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## Impact of Climate Change and Sea Level Rise on Coastal Zone of Bangladesh

F. A. Samiul Islam<sup>1\*</sup>

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### ABSTRACT

Although there have been changes to the climate since the beginning, their effects have just become apparent in recent decades. The Bay of Bengal has a geomorphological and hydrological influence on Bangladesh's coastal region. Cyclones, storm surges, and increasing sea levels plague this region frequently, causing terrible damage to these low-lying coastal areas. Bangladesh's coastal regions are especially susceptible to natural catastrophes because of their position and the consequences of climate change. Increased stress and adverse effects on coastal ecosystems, biodiversity, livelihoods, the economy, and food security are all consequences of increasing climate change. Bangladesh, a coastal nation on the Bay of Bengal with a 710-kilometer coastline, is experiencing several effects from sea level rise. Bangladesh has already seen soil erosion, salt intrusion, and biodiversity loss as a result of it, and its possible risks are just going to get worse. Salinity intrusion, flooding, crop failure, infrastructure damage, fisheries devastation, biodiversity loss, and river bank erosion are all consequences of sea level rise. Approximately 20% of Bangladesh's total land area and over 30% of its fertile land are located along the coast. Estuaries, coral reefs, dunes, wetlands, and the Sundarbans, the biggest mangrove tract in the world, are among its many different ecosystems. Climate change is already having several effects on the nation, including stronger cyclones, the possibility of flooding, erosion, rising water levels, saltwater intrusion, and biological effects. The most susceptible coastal habitats are low-lying coastal plains, mangroves, tidal deltas, coral reefs, coastal wetlands, sand beaches, and estuaries. The environment and, eventually, the coastal region's socioeconomic structure will be impacted by these biophysical resources. The nation's most significant ecosystem, the Sundarbans, will be devastated if sea levels rise by one meter. The purpose of this study is to determine the current state of climate change and its historical effects at the regional level, as well as the justification for evaluating coastal risk, environmental effects, risk potential, and climate change adaptation tactics.

### INTRODUCTION

These days, climate change is a major concern. The world's temperature is rising due to a variety of human activities. Global warming, or climate change, is the end effect. The world's low-lying coastal regions and deltas are impacted by sea level rise, which is caused by rising atmospheric temperatures. According to the 1990 Intergovernmental Panel on Climate Change, if greenhouse gas emissions continue at their current rate, the world would be 3.30C warmer by the end of the next century, with a range of uncertainty between 2.2 and 4.90C (Warrick *et al.*, 1993). As temperatures rise, these layers will expand as a result of thermal expansion and ice melting.

Based on geographical features, Bangladesh's coastal region is divided into three parts: the eastern, central, and western regions. Numerous canals and creeks crisscross the semi-active delta in the western area, known as the Ganges tidal plain. The most vigorous and ongoing accretion and erosion processes occur in the center region, which contains the Meghna River Estuary. More stable hilly terrain covers the eastern region (Thomas & Wratten, 1992).

Sea level rise brought on by human-caused global climate change can have a significant negative impact on coastal

ecosystems. Increases in CO levels brought on by the burning of fossil fuels, aerosols, and cement production are the main causes of human-induced climate change. Additional elements include deforestation, animal husbandry, ozone depletion, and land use. There were roughly 280 parts per million of carbon dioxide in the atmosphere. It is at 350 ppm and growing. Methane and nitrous oxide, two more greenhouse gases, were shown to have increased similarly (Minar & Hossain, 2013).

"Global warming is now a debatable topic, and it has had effects on the climate. The climate is changing rapidly due to global warming. Fuel burning in vehicles and industries generates excess heat and disturbs the thermal balance of nature. As a result, chaos has arisen in nature (Islam, 2023)." Known as a zone of vulnerability, Bangladesh's coastal region is susceptible to several natural calamities. Climate hazards have been present in some developing nations, and certain dangers cannot be avoided and may result in increased property damage and fatalities. Storm surge, sea level rise, water logging, salinity intrusion, and coastal flooding are all consequences of the ongoing storms that affect Bangladesh's coastal regions (Ahmed & Jahra, 2019).

<sup>1</sup> Independent Scientist and International Reviewer, Dhaka, Bangladesh

\* Corresponding author's e-mail: [samir214100@yahoo.com](mailto:samir214100@yahoo.com)

### LITERATURE REVIEW

The climate of Bangladesh is tropical, warm, and humid. Monsoons dominate its climate, with pre-monsoon and post-monsoon circulations also having an impact. Originating over the Indian Ocean, the south-west monsoon brings with it warm, humid, and erratic air. Although the dates vary slightly from year to year, the monsoon season begins in the first week of June and concludes in the first week of October. The easterly trade winds, which provide warm and comparatively drier circulation, are active in addition to the monsoon. Pre-monsoon (March to May), monsoon (June to early October), post-monsoon (late October to November), and winter (December to February) are the four main seasons of Bangladesh (Teeto, 2003).

Bangladesh is prone to natural disasters, and its coastal population constantly faces these challenges. The country's environmental pollution, carbon emissions, and deforestation are the main sources of these natural risks. Because of the gradual changes in the climate, adversity has a significant negative influence on livelihood in coastal areas. Sea level rise, floods, tornadoes, cyclones, landslides, droughts, wildfires, salinity, glacier melting, and the spread of different species and illnesses are all consequences of human-caused global warming (IPCC,

2001).

The primary crop is rice, and production is declining in the coastal regions of the southwestern part of Bangladesh, especially in the districts of Khulna, Bagherhat, and Satkhira. This is because fresh water is scarce and salty water reduces soil fertility (Ali, 2000). The country's agricultural industry is at long-term risk due to climate change, which makes Bangladesh one of the most vulnerable nations, especially in regions that experience drought, saltwater intrusion, and flooding.

The negative consequences of climate change and environmental degradation are forcing an increasing number of people to relocate or put themselves in danger in the southwest region of Bangladesh. Bangladesh is especially at risk from the climate problem. Rising sea levels, storms that get stronger, high heat, and flooding are all problems for the Bay of Bengal's coastline region. The negative consequences of climate change and environmental degradation are forcing an increasing number of people to relocate or put themselves in danger in the southwest region of Bangladesh. Bangladesh is especially at risk from the climate problem. The Bay of Bengal's coastline region is subject to excessive heat, cyclone intensification, catastrophic flooding, and increasing sea levels.



**Figure 1:** Climate change impacts in the coastal region of Bangladesh.

Source: Akter et al. (2010)

Bangladesh's coastal regions are distinct from the rest of the nation due to their distinct geophysical features and many sociopolitical ramifications, which frequently restrict people's access to resources and increase risk and vulnerabilities. The coast of Bangladesh is the most

vulnerable to natural disasters and is particularly impacted by climate change, with issues like cyclones, flooding, soil erosion, salt, and waterlogging. In addition, coastal islands and wetlands are vulnerable to flooding, significant erosion, and salinization, which could jeopardize the

region's biodiversity, ecosystems as a whole, livelihoods, sediment dynamics, and geomorphology.

### MATERIALS AND METHODS

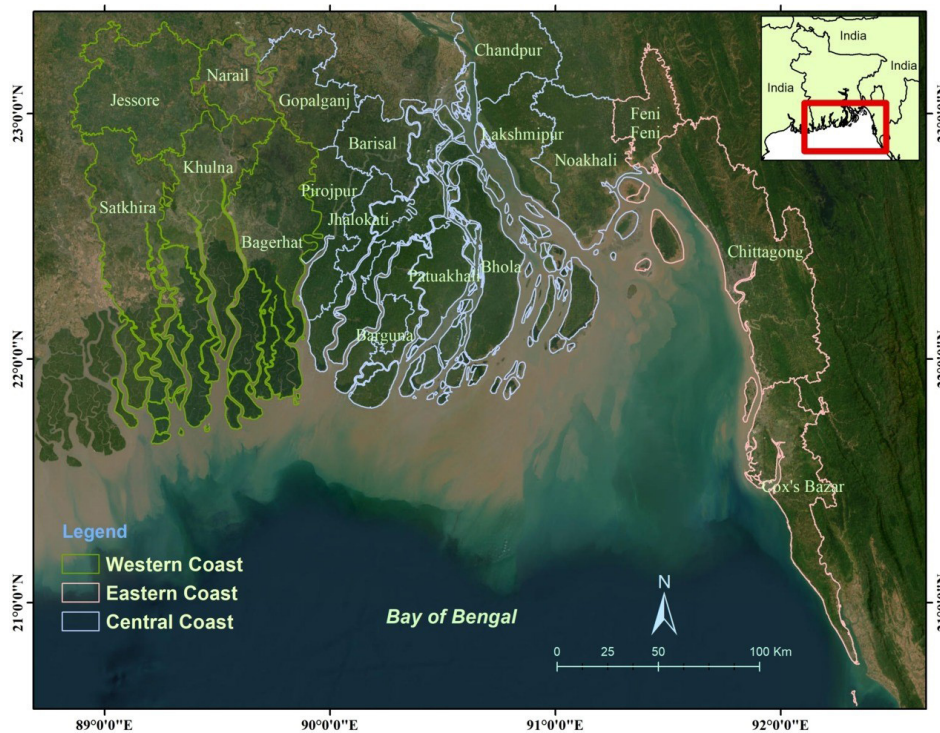
The Scopus Index, PubMed, Academia, Research Gate, and Google Scholar were used to search the literature, and the results of that search and any related ones were taken into account. The data used in this study came from secondary sources. Secondary data was gathered by doing an extensive online and offline literature review on climate change, its effects, the present situation of Bangladesh's climatic condition, coastal government surveys, and agriculture statistics, difficulties in Bangladesh. Furthermore, pertinent government papers and policy documents were gathered from government organizations. Books, government reports, international reports, scientific journals, news pieces, and internet publications that concentrate on climate change-related

concerns in Bangladesh are among the resources. For the task, some research in the same topic conducted in other countries was also taken into consideration. This approach is a research tool used to read and code textual material to extract valuable information about various subjects.

### RESULTS AND DISCUSSION

#### The Coastal Zone of Bangladesh

Bangladesh is a country of rivers and canals, situated in a flood plain delta. At the southern end, the nation meets the Bay of Bengal, and it slopes gently from the north to the south. The entire coastline is 710 km long and goes parallel to the Bay of Bengal. According to the Government of Bangladesh's coastal zone policy (CZPo, 2005), 19 of the 64 districts, or 147 upazillas<sup>1</sup> (Figure 2), are located in the coastal zone. Just 12 of these 19 districts have a direct connection to the sea or lower estuary.



**Figure 2:** Coastal zone of Bangladesh

Source: Shampa et al. (2023)

#### Eastern coastal zone

From the southernmost point of the continent, Bodormokam, to the estuary of the Feni River, the eastern coastal zone begins. It's a fairly little area. Alongside this area are many little hills. The Sangu and Matamuhury rivers empty into the Bay of Bengal at this point. The Bay of Bengal, where the Naf River drains, divides Bangladesh from Myanmar. The predominant soil features in the eastern coastal zone are mudflats and submerged sands (Islam, 2001). From Cox's Bazar to Teknaf, the zone's submerged sand has formed a lengthy sandy beach stretching 145 km. In terms of tourism, this coastal area is home to Patenga and Cox's Bazar, two of the nation's most significant sandy beaches. The primary

economic activities of the area include salt production, bay fishing, fish farming, and tourism.

#### Central coastal zone

The Noakhali, Barisal, Bhola, and Patuakhali districts are all part of the central coastal zone, which stretches from the estuary of the Feni River to the eastern edge of the Sundarbans. A significant amount of silty deposition is formed in the area due to the Ganges, Brahmaputra, and Meghna river system's heavy discharge. According to Allison et al. (2003), silt makes up about 70% of the region's sediment load, with sand making up the remaining 10%. Erosion and accretion rates are high in the area due to the zone's highly dynamic morphology

caused by the sediment discharge and strong current. There are many islands in the region, notably Bhola, the only island district in the nation. In recent years, the process of land accretion has created a large number of islands in the region. Many have also been lost or corroded at the same time (Rahman *et al.* 1993). Located in the Patuakhali district's Khepupara upazilla is Kuakata, a charming sandy beach.

**Western coastal zone**

The Sundarbans mangrove forest, which is situated along the western coast, covers Greater Khulna and a section of the Patuakhali district. Because of the mangrove forests in the area, soil erosion is quite constant. Tidal creeks, mangrove swamps, tidal flats, and natural levees are some of the zone's features. Fish and shrimp species use the mangroves in the area as feeding and breeding grounds, which enhances the region's fisheries biodiversity. The elevation of the region is between 0.9 and 2.1 meters above mean sea level (Iftekhar & Islam, 2004). The soil types present in the western coastal zone are alluvium and silty loams. According to Islam (2003), mangrove-dominated coastal areas have developed on newly formed soil formations composed of alluvium that spilled down from the Himalayas. The region is also home to Sundarbans tourist attractions.

**Islands**

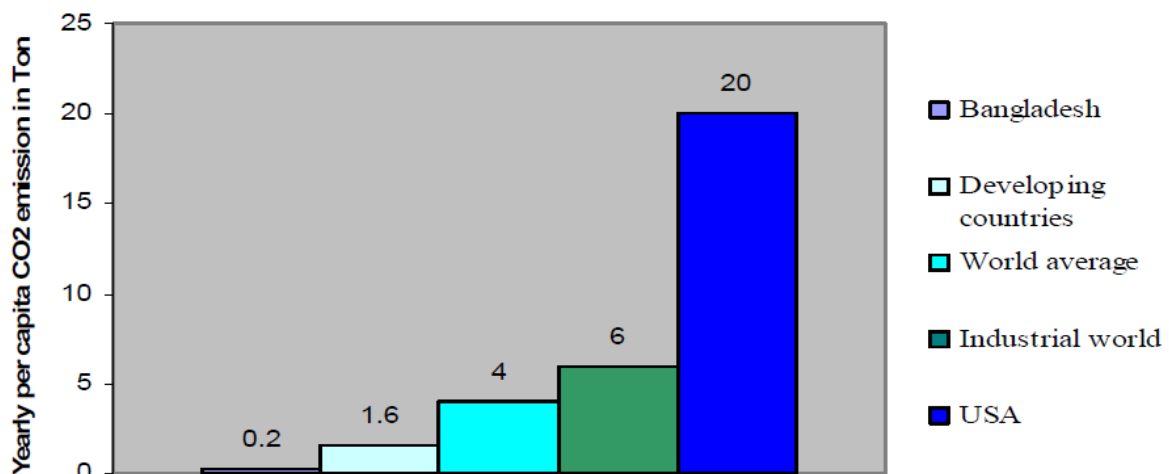
As of right now, the coastal zone has about 60 islands identified (Islam, 2004). The majority of the islands are found in the central coastal zone due to the Ganges, Brahmaputra, and Meghna river system's dynamic water movement. There are four larger islands in the area: Bhola, an administrative district, Hatia, Sandweep, and

Maishkhali, three upazilas. Some islands are only accessible from a tiny village. Situated around 9.8 kilometers to the southeast of the mainland in the Bay of Bengal, St. Martin is the only coral island in the nation (Hossain, 2001). The island is located in the Cox's Bazar district's Teknaf thana and covers an area of 7.5 km<sup>2</sup>. Additionally, there are 177 char lands in the coastal zone (Islam, 2004).

**Causes of Sea Level Rise**

The earth's atmosphere accumulates carbon dioxide (CO<sub>2</sub>) and other greenhouse gases as a result of several human activities, which causes climate change. The volume of the ocean increases in two ways when temperatures rise. It first causes the bulk volume of ice in the polar regions to melt, and then it causes the ocean's water to expand thermally. According to Wigley and Raper (1987), estimates of the proportional contributions of thermal expansion and glacier melting to this sea level increase differ greatly, ranging from a negligible expansion effect to nearly equal roles for expansion and ice melting to a significant expansion effect. Both of these elements contribute to the earth's ocean water volume and sea level rise.

The primary human cause of sea level rise and global warming is the burning of fossil fuels. One more human activity that is causing the CO<sub>2</sub> sink to shrink is deforestation. According to Miller (2004), burning fossil fuels has been responsible for 75% of human-caused CO<sub>2</sub> emissions since 1980, with deforestation, agriculture, and other human-caused land use changes accounting for the remaining portion. Current CO<sub>2</sub> emissions are mostly caused by over 700 million gasoline-powered motor vehicles (555 million of which are cars) and thousands of coal-burning power and industrial facilities worldwide.



**Figure 3:** Worldwide per capita carbon dioxide emission  
*Source: NAPA, (2002)*

The emissions from U.S. coal-burning power and industrial facilities alone exceeded the total CO<sub>2</sub> emissions of 146 countries, which comprise 75% of the world's population (Miller, 2004). Considering its small size, Bangladesh contributes very little to greenhouse gas emissions. The National Adaptation Programs of Action (NAPA, 2002) debate states that Bangladesh emits 0.2 tons of CO<sub>2</sub> per person annually. However, the corresponding figures for the industrial world, emerging nations, and the United States of America (USA) are 1.6, 4.0, 6.0, and 20.0 tons, respectively (Figure 3).

Only one nation, the United States of America, is accountable for 23% of the annual carbon emissions from fossil fuels into the atmosphere. Bangladesh makes up a pitiful 0.06% of the contrast (Warrick *et al.*, 1993).

In addition, the process of sea level rise is influenced by thermal expansion, glacier melting, and some local characteristics including siltation and subsidence.

### Sea Level Rise in Bangladesh

Due to its dense population and smooth terrain, which includes both small and wide ridges and depressions, Bangladesh is extremely vulnerable to sea level rise (Brammer *et al.*, 1993). By 2020, 2050, and 2100, sea levels will increase by 10 cm, 25 cm, and 1 m, respectively, affecting 2%, 4%, and 17.5% of the total land mass, according to World Bank estimates from 2000 (Table 1). According to Md. Golam Mahabub Sarwar, Patrik Wallman, (2005), Bangladesh's sea level is rising by 1.0 cm per year.

**Table 1:** Sea level rise (SLR) in Bangladesh and its possible impacts Year (Adapted from World Bank, 2000).

Year	2020	2050	2100
<b>Sea Level Rise(SLR)</b>	10cm	25cm	1 m (high end estimate)
<b>Land below SLR</b>	2 % of land (2,500 km <sup>2</sup> )	4 % of land (6,300 km <sup>2</sup> )	17.5 % of land (25,000 km <sup>2</sup> ). Patuakhali, Khulna and Barisal regions will be most affected
<b>Storm surge</b>	---	The 1991 cyclone recurs with a 10% increase in strength, a 0.2 m sea level rise, a 7.2 m storm surge, and a wind speed that rises from 225 to 248 km/h.	When sea level rises by one meter, storm surge increases from 7.4 to 9.1 meters.
<b>Flooding</b>	An increase in flooding of 20%.	Flooding in the Ganges and Meghna floodplains has increased. Floods during the monsoon season enhance yield loss.	The area under water and the severity of the flood will both rise significantly.
<b>Agriculture</b>	Inundate 0.2 million tons of production (less than 1% of the present quantity).	0.3 metres Sea level rise submerges 0.5 million tons of production, or 2% of the existing total.	In any given year, a devastating flood could result in crop failure.
<b>Ecosystem</b>	15% of the Sundarbans are submerged.	40% of the Sundarbans are under water.	The loss of the Sundarbans would occur. Estuarine fish populations would decline if the Sundarbans and other coastal wetlands were lost because fewer fish would have breeding habitats.
<b>Salinity</b>	Increase	Increase	Increase

According to UNEP (1989), the coast of Bangladesh would see a 1.5 m sea level rise by 2030, impacting 22,000 square kilometers (16% of the country's total landmass) and 17 million people (15 percent of its total population). The predicted pace of sea level rise has changed due to uncertainty since this scenario was computed in 1989. This scenario will arise in roughly 150 years if current trends continue. However, the number of potential residents impacted by the UNEP's 1.5-meter sea level increase (17 million) and the World Bank's 1-meter sea level rise (17.5 million) projections is comparable. "Plastic waste emits greenhouse gases at every stage, as the extraction and transportation of plastics are dependent on oil, gas, and

coal. The production and disposal of plastic also emit tons of carbon (Samiul Islam, 2023)."

"Pollution of carbon dioxide (CO<sub>2</sub>) and methane (CH<sub>4</sub>), two potent greenhouse gases that hold heat in the atmosphere and produce global warming, results in rising temperatures, melting glaciers, rising sea levels, extreme weather events, and ecological damage. Methane is especially powerful because of its greater capacity to trap heat despite having a shorter lifespan than carbon dioxide. (Samiul Islam, 2025)" Bangladesh will have to deal with the severe effects of sea level rise as a low-lying deltaic nation, including the permanent flooding of massive land masses along the shore. There is ample

proof that Bangladesh’s climate is changing, leading to variations in precipitation, an increase in the country’s yearly mean temperature, and a rise in sea level. The yearly mean temperature rose at a rate of 0.0037 degrees

Celsius between 1961 and 1990, but not at all between 1961 and 2000. Over the past ten years, the average yearly temperature increase has nearly doubled compared to prior years.

**Table 2:** Predicted changes in temperature and precipitation

Year	Sea Level Rise (cm)	Temperature Rise (°C)	Percentage of Changes in precipitation (Base 1990)
<b>The World Bank’s second IPPC forecast from 2000</b>			
2030	30	Monsoon: +0.7 Winter: +1.3	Winter: -3 Monsoon: +11
2050	50	Monsoon: +1.1 Winter: +1.8	Winter: -37 Monsoon: +28
<b>Agarwala et al. (2003)’s third IPPC projection</b>			
2030		Monsoon: +0.8 Winter: +1.1 in	Winter: -1.2 Monsoon: +4.7
2050		Monsoon: +1.1 Winter: +1.6	Winter: -1.7 Monsoon: +11.8
2100		Monsoon: +1 Winter: +2.7	Winter: -3.0 Monsoon: +11.8
2030	30	The monsoon and winter seasons have increases of 0.7 and 1.3, respectively.	11% more during the monsoon and 3% less during the winter.
2050	50	The monsoon and winter seasons have increases of 1.1 and 1.3, respectively.	28% more during the monsoon and 37% less throughout the winter.

Source: Shamsuddoha et al. (2007)

We all thought that the expected sea level rise will probably destroy most of the existing coastal areas and create climate change globally due to the greenhouse effect if preventive measures are not put into place with a coordinated global effort. In Bangladesh, there is virtually little factual data on the degree of sea level rise. The Bay of Bengal’s sea level has risen by 0.5 meters and Bangladesh has warmed by roughly 0.5 degrees Celsius over the past century (Shamsuddoha et al., 2007). Sea levels are rising at a rate of 5.18 mm per year in the southwest Khulna region, and by 2050, they could reach 85 cm. Twenty million people will become environmental refugees as a result of a 100 cm sea level rise in Bangladesh over the next 100 years, according to a World Bank study on

the subject. A nation like Bangladesh may not be able to house such a large number of displaced people. The country’s low-lying areas would be 29 percent more likely to flood with a 2-degree temperature increase and a 45 cm rise in sea level, which could permanently inundate 145 km of coastline from Cox’sbazar to Badar Mokam. The frequency and impact of floods, cyclones, droughts, infectious diseases, and other linked effects of climate change are on the rise, even though changes in the weather appear minor and even gradual. Based on the increasing trend, annual average temperature will increase by 0.22°C by 2050 and by 0.41°C by 2100. Annual average precipitation will increase by 296 mm by 2050 and by 543 mm by 2100.

**Table 3:** The sea level rise(SLR) forecast for 2050 and 2100

Parameters	Typical Situation		The Worst Situation	
	2050	2100	2050	2100
Relative sea level rise overall, cm	83	340	153	460
Absolute sea level rise, cm	13	200	13	220
Subsidence of land, cm	70	70	140	240
Erosion of the shoreline, kilometer	1	2	1.5	3
Loss of livable land, in kilometer <sup>2</sup>	1	26	16	34
Population displaced, %	7	30	13	40
Mangrove area reduction	50	75	79	95

Source: Shamsuddoha et al. (2007)

### **Impacts of Sea Level Rise on the Coastal Zone of Bangladesh**

One of the primary threats that could increase Bangladesh's coastline's susceptibility to the consequences of climate change is sea level rise. According to projections, 40% of the productive land in the southern part of Bangladesh will be lost due to a 65 cm rise in sea level by the 2080s. Approximately 20 million residents in the coastal region are already impacted by salinity (CCC, 2009).

#### **Salinity Intrusion**

Salinity intrusion into the coastal aquifer poses the biggest threat to the provision of drinkable water for households. Public health and livelihoods are immediately at risk due to the consequences of increased salinity brought on by saltwater intrusion on agriculture, infrastructure, aquaculture, coastal ecosystems, and the availability of freshwater for residential and commercial use. In Bangladesh, salinity affected 83.3 million hectares of land in 1973; this number increased to 102 million hectares in 2000, then to 105.6 million hectares in 2009, and it continues to rise (Ahmed & Jahra, 2019). Salinity intrusion is slowly moving toward inland water due to the growing effects of climate change.

#### **Impact on salt industry**

Bangladesh is among the nations that produce salt. Bangladesh's Cox's Bazar coastline is suited for salt production. Along the nation's Cox's Bazar coast, an area of about 19,670 hectares has been used for salt production. Only the Chakaria and Cox's Bazar Sadar thana of the region include 216 salt pans, totaling 8,153 hectares, which produce 175,030 metric tons of salt a year (Hossain & Lin, 2001). This coastal industry is entirely dependent on the level of the seawater.

#### **Impact on fisheries and aquaculture**

The river estuary's location would shift due to sea level rise, significantly altering the fish's habitat and breeding grounds. In brackish water, where fresh and salt water mix, prawns breed and grow. Prawn habitat would change when sea level rise reverses this interaction. According to Haque (2003), the coastal zone is home to 124 shrimp processing facilities and 60 shrimp hatcheries. In the Cox's Bazar district, the hatcheries are situated in Teknaf, Ukhia, and Sadar Thana. Establishing hatcheries in an area is primarily motivated by favorable environmental conditions and the availability of brood stock. Test production has also begun at a few hatcheries on the coasts of Satkhira and Chittagong. Shrimp fields and hatcheries are particularly susceptible to the phenomenon of sea level rise. Sea level rise is detrimental, but it is also beneficial for shrimp farming since it brings salinity to the coastal region. Flooding is one further effect of sea level rise that is seriously harming the industry by overflowing shrimp ponds and releasing the shrimp into open water. (Sarwar, 2005)

### **Impact on agriculture**

One disadvantage of growing shrimp in salty water is that it reduces rice output because the soil quality deteriorates. The situation is typical of practically all rice fields in the districts of Khulna, Satkhira, and Bagerhat, and the rate of decline is extremely high. According to a World Bank research from 2000, a 0.3-meter rise in sea level will result in increased salt alone, which will reduce rice production by 0.5 million metric tons. Rice production in particular is impacted by sea level rise in two ways. The degradation of soil quality caused by salinity intrusion reduces or stops rice production. Because there are fewer rice field areas when the rice fields are turned into shrimp ponds, the overall amount of rice produced falls.

#### **Water Logging and Coastal Flooding**

Because of its distinct topography, geographic location, and vulnerability to tropical storms, Bangladesh is among the nations most vulnerable to flooding worldwide. Coastal flooding is a frequent issue because 50% of the land is less than 8 meters above sea level and there is about 600 km of coastline. Approximately 45.5 million people are at risk of experiencing severe and moderate floods, such as tidal, flash, and river floods. Floods in 1974, 1987, 1988, and 1998 destroyed infrastructure and crops and claimed 30,000, 1657, 2379, and 1000 lives, respectively (CCC, 2009).

#### **Cyclones**

Cyclones seriously harm Bangladesh's economy, environment, coastal infrastructure, and property in addition to taking a large number of people. Nearly every year, a destructive cyclone strikes the coastal zone. In the last 50 years, tropical cyclones have killed almost 718,000 people in Bangladesh, making it particularly vulnerable. The post monsoon months of October through December and the pre monsoon months of April through May are when the Bay of Bengal is most susceptible to cyclones. An increase in sea surface temperature was linked to a prediction of stronger tropical cyclones and the storm surges that accompanied them (Ahmed & Jahra, 2019).

#### **Impacts on tourism**

Sandy beaches are a major feature of Bangladesh's coastline and draw tourists. Popular tourism spots in the country include Kuakata Beach in Patuakhali district, Patenga Beach in Chittagong district, and Cox's Bazar Beach in Cox's Bazar district. The world's largest complete sandy beach is Cox's Bazar Sea Beach, which stretches 145 kilometers (Hossain & Lin, 2001) draws both domestic and foreign tourists. The Bangladesh Parjatan Corporation (BPC) has chosen 18 tourist attractions, five of which are in the coastal region: Chittagong, Cox's Bazar, Kuakata, Khulna, and the Sundarbans. Due to its proximity to the shore and greater vulnerability than Cox's Bazar and Chittagong, Kuakata's tourism industry will be the most negatively impacted. However, every place listed is extremely susceptible to natural disasters

like floods and storm surges brought on by sea level rise. (Ahmed *et al.*, 2018).

**Storm surge**

Storm surges linked to strong tropical cyclones are the most dangerous coastal marine hazard in the world. They can result in significant property and human casualties, damage to coastal infrastructure, and agricultural losses in the impacted nations. According to Ahmed and Jahra (2019), the low-lying ground and inadequate protection against surge waves make the western coastal zone especially susceptible to surge floods. The region in the world with the greatest risk of a catastrophic death toll from a storm surge linked to a tropical cyclone is the Bay of Bengal. Chittagong, Noakhali, Barisal, Patuakhali, and Khulna, as well as certain inland places of Comilla, Faridpur, and Dhaka, experience storms more frequently in the southern regions of Bangladesh.

**Land erosion of coastal areas**

Since Bangladesh’s central coastal region is the most morphologically active, the coast erosion there is terrible. The Meghna river estuary’s coastal region is among the world’s most morphologically changeable places. According to a GIS-based analysis, the central coastal zone of Bangladesh has seen 1183 km<sup>2</sup> of land erode at a rate of 118.3 km<sup>2</sup> per year between 1995 and 2005 and 1194 km<sup>2</sup> between 2005 and 2015. The Meghna Estuary and the shores of important islands, including the eastern coast of Bhola, the northern coast of Hatiya, and the southwest coast of Sandwip, saw significant erosion

**Impact on Health**

The average seawater salinity is 35 parts per thousand, or 3.5%. When dissolved in water, sodium chloride (NaCl), which makes up the majority of the salt found in seawater, separates into the ions Na<sup>+</sup> and Cl<sup>-</sup>. for the reason that cholera sickness breeds and grows in coastal areas. According to Jacobsen *et al.* (2002), the water salinity in Bangladesh’s coastal regions ranges from 0 to 20 parts per thousand. The distribution of water salinity in coastal areas is rising as sea levels rise (Alam, 2003; IPCC, 2001a; World Bank, 2000). In coastal areas, cholera germs are gaining favorable habitat and proliferating due to the increased salt density and distribution. Therefore, cholera sickness is closely linked to coastal water and its salty environment. Cholera outbreaks frequently follow flooding due to contaminated water supplies (Sarwar, 2005). Sea level rise therefore raises the danger of cholera outbreaks by raising the chance of flooding.

**Impact on Ecosystem**

A one-meter rise in sea level will result in the total loss of the Sundarbans (World Bank, 2000). When the Sundarbans disappear, a lot of heritage, biodiversity, fishery resources, lives, and livelihoods are lost, and ultimately, a highly productive ecosystem is lost. (Md. Golam Mahabub Sarwar, Patrik Wallman, 2005) Table 4 depicts the Sundarbans area that has been submerged by various sea level increase scales.

**Table 4:** What happened to the Sundarbans when sea levels rose differently, (Adapted from World Bank, 2000)

Event of Climate Change	Possible Effects
Sea Level Rise(SLR)	<ul style="list-style-type: none"> <li>• 10 cm SLR (Sea Level Rise) will inundate 15% of the Sundarbans.</li> <li>• 40% of the Sundarbans will be submerged due to sea level increase of 25 cm.</li> <li>• 75% of the Sundarbans will be submerged due to sea level increase of 45 cm.</li> <li>• The entire Sundarbans will be submerged due to a 60 cm rise in sea level.</li> <li>• A one-meter rise in sea level will wipe out the entire Sundarbans.</li> <li>• Less valuable Goran and Gewa would take the place of species like Sundari, which are the primary economic species in the Sundarbans.</li> <li>• Inland migration is prevented by the possibility of human settlement.</li> <li>• The number of estuarine fish may decline if the Sundarbans and other coastal wetlands disappear because fewer fish would have breeding habitats.</li> </ul> <p>Increasing sea levels would cause salty water to flow deeper into the delta. Freshwater fish habitat would be diminished, whereas estuarine fish habitat might be expanded.</p>

**Effect on Bangladeshi people’s fundamental necessities**

Bangladeshis’ fundamental necessities include food, clothes, housing, healthcare, and education. The impact

of sea level rise on the fundamental requirements of a significant portion of the population is explained in Table 5. Sea level rise threatens food security and other well-being security by affecting basic requirements.

**Table 4:** Effects of sea level rise on Bangladeshis’ fundamental necessities

Essential Needs	The Impact of Sea Level Rise
Food	Parts of Bangladesh's deltas and agricultural plains would be inundated by rising sea levels (Miller, 2004; Bennett <i>et al.</i> , 1991) that will result in a lack of food by reducing food output. The only factor lowering rice yield by 0.2 million metric tons is saline intrusion brought on by sea level rise. (WB, 2000).

Cloths	Rising sea levels will make poverty worse. Growing poverty will reduce Bangladeshis' ability to purchase apparel.
Housing	Sea level rise will result in the loss of 29,846 square kilometers of land and the loss of dwellings for 14.8 million people in Bangladesh (IPCC, 2001a).
Health	Sea level rise will raise the danger of cholera by expanding the coastal region and raising the salt in the area. It will also intensify floods and make it easier for diarrheal diseases to spread. (World Bank, 2000)
Education	Infrastructure, especially educational institutions, will be destroyed by sea level rise. Additionally, students from families affected by floods or other sea level rise will drop out of school or college to find employment to help support their families.

Source: Samur (2005)

### Reasonable Response To Sea Level Rise In Bangladesh

Even though Bangladesh has very little room for mitigation, it still needs to think about adaptation possibilities. This is due to adaptation being more localized and mitigation requiring global efforts to implement. Therefore, effective adaptation policies and mitigation techniques should be developed and put into place to lessen the effects of sea level rise on Bangladesh.

#### Adaptation

Adjustments to policies that reduce resource strain, improve environmental risk management, and increase adaptive capacity can help adapt to sea level rise. Since farmers and fishermen make up the majority of the people in Bangladesh's coastal communities, adaptation strategies should focus on these two industries to help them deal with the problems that are expected to arise. Salinity-tolerant organisms for the coastal fishing industry can be discovered through effective study. Selection of species should be carried out for environments with low, moderate, and high salinity levels. The fisherman should receive training on growing, cultivating, and harvesting the species once different species have been chosen for various zones or saline conditions. New or sophisticated technology for the industry will also be identified by research. The sea level rise-affected coastal regions of Bangladesh should be prepared for alternate forms of agriculture, and those working in the salt industry should be informed about the potential effects on the industry. To identify the existence of cholera disease-causing bacteria, the coastal water should be regularly studied. Given the threat of water-borne cholera and diarrheal illness to the coastal zone, there should be more options for fresh water supply. Facilities for water treatment ought to be installed nearby. Adapting to the ecosystem's changes is a highly difficult and occasionally impossible undertaking. The Sundarbans should get the majority of attention because it is anticipated that they would be the ecosystem most impacted by sea level rise. It is also necessary to introduce the Sundarbans animal species to newly established mangrove plantation regions. The Royal Bengal Tiger's last home is the Sundarbans, of which only 362 are known to exist in Bangladesh; a nearly equal number are found in the Indian portion

of the forest. To prevent the extinction of this species, extra care should be taken. By implementing cutting-edge agricultural technologies and growing high-yield varieties in other regions of the nation, rice output that has been lowered by the predicted rise in sea level should be made up. The farmer should be trained on high-yield rice seedlings and modern agricultural techniques.

#### Mitigation

The excessive population expansion in Bangladesh must be reined in. Coastal reforestation offers the ability to expand the nation's forest cover. Mangrove plantings in the area will provide effective coastal defense against soil erosion, storm surges, and cyclones. Increasing the mangrove afforestation in the area will improve the plantation survival rate by preventing soil erosion. The main issues facing the mangrove plantation in the coastal zone are site suitability, encroachment, pest infection, and provision for the second rotation crop (Iftekhar & Islam, 2004).

### CONCLUSION

Bangladesh has 176.42 million inhabitants, many of whom are expected to become environmental refugees as a result of sea level rise. It may pose a threat to the fundamental human rights of a significant portion of the population. The Bangladeshi government must therefore protect this large community from harm. Even if Bangladesh immediately stops CO<sub>2</sub> emissions, the problem will persist at the same level. The country needs financial and technical assistance from the international community to counteract the effects of sea level rise. Additionally, crucial are the assistance of international development groups and technical specialists. Bangladesh too lacks the self-sufficiency to deal with such a significant issue. To save the nation, international action should be taken because it is a global issue.

Ignoring sea level rise or waiting to see what happens in the future are not smart moves. It is worthwhile to research to produce species that can withstand salinity for the agricultural and fisheries industries and to identify practical solutions to potential issues. Building plans for cyclone shelters and the necessary actions to relocate anyone who might be impacted by the disaster should be started. There should be adequate drainage facilities for

the coastline protection efforts. Coastal resources should be used to recover adaptation costs using economic tools. Additionally, research must determine how to keep the nation's diverse biodiversity safe from the impending calamity.

Bangladesh suffers greatly from sea level rise even though it makes relatively little contribution to the greenhouse gas emissions that cause climate change and sea level increase. Bangladesh's existence is seriously threatened by sea level rise, which affects the country's crucial ecosystem and a variety of livelihood activities. Therefore, to protect its citizens, the government of Bangladesh must give the problem careful consideration and devise a plan to counteract the effects of sea level rise and climate change.

### Recommendations

- i. To generate seedlings during prolonged coastal floods and many peaks, floating platforms like Vela are utilized.
- ii. Establishing databases and monitoring tools for coastal risk assessment to identify other related hazards.
- iii. Emphasis on cooperation between the international and national levels.
- iv. Coastal risk identification and appropriate adaptation issues and options.
- v. Creating a green belt through mangrove plantations in the central and western coastal areas
- vi. Developing coastal risk assessment monitoring technology and databases for further related risk identification
- vii. Adoption of sustainable coastal resource management policies and guidelines.
- viii. Future research is necessary to understand the threats posed by climate change and sea level rise in Bangladesh.

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