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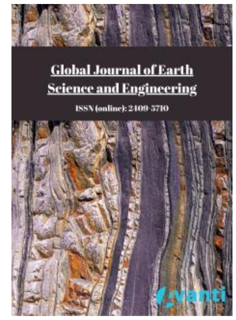

Coastal Erosion Pattern and Rehabilitation of Climate Displaced Communities of 3 Coastal Islands in and Around the South-Eastern Coast of Bangladesh

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ABSTRACT

Climate-induced displacement has evolved into a major global issue in recent years. Bangladesh experiences many forms of migration and human movement, which directly and indirectly impact national policies. In this book chapter, the authors explored the trend of coastal erosion and displacement of the communities of 3 coastal islands of the South-Eastern Coast of Bangladesh. Assessing the spatial dynamics of the coastal system requires looking back at the past development and temporal morpho-dynamics of shoreline position and shape. The current study set out to assess the potency of various statistical methods for forecasting shoreline changes and their dynamic nature. In this case, the vulnerability to coastal erosion was quantified using GIS and Remote Sensing. The authors examined how much the land area of Sandwip and Kutubdia islands has shrunk over the last 40 years (1957 to 2018), at rates of 0.822 and 0.242 times respectively. The neighbouring island, Maheskhali, is likewise experiencing coastline erosion, however satellite images show that the island's land area is growing 1.174 times every year. This is taking place as a result of new char land being formed at various points on the Maheskhali island, which has also eroded into the sea at various points. Even when the wind's direction changed and occurred at almost the same maximum values, the erosion scenario at Maheskhali, Sandwip, and Kutubdia remained unchanged. As a result, it may be concluded that Bangladesh's coastal erosion is relatively unaffected by wind speeds, despite fluctuations in wind direction. The authors explored that the rehabilitation of climate-displaced people is very limited compared to the large numbers of people displaced from the coastal islands. Besides, after the displacement, people lose their harmony, identity, and livelihood opportunities after migrating to? New places that are far from the origin. The authors found that if the community-based relocation program is introduced in the living places in the same areas for displaced people around the community living places, that will be most effective.

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1. Introduction

In the context of global warming, accelerated sea-level rise, recurrent catastrophic climate events, and heightened human production activity, coastal zones are experiencing progressively severe coastal erosion disasters. This presents significant risks to coastal engineering, natural ecological shorelines, and ecosystems [1]. Coastal erosion is a dynamic process of coastal alteration marked by a deficit resulting from an imbalance in the sediment budget within a certain coastline segment. This process is principally demonstrated by the retreat of the shoreline, the erosion and incision of the beach surface, the incision of low tidal flats while high tidal flats remain stable, and the coarsening of sediments [2]. Research in coastal erosion science has diversified due to continuous in-depth investigation. This research encompasses the examination of coastal erosion processes and mechanisms [3, 4], the analysis of erosion patterns and models, the assessment of erosion hazards [5, 6], the evaluation of coastal erosion vulnerability [7-11], and the investigation of the quantitative relationship between erosion protection management and economic factors.

Coastal erosion and displacement of the coastal communities are interlinked. Coastal Erosion can negatively impact the cultural links people have to the special parts of the landscape, which plays a major role in socio-economic changes too. Due to erosion, displaced people suffer from poverty, income erosion, occupation change, displacement, social destruction, degradation of quality of life, and many others. The researcher recorded the significant changes of erosion points in the study areas and the rate of erosion over the 40 years found from the findings of the study, which will be helpful for policymakers to take an action plan of preventing erosion in the future.

The severity of coastal erosion indicates the pronounced scouring and degradation of the coastline, encompassing the rate of landward retreat and the down-cutting occurring on the beach [12]. Coastal erosion severity is influenced not only by hydrodynamic circumstances, including tides, waves, and typhoon storm surges, but also by the cumulative effects of local coastal geology, topography, and sand supply conditions along the beaches [10]. Historically, conventional evaluations of coastal erosion intensity mostly concentrated on singular indicators, including the coastline retreat rate, the beach down-cutting rate, and the sediment coarsening rate on the beach surface for individual assessment. The approach of "selecting the maximum value" was implemented, utilizing the most severe outcome from each evaluation metric as the conclusive assessment of coastal erosion disaster intensity [10].

Climate Change Induced Displacement-a phenomenon expected to, in the end, affect loads of millions of humans by its very nature, implies that human beings or groups can not live in their traditional houses and that they may require new living preparations to replace their former homes and lands. Climate Change-induced displaced people are persons or groups of persons who, for compelling reasons of sudden or progressive changes in the environment as a result of climate change that adversely have an effect on their lives or residing situations are obliged to go away their habitual houses, or pick to do so, either briefly or completely, and who circulate both inside their nation or abroad [13]. The presently ordinary definition of an Internally Displaced character (IDP) is: “Men and women or companies of men and women who have been pressured or obliged to escape or to depart their houses or locations of recurring residence, specifically due to or that allows you to keep away from the effects of armed battle, conditions of generalized violence, violations of human rights or natural or human-made failures, and who have not crossed an the world over identified nation border”) [14].

Coastal erosion is one of the most destructive impacts of climate change happening in the coastal area of Bangladesh, especially the south-eastern coastal area. The natural form of Bangladesh coastal areas is controlled through dynamic processes such as tides, wave actions, strong winds, and sea level variations. Over the last two centuries, enormous changes have taken place because of continuous land erosion and accretion along the coastline. The inhabitants in the coastal area are escalating, and they are the worst victims of erosion problems. Most of the erosion of the Bay of Bengal front was because of storm surges and continuous wave actions [15].

South Asia, with almost 2 billion humans living in this place, which is an area of 5.2 million square kilometers. Km. Bangladesh, India, Pakistan, Afghanistan, Bhutan, Maldives, Nepal, and Sri Lanka are the nations of South Asia, where about a 3rd of whom are nevertheless dwelling inside the condition of poverty, faces a prime task in accomplishing speedy economic boom to reduce poverty and achieving different Sustainable development desires in an technology of emphasized dangers posed with the aid of international weather alternate [15]. South Asia recognized as a time-honored weather trade caused catastrophe hotspot in the second and the year of 2019, 9.5 million human beings compelled to be displaced because of special natural hazards as the most record of information since 2012. The information on climate displacement indicated that during the 12 months of 2019, 5 million people were displaced in India, which is the maximum number in the world. In 2019, there were five million new catastrophe displacements in India, the best in the world. At some stage in the Amphan outbreak, which outbreak may additionally 31, 2020, 3,50,000 people had been displaced in Bangladesh and India [16].

Zhang and Hou [17] analysed the data of 9035 islands of South-East Asian countries and found that nearly 10% of islands have recorded changes of coastlines, resulting in an average decline of nearly 86 km^2 in place and 60,000 km in coast displacement. Besides, the coastline length increased by 532 km from 2000 to 2015. Natural coastlines reduced by 2600 km, while the artificial coastlines raised by 3050 km. Among the total coastlines, 11% changed: 5% exhibited deposition, while 6% experienced retreat. Ford *et al*. [18] carried out a protracted-term evaluation of coastline adjustments on six atolls and two marine reefs in the Republic of the Marshall Islands. This study discovered that since the mid-twentieth century, the Coastlines aggraded more than they eroded; erosion accounted for 17.23%, enlargement accounted for 39.75 %, and no change accounted for 43.03%. The qualitative analysis indicated that sea level rise, storm surges, island morphology and geomorphology performed important roles in island shoreline modifications. Duvat *et al*. [19] summarized 709 islands in 30 atolls within the Pacific Ocean and the Indian Ocean based on coastline datasets (1896–2014) from the literature. The effects indicated that 518 of the 709 islands remained solid (73.1%), 110 islands exhibited Deposition (15.5%) and 81 islands skilled retreat (11.4%). He proposed a worldwide fashion in which the atolls remained stable, even in areas wherein sea level rose unexpectedly.

One of the most dramatic impacts is the forced movement of people throughout Bangladesh as the consequences of losing their homes, lands, property, and livelihoods due to the effect of climate change. 70% of the land of Barisal and Khulna divisions are affected by the different degree of salinity, which reduces agricultural productivity [20]. The island of Bangladesh, named Kutubdia, almost reduced its size by 50% in the last 20 years due to climate change [21]. Since 1991, six villages on the island have entirely gone to the sea, and about 40,000 people have fled, and most of them got temporary shelter on the coast near Cox's Bazar. The massive majority of these people will be displaced domestically – not across international borders – presenting the government with enormous challenges, particularly when it comes to finding places to live and work for those who have been displaced [12, 22, 23]. There is evidence that inhabitants of the 26 coastal and mainland districts among the 64 districts of the country have experienced displacement due to different natural disasters. It also found that almost 60 Lakh people were displaced from their home and land due to climate change in Bangladesh [12]. Over 35 million human beings can be displaced from 19 coastal districts of Bangladesh within the event of a 1-meter sea level rise this century. Many people have already migrated to the urban slums from the coastal zones of Bangladesh due to frequent cyclones, storm surges and river erosion. About 46 % of people temporarily displaced and 12% of people permanently displaced due to different hazards in four climate hotspots of Bangladesh [24].

Coastal and riverside households in Bangladesh are the most susceptible to the impacts of climate-driven hazards, including riverbank erosion [25]. Riverbank erosion, one of the most devastating natural disasters in Bangladesh, is responsible for untold miseries every year to thousands of people living along riverbanks. This is recorded that 20 out of 64 districts of Bangladesh are prone to riverbank erosion [22, 26]. Another finding by [27] stated that some parts of 50 districts of Bangladesh are situated in a risky zone of riverbank erosion. Every year about 8700 hectares (ha) of land are lost due to riverbank erosion, which displaces around 200,000 people each year and thrust them into vulnerable circumstances of food insecurity and poverty [22, 28]. About 15 to 20 million people are in jeopardy from the impact of erosion in the country, while about 1 million people living in 94 upazilas are directly impacted by riverbank erosion every year. The north-western part of the country is mainly prone to river erosion that turned the region into an economically miserable area.

One of the most severe consequences of a changing climate is that communities are being forced to leave their homes, lands, and livelihood because they have been wiped out by the climate change-induced natural disasters. These processes stand to displace many tens of millions of people in coming years. Nearly 46% of people temporarily displaced and 12% of people permanently displaced due to different hazards in four climate hotspots of Bangladesh [23]. Besides, population displacement of coastal Bangladesh affected the natural growth rate compared to the other region of the country. About 361 hectares of land were lost throughout the last 18 years from 1990 to 2008. As a result, 93% of people in South-West coastal Bangladesh were forced to move to other places for at least one time in their life. The primary reason for displacement found the loss of land and occupation caused by the cyclone, storm surge and erosion [29, 30].

Kutubdia, Maheskhali, and Sandwip are the most important offshore islands, lying on the south-eastern part of Bangladesh coast, have got much attention in the world at present. Speedy lack of land to sea, which has grown to become out to be a recurrent phenomenon recently because of sea level upward thrust. This chapter focuses on the historical pattern of the rate of coastal erosion of Sandwip, Maheskhali, and Kutubdia from 1975 to 2017 through the satellite image and GIS map. The author also attempts to estimate the rate of changes in the study areas' coastline with the help of geospatial techniques using nine multi-temporal satellite imagery. Besides, some rehabilitation programs of the Bangladesh Government are also highlighted in the manuscript along with sustainable adaptation approaches for rehabilitation of climate-displaced peoples of Bangladesh, which will be significant pathways for the climate victims' rehabilitation attempts for the world.

2. Methodology of the Study

There are three coastal islands of the South-Eastern coast of Bangladesh, named Sandwip of Chittagong district and Kutubdia, including Maheskhali islands of Cox's Bazar district, are selected for the study due to their vulnerability and previous record of people displacement and movement from the island to urban areas of the country. Kutubdia Island belongs to Cox's Bazar district with an area of 215.8 km^2, which is bounded by the Bay of Bengal. Maheskhali Island is another coastal island that belongs to Cox's Bazar district with an area of 362.18 km^2 that is also bounded by the Bay of Bengal. The Sandwip Island belongs to Chittagong district with an area of 762.42 km^2. These islands are created by tidal, supra-tidal and fluvial processes of the Ganges river, particularly the topography is mudflat, sandy and gentle slope (Fig. **1**).

The study was carried out using the integrated technology of Remote Sensing (RS) and Geographic Information System (GIS). Standard procedures of Geo-referencing, image interpretation and on-screen digitisation to generate water body data layers were carried out using ERDAS Imagine 2014 software. GIS analyses were carried out using ArcGIS 10.4 software package to reveal the changing scenario of water bodies in the study area. Available different 'Landsat' satellite images were downloaded from the 'earthexplorer.usgs.gov' website for free. Satellite images were analysed to investigate the changing patterns of coastal erosion of Kutubdia, Sandwip and Maheskhali from 1975, 1980, 1985, 1990, 1995, 2000, 2005, 2010, 2015, 2016, 2017 and 2018 (Fig. **2**).

The remote sensing data used in the study are Landsat TM images. Detail information of the image is given below in Table **1** and **2**.

The Satellite image of the study area was downloaded from the Earth Explorer. This image was used as the reference image for geometric correction of the satellite images of 1975, 1980, 19985, 1990, 1995, 2000, 2005, 2010, 2015, 2016, 2017, and 2018. The projection used for the images was Transverse Mercator. The correction procedure involves generation of ground control points (GCP), calculation of transformation metrics using the GCPs and resampling of the image to be geometrically corrected using the transformation metrics. The GCPs have been generated from the reference image (1975), using the ERDAS Imagine software. Nearest neighbour method was used for re-sampling of the image. After geometric correction of the full image (185 Km *185 Km), the image of the study area was extracted from it using the subset tool of ERDAS Imagine software.

Overlay of the coastal erosion spot layers of all the study years was carried out to form a composite data layer. The composite data layer contained identification of coastal erosion of each study year, which was used for addressing it to generate change classes of coastal erosion over the study period. Logical operations were carried out on the composite data layer to generate the multi-temporal change classes. Statistical information on the area of erosion in each year and on the change classes was derived from the attribute table of the composite data layer. ArcGIS software was used for data management and change detection analysis.

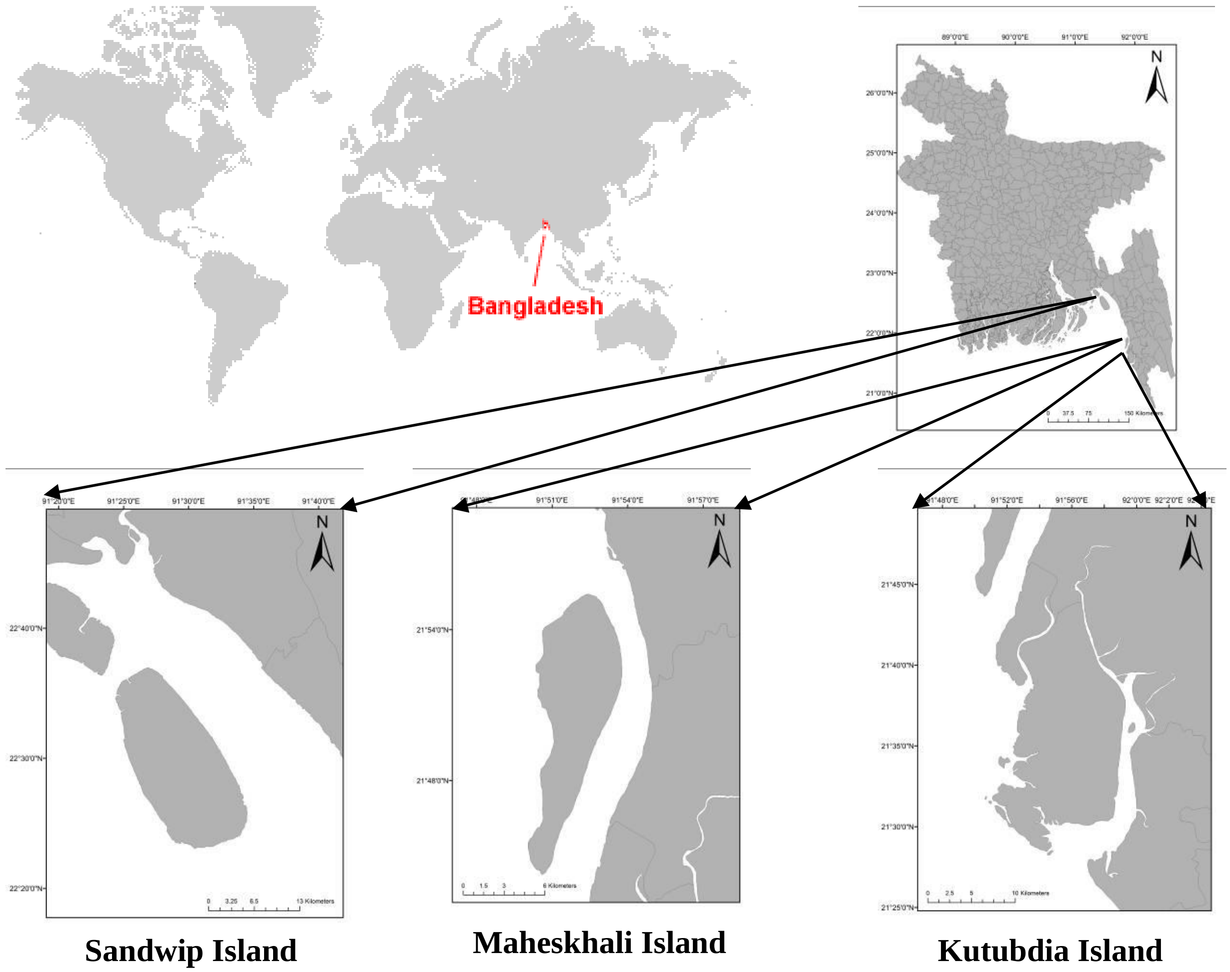

Figure 1: Geographical location of the study areas.

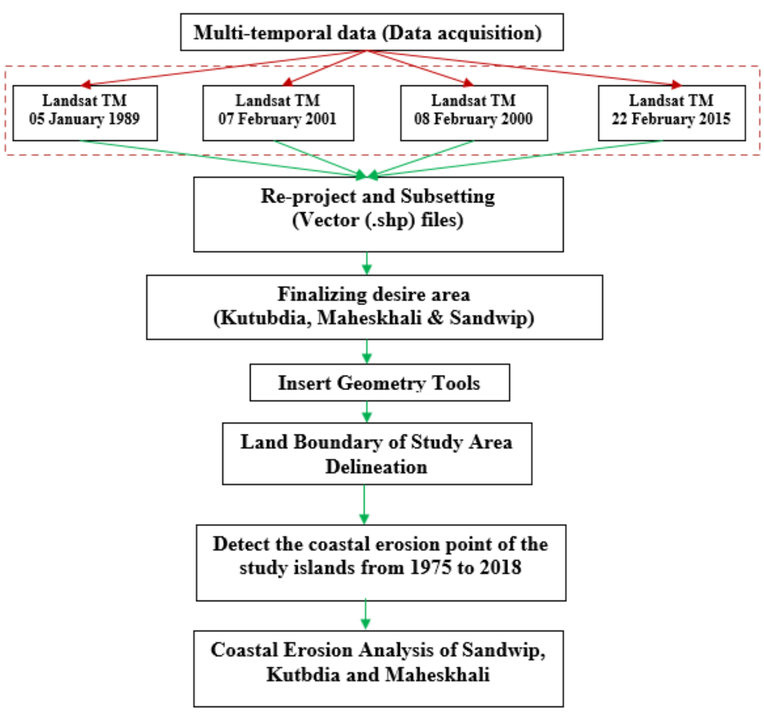

Figure 2: Processing of satellite image of different years of the study areas.

Table 1: Data characteristics for the satellite image used.

S. No	Satellite (Sensor)	Bands	Resolution / Scale	Date of Acquisition	Year	Source
1	Landsat TM	1, 2, 3, 4, 5	30m	20-02-1975	1989	Earth Explorer (SPARRSO)
2	Landsat TM	1, 2, 3, 4, 5	30m	07-02-2001	2001	
3	Landsat TM	1, 2, 3, 4, 5	30m	08-02-2010	2010	
4	Landsat OLI	2, 3, 4, 5, 6	30m	22-02-2015	2015	

Source: LANDSAT, 1975, 1980, 1985, 1990, 1995, 2000, 2005, 2010, 2015, 2016, 2017 and 2018; TM: Thematic Mapper; OLI: Operational Land Imager.

Table 2: Radiometric characteristics of landsat TM 1, 2, 3, 4, 5 and OLI 2, 3, 4, 5, 6.

Satellite	Spectral Resolution (μm)	Band	Spatial Resolution (m)
Landsat 1, 2, 3, 4, 5	TM		30m
Landsat TM 1975, 1981989, 2000 and 2010		Red	30m
		Green	30m
		Blue	30m
Landsat 2, 3, 4, 5, 6	OLI		30m
Land TM 2015		Red	30m
		Green	30m
		Blue	30m

μ: Micrometer, m: meter.

3. Results

From the study, the authors found that the shape of Sandwip in satellite imagery shows that erosion is very active in the western part. Generally, erosion is the geological process in which the earth's surface is worn down by natural forces such as tides, currents, waves. The erosion process is much vigorous in the south-western part of Sandwip. Visual examination as well as the satellite image data analysis from the figure, revealed that the coastal shoreline and erosion problem can be classified in to the following patterns, namely, (a) severely eroding southern side (b) moderately eroding western side, (c) moderately accreting eastern side and (d) rapidly accreting northern side. The substantial load of the sediments transferred by estuarine system from the upper Meghna leads to advancement of the shorelines by accretion in the north and eastern sides whereas the south and western side is affected by longshore drift current associated with wave action coupled with huge incoming water fore from the upper Meghna pushed the shoreline back from its earlier position leading to retreating of shorelines (Fig. **3**).

It was found that the area of the Sandwip island in 1975 was 254.788 Sq. Mile (659.897 Sq. km). Moreover, the long-term erosion rate also shows unpredictable, and it is 223.234 Sq. Mile (578.45 sq.km) during 2018 (Table **3**).

Net erosion volume and rates calculated for the Island using ArcGIS 10.1, for the same boundaries between the zones for 1975, 1980, 1985, 1990, 1995, 2000, 2005, 2010, 2015, which indicated a year interval erosion map and data for the study area. The researcher also explores the coastal erosion map from 2015 to 2018 for a continuous erosion study. Satellite images show that erosion of the island has increased from 1985, and after the cyclone in 1991, coastal erosion of the Sandwip island remarkably increased. The erosion rate was continuously increasing since the last two decades, and it was argued that the erosion rate was almost 5 square miles calculated from 2006 and 2014 images, whereas it was 3 square miles. Mile from 1978 to 1989 (Table **4**).

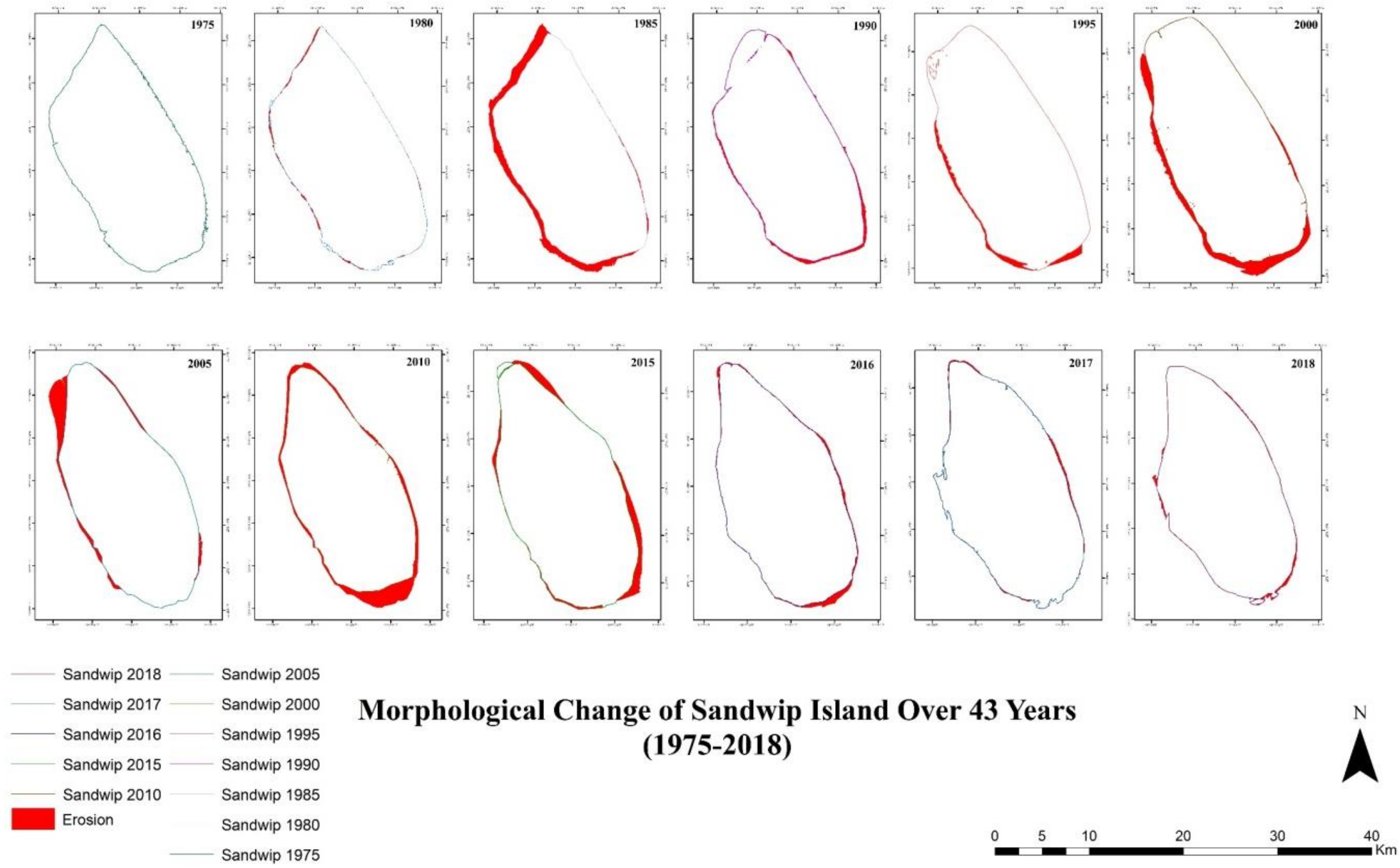

Figure 3: Morphological changes of the Sandwip island.

Table 3: Changing trend of total area of Sandwip from 1975 to 2018.

Year	Total Area (Sq. mile)
1975	254.788592
1980	256.621319
1985	232.857306
1990	236.099729
1995	266.313453
2000	251.115234
2005	250.065575
2010	226.791149
2015	216.5771
2016	212.592824
2017	223.2275
2018	223.234387

Table 4: Total length of eroded area of Sandwip over 1975-2018 during 5 years interval.

Period	Erosion Area (Sq. mile)
1975-80	2
1980-85	25
1985-90	8
1990-95	9
1995-2000	22
2000-2005	16
2005-10	25
2010-15	16
2015-16	6
2016-17	3
2017-18	3

From the graphical presentation, it is found that the area of Sandwip decreases 0.822 times every year from its previous counterpart. Thus, the correlation coefficient between the year and erosion $\sqrt{R^2} = r = 0.713$, and the correlation was positive (Fig. **4**).

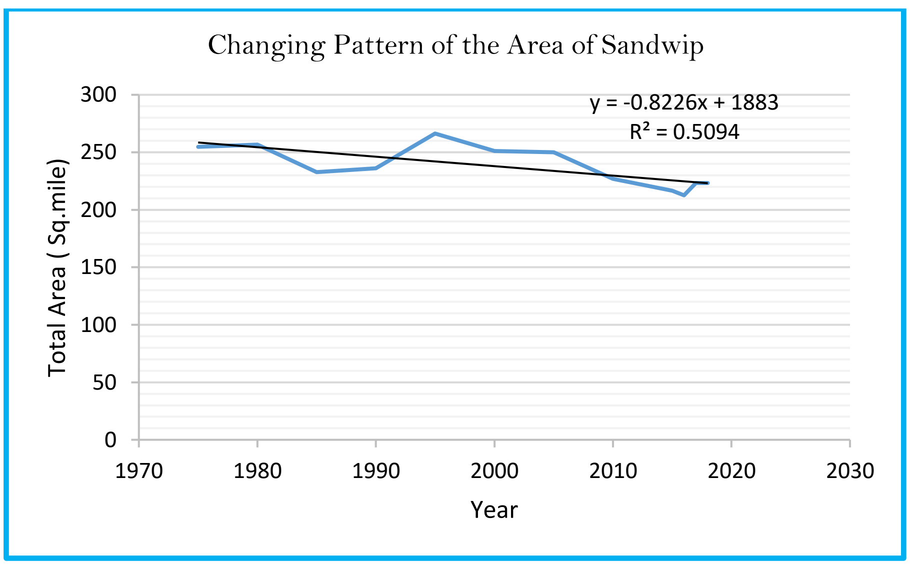

Figure 4: Changing pattern of the area of Sandwip.

According to [31], during the time of the 1981 population census, there were 17 unions in Sandwip, of which nine were vulnerable to land erosion. From the 1981 to 2011 census, among the nine affected unions, three unions (Neamasti, Batajora, and Kathghar) covering 2176 hectares already disappeared due to land erosion. Besides, six more unions (4573.64 hectares) were partially eroded during these three decades, of which Magdhara, Sarikait, and Rahmatpur are notable (Fig. **5**).

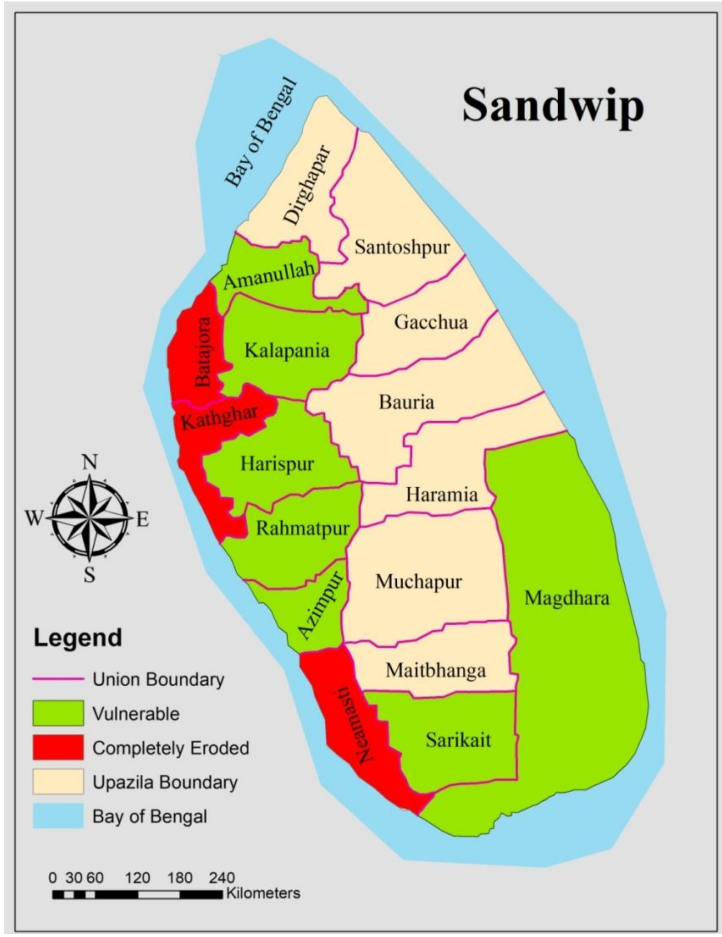

Figure 5: Vulnerability and erosion map of Sandwip upazila.

The Sandwip channel has become isolated from the Meghna river estuarine discharge, which was feeding sedimentation in the south-eastern part of the island. On the other hand, the sediment carried by the lower Meghna river to the Bay of Bengal could now be trapped by the tidal influence and precipitate in the north-eastern part and the eastern part of the Hatiya channel.

The Kutubdia, one of the significant off-shore islands, lying on the south-eastern part of Bangladesh coast, has got much attention due to its rapid loss of land to the sea, which has turned out to be a recurrent phenomenon in recent times due to sea level rise. The present analysis attempts to estimate the rate of changes on the Kutubdia coastline with the help of geospatial techniques using nine multi-temporal satellite imagery. The study area was facing strong longshore currents in the rainy season, which eventually caused rapid erosion in the southern and western shorelines. This area is characterised by a tropical and subtropical climate. The perpendicular transects location between the measurement baseline and historical shoreline was used to determine the rate of shoreline changes of Kutubdia Island. The rate of shoreline change is analysed in four locations of the island: North, South, East, and West (Fig. **6**).

Coastal erosion is dominant in the whole island. The satellite image and mentioned figure exhibit the highest erosion rates around the southern part of the island. However, erosion also occurs every year during the high monsoon tides. A government-built embankment has changed the world, as the erosion has increased in recent years. However, where the embankment does not exist or is broken, the sea continues to swallow up land. There is evidence that the rate of erosion has increased in Kutubdia in the past few years. This erosion is making the area more vulnerable. From the findings of the study, it is found that during the year 1975, the area of the Kutubdia Island was 73.007 Sq. Mile (189.087 sq. km). Now the Area of the island found 65.62 Sq. Mile (169.95 sq.km) (Table **5**).

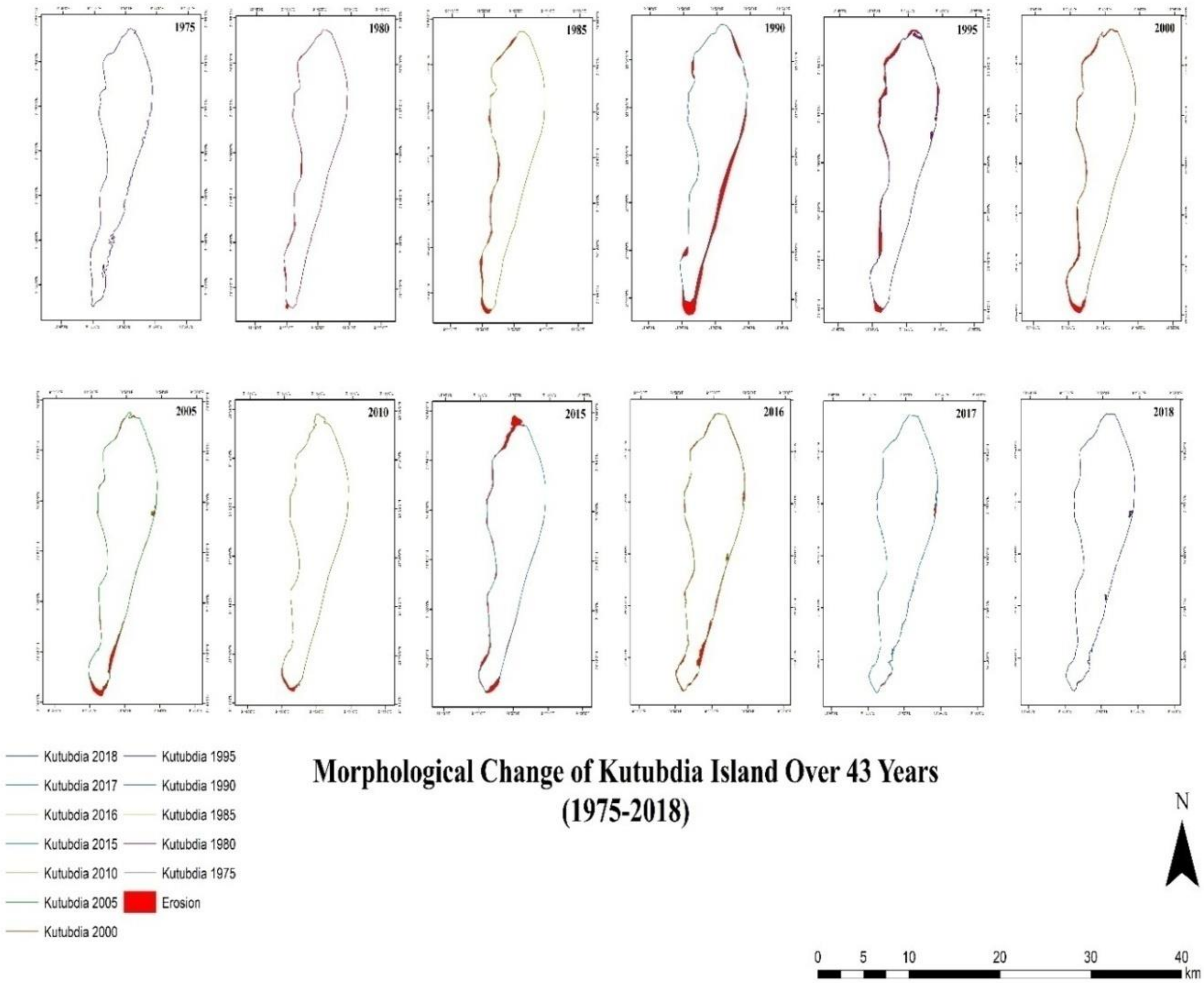

Figure 6: Morphological change of Kutubdia island.

Table 5: Changing trend of total area (Sq. mile) of Kutubdia from 1975 to 2018.

Year	Total Area (Sq. mile)
1975	73.007688
1980	76.405572
1985	77.195467
1990	74.157693
1995	71.51546
2000	69.546598
2005	67.805721
2010	71.771207
2015	68.110094
2016	65.234633
2017	64.93642
2018	65.621564

Net erosion volume and rates calculated for the Island using ArcGIS 10.1, for the same boundaries between the zones for 1975, 1980, 1985, 1990, 1995, 2000, 2005, 2010, 2015, which indicated a year interval erosion map and data for the study area. The researcher also explores the coastal erosion map from 2015 to 2018 for a continuous erosion study. Satellite images show that erosion of the island has increased from 1980, and after the cyclone in 1991, coastal erosion of the Kutubdia island remarkably increased. The erosion rate was continuously increasing in the last two decades (Table **6**).

Table 6: Length of eroded area of Kutubdia five years interval from 1975 to 2018.

Period	Erosion Area (Sq. mile)
1975-80	1
1980-85	2
1985-90	7
1990-95	4
1995-2000	3
2000-2005	2
2005-10	1
2010-15	4
2015-16	3
2016-17	1
2017-18	1

From the graphical presentation, it is found that the area of Kutubdia decreases 0.241 times every year from its previous counterpart. Besides, the correlation coefficient between the year and erosion rate of Kutubdia found $\sqrt{R^2} = r = 0.872$ and the correlation was positive (Fig. **7**).

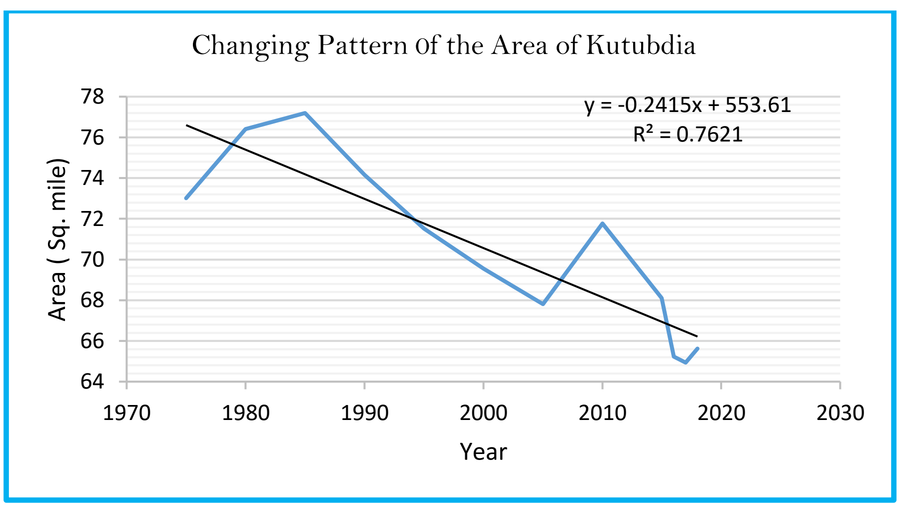

Figure 7: Changing pattern of the area of Kutubdia.

A traditional earth dike was built by the government to protect the settlement in Kuzier Tek of Ali Akbar Union, Kutubdia on 1960. It proved unsuccessful: about 20000 households were displaced by land erosion, sea-level-rise and cyclone-induced flooding between 1960 and 1997. The displaced households first resettled nearby on land they or their relatives owned. Over time, the number of displaced households increased and most resettled 4-5 times. Around 1998 there was no land left. Some households moved behind a nearby government-owned dike with the hope of returning after accretion. Accretion did not take place, and further erosion displaced more households. With the assistance of relatives, some of the households moved to other parts of the island. Vulnerability mapping in terms of erosion and displacement factors, following Fig. (**8**), indicating the shoreline status of Kutubdia.

Figure 8: Vulnerability of erosion map of Kutudbia upazila.

The coast of Kutubdia is exceptionally dynamic. Time series analysis of Landsat imagery from 1975 to 2018 has revealed that more than 400 transects appeared to have experienced a change mostly in erosion phase. Segments based analysis of shoreline changes reveals that the southern part of the shoreline is suffering from severe erosion, whereas the eastern, western, and northern segments are having comparatively less erosion during the last 42 years.

Physiographically, the investigated area is divisible into Moheshkhali Hills, Piedmont. Plain, Old Coastal Plain, Young Coastal Plain and Active Coastal Plain. The Moheshkhali hills, characterised by low elevated hills, the peripheral areas of these hills are encircled with the piedmont plains. Whole Moheshkhali Island and its adjacent areas like Sonadia and Matarbari islands are occupied by the young coastal plain of recent time. Moheshkhali Island, together with Matarbari and Sonadia islands, is in the gaining phase since 1972. From the study, it is found that the erosion rate of Maheskhali island is lower than that of the other two study areas. Possibly, the immense accretion in Moheshkhali is largely influenced by increased erosion of the Moheshkhali Hills and northward drift from Cox s Bazar coast afterwards the considerable destruction of Cox's Bazar beach by the severe cyclone of 1991 and 1993 (Fig. **9**).

Maheskhali, one of the significant offshore islands, lying on the south-eastern part of Bangladesh coast, has got much attention due to its rapid loss of land to the sea, which has turned out to be a recurrent phenomenon in recent times due to sea level rise. The present analysis attempts to estimate the rate of changes of Kutubdia coastline with the help of geospatial techniques using nine multi-temporal satellite imagery. The study area was facing strong longshore currents in the rainy season, which eventually caused rapid erosion in the southern and western shorelines. This area is characterised by a tropical and subtropical climate.

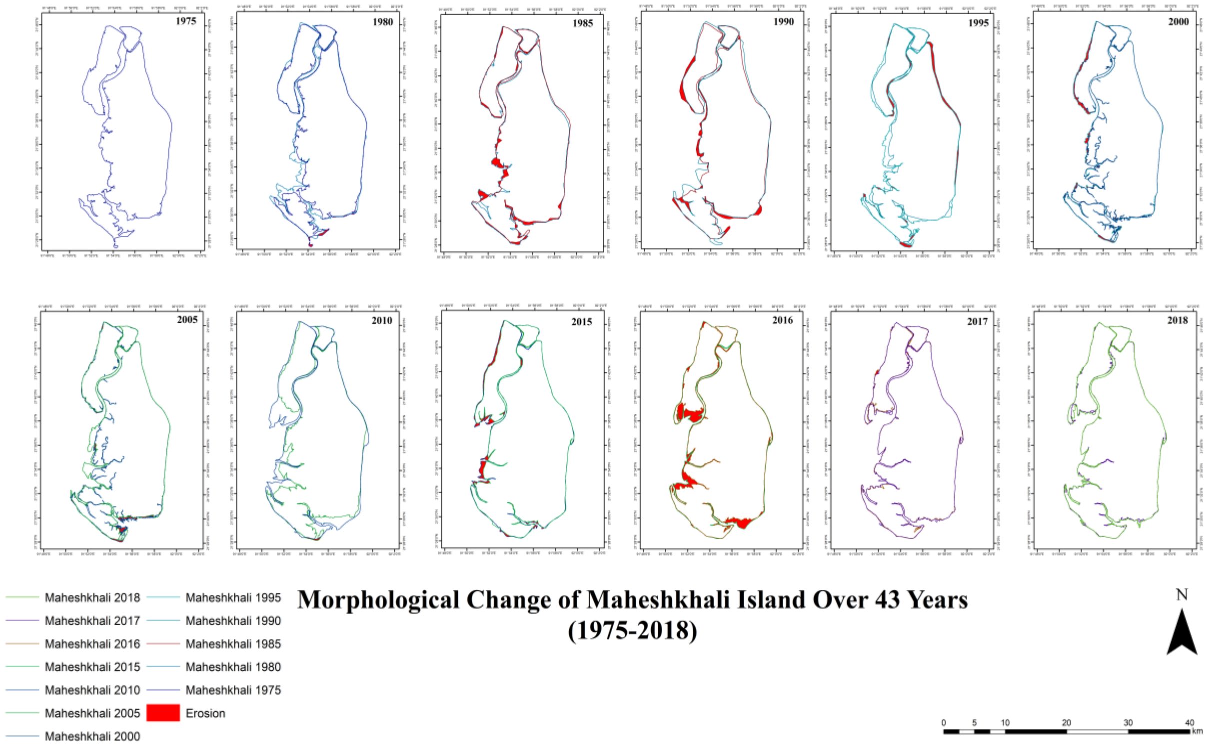

Figure 9: Morphological changes of the Maheskhali island.

The morphodynamic setting of this area is largely influenced by the denudation of the Moheshkhali hills to the northeast, the sediment input of the Matamuhuri River through the Moheshkhali Channel along the east coast from the mainland of Cox's Bazar. From the findings of the study, it is found that during the year 1975, the area of Maheskhali island was 275.188 Sq. Mile and now the area of this island found 327.064 Sq. Mile (Table **7**).

Table 7: Changing trend of total area (Sq. mile) of Maheskhakli from 1975 to 2018.

Year	Total Area (Sq. mile)
1975	275.188033
1980	297.077192
1985	292.3796
1990	296.37
1995	305.946977
2000	298.771938
2005	307.354124
2010	349.082374
2015	341.2297
2016	319.022179
2017	321.863594
2018	327.064976

However, the distribution, and deposition and re-deposition of incoming sediments are largely dependent on hydrodynamic factors like the tide, wave, seasonal circulation pattern of the littoral drift, sea-level condition, and energy level. There are many chars, and small islands noticed in the Bay of Bengal, which also submerged after some years, as found available in the satellite map. So, that erosion rate found lower in the Maheskhali island compared to the acceleration (Table **8**).

Table 8: Length of eroded area of Maheskhali island over 1975-2018.

Period	Erosion Area (Sq. mile)
1975-80	3
1980-85	13
1985-90	13
1990-95	9
1995-2000	10
2000-2005	5
2005-10	1
2010-15	11
2015-16	22
2016-17	2
2017-18	1

From the graphical presentation, the area of the Maheskhali increasing 1.174 times every year from its previous counterpart. It is also found that the correlation coefficient between the year and erosion rate of Maheskhali is $\sqrt{R^2} = r = 0.842$ and the correlation was positive (Fig. **10**).

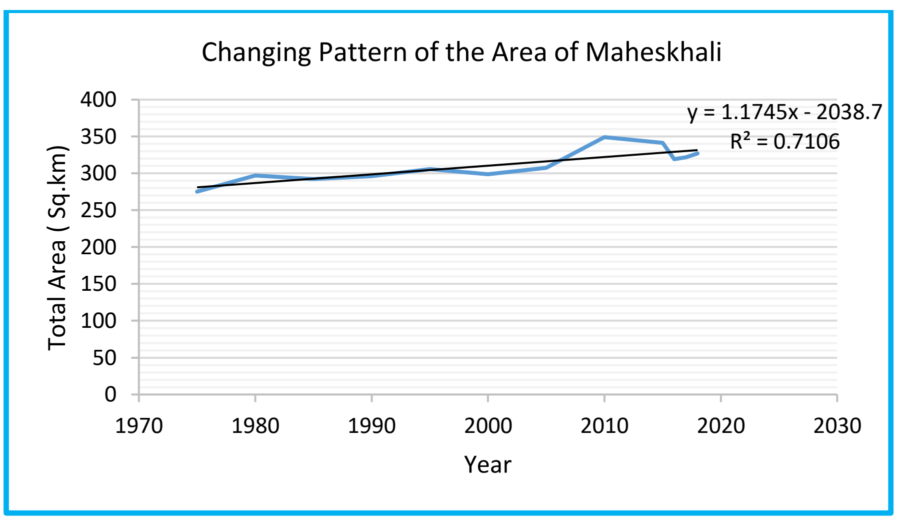

Figure 10: Changing pattern of Maheskhali area from 1975 to 2018.

Despite the dynamic (erosion and accretion) nature of the coast, the total land mass of Maheskhali upazila has increased in the last forty years. Though the island is expanding over time, the shoreline length has reduced (Fig. **11**).

Figure 11: Disaster vulnerability map of Maheskhali upazila.

Because of the effects of floods, cyclones, and storm surge as well as altering river courses, land development, and erosion, the Bengali communities have a generation of experience adapting to changing climatic circumstances. To account for small-scale variations in soil and hydrological conditions, they carefully modified their customary cropping strategies and practices. Since the construction of the first substantial flood embankments in the 1950s and later with the spread of dry-season irrigation and the introduction of high-yielding crop varieties, they have continued to adapt during the period of fast change. Bangladesh is not dependent, therefore, against coping with sea-level rise, but it probably needs financial and technical assistance with providing practical mitigation measures in response to climate change vulnerability.

Rahman and Rahman [32] stated that modifying the threat of crop loss and deterrence of adverse impact on crop production are the most feasible adaptation options in Bangladesh. Another research work done by [33] proposed various adaptive strategies such as: sharing losses, modifying the threats, preventing impacts, changing use, changing the location, and restoration. Islam *et al*. [34] articulated the challenge of adapting to climate change, such as awareness creation, identifying suitable adaptation options, and resource allocation for practising the adaptation. Mallick *et al*. [35] recommended three adaptive options: retreat, accommodation, and protection, and elaborated some adaptation approaches for the coastal area of Bangladesh, such as afforestation, cropping pattern change, and embankment repairing and construction. Barua *et al*. [36] analyzed the Climate-induced displacement strategies and explored that the strategies is broadly categorized through the relocation and the sustainable rehabilitation actions with the exacting accent on (1) relocation in build houses, (2) skill development training and rehabilitation and (3) coping and resilience mechanisms to decline the vulnerabilities of natural disasters (Fig. **12**).

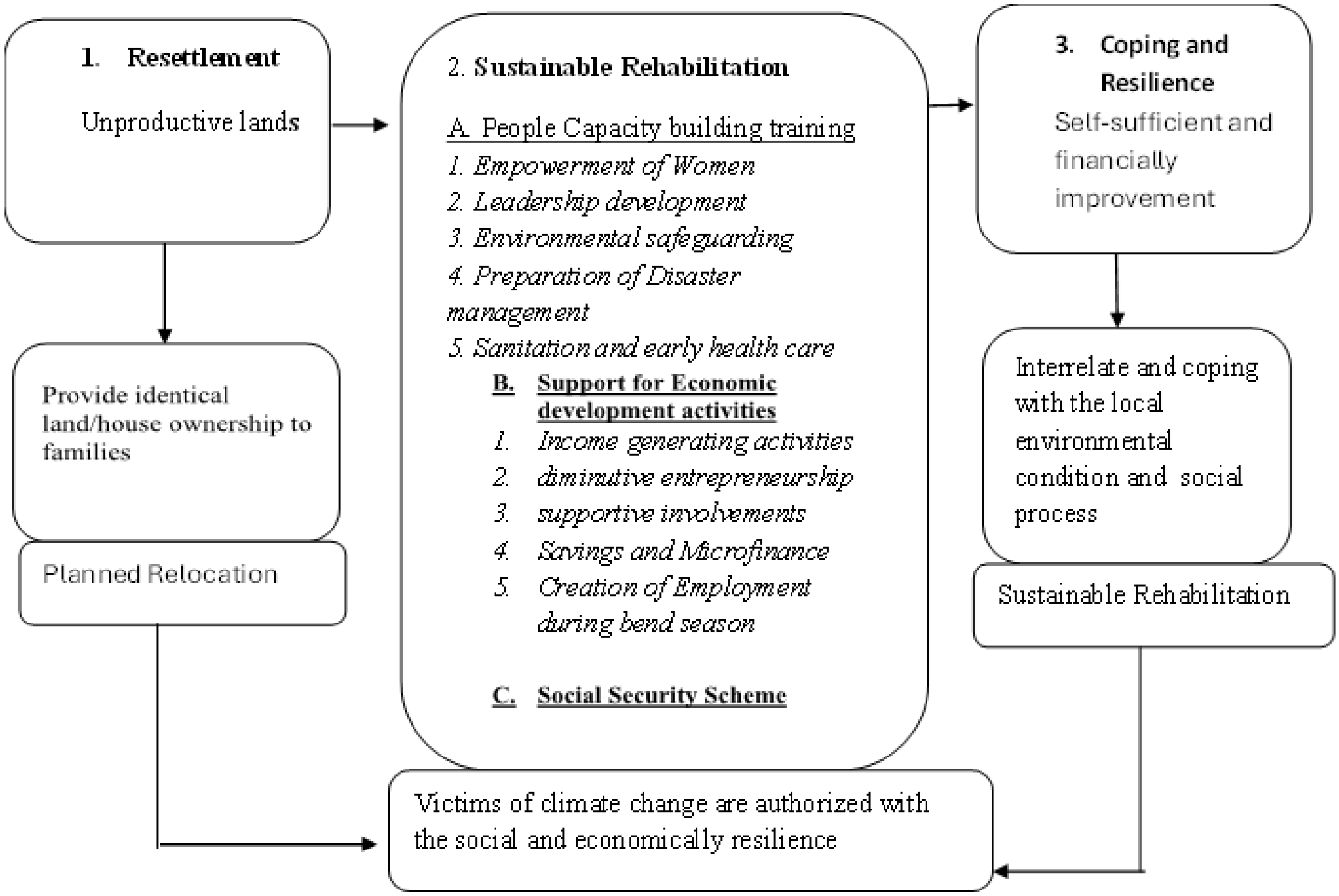

Figure 12: Rehabilitation and relocation model for climate displacement in Bangladesh [36].

Coastal mangrove forest belt is one of the exceptional model practices to guard local, coastal, and local-areas from storms, cyclones, and tidal surges. It is essential to reduce the wind speed by planting appropriate tree species, which can withstand the high speed of the wind and break the wind speed. Naturally grown halophytic plants have the unique adaptation for withstanding in the littoral zones with clayey alluvial soil, tides, and strong salinity and winds. There are numerous palm species and swamp grasses having soil binding ability to govern erosion. They also reduce the speed of tidal surges [37].

Starting from the Seventies, the government of Bangladesh implemented numerous packages to supply housing for poor families, in particular through resettlement schemes, and additionally promoting people's return to rural regions. Social housing projects in urban and rural areas in Bangladesh have targeted the various vulnerable and disadvantaged groups, namely landless and homeless poor households, (widowed/ divorced) women-headed households, and single destitute. Many of the governmental housing projects tried to ease the pressure on urban areas by relocating or promoting the return to rural areas. These programs include:

- ***The Ghore Phera Program:*** released in 1999, the program endorsed people to return to their villages by offering loans for income-generating sports in rural regions. Any of the governmental housing projects tried to ease the stress on city regions by relocating or selling the return to rural regions.
- ***The Ashrayan Project:*** This project, started in the coastal areas of Bangladesh in 1996, included the construction of basic housing in a barrack-style.
- ***The Adarsha Gram Prokolpo (Ideal Village Project):*** Completed in 1998, it offered credit for relocation from cities to the rural areas.
- ***The Ashrayan-2 Project:*** It is a poverty alleviation program; its actions include: building homes, providing people with public facilities, and providing interest-free loans (SSHI, 2013).

In 1987, the Government formed *Guccha Grams* (clustered villages) for landless people. Several NGOs took the opportunity to cooperate with the Government in the land distribution tasks. This cooperation has continued. Furthermore, NGOs have assisted the government in its program of *Adarsha Gram* (typical villages) which aims to provide comfort by constructing houses for the distressed poor. NGOs also rehabilitated the displaced and landless people, establishing *Gucchagram* (cluster village) through purchasing land with financial support from donors. Similarly to the rehabilitation of displaced people through organizing cluster villages, the NGOs of Bangladesh were using some of the strategies and procedures to get better and distribute *Khas* land among the landless poor, including mobilization, identification, and redistribution of *Khas* land, legal aid, lobbying, and advocacy (Fig. **13**).

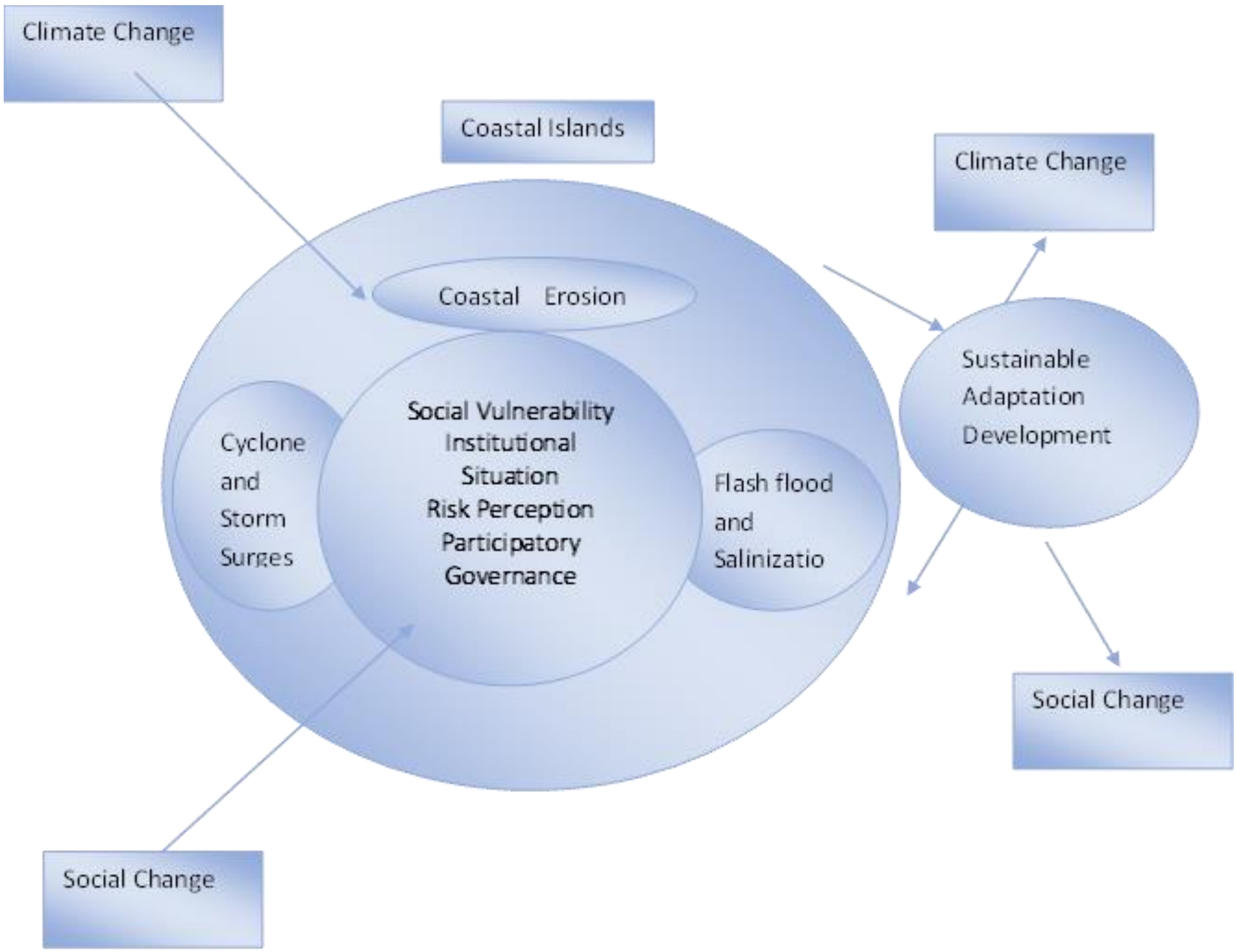

Figure 13: Building of sustainable adaptation for climate displaced people.

Discussion

For the engineers, scientists, and implementing agencies involved in coastal management, the understanding of the coastline and its changes is a crucial component. For the design of coastal protection measures, coastal development plans, and the calibration and testing of geometric models, the location of the coastline and its historical evolution can provide crucial information [38]. Therefore, the overall control strategy must be backed up by a tracking issue of the coastline, which will necessitate frequent surveys to keep track of seasonal variability, storm events, and other natural phenomena that are involved in the pattern of coastal erosion in the various climate hotspot areas. Due to this, remote sensing technology has recently gained popularity when used to monitor coastlines, as evidenced by comparisons to GPS survey, aerial photography, airborne videography, and video systems. Compared to photogrammetry, it enables very quick statistics collecting and processing. Similar to other survey methods, satellite photos with high spatial resolution offer equivalent accuracy. The high temporal resolution satellites have a brief returning period that enables monitoring studies of the area under study using images taken at various intervals.

Shoreline alterations are a significant issue for coastal areas, marked by erosion, accretion, and transformations in coastal ecosystems resulting from climate change and anthropogenic activity. The National Oceanic and Atmospheric Administration (NOAA) indicates that around 2,000 miles of U.S. coastline are undergoing substantial erosion at an average rate of nearly 1.5 feet annually (NOAA, 2020). In Florida, shoreline erosion resulting from sea level rise is anticipated to impact almost 3 million individuals by 2060, underscoring the critical necessity for adaptation techniques [39]. Coastal locations in Japan are seeing comparable issues, as research reveals that over 40% of the nation's coastline is experiencing erosion, with rates in certain parts escalating to 2 meters annually [40]. These developments highlight the imperative for efficient coastal management strategies to alleviate the effects of shoreline alterations. The Environment Agency in the United Kingdom indicates that over 30% of the coastline is undergoing erosion, with certain regions, especially in East Anglia, facing rates of up to 2 meters annually. This erosion endangers essential infrastructure and local populations, requiring significant investments in coastal fortifications. In Australia, elevated sea levels have resulted in heightened erosion rates throughout the eastern coastline, with a loss of 1.2 meters annually in certain areas, impacting both natural ecosystems and urban infrastructure [41]. These developments underscore the pressing necessity for efficient coastal management techniques to alleviate the effects of shoreline alterations.

In Canada, alterations to shorelines are becoming troublesome due to the effects of climate change and extreme weather occurrences. In sensitive locations of British Columbia, coastal erosion rates have escalated to 3 meters per year, jeopardizing local residents and infrastructure [42]. The provincial administration has launched initiatives to assess erosion and establish coastal defense mechanisms, demonstrating a proactive strategy in addressing these alterations. Coastal parts in France, particularly the Vendée, are seeing considerable shoreline erosion, with certain sections receding by more than 1 meter annually as a result of rising sea levels and anthropogenic influences [42]. These developments require extensive coastal management strategies to protect against additional erosion and habitat degradation.

In the Netherlands, alterations to the shoreline are closely associated with the nation's comprehensive system of dikes and flood protection measures. Certain parts of the Dutch coast, especially along the Wadden Sea, are undergoing erosion at rates of approximately 1 to 2 meters annually [43]. This erosion presents difficulties for the nation's flood management policy, which depends significantly on sustaining a strong coastal defense system. Australia confronts considerable issues; the coastal town of Byron Bay has encountered an average erosion rate of 2.5 meters annually, affecting local infrastructure and tourism [44]. These instances underscore the necessity of continuous study and adaptive management to properly handle coastal alterations.

In underdeveloped countries, alterations to shorelines pose significant problems, frequently intensified by insufficient resources for adaptation and management. In Bangladesh, coastal erosion impacts over 1,000 kilometers of shoreline, with certain regions experiencing an average erosion rate of 100 meters annually, profoundly affecting local residents and their livelihoods [45]. In the Philippines, the coastal region of Zambales has encountered erosion rates reaching 10 meters a year, attributed to rising sea levels and typhoon activity [46]. The loss of land endangers residences and affects agriculture and fisheries, hence compromising food security in these areas. These instances underscore the pressing necessity for focused interventions and community-oriented strategies to tackle shoreline alterations in developing countries.

In Vietnam, coastal erosion has impacted more than 3,000 kilometers of shoreline, with rates in certain regions reaching 5 meters a year, significantly affecting agriculture and fisheries. This erosion jeopardizes the lives and food security of numerous coastal people. In India, the state of Odisha is seeing considerable shoreline alterations, with about 50% of its coastline subjected to erosion as a result of rising sea levels and heightened cyclone activity, endangering both ecosystems and human communities [47]. These examples underscore the necessity for focused interventions and sustainable methods to effectively address shoreline alterations in emerging regions.

Coastal erosion is a significant concern in Indonesia, impacting around 2,000 kilometers of beachfront. Recent studies reveal that specific regions, especially around Java, are experiencing erosion rates of up to 7 meters annually, influenced by both natural phenomena and anthropogenic activities such as sand mining [48]. This erosion endangers coastal communities, agriculture, and biodiversity. The northern coastline of Egypt along the Mediterranean Sea is undergoing significant erosion, with certain regions losing up to 5 meters a year, intensified by climate change and rising sea levels [49]. These examples demonstrate the pressing necessity for adaptive strategies and sustainable practices to address shoreline alterations in emerging areas.

In Bangladesh, shoreline alterations have a significant impact, with coastal erosion damaging over 3,500 kilometers of coastline, especially in the Sundarbans area. Erosion rates may attain 15 meters annually, resulting in considerable displacement of populations and the loss of arable land [50]. The coastal metropolis of Lagos, Nigeria, is experiencing significant shoreline alterations, with erosion impacting around 1,000 kilometers of coastline at rates of 3 to 5 meters annually, influenced by urban growth and rising sea levels [51]. These instances underscore the pressing necessity for sustainable coastal management measures in developing countries to safeguard at-risk communities and ecosystems.

In Sub-Saharan Africa, alterations to shorelines are becoming more pronounced due to climate change and human activities. In Ghana, the Volta Delta is experiencing significant erosion, with rates estimated at around 5 meters annually, impacting thousands of residents and essential infrastructure [52]. In Mozambique, alterations to the shoreline have led to the erosion of approximately 70 kilometers of coastline, with forecasts suggesting that by 2030, more than 1.5 million individuals could be relocated as a consequence of rising sea levels [53]. The ramifications for local economies and social frameworks are significant, as communities dependent on coastal resources encounter heightened susceptibility. Confronting these problems necessitates improved regional collaboration and investment in adaptive strategies to protect livelihoods and ecosystems.

The Niger Delta region of Nigeria is facing erosion rates of up to 10 meters year, exacerbated by rising sea levels and oil drilling activity, leading to significant land loss and environmental [51]. This erosion profoundly affects local livelihoods, especially in fishing and agriculture. The coastal town of Mombasa in Kenya experiences significant erosion, with reports showing an annual coastline loss of 2-5 meters, resulting in relocation and economic detriment [54]. These patterns highlight the pressing necessity for community-oriented adaptive methods and regional cooperation to tackle the problems presented by shoreline alterations in Sub-Saharan contexts.

Coastal towns in Senegal, especially in the Dakar region, are experiencing substantial effects due to coastline alterations. Erosion rates are estimated at around 1.5 to 3 meters per year, jeopardizing infrastructure and communities reliant on coastal resources [55]. In Tanzania, coastline erosion along the eastern seaboard has escalated to concerning rates of up to 10 meters annually in certain regions, attributed to rising sea levels and anthropogenic alterations. These shifts present significant threats to local economies, especially fisheries and tourism, requiring comprehensive coastal management plans that engage local communities. Resolving these challenges necessitates cooperative initiatives and investments in robust infrastructure to safeguard at-risk coastal communities.

In Mozambique, coastal alterations are significant, with the main city, Maputo, seeing erosion rates of between 2 to 4 meters per year. This erosion endangers essential infrastructure and livelihoods in coastal communities, highlighting the necessity for integrated coastal zone management [53]. In Namibia, coastal erosion along the Atlantic Ocean is impacting critical regions such as Walvis Bay, with a rate of approximately 1.5 meters per year, threatening both human habitation and marine ecosystems [56]. These developments emphasize the imperative for collaborative coastal management strategies that involve local people and stakeholders in Sub-Saharan Africa.

Analyzing the effects of global warming entails investigating the complex repercussions of increasing temperatures on ecological and societal systems. A notable consequence is the rise in sea surface temperatures, which accelerates the melting of polar ice and glaciers, resulting in elevated sea levels. The increase in sea levels has significant consequences for shoreline alterations, encompassing heightened coastal erosion and habitat destruction. A vital factor is the escalation of extreme weather phenomena, including hurricanes and storms, which can aggravate coastal flooding and modify sediment dynamics along shorelines [57]. Moreover, alterations in precipitation patterns might modify freshwater influx into coastal ecosystems, impacting salt levels and the resilience of coastal habitats [36].

A significant consequence of global warming is ocean acidification, caused by the heightened absorption of carbon dioxide by saltwater. This phenomenon adversely affects marine life, especially calcifying species like corals, which are essential for coastal stabilization. The degradation of coral reefs, caused by warming and acidification, reduces their effectiveness as natural barriers against wave action, resulting in heightened shoreline erosion. Moreover, alterations in the distribution of marine species resulting from temperature fluctuations might disrupt local fisheries and incomes, hence adversely affecting coastal people [58]. Comprehending these interrelated effects is crucial for formulating adaptive management measures to alleviate shoreline alterations and bolster resilience in susceptible coastal regions.

Most particularly the western part of the Sandwip experienced more erosion than the other side. A mentionable part of the western part of Sandwip Island has been lost due to coastal erosion. The reasons for erosion were attributed to wave movement due to vigorous southwest monsoon winds, high currents, regular and hazardous storm surges in the Bay of Bengal. Once Sandwip was a large island, now it is decreasing with time because of very active coastal dynamics. According to Brammer [59], the main reason behind its continual decrease in the area is severe land erosion; 40% of the land was eroded in the last 200 years, which is still very active in this island.

The result of this research explored that the total land area of the Sanwip island was 254.788 square miles in 1975, which has been reduced to 223.23 square miles in 2018. It also illustrates the substantial reduction of land area over the last 40 years with a rate of 1.70 square miles per year. The net loss of land area between 1975 and 2018 was therefore a square mile. In contrast, accretion is much slower, which has mainly been happening towards the eastern and northern portion of the island. The researchers found from the temporal analysis of satellite image that erosion is most active in the western, southern, and southeastern part of the island, although it varies in places depending on time. This is happening due to a large amount of sediment pulses coming from the Ganges-Brahmaputra-Meghna river system, which is directly hindered by the northern part of the island, which forces sediments to be deposited there. On the eastern side of the island, fluvial actions like a wave and flow velocity are a bit weaker throughout the year, except the flooding seasons, and hence sediments are deposited here forming new lands. However, during the 1975 to 1980 period Sandwip did not experience any new land formation, but rather severe erosion all around the island periphery. During this time, Sandwip also experienced 20.68 square miles of land loss in the northern and eastern parts of the island. During the last 40 years, Landsat-based areal analysis found that the island experienced maximum loss of land from 2001 to 2011 (33.75 square miles) in the whole periphery except the easternmost part of the island. However, all results revealed a very high magnitude of erosion scenario compared to all coastal islands of the country, and due to this dynamism, Sandwip has been losing its most stable land at the rate of 1.5 square miles per year.

According to the experimental modeling conducted by Braudrick *et al*. [60] and the research on tropical river dynamics by Schwendel *et al*. [61], it can be inferred that the sinuous Bengal River system experiences lateral sediment transfer, with sediment migrating from the outer bank to the inner bank across extensive floodplains, ultimately resulting in the formation of point bars. The dynamic character of rivers can modify the surrounding landscapes, especially floodplains. The accelerated delta progradation, coupled with several regulating factors, renders the Bengal River system more unstable [62]. The dynamic features may induce the migration of rivers and channels, but numerous other factors can also contribute. Factors like land subsidence, accumulation of alluvial ridges, subsurface fluid extraction [63], and seismic activities [64] are likely the most prevalent in this instance. Furthermore, it is essential to comprehend the influence of anthropogenic activities on the evolution of rivers, floodplains, and coastal areas, irrespective of their intensity. The rise in global sea levels during the past century is a critical issue, influencing coastal morphology and significantly impacting communities reliant on coastal regions [65, 66].

The coastline of Bangladesh is considered one of the most susceptible regions globally to increasing sea levels. Coastal flooding presents a considerable challenge for nations with low-lying topographies, such as Bangladesh, where the protection of communities from the impacts of rising sea levels depends on sustainable flood mitigation strategies within the mangrove ecosystem [67-69]. The efficacy of long-term mangrove afforestation on vulnerable beaches along the Bangladesh coast has yet to be ascertained due to data limitations. Understanding the stability of the Sundarbans, the world's largest mangrove forest designated as a UNESCO World Heritage Site, and other coastal regions of Bangladesh in relation to increasing sea levels is crucial.

The primary aim of this project is to revise Bangladesh's surface (Quaternary) geological map, which has not been updated for over thirty years. The principal rationale for updating the surface geological map pertains to comprehending the evolution of the nation's fluvial system and coastline landscape during the last 32 years. The existing geological map of Bangladesh [70] provides critical surface geological information along with the most precise river flow paths at that time, enabling an analysis of alterations in river flow directions when compared to the latest high-resolution Sentinel-based remotely sensed data. A comparable methodology is beneficial for comprehending alterations in the nation's coastal landscape, wherein coastal stability can be assessed through a GIS-based analysis. Climatic factors, such as variations in yearly precipitation, are crucial for comprehending river and coastal water levels during dry or rainy times, as well as for understanding the rising or falling trends of surface water levels and their impact on landscape changes. Due to the paucity of multi-decadal studies examining the near-shoreline landscape history of the Bengal Delta, this remote sensing analysis will facilitate the comprehension of dynamic natural processes within the Bangladesh floodplain and coast, along with any related anthropogenic concerns.

In the last three decades, more than 39,000 people have migrated to other unions of which Harispur itself lost 21,617 people. Though Magdhara union is the most erosion inclined region in Sandwip, its population increased by 18,880 from 1981 to 2011. Being the largest union in Sandwip with the highest amount of agricultural and fallow lands, erosion affected people from other unions, who relocate to the central and northern part of this union, which is the main reason for the population increase [12].

Roy and Humayun [31, 71] attempted to find the relationship between erosion and accretion happening in Sandwip Island using hydrological data from 1965 to 2012. They found a significant positive relation between water level and erosion (R^2 = 0.9974), data, which means that increasing water level dramatically triggers land erosion in Sandwip. During excessive water level durations, financial institution erosion happens due to the fact excessive water glide and velocity beautify scraping of steep lands by abrasion of sediments found in water. Moreover, high velocity water causes base level erosion that makes the upper land more susceptible to erosion due to gravitational pull. A positive relation of erosion is also found with water discharge data (R^2=0.108), which implies that as the water level data discharge also acts as a positive factor behind land erosion in the coastal area of Bangladesh.

Kutubdia has got much attention due to its rapid loss of land to the sea, which has turned out to be a recurrent phenomenon in recent times due to sea level rise. Kutubdia Island is less than 1 metre above the mean sea level. Land erosion has increased substantially in the south-western part of the island known as Kuzier Tek since the 1960s. Locals consider sea-level-rise, floods and changes in the direction of currents as the main reasons for accelerating land erosion.

Fine sediments, with few sand particles, predominate the central coastline of southeastern Bangladesh [72]. Satellite data delineates the region's proximity to the Meghna Estuary, flanked by tidal mud and estuary deposits to the east and tidal deltaic sediments to the west. Our research highlights significant land erosion in this area during the last 32 years. The narrower Upper Meghna converges with the broader Lower Meghna, gradually merging into the Bay of Bengal to the south, where the flow velocity of the river diminishes. The slower-moving channel, with diminished energy for sediment transport, results in significant deposition of loose sediments, so creating widespread but unstable land accretion. This indicates the significant susceptibility of the central coast to sea-level rise.

The southern shore features a dominant silty or sandy clay surface resulting from tidal deposition [73, 74] . In the Sundarbans Forest, a significant increase of 0.5 °C per decade in surface water temperature [75] is modifying monsoonal patterns, contributing to sea-level rise, and intensifying coastal erosion. Our data revealed the relative stability of the Sundarbans Mangrove Swamp shoreline in the southwest during the past thirty years. This is probably due to the root-stabilization and ocean-energy dissipation effects of the vegetation. The region's land stability is being confronted by anthropogenic challenges from human settlements, agriculture, and aquaculture, which may result in groundwater contamination [76]. Although the existing sandy clay layer along the shoreline has the capacity to function as an aquitard, safeguarding groundwater from surface pollutants [77], unregulated land use activities pose a considerable long-term threat to the region's natural resources. Allison [78] determined that the Meghna Estuary landscape saw development rates of 15 km^2 annually from 1792 to 1840, and 4.4 km^2 per year from 1840 to 1984. Brammer [59] recorded a 451 km^2 land growth in the Meghna Estuary from 1984 to 2007, averaging 20 km^2 per year. Our research indicates a heightened yearly landform development rate of 84 km^2 adjacent to the Meghna Estuary. The results confirm the Meghna Estuary's continuous seaward accretion during the last 230 years, notwithstanding the rising sea levels.

Since 1990, the average annual precipitation in Bangladesh has experienced a little reduction. Precipitation patterns affect sediment movement and deposition; thus, a reduction in rainfall may add to sediment accumulation, potentially resulting in increased land acquisition during this period. Despite the country experiencing elevated mean annual rainfall between 2015 and 2017, these figures are likely anomalies. The rapid coastal land growth rate surrounding the Meghna Estuary exceeded all anticipated sea-level rise and land loss impacts. This understanding is particularly significant for Bangladesh, a low-lying country confronting an 18% chance of irreversible coastal land loss due to a probable one-meter rise in sea level in the near future [79, 80].

The Brahmaputra River, referred to as the Jamuna River, is a transboundary river [81] that originates in Tibet and traverses China, India, and northeastern Bangladesh before discharging into the Bay of Bengal (Fig. **1**). All principal tributaries of the Brahmaputra, including Teesta, Dharla, and Dudhkumar, are situated upstream of their confluence with the main river. This analysis confirms that, over the last 32 years, the Jamuna River has retained its natural braided structure while preserving a generally consistent valley trajectory and flow direction. Nonetheless, the distinct channels of this multi-thread river system have markedly altered their flow trajectories.

The braided Jamuna River is rich in sandy midbars, characterized by anastomosing-like formations on the bigger bars. The riverbed and valley consist predominantly of alluvial sand, resulting in erosion on both banks and mid-bars, which generates new bars. This aligns with Bristow's [82] remote sensing investigation, which similarly detected patterns in this river system using Landsat imagery and a historical database. The tectonic influence on the Brahmaputra River has persisted for several centuries, perhaps resulting in alterations to its path [83]. The collision between the Indian Plate and the Eurasian Plate along the Jamuna Fault may cause the Brahmaputra River to alter its path, potentially resulting in the formation of new channels while forsaking the existing ones. Coleman [84] had posited a westward avulsion of the Brahmaputra in the late eighteenth century resulting from a significant earthquake, but Hirst [85] suggested that the Brahmaputra's directional shift was affected by the Teesta's avulsion in 1787.

The elevated sinuosity of the Teesta River (2.11) indicates a pronounced meandering characteristic, however it has experienced a little reduction since 1990. The decrease in the length and sinuosity of the Teesta River during the past 32 years indicates alterations in its path, potentially influenced by the lack of surface water during the dry season resulting from upstream construction at the Teesta Barrage in India [86]. Furthermore, after 1996, the Gozoldoba segment of the Teesta Barrage commenced construction, potentially resulting in diminished discharge and modified downstream economic and social conditions, along with agricultural practices in Bangladesh [87]. Consequently, augmented human intervention is a significant influence in transforming the land use pattern of the Teesta River watershed over time. Precipitation, as evaluated in our study (Fig. **6**), exhibits a decreasing tendency in the Bogura and Dinajpur districts (Northwest Bangladesh), corroborating the findings of [87], which identified a decrease trend in dry season rainfall for Teesta.

The Dudhkumar River, the northernmost tributary of the Brahmaputra, presently has a meandering configuration. The investigation of river morphometry indicates that Dudhkumar now exhibits a sinuosity of 1.58, an increase from 1.23 in 1990. The Dharla River exhibits a comparable shape, with a present sinuosity of 1.9, an increase from 1.64 in 1990. Consequently, both waterways have a pronounced meandering pattern, facilitating greater migration across their floodplains.

Notably, the Dudhkumar River exhibited indications of rejuvenation in 2022, including the emergence of meander cutoffs adjacent to the Bangladesh-India border, where it displayed a stagnant stream pattern in 1990. Numerous oxbow lakes were detected in the Kurigram district of Northwest Bangladesh, formed during the meander cutoff process as the Dudhkumar and Dharla rivers abandoned their meander loops during channel evolution. The Ganges and its tributaries, starting from the Gangotri Glacier in the Himalayas, form a significant river system that acts as a principal supply of surface water in Bengal, traversing roughly 2,900 km before emptying into the Bay of Bengal [88]. The flow pattern of the Ganges River in India, located in the Mesozoic Rajmahal Traps bedrock [89], is presumed to differ from that of its Bangladeshi equivalent, exhibiting diverse geomorphic settings with Holocene deposits.

The Farakka Barrage, constructed in 1975 on the Ganges, has drastically altered the distribution of river water between India and Bangladesh. In recent years, the Ganges River in India has undergone significant channel migration and increased discharge rates [90], but the Padma River in Bangladesh has seen a reduction in water and sediment discharge [91]. Research by Rahman & Rahman [74] indicates a substantial decline in both annual average and minimum water discharge in the Ganges-Padma system in Bangladesh since the post-Farakka era following 1975, accompanied by occasional sudden spikes in yearly maximum water levels.

Furthermore, a continuous decline in national mean annual precipitation has been noted over the past thirty years, contributing to a reduction in channel width and a diminishment of river strength. Consequently, the older, more braided (multi-thread) Ganges-Padma channels have gradually transitioned to a predominantly single-thread, sinuous configuration, indicating the direct influence of the Farakka Barrage, coupled with a slight reduction in precipitation, which has led to a decline in water discharge through the Ganges-Padma over time. The upper section of the Ganges River has a distinct meandering pattern originating in India, featuring two large meander spirals gradually stretching along the opposing banks. While the Padma River exhibited moderate sinuosity (S = 1.08 to 1.19) throughout the study period, the Ganges River had a significant increase in sinuosity in 2022 (S = 1.88), rising sharply from 1990 (S = 1.6). Consequently, the Ganges might be regarded as a very meandering river due to its increasing sinuosity.

The measured average distance of 3.7 km between current and historical flow pathways indicates a significant continuous evolution of the Ganges, as evidenced by the separation between the abandoned and active meanders The Ganges, due to its dynamic characteristics, can influence nearby land use, infrastructure, and ecosystems, particularly in the Kushtia, Ishwardi, and Pabna districts. This also suggests that Bangladeshi individuals living in these areas may have considerable risks of landscape modification and environmental relocation in the forthcoming years.

The Meghna River is part of the Surma-Kushiyara river system, which flows through Bangladesh via the Barak River, beginning from the mountainous regions of eastern India [92]. In comparison to the Ganges-Padma and Jamuna River systems, the Upper Meghna River network has a reduced propensity for channel shifting. The sinuosity of the Upper Meghna has remained within a moderate range of 1.21 to 1.35 during the past few decades. The Upper Meghna riverbanks exhibit multiple unique anastomosed patterns, indicating a greater resistance to erosion and demonstrating resilience of the floodplain. The tectonically subsiding Surma Basin, characterized by its dense and consolidated sediments [93], likely led to a stable and anastomosed configuration of the Upper Meghna River. The channels diverged and converged at multiple sites, adhering to very similar flow trajectories in 1990.

Notwithstanding significant land accretion in recent years, the Lower Meghna River exhibits a greater width in the Meghna Estuary due to the confluence of the Jamuna and Padma Rivers, which transport substantial volumes of water and sediment. This discovery aligns with previous studies conducted by Allison, Brammer and Steckler *et al*. [78, 59, 91]. The convergence of all principal fluvial networks at a littoral zone, along with the recent increase in sea level, has rendered the Lower Meghna River shoreline susceptible to erosion. This work offers significant insights into coastal stability, landscape development, and channel migration through remote sensing data, although it possesses intrinsic limitations.

The principal constraint pertains to the precision and resolution of satellite imagery. Remote sensing offers a two-dimensional perspective of surface alterations, which may inadequately represent subsurface phenomena, such as groundwater flows or sediment composition. A further issue is the lack of thorough field validation. Although remote sensing data provide extensive temporal coverage, ground-truthing by field surveys is essential to authenticate the observed landscape alterations and sedimentary patterns. In the absence of field data, including sediment samples or geotechnical analysis, the study's conclusions about erosion, deposition, and landform stability rely exclusively on indicators generated from images. The future incorporation of fieldwork, including soil sampling, hydrological measurements, and GPS-based surveys, can enhance the interpretation of satellite-derived data and offer a more comprehensive understanding of the region's geomorphological processes.

Due to the dynamic characteristics of Bangladesh's river systems and coastal areas, regular monitoring is crucial to observe landscape alterations. Future research should concentrate on developing long-term observation networks that integrate remote sensing data with systematic field validation to ensure precision and enhance predictive capabilities. Furthermore, high-resolution satellite images from commercial sources may be utilized to provide a more comprehensive investigation of minor landscape alterations, especially in swiftly changing regions such as the Meghna Estuary and the Jamuna-Brahmaputra River system.

Furthermore, formulating adaptive management solutions is essential to alleviate the risks associated with climate change, sea-level rise, and human-induced stresses. Future study should investigate the utilization of hydrodynamic and sediment transport models to estimate the possible effects of various climatic scenarios on the coastal and riverine landscapes of Bangladesh. Examining the function of ecosystem-based strategies, such as mangrove restoration in the Sundarbans, may yield sustainable methods for improving coastal resilience. Involving local people and officials in the formulation of these adaptation strategies will guarantee that scientific discoveries are converted into practical and effective mitigation measures.

From the study, it was explored that the major part of the Kutubdia Island (South and west segment) is exposed to open sea and is influenced by the strong wave actions and seasonal cyclones, sea level rise, and de-sedimentation eventually accelerated the erosion, however the effect of longshore currents could not be overlooked. On the other hand, the north and east part of the island experience relatively less erosion. From this particular study, it is recommended to take special care for the future planning and management of Kutubdia for further erosion. However, care needs to be taken at some point of engaging in the mitigation measurements so that the natural strategies aren't obliterated.

The erosion scenario of Maheskhali, Sandwip, and Kutubdia did not change even with changing the wind direction and occurred at similar maximum values. It can therefore be concluded here that the wind speeds have no significant erosion effects along the coast of Bangladesh despite its directional changes (Fig. **14**).

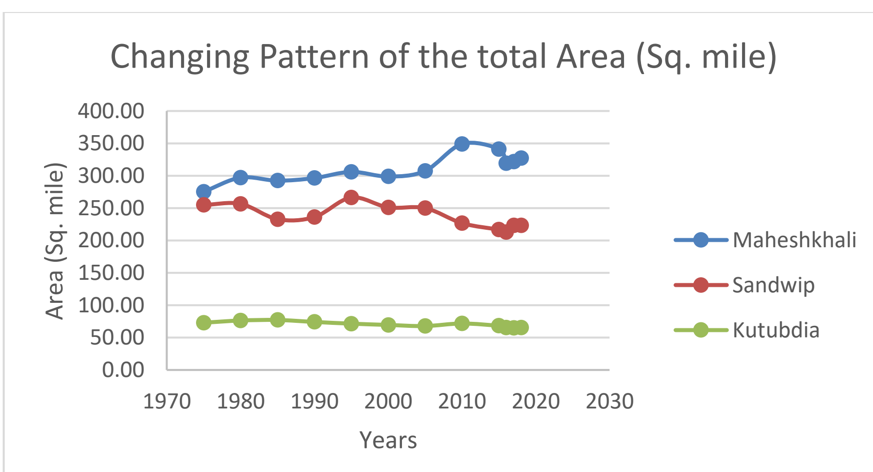

Figure 14: Comparison of changing area pattern of the 3 study areas.

From the findings of the study on coastal erosion, it is clear that wave orbital velocity without bottom friction is higher or at least equal to the wave orbital velocity with bottom friction, and bottom friction reduces the wave orbital velocity. The trend of erosion along all cross sections done through the GIS mapping of 3 islands is similar, and this means that the higher the wind speed, the higher the rate of erosion. There is fluctuation in the rate of erosion along different cross sections, which is mainly due to fluctuation in water depth along that cross section. So, the higher the wind speed or the higher the steady wind fetches, the higher the rate of erosion and vice versa.

River erosion transpired in a 62-square-kilometer region from 1991 to 2001. New characters have emerged in a region spanning 61 square kilometers at this time. The river has stayed unaltered throughout a 53-square-kilometer expanse. The river's erosion and accretion were approximately equal, measuring 57 square kilometers, from 2001 to 2021. The corresponding site stayed unchanged. In 2011, river erosion affected 75 square kilometers, while sedimentation obscured 56 square kilometers. The above research Akter *et al*., [29] indicates that the Teesta River is experiencing simultaneous erosion and accretion. The individuals residing along the banks of the Teesta River are the most adversely affected by erosion and accretion [94]. The Teesta is a formidable and vibrant river with an extensive history. River erosion has historically been a natural occurrence to which people have adapted. In the 1990s, the Indian government sought to regulate the flow of the Teesta River by erecting the Gajoldoba Barrage upstream [95].

In 1991, Agriculture constituted the highest proportion of land use and land cover categories, accounting for 63% (2060 sq km) of the total area. This class had a decline, down to 47% (1544 sq km). However, this declining rate is not evident in the period from 2011 to 2021. This occurred due to various circumstances, including technological progress, specifically the development of drought-resistant food crop varieties. Due to these new types, individuals can now grow in tough terrains such as the char regions. They transformed a significant amount of uncultivated land into arable land. The government offers incentives to farmers and has implemented various programs to enhance agricultural output in the study region [96]. The COVID-19 epidemic has also indicated a favorable trend in crop output within the research area [97].

The other category that experienced a decline over the study period was waterbody. In 1991, this class included 8% (276 sq km) of the total land, which decreased to 3% (110 sq km) by 2021. The settlement area had a significant increase. The percentage rose from 23% (763 sq km) in 1991 to 42% (1362 sq km) in 2012. This analysis indicated an increase of almost 179% in settlement area from 1991 to 2021. This image illustrated the significant alteration in land cover within the built-up surface category, exerting substantial pressure on non-built-up surfaces, especially agricultural lands.

A substantial expanse of land was eroded by the river; nevertheless, a significant area was revealed following the char, prompting the diligent inhabitants of North Bengal to resume cultivation, so transforming the settlement into agricultural land. Individuals have been cultivating land near their residences to accommodate the needs of a growing population [29]. Consequently, the settlement may potentially be transformed into agricultural land. Between 1999 and 2001, approximately 158 square kilometers of land was transformed from aquatic to agricultural use. The Teesta River desiccates in winter due to insufficient water, rendering extensive areas along its banks conducive to agriculture. Moreover, the increase of chars in the river has prompted individuals to cultivate those regions, leading to a transformation [95].

From the total land area analysis of the study areas, it is noted that the land area of Maheskhali upazila increased compared to Sandwip and Kutubdia. It was found that although erosion takes place in Maheskhali and the number of people displaced from the island, many chars created in the Maheskhali channel where no human settlement was there. From the satellite image, it was found that coastal erosion is highest on Maheskhali island compared to the other 2 study areas. This occurs because a number of chars like Haserdia, Maynarghona were created around the Maheskhali channel after 2000, but now due to sea level rise, none of the chars located in the map of the Maheskhali Island. Some of the char also found in the map nearby island, which indicated the area of Maheskhali increased over the year.

From the findings of the present study, the aforementioned study's findings, consultations with experts, local government representatives, government officials, and the researchers' own research experiences have led to the following recommendations, which have been put forth in light of the study's conclusions. These suggestions will aid in the effective management of the nation's inland regions as well as the entire country of Bangladesh's rehabilitation programs, Khas land allocation, and governance practices. With the implementation of these suggestions, the government, NGOs, and development partners would work together effectively to manage the relocation program. the following

Individuals temporarily displaced by a disaster may return to their residences for a limited duration if their properties remain secure. However, if they lose their homestead, they must seek alternate shelter for survival. Displacement of individuals in the studied areas is a prevalent occurrence due to disasters triggered by climate change. The inhabitants of these three upazilas are relocating in search of shelter and sustenance for survival following their relocation. They frequently must commence anew in unfamiliar settings, including shelters, environments, livelihoods, and lifestyles, which places them in a highly challenging predicament. This study aims to examine the lives and livelihoods of displaced individuals in comparison to their places of origin and current destinations. Table **9** aimed to examine the correlation between the life and livelihood patterns of displaced individuals in the pre- and post-displacement contexts of both research locations. To conduct a more rigorous analysis of the data, an effort has been made to statistically analyze the relationship between the life and livelihood patterns of displaced individuals in both pre- and post-displacement contexts.

The Chi-square test has been conducted after cross tabulation. Table **9** presents the outcomes together with the significance levels for the chi-square (χ^2) test. The results suggest a significant disparity in livelihood situations between the pre- and post-displacement phases in both study locations. Table **9** demonstrates that monthly income, occupational categories, housing patterns, sanitary conditions, children's educational status (research area-II), and security nature were important factors in both pre- and post-displacement contexts throughout both study areas. Consequently, it is demonstrated that the lives and livelihoods of displaced individuals undergo significant transformation when comparing the periods before and after relocation. An effort has been undertaken to quantitatively analyze the correlation between the socioeconomic conditions of displaced individuals before and after displacement. The null hypothesis is stated as follows: Ho: There are no changes in the socioeconomic conditions of displaced individuals when comparing the pre-displacement and post-displacement scenarios. Nonetheless, the availability of drinking water and healthcare services has improved in the current residential areas (Table **9**).

The study revealed that the majority of displaced individuals are either illiterate or possess incomplete literacy (signature) in both regions. The majority are involved in agriculture, fishing, and salt cultivation in their regions of origin, whereas in the destination locations, they participate in day work and small enterprises. A significant proportion of individuals belong to the lowest income bracket in both regions, earning less than five thousand per month. The housing situation of displaced individuals is temporary; just 21% in Kutubdia, 25% in Maheskhali, and 30% in Sandwip reside on their land, while the remainder occupies either government land (predominantly on embankments and roadways) or private properties.

The study examined the alterations in monthly income, occupational categories, housing patterns, sanitary conditions, children's educational status, and security nature in the pre- and post-displacement contexts of both study locations. Despite an increase in income levels from the pre- to post-displacement condition, satisfaction levels remained low compared to the pre-displacement period in both study locations. The current location is characterized by high living costs, insecurity, a detrimental environment, lack of social connections, and persistent psychological stress.

Conclusion and Recommendations

This investigation, among the initial studies on geological and landscape mapping of the Bengal Basin and Bangladesh, identified significant findings about channel migrations and landform evolution during the previous 32 years. This study examined the evolution of Bangladesh's principal rivers, namely the Ganges, Brahmaputra, Meghna, and their tributaries. A comparison investigation of landscape maps from 1990 to 2022 indicated substantial alterations in river trajectories and shoreline topography.

Table 9: Socioeconomic condition of displaced people compared with before and after displacement situation.

1st Variable (Before Displacement)	2nd Variable (After Displacement)	Study Area- I (Kutubdia)					Study Area-II (Sandwip					Study Area-II (Maheskhali)				
		Chi-square (χ^2)					*Chi-square* (χ^2)					*Chi-square* (χ^2)				
		Cal value	Tab value	Result	Df	Sig.*	Cal value	Tab value	Result	Df	Sig.*	Cal value	Tab value	Result	Df	Sig.*
Monthly Income	Monthly Income	40.45	26.29	14.16	16	S	30.07	26.29	4.41	16	S	25.07	20.29	4.78	16	S
Types of Occupation	Types of Occupation	45.20	26.29	18.91	16	S	40.59	26.29	14.3	16	S	50.49	30.50	19.99	16	S
Pattern of Housing	Pattern of Housing	34.74	26.29	8.45	16	S	56.03	26.29	29.74	16	S	45.23	30.45	14.78	16	S
Source of drinking water	Source of drinking water	1.44	26.29	-24.85	16	N	2.05	26.29	-24.24	16	NS	5.45	30.49	-25.04	16	NS
Sanitation condition	Sanitation condition	62.46	26.29	36.17	16	S	63.84	26.29	37.55	16	S	48.54	22.49	26.05	16	S
Health care facilities	Health care facilities	1.26	26.29	-25.03	16	NS	1.76	26.29	-24.53	16	NS	3.65	20.49	-16.84	16	NS
Children education	Children education	1.26	26.29	-25.03	16	NS	98.89	26.29	72.6	16	S	70.55	27.49	43.06	16	S
Nature of Security	Nature of Security	77.35	26.29	51.06	16	S	35.52	16.91	18.61	9	S	35.52	14.90	20.62	16	S
Social and cultural harmony	Social and cultural harmony	55.26	26.29	28.97	16	S	59.33	26.29	33.03	16	S	45.33	23.49	21.84	16	S

Although historical avulsion of the Brahmaputra (Jamuna) River may be attributed to the movement of the Jamuna Fault, our investigation uncovered fascinating instances of river regeneration in the tributaries of the Brahmaputra. Anastomosing and meandering patterns characterize the examined fluvial networks, but the Brahmaputra River displays a braided, multi-thread architecture featuring numerous mid-bars. Anthropogenic influences, like the Teesta and Farakka Barrages, regulate the dynamics of significant waterways (Ganges and Brahmaputra), resulting in diminished water discharge and a slight reduction in precipitation, which have led to the Ganges-Padma River system constricting into single-thread channels. The braided Brahmaputra River continues to exhibit its multi-threaded characteristics; nevertheless, it has seen reduced discharge as a result of the Teesta Barrage in India. All principal tributaries of the Brahmaputra River exhibit moderate to high sinuosity, with ongoing anthropogenic activities in the upper Teesta exerting partial influence.

The Ganges and Brahmaputra Rivers possess unstable floodplains, whereas the Upper Meghna fluvial system features the most stable floodplain and channel trajectory, perhaps attributable to the sinking of the Surma Basin. The convergence of all rivers at the Meghna Estuary expands the Lower Meghna fluvial system and promotes swift land accretion, notwithstanding the effects of sea-level rise. The alteration of river courses and topography in the Bengal fluvial system has profound implications for the millions residing in the floodplain.

The Bengal Delta is the largest delta globally and is significantly susceptible to cyclones, flooding, and increasing sea levels. This study discovered both stable and unstable landscapes, particularly in the coastal regions of Bangladesh. The revised geological map of Bangladesh facilitated the examination of lithologic variation and topographical alteration. Nonetheless, due to the ubiquity of "Undefined Quaternary Deposits" along the coastline and riverbanks, additional field investigations may aid in elucidating the specific lithology of this unit.

Satellite data indicated substantial changes to alluvial sand and silt deposits along the nation's river floodplains and coastal areas. The recently accreted lands in the Meghna Estuary necessitate a comparison with comparable coastal zones to assess landform stability. This research determined that the Sundarbans Mangrove Forest, located on the southwest coast, exhibits remarkable stability despite the recent increase in sea levels. Considering that one-fourth of the nation's population resides along the coast, it is essential to ascertain if coastal shorelines may attain geomorphic stability by natural or artificial afforestation.

The 2022 dry-season Sentinel-2 imaging indicated a substantial land increase of 2,677 km^2 along the coast, demonstrating sixfold land growth relative to the prior analysis by Brammer [59]. The increasing stability of coastal land in Bangladesh has become a critical subject for future research, with ramifications for other deltas. This research can serve as a significant reference for future studies aiming to tackle global landscape and environmental concerns. Integrating the study's findings into policy formulation and sustainable management practices can substantially improve initiatives to alleviate the effects of climate change and human activities in the Bengal Basin and coastal Bangladesh. The recognition of river rejuvenations, channel migrations, and terrain alterations over the past 32 years offers essential insights for floodplain management, disaster preparedness, and urban development.

The observed land accretion around the Meghna Estuary may guide coastal zone management policy, advocating for the utilization of natural landform developments as protective barriers against sea-level rise and storms. Furthermore, comprehending the effects of barrages such as Farakka and Teesta on river discharge and dynamics provides essential insights for transboundary water management discussions, ensuring that upstream actions do not disrupt downstream ecosystems or communities. The resilience of the Sundarbans Mangrove Forest, in the face of increasing sea levels, underscores the necessity of preserving mangroves as a natural barrier against coastal erosion and inundation. These findings underscore the necessity for afforestation and reforestation programs to enhance coastal resilience. By incorporating these insights into regional and national initiatives, policymakers can more effectively reconcile development requirements with environmental sustainability, mitigating susceptibility to climate-induced calamities while fostering sustainable lifestyles for the millions residing in the delta.

The authors have a look in the book chapter at how families have incredibly responded to the cyclone, tidal flood, and coastal erosion hazards and other weather alternate-caused troubles via adopting quite several adaptation practices that depend on their socioeconomic and household characteristics, and access to institutional facilities and social capital. The important fences to adopting the sustainable adaptation options include a lack of information on coastal erosion and related climatic issues, poor knowledge about appropriate strategies, inappropriate crop varieties, the limitations of one's land, and limited access to credit services. Sustainable adaptation is essentially a global issue since social equality and environmental integrity are important for all populations to achieve sustainable responses to climate change. The adaptation processes have and will generate explicit deliberation of the risks of a sea-level increase in the planned planning processes of local governments throughout the study areas, including the coastal area of Bangladesh.

Climate displacement is not the concern of the future, which is already underway in Bangladesh. Climate change-induced slow and sudden onset events are recurrent in the coastal areas of Bangladesh and displacing hundreds of thousands of people from their homestead every year. However, due to the limited rehabilitated program by the Government of Bangladesh, forcing displaced people to move to big urban areas of the country from their origin. Besides, existing rehabilitated options have been stigmatised and formed many difficulties in their present living and destination places like an identity crisis, the threat from local people to leave the place, lack of good relationships with the local researchers and land ownership, the nonexistence of cultural harmony and absence of any assistance from local neighbours.

To ensure the solution of non-cooperation from local people, the community-based rehabilitation approach not only ensures their permanent settlement but also secures their dignity, local food, culture, society, and wisdom. Besides, ensure proper coordination between the Government and NGOs or development partners during the distribution of the short-term rehabilitation program, especially the distribution of basic needs for climate-displaced people in disaster-prone areas of Bangladesh.

Besides, Multidisciplinary, robust investigations on the links between climate change, displacement and migration are limited in Bangladesh. The investigation is constrained by the complexity and interrelatedness of the drivers of human mobility, which concurrently serve as drivers of vulnerability to climate hazards and change.

Estimates of displacement and migration because of climate change have to disentangle not only social, political, cultural, and economic elements, however, additionally different environmental elements, which include mismanagement of natural resources. Disagreements as to how to link climate change as an environmental stressor with other factors of migration persist.

Displaced people generally make shelters on the polder area with the hope of relief that has been promised by the government and different organizations. The citizens of Sandwip, Maheskhali, and Kutubdia Islands have been looking to protect themselves for the reason that human beings began to live here. The study results revealed that most adaptation strategies of the households were autonomous. It additionally determined that families have for my part sought to undertake applying very traditional and manual techniques. However, the households also acted as a group, led by the social leader, in requesting government assistance so that they could cope with the climate change vulnerabilities. Their movement may be considered as one type of collective edition.

Since the finding of the study, resettlement is one of the most important tasks for this forced migrant, which is very difficult to tackle for the least developed countries like Bangladesh. During the investigation and field visit, however, Bangladesh is quite unable to take resettlement measures due to the shortage of finance and land resources (which is much more valuable for food security). Administrative management is another big question. A mammoth amount of money is needed for building civic infrastructures like housing, electricity, water, and sanitation facilities, which are quite difficult for Bangladesh. The other questions, along with adapting to a brand new social environment, employment, and behavior of local human beings with the settlers and social unrest, are dangers of resettlement as the Bangladeshi society is not multidimensional. Every other large subject is associated with the coverage association. Bangladesh has no policy on displacement and internal migration or resettlement. Some international initiatives, e.g. UNFCCC process, have failed in addressing the issue due to its lengthy negotiation of mitigation, adaptation, and climate financing. However, the findings of this study have a number of policy implications on disaster management, urban development and urban housing, and rural development and poverty alleviation in Bangladesh.

1) Coastal embankment/polder should be constructed or repaired using triangular concrete with stone blocks, and coastal afforestation by mangrove or saline resistance plant species should be initiated alongside embankment. A local joint monitoring team should be established to oversee the afforestation and embankment;
2) It is important to develop climate change-induced catastrophe resilience, especially for the agricultural sector (saline water and flood-resistant crop species, seed preservation during harvest), as well as for the displaced population;
3) The government should uphold eight rights for those who have been forcibly displaced, including access to humanitarian aid during times of need, adequate housing and shelter, land, food, water, and adequate sanitation, schooling for children, access to medical facilities, freedom of movement, and the right to choose their new home.
4) To adequately address this issue of displacement, the government should create and execute a national climate displacement monitoring apparatus to track and record all displacement caused by disasters brought on by climate change.
5) It is important to develop climate change-induced catastrophe resilience, especially for the agricultural sector (saline water and flood-resistant crop species, seed preservation during harvest), as well as for the displaced population;
6) The government should uphold eight rights for those who have been forcibly displaced, including access to humanitarian aid during times of need, adequate housing and shelter, land, food, water, and adequate sanitation, schooling for children, access to medical facilities, freedom of movement, and the right to choose their new home.
7) To adequately address this issue of displacement, the government should create and execute a national climate displacement monitoring apparatus to track and record all displacement caused by disasters brought on by climate change.

8) The government should make sure that all parties are coordinated, especially those with government ties, NGOs, and development partners. It will provide the most efficient relocating and rehabilitation of displaced persons.

9) The area that has been renovated should be free from calamity, have easy access to neighboring communities' basic facilities, be free from local political and mussel man violence, and coexist in religious, social, and cultural harmony on an equal footing.

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