. Constraints and obstacles to adaptation ascend due to the greater milieu within which the people and local adaptation process. Obstacles to adaptation can avoid the progress of adaptations from people's expectations. Due to incidence of obstacles high adaptive capability does not unavoidably explain into effective adaptation.

In many situations local adaptation actions are sensitive and short-term coping mechanisms that may limit long-term adaptation potential such as shrimp farming and Crab fattening in the SWRCB.

Through the analysis of this research findings found that the inhabitants were anticipating the SWCRB's upcoming adaptation mechanism process which gives a scenario that long term adaptation still gaps. These include raising the elevation of the ridge (embankment), availability of pure drinking water, rainwater collection system, provision of pond sand filters to ensure uncontaminated drinking water, availability of government hospital, obtainability of agricultural apparatus, soil fecundity by exploitation of organic fertilizer, planting salt-tolerant trees, reduce shrimp farming were some of the anticipated adaptation measures.

The rise in sea level, the rise in temperature, the changing of rainfall patterns, and the disappearance of ice and snow over the 20th century are all evidenced by records found in the field of global climate change (Michener et al., 1997). This had a direct impact on the entire environment and caused significant changes. This demonstrates that the worldwide issue of climate change is also a serious one in the twenty-first century. Yet, it should be noted that wealthy and poor countries are not equally affected by the climate change brought on by the buildup of carbon dioxide (Eckstein et al., 2019). Rural and impoverished communities in developing countries are actually the most impacted since they depend so heavily on delicate climate-related activities. Governments at the national level may not always advance the interests of residents in rural and coastal areas equally. Local communities therefore still have limited influence over global efforts to reduce greenhouse gas emissions, even though they are expected to be exposed to major climate change impacts. Although taking adaptation strategies into consideration should be a priority, reducing greenhouse gas emissions is still essential for slowing down climate change at this time. The international system of global climate regulation, climate change poses a grave moral quandary (Burkett, 2013; Boas, 2015; Van and Steg, 2019). The idea of adaptation is not judged possible in the topic of local context climate change because we are unable to eliminate greenhouse gasses due to the lack of a global political thought and climate justice (Pielke, 1998; Burton, 2011; Schipper et al., 2016; Porter et al., 2020).

The impacts of climate change occur primarily at the local level, so local adaptation practices are important for proper resilience; thus, adaptation plans and strategies should be managed and implemented locally. It is essential that the vulnerability of areas be considered while devising these plans.

Book chapter: Agricultural Vulnerability and Adaptation Strategies by Farmers to Climate Change in South-Western Coastal Bangladesh

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Research Question: What are the effects of climate change on agriculture vulnerability? And how can we reduce this vulnerability?

Farmers and agricultural communities all across the world confront escalating difficulties as a result of those devastating effects as our planet's climate continues to warm. Bangladesh has become one of the world's most vulnerable nations as a result of the rise in sea level brought on by human activity (Jurgilevich, A. et al., 2017). Saline soils and water have been caused by sea level rise brought on by climate change, forcing coastal farmers in Bangladesh to limit agricultural output. Farmers in Bangladesh are already switching from rice farming to shrimp and crab farming as a result of frequent flooding with salt water, but all coastal farmers are unable to preserve their agricultural livelihoods, pushing them into poverty and compelling them to flee their homes. Due to its proximity to the coast, low terrain, the important confluence of the Ganges, Brahmaputra, and Megna (GBM) Rivers, a depleted supply of freshwater upstream, and vulnerable agricultural ecosystems, the SWCRB is more vulnerable to climate change. Cyclones, tidal surges, floods, droughts, salty water imposition, waterlogging, and land sinking are among the hydro-meteorological disasters that frequently hit coastal Bangladesh (Karim, & Mimura, 2008). In this study, the effects of CCSLR (climate change and sea level rise) were investigated on the agricultural lands of Shyamnagar Upazila in the Satkhira District in Bangladesh's south-western coastal region (SWRCB). The 12 unions of the Shyamnagar Upazila in the Satkhira District on the south-western coast of Bangladesh have been the site of the investigation. Climate risks like SLR-induced storm surges, salinity imposition on farming land, and the tidal flood of the coast severely affect each of the 12 unions of Bangladesh's south-western coastal region. Crop productivity in the SWRCB has been adversely impacted by salinity intrusion, as well as drought, flooding, altered rainfall patterns, increased shrimp farming, and the consequences of the Farakka Barrage.

With the exception of the majority of landowners, who are motivated by lucrative profits, the populace in the SWRCB is moving away from agriculture and toward other occupations as a result of increased saline incursion. Families in the middle and lower classes work in different professions to meet their fundamental requirements. Furthermore, powerful landowners hire landless farmers as farm laborers to cultivate shrimp and crabs rather than cultivate the fields. Climate change is causing coastal residents to switch from farming to non-agricultural occupations (Rana & Titumir, 2014). All respondents agreed that CCSLR has a negative impact on agriculture, alters agricultural patterns, creates health risks, unemployment, poverty, and pushes people to migration. The negative effects of the CCSLR on agricultural areas were also noted by respondents, who included high saline levels, uncultivable land, the abolition of traditional farming, decreased crop yield, and agricultural land losses. SLRs increase salinity intrusion due to cyclones and storms, negatively reducing the amount of freshwater available for irrigation and reducing crop yields. Due to CCSLR, traditional farming practices have also declined as the Aman (winter) rice production is delayed due to waterlogging. Focus group discussions (FGDs) for this study revealed that the following factors characterize farmers in Shyamnagar upazila as vulnerable: (1) twelve unions are disaster-prone; (2) most farmers have been and continue to be severely affected by floods, cyclones, river erosion, SLR and soil and water salinization over the past two decades; (3) significant degradation of livelihoods, little to coping or

recovery; (4) Poor and irregular source of income <5000 Bangladesh Taka (BDT) i.e. 55.55 \$ US per month, (5) Land ownership <0.5 acres, (6) Inability to obtain adequate food sources, (7) Socially fragile.

According to research, infrastructure is also harmed by floods, and out of 121 km of embankments, >40 km of dams are breaking. The Shyamnagar Upazila sustained serious damage to around 331,200 acres of arable land as a result of increasing soil salinity, and 121,360 individuals experienced financial losses, food shortages, and nutritional deficiencies in addition to more than 64,000 people becoming homeless. The Bay of Bengal is experiencing catastrophic storm surges brought by increased temperatures that are speeding up SLR and causing tropical cyclones, floods, and river erosion.

River embankments are built on each side of rivers to stop erosion, but many of them collapse under heavy floods, destroying neighboring arable land that wasn't covered by the embankments. In Bangladesh, river erosion and the loss of livable and cultivable land in coastal zones are serious national problems (Shamsuddoha and Chowdhury, 2007). Locals say they want sustainable dams rather than relief as river erosion rates are high in coastal areas. Sources of income and availability of work have changed before and after river erosion. Due to loss of houses, agricultural land and jobs, people migrate to meet their basic needs, to find land for cultivation, to find employment opportunities, to improve their standard of living and to find educational opportunities.

Fish abundance has reduced as a result of CC, and the main reason for the decline is the hilsa fish's (*Tenualosa ilisha*) migration to less salinized water to produce eggs for reproduction. The productivity of hilsa fish (*Tenualosa ilisha*) in inland waters has fallen by around 20% over the past two decades, while yields in marine waters have increased by a factor of three, and the majority of hilsa captures have shifted from inland to marine waters (Hossain et al., 2018). Increased water temperatures and salinity, a shortage of freshwater, the destruction of ecosystems, and decrease in dissolved oxygen in the water are the main causes of fish loss. As a result, poorer individuals will likely have less access to the fish farming industry, which would likely result in a wider disparity in income. Locals think salinity is to blame for the demise of native fish and the extinction of new local fish species.

Most farmers (marginal and small-scale) in the study area are facing financial hardship and agree that the effects of CC are noticeable in the lack of rainfall caused during the dry season, depletion of freshwater resources, and crop damage. However, over the last two decades, agricultural growth has consistently decreased after SWCRB's food security.

The results suggest complex interactions between the effects of changing climate and SLR and negative feedback loops consisting of adaptation that further cause the region to be increasingly vulnerable. This research completed multinomial regression analyzed the relationship between adaptive measures and socioeconomic factors, and determined that age, gender, and total earnings of survey respondents affected the chosen adaptive measures. Though farmers have innovated in several methods for adapting to their vulnerability to changing climate, they recognize that their efforts will not suffice in ameliorating the increasing adverse effects of changing climate and SLR.

With a focus on the key themes of SDGs, this research was contributed to the UN Agenda 2030, namely the climate action and sustainable agriculture. The research is contributing significantly to reduce climate hazards as well as producing knowledge about less agriculture vulnerability.

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1st phase Questionnaire

1. Gender
 - a) Male,
 - b) Female
2. Age
 - <30
 - 30-39
 - 40-49
 - 50-59
 - 60-69
 - ≥70
3. Education
 - a. Primary
 - b. High School
 - c. SSC
 - d. HSC
 - e. Hon's
 - f. Masters
3. Respondent category
 - a) Upper Class
 - b) Middle Class
 - c) Poor
 - d) Extremely Poor
3. Food Security Level
 - a) Food secure
 - b) Slightly food insecure
 - c) Temperately food insecure
 - d) Severely food insecure
4. Union
 - 1 Burigoalini
 - 2 Ramjannagar
 - 3 Gabura
 - 4 Kolikhali
 - 5 Atulia
 - 6 Ishwaripur
 - 7 Munsiganj
 - 8 Kashimari
 - 9 Nurnagor
5. Sub district
 - a) Shyamnagar
5. District
 - a) Satkhira
6. Number of family member male
6. Number of family member female
6. Number of family member total
7. Religious faith of respondent
 - b) Islam
 - c) Hindu
 - d) Christian
 - e) Buddhist
 - f) Others
8. Primary income source
 - a) Day Laborer
 - b) Agriculture
 - c) Service
 - d) Fishing/Fish cultivation
 - e) Crab cultivation/Fattening
 - f) Cow Rearing
 - g) Goat/sheep rearing
 - h) Chicken/Duck/Pigeon farming
 - i) Rickshaw/Van pulling
 - j) Driver of Motorbike/Taxi
 - k) Grocery Shop
 - l) Tailoring
 - m) Vegetable Cultivation
 - n) Hawker
 - o) Mid Servant
 - p) Teacher/House Tutor
 - q) No permanent job
 - r) Other
 - s) No earning
8. Primary income amount
8. Secondary income source

- a) Day Laborer
 - b) Agriculture
 - c) Service
 - d) Fishing/Fish cultivation
 - e) Crab cultivation/Fattening
 - f) Cow Rearing
 - g) Goat/sheep rearing
 - h) Chicken/Duck/Pigeon farming
 - i) Rickshaw/Van pulling
 - j) Driver of Motorbike/Taxi
 - k) Grocery Shop
 - l) Tailoring
 - m) Vegetable Cultivation
 - n) Hawker
 - o) Mid Servant
 - p) Teacher/House Tutor
 - q) No permanent job
 - r) Other
 - s) No earning
8. Secondary income amount
8. Total earning
8. Total Earning Range
- a) 0-5000
 - b) 5000-10000
 - c) 10000-15000
 - d) 15000-20000
 - e) 20000-25000
 - f) 25000-30000
 - g) >30000
9. What is the type of your housing structure?
- a) Cemented Building (Pacca)
 - b) Semi-Pacca Building with Tin Roof
 - c) Thatched House
 - d) Tin/Wood/Bamboo
 - e) Mud/Straw
 - f) Others
10. Can your living house withstand strong winds, severe rain, flooding or hail without significant damage?
- a) No
 - b) Yes
 - c) Yes, with minor damage
 - d) Perhaps, but with significant damage likely
 - e) Little to no extreme weather in this region
11. Has your home suffered from any damage (natural calamities) in the last 5 years?
- a) No
 - b) Yes
 - c) Yes with significant damage
 - d) Others
12. What is the main drinking source of water for your household uses?
- a) Deep tube well
 - b) Hand pump/Shallow Tube-well
 - c) Supply
 - d) River
 - e) Pond
 - f) Canal
 - g) Rain water harvesting without proper knowledge
 - h) Others
12. Drinking water is sufficient to meet your requirement round the year?
- a) Yes
 - b) No
12. What is the main cooking source of water for your household uses?
- a) Deep Tube Well
 - b) Hand pump/Shallow Tube-well
 - c) Supply
 - d) Rain water harvesting without proper knowledge
 - e) Pond
 - f) Canal
 - g) River
 - h) Others
12. Cooking water is sufficient to meet your requirement round the year?
- a) Yes
 - b) No
12. What is the main irrigation source of water for your household uses?
- a) Deep Tube Well
 - b) Hand pump/Shallow Tube-well
 - c) Supply
 - d) Rain water harvesting without proper knowledge
 - e) Pond
 - f) Canal
 - g) River
 - h) Others

12. Irrigation water is sufficient to meet your requirement round the year?

- a) Yes
- b) No

13. Toilet facility does your household usually use

- a) None (Open defecation)
- b) Open or enclosed pit
- c) Hanging latrine
- d) Slab without ring
- e) Slab with ring
- f) Sanitary latrine

14. Did your family suffered from any water-borne and contaminated water related diseases in the last 15 years?

- a) Diarrhea
- b) Dysentery
- c) Cholera
- d) Typhoid
- e) Jaundice
- f) Skin disease
- g) Worm
- h) Others

14. Do you think about Direct and indirect impacts of climate change on physical conditions of individual in the last 5 years?

- a) Yes
- b) No
- c) No Answer

15. Does your SWCR inhabitants require migrate in other places due to CC and SLR?

- a) Yes
- b) No
- c) Don't Know

16. Who requires to migrate, usually where do they migrate?

- a) Urban
- b) Village
- c) Middle East
- d) Europe
- e) Malaysia
- f) Others
- g) India
- h) Don't Know

17. Migration for What business

- a) Day Laborer

- b) Hawker
- c) Rickshaw/Van Pulling
- d) Bus driver/helper
- e) Garment Worker
- f) Seasonal Migration
- g) Brick Field
- h) Agricultural Work
- i) House Building Worker
- j) Garments
- k) Other
- l) Don't Know

18. Did your neighbor migrate to the other places permanently?

- a) Yes
- b) No
- c) Don't Know
- d) No answer

19. Do you have three proper meals a day round the year?

- a) Yes
- b) No

20. Types of hazards you face every year due to climate change and sea level rise (A)

- a) Salinity
- b) Erosion/ Land loss/Embankment damage
- c) Drought
- d) Drought/Heat stress/health hazard
- e) Loss of Agriculture
- f) Loss of Livelihood /biodiversity
- g) Others

20. Types of hazards you face every year due to climate change and sea level rise (B)

- a) Tidal surge
- b) Flash flood
- c) Heavy storm
- d) Cyclone
- e) Thunderstorm
- f) Continuous heavy rainfall
- g) Others

21. Did you face strong/massive disaster within last 50 years?

- a) Yes
- b) No
- c) No Answer

22. If yes, what are these massive disasters? (A)

- a) Salinity

- b) Erosion
- c) Cold Wave
- d) Tidal Surge
- e) Cyclone
- f) Flash Flood
- g) Others
- h) Heavy Storm
- i) Thunderstorm
- j) Continuous heavy rainfall
- k) Drought
- l) Heat stress
- m) Land Loss
- n) Others

22. If yes, what are these massive disasters? (B)

- a) Salinity
- b) Erosion
- c) Cold Wave
- d) Tidal Surge
- e) Cyclone
- f) Flash Flood
- g) Others
- h) Heavy Storm
- i) Thunderstorm
- j) Continuous heavy rainfall
- k) Drought
- l) Heat stress
- m) Land Loss
- n) Others

23. Where did you go at the disaster period in the last disaster due to CC and SLR?

- a) Went to Shelter center
- b) Relatives' house
- c) Stay in own house
- d) Stay in Bandh
- e) Other

24. Can you remember what loss you conceived during the hazard due to CC and SLR in last 50 years? (A)

- a) Life Loss
- b) Injured
- c) Cattle Loss
- d) Crops Loss
- e) Land Loss
- f) Capital Loss
- g) Tree Loss
- h) Others
- i) Biodiversity Loss

- j) Health Loss
- k) Shrimp Cultivation Loss
- l) Rivate Fish Farming Loss
- m) Agriculture Loss
- n) No Answer

24. Can you remember what loss you conceived during the hazard due to CC and SLR in last 50 years? (B)

- a) Life Loss
- b) Injured
- c) Cattle Loss
- d) Crops Loss
- e) Land Loss
- f) Capital Loss
- g) Tree Loss
- h) Others
- i) Biodiversity Loss
- j) Health Loss
- k) Shrimp Cultivation Loss
- l) Rivate Fish Farming Loss
- m) Agriculture Loss
- n) No Answer

25. During disaster, did you get any assistance from government / Disaster Management Committee?

- a) Yes
- b) No
- c) No Answer

26. If yes, what were their activities for assisting people for "during disaster" period?

- a) Rescue
- b) Evacuation
- c) First Aid Support
- d) Others
- e) Relief

27. After Disaster Period did you receive any relief?

- a) Yes
- b) No

28. Who provided relief after disaster?

- a) Govt
- b) NGO
- c) Community
- d) Others

29. Did your neighbor move to another city because of pre-disaster awareness?

- a) Yes
- b) No

- c) Don't Know
30. Did the agro lands in your area affected by the CC and SLR?
- a) Yes
b) No
31. If yes, what negative impact happened in the land?
- a) Increased level of salinity in the land
b) Land become uncultivable
c) Traditional cultivation has been eliminated
d) Others
e) Decrease crop
f) Land loss due to sea level
g) No Answer
32. Did the mangrove forest (Sundarbans) affected by the CC and SLR in past 50 years?
- a) Yes
b) No
33. If yes, what type of negative impact happened to Sundarban?
- a) Destroyed tree
b) Extinct animals
c) Destroyed other species and ecological setting
d) Other
e) Subsistence livelihood
f) Loss of land
g) destroy ecological settings
34. Do you think oldest, disable, children and women are most vulnerable at the time of disaster?
- a) Yes
b) No
35. Do you have any idea about climate change and SLR?
- a) Yes
b) No
c) Don't Know
36. If yes, what is the reason of climatic pattern shifting?
- a) Increasing harmful gases
b) Cutting down of trees in increased rate
c) Global warming
d) Increasing CO/CO2
e) Destroying barrage
f) Sea level rise
- g) Unconscious Livelihood around the world
h) Hill cutting
37. What is the consequence of risk posed by climatic pattern shifting? (A)
- a) Migration
b) Destroyed Agriculture
c) Change agriculture pattern
d) Increased salinity in water
e) Health hazards
f) Damaged biodiversity
g) Loss of infrastructure/land
h) Damaged house
i) Damaged communication
j) Lost life
k) Global worming
l) Other/poverty/woman vulnerability
m) Most land will be underwater in near future
37. What is the consequence of risk posed by climatic pattern shifting? (B)
- a) Migration
b) Destroyed Agriculture
c) Change agriculture pattern
d) Increased salinity in water
e) Health hazards
f) Damaged biodiversity
g) Loss of infrastructure/land
h) Damaged house
i) Damaged communication
j) Lost life
k) Global worming
l) Other/poverty/woman vulnerability
m) Most land will be underwater in near future
38. What is the adaptation mechanism of you due to climate change?
- a) Planting of saline tolerable crop/agriculture
b) Climate Justice
c) Availability of boat always
d) Tree plantation
e) Place for shelters
f) Environmental friendly shrimps farming
g) Water Planning
h) Awareness & Planning
i) Went to high place
j) Others
k) By the help of NGO
l) Security

- m) Help by Govt
39. Did you take any mitigation of climatic pattern shifting planned at the neighborhood stage?
- Yes
 - No
 - Don't Know
40. What are the mitigation steps should be taken due to climatic pattern shifting?
- Shelter in the house
 - Collect dry food
 - Practice Energy efficiency
 - Greater use of renewable energy
 - improve barrage
 - Sea polder
 - Other
41. Do you know government /NGO has adaptation and mitigation initiatives?
- Yes
 - No
 - Don't Know
42. If yes, what types of adaptation and mitigation initiatives they have taken?
- Tree Plantation
 - Embankment renovate
 - Safe drinking water supply
 - Green infrastructure development
 - Communication development
 - Renewable Energy
 - Non-renewable energy
 - Others
43. What type of mitigation initiatives government should take place?
- Tree Plantation
 - Embankment renovate
 - Safe drinking water supply
 - Green infrastructure development
 - Communication development
 - Renewable Energy
 - Non-renewable energy
 - Others
 - Propose new technology
 - demand climate justice at global level
44. Do you think sea level has raised than before?
- Yes
 - No
 - Don't Know
45. If yes, how sea level rise change over the time (from your childhood)?
- Yes
 - No
 - Don't Know
46. Do you think marine species has been extinct due to climate changed and it consequence of natural disaster?
- Yes
 - No
 - Don't Know
47. Do you think fish availability has been reduced than before?
- Yes
 - No
 - Don't Know
48. If yes, how percent fish reduced do you think so?
- Yes
- No
- 48.If yes, how percent fish reduced do you think so? If we compare with before 15 years
- 1-20
 - 21-40
 - 41-60
 - 61-80
 - 81-100
49. How river bank erosion you observed due to sea level rise
- Low
 - Medium
 - High
50. Do you think rain fall intensity has been increased recent decade?
- Yes
 - No
51. What type of vulnerabilities you or local people face due to increased rain fall intensity? (A)
- House Damage
 - Agriculture
 - Flash Flood
 - Land Use Change
 - Impact on Everyday Livelihood
 - Economy
 - Sustainable Economy
 - Loss of agriculture and biodiversity

- i) Loss of fisheries
 - j) Other
 - k) Food insecurity
 - l) Water logging
 - m) Impact on health (Bacteria, Malaria, Dengue)
51. What type of vulnerabilities you or local people face due to increased rain fall intensity? (B)
- a) House Damage
 - b) Agriculture
 - c) Flash Flood
 - d) Land Use Change
 - e) Impact on Everyday Livelihood
 - f) Economy
 - g) Sustainable Economy
 - h) Loss of agriculture and biodiversity
 - i) Loss of fisheries
 - j) Other
 - k) Food insecurity
 - l) Water logging
 - m) Impact on health (Bacteria, Malaria, Dengue)
52. Do you take any preparedness against hazards due to CC and SLR at the household level?
- a) Yes
 - b) No
53. If yes, what are the preparedness at household level?
- a) Dry Food
 - b) Moveable woven
 - c) Savings
 - d) Firewood
 - e) Supporting / tiding house with bamboo and rope
 - f) Plinth rising homestead
 - g) First aid box
 - h) Tree plantation surrounding the house
 - i) Any other
 - j) Other
54. Do you have an early warning system in place?
- a) Yes
 - b) No
55. If yes, how do you get these early warnings?
- a) From CPP volunteer
 - b) Radio
 - c) Television
 - d) Miking (announcement)
 - e) FFWC
 - f) Others
56. Is your land protected by embankment?
- a) Yes
 - b) No
 - c) Don't Know
57. Do you have any training for climate change adaptation, or disaster reduction, etc?
- a) Yes
 - b) No
 - c) I did not take any training
58. If yes, what can you remember from the participation in the training?
- a) Training on Early warning
 - b) Training on Community Based Disaster Risk Reduction
 - c) Training on Search and Rescue and First Aid
 - d) Training on shelter management
 - e) Training on management of persons with disability during Disaster
 - f) I am willing to participate in future
 - g) Others
58. If yes, from where did you get turning?
- a) Govt
 - b) NGO
 - c) Others
 - d) I am willing to participate in future
59. Do you understand the signals for CC disasters like cyclones?
- a) Yes
 - b) No answer
 - c) No
60. If yes, what is the meaning of signal Seven?
- a) Leave house and go to shelter
 - b) Others
 - c) Pregnant mother, children, PWD & old age people should go to shelter
 - d) Bring cattle to the shelter
 - e) Reserve important materials
61. Where did you learn these messages?

- a) WDMC
- b) UDMC
- c) Neighbors
- d) CPP Volunteers
- e) SMC
- f) Electronic Media
- g) Others

62. Do you think women, children, oldest and disable are most vulnerable due to climate shifting pattern?

- a) Yes
- b) No
- c) Don't Know

63. If yes, what type of vulnerability usually they faced?

- a) Nervousness & Fear
- b) Helplessness
- c) Physical weakness of women
- d) lack of high place
- e) Cyclone shelter is so far from home
- f) Cannot run fast
- g) water and food problem
- h) Women did not know swimming
- i) Other

64. Did you ever been shifted your traditional livelihood due to climate changed or SLR?

- a) Yes
- b) No

65. If yes, what was/were these?

- a) Day laborer
- b) Saline tolerant crop cultivation
- c) Shrimp/fish cultivation
- d) Crab cultivation/fattening
- e) Livestock rearing
- f) Rickshaw/van pulling
- g) Tailoring
- h) vegetable cultivation
- i) Hawker
- j) Other
- k) Don't Know

66. Are you satisfied with the present form of livelihood?

- a) Yes
- b) No

67. If not, what problems do you face in your present form of livelihood? (A)

- a) Flash Flood

- b) Lack of knowledge about climate adaptive livelihood options
- c) Water logging
- d) Damage land due to salinity
- e) Lack of skill in managing livelihood options
- f) Lack of demand in the market
- g) Lack of access to extension service providers
- h) Lack of capital
- i) Social injustice
- j) Other

67. If not, what problems do you face in your present form of livelihood? (B)

- a) Damage land due to salinity
- b) Lack of knowledge about climate adaptive livelihood options
- c) Water logging
- d) Flash flood
- e) Lack of skill in managing livelihood options
- f) Lack of demand in the market
- g) Lack of access to extension service providers
- h) Lack of capital
- i) Social injustice
- j) Other

68. Has the salinity increased in your area due to climate change or SLR?

- a) Yes
- b) No

69. If yes, does the people adopted or forced saline tolerable livelihoods?

- a) Yes
- b) No

70. If yes what are these?

- a) Shrimp or fish enclosure
- b) Crab cultivation
- c) Crop
- d) Others
- e) No Answer

71. If shrimp or fish enclosure, what are the advantages?

- a) Early Growing
- b) Easy to cultivate
- c) Demand
- d) Exportable

- e) Profitable
- f) Shrimp are exporting in other country
- g) create Employment facility

72. If shrimp or fish enclosure, what are the disadvantages?

- a) Virus Problem
- b) Risk of Loss
- c) Have to manage salt water
- d) Difficult to collect water

73. Comments of respondents to climatic resilient (A)

- a) Other
- b) Building Barrage
- c) Decrease CO2
- d) Water Security
- e) Provide Training
- f) Prevent Global Warming
- g) Reduce Vehicles
- h) Reduce Greenhouse gases
- i) Government initiatives
- j) Industrial Control
- k) Digging Canal
- l) Have to build some roads
- m) Reduce salinity
- n) Stop Deforestation
- o) Taking proper step by govt
- p) Repair Embankment
- q) Setup sanitariatrin
- r) Improve Agricultural System
- s) Plant trees/saline tolerable trees
- t) Make people conscious
- u) Ensure climate justice

73. Comments of respondents to climatic resilient (B)

- a) Other
- b) Building Barrage
- c) Decrease CO2
- d) Water Security
- e) Provide Training
- f) Prevent Global Warming
- g) Reduce Vehicles
- h) Reduce Greenhouse gases
- i) Government initiatives
- j) Industrial Control
- k) Digging Canal
- l) Have to build some roads
- m) Reduce salinity
- n) Stop Deforestation
- o) Taking proper step by govt

- p) Repair Embankment
- q) Setup sanitary latrine
- r) Improve Agricultural System
- s) Plant trees/saline tolerable trees
- t) Make people conscious
- u) Ensure climate justice

74. What do you think about Direct and indirect impacts of climate change on physical conditions of individual in the last 10 years? (A)

- a) Mental Illness
- b) Diabetics
- c) Injuries
- d) Infectious Diseases
- e) Respiratory Diseases
- f) Undernutrition/Malnutrition
- g) Pregnancy difficulties
- h) Pre mature baby
- i) vector-borne diseases

75. What do you think about Direct and indirect impacts of climate change on physical conditions of individual in the last 10 years? (B)

- a) Hair fall
- b) Skin disease
- c) Acidity
- d) Anemia
- e) Water Borne Diseases

76. What do you think about Direct and indirect impacts of climate change on physical conditions of individual in the last 10 years? (C)

- a) Fatigue
- b) Muscle Pain
- c) Cancer
- d) Neurological disease
- e) Cardiovascular disease

77. What do you think about Direct and indirect impacts of climate change on physical conditions of individual in the last 10 years? (D)

- a) Early puberty
- b) Leucorrhoea and Nagimitis
- c) Breast tumor
- d) Breast pain
- e) Galactorrhoea (lactating without pregnancy)
- f) Lactation insufficiency
- g) Menstruation problem

78. Can you please inform me about the status of migration in SWCRB?

- a) Temporary
- b) 6 months of absence
- c) Permanent > 6 months of absence)
- d) Take place domestically
- e) Internationally

79. Main reason for migration

- a) Due to land loss
- b) Due to reduce agriculture production
- c) Due to reduce subsistence economic activities
- d) Better employment opportunities (rural-urban-international migration)
- e) Better Employment opportunities in agriculture
- f) Others

80. Types of migration destination

- a) Temporary migration with in Bangladesh
- b) Permanent Migration with in Bangladesh
- c) Temporary migration in international
- d) Permanent Migration in International

81. Causes of Sea Level Rising

- a) Anthropogenic Global Warming/CO2 emission
- b) Human Forcing besides Greenhouse Gases /CO2 Emissions
- c) Bio-thermostat
- d) Cloud Formation and Albedo
- e) Ocean Currents
- f) Planetary Motion
- g) Solar Variability

82. What do you think about the impact of sea level rise in coastal Bangladesh? Below which impact you feel most? (A)

- a) Other
- b) Destroy Agriculture
- c) Water Logging
- d) Loss of Health
- e) Loss of Tourism
- f) Frequent Natural Disaster
- g) Monsoon flooding
- h) Decline in Soil Quality
- i) Species Disappearing
- j) Coastal Erosion
- k) Unemployment

- l) Infrastructure Destruction
- m) Emergence of Climate Refugee
- n) High Cost of Natural Disasters
- o) Lost of GDP and Emergence of Macroeconomic Tension
- p) Risk on Education System
- q) Appearance of Climate Poverty
- r) Women vulnerability
- s) High Economic Cost of Loosing Natural Resource

82. What do you think about the impact of sea level rise in coastal Bangladesh? Below which impact you feel most? (B)

- a) Other
- b) Destroy Agriculture
- c) Water Logging
- d) Loss of Health
- e) Loss of Tourism
- f) Frequent Natural Disaster
- g) Monsoon flooding
- h) Decline in Soil Quality
- i) Species Disappearing
- j) Coastal Erosion
- k) Unemployment
- l) Infrastructure Destruction
- m) Emergence of Climate Refugee
- n) High Cost of Natural Disasters
- o) Lost of GDP and Emergence of Macroeconomic Tension
- p) Risk on Education System
- q) Appearance of Climate Poverty
- r) Women vulnerability
- s) High Economic Cost of Loosing Natural Resource

83. From below which answer you agreed to Climate change associated impact on gender specific? (A)

- a) To Physical and Social Setting of women
- b) Linkages among Climate Change, Livelihoods, Poverty, and Women
- c) Women are affected differently and more severely
- d) Women are under-represented in decision-making
- e) Impact of climate change on women's economic livelihoods

- f) Nature of Challenges of Women, Children, Disabled and Elderly People
 - g) Income and Occupational Challenges after Natural Hazards for women
 - h) The inadequacy of shelter capacity
 - i) The impact of climate change on women's triple role
83. From below which answer you agreed to Climate change associated impact on gender specific? (B)
- a) To Physical and Social Setting of women
 - b) Linkages among Climate Change, Livelihoods, Poverty, and Women
 - c) Women are affected differently and more severely
 - d) Women are under-represented in decision-making
 - e) Impact of climate change on women's economic livelihoods
 - f) Nature of Challenges of Women, Children, Disabled and Elderly People
 - g) Income and Occupational Challenges after Natural Hazards for women
 - h) The inadequacy of shelter capacity
 - i) The impact of climate change on women's triple role
84. Do you think adaptation measures impact differently on men and women?
- a) Yes
 - b) No
 - c) Don't Know
85. If yes, is it possible women friendly adaptation mitigation in coastal reason? (A)
- a) Through female empowerment
 - b) Through employment
 - c) Others
 - d) Women friendly agriculture
 - e) To build strong partnership
 - f) Build awareness
 - g) Micro finance
 - h) Ensure security
 - i) Policy or activity implemented in terms of gender equality
 - j) Involvement of female experts
 - k) Incorporate climate change related information in academic curriculum
 - l) Organizations and stakeholders with equal access and involvement of women
- m) Use the idea development from women
85. If yes, is it possible women friendly adaptation mitigation in coastal reason? (B)
- a) Through female empowerment
 - b) Through employment
 - c) Others
 - d) Women friendly agriculture
 - e) To build strong partnership
 - f) Build awareness
 - g) Micro finance
 - h) Ensure security
 - i) Policy or activity implemented in terms of gender equality
 - j) Involvement of female experts
 - k) Incorporate climate change related information in academic curriculum
 - l) Organizations and stakeholders with equal access and involvement of women
 - m) Use the idea development from women
86. Do you think Climate Change creates Poverty?
- a) Yes
 - b) No
 - c) Don't Know
87. If yes, what is your opinion from below answer in regarding Poverty causes by climate change? (A)
- a) Others
 - b) Sea level rise effects on many more channels
 - c) Floods
 - d) Droughts
 - e) Tropical Cyclones
 - f) Thermal and water stress
 - g) Increased Temperature
 - h) Reduced soil moisture
 - i) Increase land degradation and desertification
 - j) Increased deforestation
 - k) Climate is likely to affect poverty through many more channels
 - l) Rising sea levels are giving rise to poverty and sinking local culture
 - m) Through heightened cyclonic inundation, rising river salinity, and increased soil salinity
 - n) No Answer
87. If yes, what is your opinion from below answer in regarding Poverty causes by climate change? (B)

- a) Others
- b) Sea level rise effects on many more channels
- c) Floods
- d) Droughts
- e) Tropical Cyclones
- f) Thermal and water stress
- g) Increased Temperature
- h) Reduced soil moisture
- i) Increase land degradation and desertification
- j) Increased deforestation
- k) Climate is likely to affect poverty through many more channels
- l) Rising sea levels are giving rise to poverty and sinking local culture
- m) Through heightened cyclonic inundation, rising river salinity, and increased soil salinity
- n) No Answer

88. What is the adaptation and mitigation measure to reduce poverty?

- a) Strengthening coastal embankments
- b) Multipurpose emergency shelters
- c) Improving early warning and evacuation systems
- d) Build awareness?
- e) Micro Finance
- f) Promote asset bases (e.g. housing)
- g) Promote public infrastructure (e.g. piped water, sanitation, drainage, roads and footpaths)
- h) Promote provision of basic services (e.g. health and education)
- i) Promote safety-nets for those unable to pay for services
- j) Promote environment friendly Agriculture
- k) Decrease shrimp and carve cultivation
- l) No Answer

89. What are the severe threats of shrimp cultivation to the coastal area of Bangladesh (A)

- a) Others
- b) Loss local ecological systems
- c) Deterioration of soil
- d) Water quality
- e) Depletion of mangrove forest
- f) Decrease of local variety of rice and fish

- g) Saline water intrusion in ground water
- h) Local water pollution and Change of local hydrology
- i) Significant losses of biodiversity of fisheries and forest species
- j) Loss of crop production/agriculture
- k) Loss of fruit and other indigenous floral species
- l) Water quality/fresh water crisis
- m) No Answer

89. What are the severe threats of shrimp cultivation to the coastal area of Bangladesh (B)

- a) Others
- b) Loss local ecological systems
- c) Deterioration of soil
- d) Water quality
- e) Depletion of mangrove forest
- f) Decrease of local variety of rice and fish
- g) Saline water intrusion in ground water
- h) Local water pollution and Change of local hydrology
- i) Significant losses of biodiversity of fisheries and forest species
- j) Loss of crop production/agriculture
- k) Loss of fruit and other indigenous floral species
- l) Water quality/fresh water crisis
- m) No Answer

90. What is your opinion land use of shyamnagor unions has been changed due to shrimp cultivation

- a) Yes
- b) No
- c) Don't Know

91. If yes what is the changes?

- a) Local Vegetation
- b) Soil Texture
- c) Organic Carbon and Organic Matter
- d) Salinity increase
- e) Presence of pH
- f) Reduce Water Quality
- g) Reduce biodiversity
- h) Reduce local fish
- i) Reduce agriculture
- j) No Answer
- k) Other

92. Do you think rainfall pattern changing over the year?

- a) Yes
- b) No
- c) Don't Know

93. If yes, what is your opinion last 10 years?

- a) Some year increases
- b) Some year decreases
- c) Rainfall happening in other seasons
- d) Rainfall happens all around the year

94. Can you please inform me from climate change and SLR following below answer which area more threat for Biodiversity/ Forest? (A)

- a) Other
- b) Deforestation
- c) Natural Ecosystems
- d) The Sundarbans mangroves and its ecosystem services
- e) On the physiographic of the Sundarbans mangrove forest
- f) On Sundarbans dependent livelihoods
- g) Salinity Intrusion and Threats to Biodiversity
- h) Changes of Floral Composition
- i) Changes of Faunal Composition
- j) Habitat loss of wildlife
- k) Behavioral change in wildlife

94. Can you please inform me from climate change and SLR following below answers which area more threat for Biodiversity/ Forest? (B)

- a) Other
- b) Deforestation
- c) Natural Ecosystems
- d) The Sundarbans mangroves and its ecosystem services
- e) On the physiographic of the Sundarbans mangrove forest
- f) On Sundarbans dependent livelihoods
- g) Salinity Intrusion and Threats to Biodiversity
- h) Changes of Floral Composition
- i) Changes of Faunal Composition
- j) Habitat loss of wildlife
- k) Behavioral change in wildlife

95. What do you think about the impact of sea level rise in coastal Bangladesh which creates climate injustice? Below which impact you feel most? (A)

- a) Destroy Agriculture
- b) Water Logging
- c) Monsoon flooding
- d) Landslide

95. What do you think about the impact of sea level rise in coastal Bangladesh which creates climate injustice? Below which impact you feel most? (B)

- a) Decline in Soil Quality/ SalinityWater Logging
- b) Coastal Erosion Landslide
- c) Reduction of Agriculture Land
- d) Frequent Natural Disaster

96. What do you think about the impact of sea level rise in coastal Bangladesh which creates climate injustice? Below which impact you feel most? (C)

- a) Loss of Health
- b) Emergence of Climate Refugee/Human Rights Violation
- c) Species Disappearing/ loss of plant species/bird species
- d) Women vulnerability

96. What do you think about the impact of sea level rise in coastal Bangladesh which creates climate injustice? Below which impact you feel most? (D)

- a) Unemployment
- b) Appearance of Climate Poverty
- c) Infrastructure Destruction
- d) Eradication of recreational activities
- e) Eradication of recreational activities

96. What do you think about the impact of sea level rise in coastal Bangladesh which creates climate injustice? Below which impact you feel most? (E)

- a) High Cost of Natural Disasters
- b) Loss of GDP and Emergence of Macroeconomic Tension
- c) High Economic Cost of Loosing Natural Resources
- d) Loss of Tourism

96. What do you think about the impact of sea level rise in coastal Bangladesh which creates climate injustice? Below which impact you feel most? (F)

- a) Increase heat stress

- b) Desertification
c) Lowering ground water level
96. What do you think about the impact of sea level rise in coastal Bangladesh which creates climate injustice? Below which impact you feel most? (G)
- a) Increase SLR
b) Increase earthquake
c) High probability of Tsunami
96. What do you think about the impact of sea level rise in coastal Bangladesh which creates climate injustice? Below which impact you feel most? (H)
- a) Reduce fisheries Food inse
b) Food insecurity
c) Loss of basic goods
d) Loss of natural resources
e) Loss of subsistence livelihood
97. What do you think SLR has adverse impacts to the coastal agriculture of Bangladesh especially in terms of the area of inundation, salinity intrusion and reduction in crop production?
- a) Yes
b) No
c) Don't Know
98. What are your judgment farmers are applying different adaptation strategies to reduce the Climate Change and SLR vulnerabilities of coastal agriculture?
- a) Yes
b) No
c) Don't Know
99. If yes, do you think that is it sufficient adaptation strategy for coastal livelihood?
- a) Yes
b) No
c) Don't Know
100. As your opinion adaptation variety in coastal farmers to climate change induced SLR?
- a) Construction of dam/dyke around agricultural land
b) Rainwater harvesting for drinking and irrigation
c) Proper drainage to remove prolonged saline water logging
d) Control the aggression of new shrimp farm
e) Cultivation of saline tolerant HYV crops
- f) Homestead gardening and floating cultivation
g) Employment of farmers through capacity building
h) Govt. and NGO facilities (subsidy, credit, insurance etc.)
i) Perform community-based adaptation options
j) Livestock Farming
k) Alternative sources of income
101. What do you think about Flood, is it happening in the coastal area?
- a) Yes
b) No
102. What type of flooding?
- a) Fluvial floods (river): tidal floods
b) Fluvial floods (river): fluvio-tidal floods
c) Fluvial floods (river): storm surge floods
d) Fluvial (Surface Water) Flooding/ rain
103. If yes what is the impact of flooding? (A)
- a) Coastal erosion
b) Waterlogging
c) Changes in spatial extent of land flooding
d) Destroy livelihood pattern
e) Loss of Ecosystem/ Biodiversity
f) Loss of economy
g) Loss of Health
h) Absence of safe drinking water
i) Infrastructure loss
j) Others
k) No Answer
103. if yes what is the impact of flooding? (B)
- a) Coastal erosion
b) Waterlogging
c) Changes in spatial extent of land flooding
d) Destroy livelihood pattern
e) Loss of Ecosystem/ Biodiversity
f) Loss of economy
g) Loss of Health
h) Absence of safe drinking water
i) Infrastructure loss
j) Others
k) No Answer
104. How can we overcome about flooding and sea level rise?
- a) River & canal dragging

- b) Take Land from land grabber
- c) Embankment
- d) Promote climate justice
- e) Reduce co2 emissions global level
- f) To use local people idea

105. What do you think Cyclone is happening in coastal area?

- a) Yes
- b) No
- c) Don't Know

106. Do you think shrimp and crab cultivation harmful for environment? From your life time experience

- a) Yes
- b) No
- c) Don't Know
- d) Others

107. Do you memorize that Riverbank erosion is happened in coastal area?

- a) Yes
- b) No
- c) Don't Know

108. What is the impact of Riverbank Erosion? (A)

- a) Of homestead and agricultural land
- b) Damage to road communication
- c) Permanent loss of cultivable and homestead land
- d) Financial loss
- e) Loss of damage to houses, roads
- f) Loss to land is never recoverable
- g) Socio-Economic/Physical geographical Impacts
- h) Displacement
- i) Loss of Crop
- j) Loss of Security
- k) Impacts on the Physical and Mental Health
- l) Others
- m) Don't know

108. What is the impact of Riverbank Erosion? (B)

- a) Of homestead and agricultural land
- b) Damage to road communication
- c) Permanent loss of cultivable and homestead land
- d) Financial loss
- e) Loss of damage to houses, roads

- f) Loss to land is never recoverable
- g) Socio-Economic/Physical geographical Impacts
- h) Displacement
- i) Loss of Crop
- j) Loss of Security
- k) Impacts on the Physical and Mental Health
- l) Others
- m) Don't know

109. What do you think climate change relating with capitalism?

- a) Yes
- b) No
- c) Don't Know
- d) Others

110. At the end, what do you think are we climate victim and is it threat for our future generation as well as changing map our country?

- a) Yes
- b) No
- c) Don't Know
- d) Others

111. If yes, what do you think developed country need to reduce CO2 emissions with plenty?

- a) Yes
- b) No

112. From your life time you faced/living with several climatic man made digesters, what do you think is it justice for us in the coastal Bangladesh as well as who are facing same problem all around the world?

- a) Yes
- b) No
- c) Don't Know
- d) Others

113. Do you think that global carbon emissions make social inequality for us?

- a) Yes
- b) No

114. According to earlier questioner you have some idea about climate susceptibility in community level in SWCRB; can you please inform me which is responsible for this?

- a) Global governance
- b) Local governance
- c) Man Made Co2 emissions

d) Others
115. Please give me your opinion about how to we achieve climate justice in global and local level?

- a) Reduce industrial emissions
- b) Require to Global and local governance committed for climate justice
- c) To change our life style
- d) Improve global economic system
- e) To build awareness

116. Is it necessary to add the topic about the consequence and bad effects of climate change in school, college, and university as well as community level?

- a) Yes
- b) No
- c) Others

117. In your coastal region during summer time you faced any drought problem

- a) Yes
- b) No

118. If yes what type of problem you faced?

- a) Water shortage
- b) Health problem
- c) Loss of Agriculture and crop production
- d) Food shortage
- e) Heat stress
- f) Others

119. Do you think economic activity risk for climate change and sea level rise and social inequality?

- a) Yes
- b) No

120. If yes what this local level and global level

- a) Technology
- b) Chemical
- c) Global Capitalism
- d) Others

121. Do you think Farakka dam contribute climate change in SWCRB

- a) Yes
- b) No

122. If yes how Farakka dam contribute climate change in SWCRB

- a) Rain session over flow in river

- b) Dry session drought
- c) Others

123. What do you think different social groups will be affected SWCRB by SLR?

- a) Yes
- b) No

124. Do you think that sea level rise will influence existent social justice issues/inequalities moreover climate injustice?

- a) Yes
- b) No

125. Do you think Bangladeshi media highlights on the issues of climate justice?

- a) Yes
- b) No
- c) Don't Know

126. According to our inequality of climate justice do you think Media should high light more news

- a) Yes
- b) No

127. Do you think in coastal community Indigenous & Marginalized people more vulnerable due to CC and SLR then other people?

- a) Yes
- b) No

128. If yes how Media should high light more news

- a) Daily
- b) Weekly
- c) Monthly
- d) Everyday News bulleting

129. Adaptive alternatives in relation to adverse Situations

- a) Financial management for health care
- b) Alternative adaption through microcredit /loan
- c) Occupational changes
- d) Migration as an alternative process
- e) Social networking
- f) Savings

g) Others

130. In your SWCRB what is the Strong or massive disasters in last 50 years

Yes

No

No Answer

List of the loss

Loss of mangrove forest and biodiversity

Loss of land and capital

Loss of health and life

Loss of fish farming

Loss of crop production and agriculture

Loss of cattle

Injured

Type of Hazards

Tidal Surge

Salinity Intrusion

Loss of agriculture and biodiversity

Heavy storm and thunderstorm

Heavy rainfall

Flash flood

Erosion and land loss

Drought and heat stress

Cyclone

2nd phase Questionnaire

1. Gender

- a) Male,
- b) Female

2. Age

- <30
- 30-39
- 40-49
- 50-59
- 60-69
- ≥70

3. Education

- a. Primary
- b. High School
- c. SSC
- d. HSC
- e. Hon's
- f. Masters

3. Union

- 1. Atulia,
- 2. Bhurulia,
- 3. Burigoalini,
- 4. Gabura,
- 5. Ishwaripur,
- 6. Kaikhali,
- 7. Kashimari,
- 8. Munshiganj,
- 9. Nurnagar,
- 10. Padmapukur,
- 11. Ramjannagar,
- 12. Shyamnagar.

4. Religious faith of respondent

- Islam
- Hindu
- Christian
- Buddhist
- Others

5. Primary income source

- Day Laborer
- Agriculture
- Service
- Fishing/Fish cultivation
- Crab cultivation/Fattening
- Cow Rearing
- Goat/sheep rearing
- Chicken/Duck/Pigeon farming

- Rickshaw/Van pulling
- Driver of Motorbike/Taxi
- Grocery Shop
- Tailoring
- Vegetable Cultivation
- Hawker
- Mid Servant
- Teacher/House Tutor
- No permanent job
- Other
- No earning

6. Primary income amount

6. Total Earning Range

- a. 0-5000
- b. 5000-10000
- c. 10000-15000
- d. 15000-20000
- e. 20000-25000
- f. 25000-30000
- g. >30000

7. What type of hazard risk you observed in the 12 Unions of the Shyamnagar Upazila?

- Cyclone
- Salinity
- Water logging
- Riverbank erosion
- Flood
- Thunderstorm
- Drought

8. How are you sorting climatic occurrence, vulnerability, and risk and capability ability in the SWCRB? (High, Low, Medium)

- 1. Capacity
- 2. Critical infrastructure of the community
- 3. Financial Risks
- 4. Population density in the SWCRB
- 5. Public live in probable vulnerable area
- 6. Certainty
- 7. Probability of climatic hazards
- 8. Resiliency of the house
- 9. Damage Severity
- 9. Socio-economic condition of the community
- 11. Vulnerability
- 12. Preparation for disaster plan
- 13. Distinctive atmospheric hazard
- 14. Diverse income options
- 15. General awareness of hazards
- 16. Vulnerability in the focus area
- 17. Minimizing disaster risk by stakeholders
- 18. Others risk, hazards and vulnerability

19. Recognized DRR legislation
 20. Status of Carbon emissions global level
 21. Disaster management by stakeholders
 10. What type of existing adaptation practices for safe drinking water ?
 Harvesting Rainwater
 Pond water refining via deep rutted knowledge
 pond water refining via govt. maintained filter
 Proper pond management for directly using pond water
 Filtering Pond
 Others

11. In your area what type of structural adaptation people taken in daily life

School cum cyclone shelter
 Raising plinth
 Lowering house roof (Low house)
 Gola (a granary, a storehouse for grain)
 Eter Paja (Household Level Brick-kiln)
 Goalghor (Cow-shed)
 Embankment renovate by local people
 Disaster resilient stronger houses
 Bamboo made piling
 Bamboo cage

12. What types of adaptations respondents want to see in future? **High, Medium, Low**

Concrete Approach

Infrastructure for flood defenses
 Safe keeping cyclone refugee
 Erect /fix sluice gate and tunnel
 Calamity-combatting house
 Increasing the roads in remote area
 Install slab
 Raise the elevation of the ridge
 Construct embankment
 Clean water shortage
 Sanitation and health
 Raising the platform of tub well
 Rain water harvesting in remote
 Initiate health care center
 Monetary funding for poor
 (PSF) for drinking water
 Dig the new pond
 Confirm micro credit
 Alternative livelihood options
 Increase rain water harvesting system
 Government hospital every unions
 Awareness different diseases
 Awareness of hand wash
 Increase paddy farming

Food safety

Reduce shrimp gher
 Harvesting fish diversity
 Soil fecundity by the organic fertilizer
 Obtainability of agricultural apparatus
 Saline resistant rice variations
 Clean water for crop cultivation
 Planting Salt lenient tree

3rd phase Questionnaire

1. Gender

- a) Male
- b) Female

2. Age

- <30
- 30-39
- 40-49
- 50-59
- 60-69
- ≥70

3. Education

- a. Primary
- b. High School
- c. SSC
- d. HSC
- e. Hon's
- f. Masters

3. Union

- 1. Burigoalini,
- 2. Gabura,
- 3. Padmapukur,
- 4. Primary income amount
- 4. Total Earning Range

- 1. 0000-5000
- 2. 5000-10000
- 3. 10000-15000
- 4. 15000-20000
- 5. 20000-25000
- 6. 25000-30000
- 7. >30000

4. Which sources of drinking water you use?

- 1. Deep tube well
- 2. Shallow tube well
- 3. Supply water
- 4. River
- 5. Pond
- 6. Rain water
- 7. Pond Sand Filter

5. Water demand for drinking and cooking per household per day

- 1. 1 to 10 litters
- 2. 11 to 20 litters
- 3. 21 to 30 litters

4. 31 to 40 litters

6. Distance of safe drinking water from household

- 1. Homestead to near home within 500 meters
- 2. Separate the homestead within 500 to 2000 meters
- 3. Far from homestead within 2000 to 4000 meters
- 4. So far from homestead within 4000 to 6000 meters
- 7. Challenges of the respondents
 - 1. Poor social cohesion in the community
 - 2. Lack of organizational support
 - 3. Very poor economic conditions
 - 4. Very far distance safe drinking water sources

8. What type of diseases children are suffering from the following

- 1. Pneumonia/ cough or cold
- 2. Malnutrition
- 3. Water borne diseases
- 4. Food poisoning
- 5. Helminthiasis
- 6. Asthma attacks
- 7. Conjunctive eye problem
- 8. Infectious diseases
- 9. Hepatitis A /others

8. General people suffered what type of following diseases in your area

- Respiratory disease: Allergy, Asthma
- Gastric
- Diabetes
- Infectious diseases
- Cardiac diseases
- Non-communicable diseases
- Physiological/ Mental illness
- Tuberculosis
- Osteoporosis
- Eclampsia
- Eye Problem/ Pain
- No appetite
- Skin Disease
- Iron Vitamin Deficiency
- Malnutrition
- Dysentery/ Diarrhea
- Mild stroke
- Mosquito-borne diseases
- Cold and Coughing
- Cancer
- Menstrual difficulty

Headache
Teeth Problem/ Pain
Water borne diseases
Others

Outside study area hospital

9. Women suffered what type of diseases in your area

Anemia
Sugar in urine/ Albumin in urine
Infectious diseases
Bleeding per vagina
Eclampsia
Miscarriage
Fever
Delay obstructed pregnancy
Water borne diseases
PV bleeding
Malnutrition
Urinary tract infection
Nipple problem
Early puberty
Breast tumor
Early born baby
Breast milk without having baby
Infant mortality
Leucorrhoea & Vaginitis problem
Cardio Vascular Problem
10. Measures taken by households for safe drinking water and health
Personal water filter
Piped water supply
Purchase of potable water
Rainwater harvesting
Pond sand filter
Periodical medical check
Temporary migration during dry period
Balanced use of water
Monitoring disease spread through
TV/newspaper
Stocking of water in advance
Personal hygiene and sanitation

11. Health care options in your area
Ayurvedic practitioner/physician
Homeopathy
Local doctor
Community clinic
Paramedical doctor
Upzila health center
Zila Health center
Private clinic