MORPHOLOGICAL ASSESSMENT OF SANDWIP ISLAND USING GIS AND REMOTE SENSING TECHNOLOGY

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ABSTRACT

In the past several decades, Bangladesh has been confronted with a plathora of challenges arising from natural disasters attributed to climate change, particularly concentrated within its coastal regions. The coastal area, particularly the shoreline, emerges as a focal point of vulnerability, accentuated by issues such as erosion and accretion. Bangladesh experiences some of the world's highest storm surges, which play a significant role in reshaping the coastal landscape through erosion and accretion. The nation confronts a yearly onslaught of riverbank erosion which have a devastating impact on people's lives and their livelihood. Coastal shoreline is mainly impacted by waves and tides which are generated by sea winds and tides driven by the gravitational forces of the moon and sun. Sandwip stands as an island positioned on the southeastern coastal shoreline of Bangladesh within the Chattogram District. The phenomenon of riverbank erosion compels a significant population of Sandwip's residents to undergo migration, resulting in profound economic hardships and considerable distress in their lives. This research offers a morphological evaluation that showcases the susceptibility of Sandwip Island through the application of Geographic Information Systems (GIS) and Remote Sensing Technology. This research leveraged Landsat Satellite imagery spanning three decades, capturing data from the years 1990, 2000, 2011, and 2020 to comprehensively assess the region. Employing advanced geospatial tools, namely ArcGIS 10.8 and Google Earth Pro, these satellite images were meticulously analyzed. Over the course of this thirty-year study, a notable trend emerged: the extent of stable land exhibited a substantial increase. In 2000, the proportion of stable land stood at 73%, a figure that surged to an impressive 86% by 2020. Within this temporal panorama, 2011 stood out as a year marked by the most significant erosion, resulting in the loss of nearly 3200 hectares of land. Significantly, among the twelve examined regions, Kamla Char stood out as the most erosion-prone area. This vulnerability was primarily concentrated in the island's southwestern sector, as elucidated in this investigation. The study's findings thus underscore the critical need for proactive measures to safeguard this threatened region from ongoing land loss.

Keywords: *Erosion, GIS, Morphology, Remote Sensing, Vulnerability.*

1. INTRODUCTION

The term "coasts" refers to the boundary between land and sea. The shorelines across the globe are ever-changing and dynamic systems (Balica et al., 2012) and they are also susceptible to a multitude of hazards (Torresan et al., 2008). It is worth noting that a significant portion of the global population resides in these areas. Coastal offshore islands, situated in close proximity to the coastline, undergo significant environmental transformations due to a multifaceted interplay of natural and human-induced factors. The natural process encompasses several factors such as rising sea levels, geological and tectonic changes, natural disasters, coastal flooding, shoreline erosion and accretion, and channel migration, in addition to other environmental consequences caused by human activities (Yanli, 2011) (Yanli, 2011). Hence, the alteration of coastal environments due to both natural and anthropogenic activity has become a global problem, necessitating a comprehensive understanding of coastlines and their transformations. The majority of the archipelagos in Bangladesh are located along the central coastal region, specifically along the Meghna estuary. There significant geomorphologic shifts are taking place quickly (Brammer, 2014). The morphology of the Meghna Estuary and its associated islands is influenced by a variety of hydrodynamic factors. These factors include the considerable discharge of main rivers, the substantial accumulation of sediment which is approximately 2.4 billion tons per year, the substantial tidal pressures, the influence of waves and winds, the consequence of seasonal storm surges, and how water circulates within the estuary. As a result of these intricate relationships, the estuary and its islands undergo continuous alterations in morphology, characterized by both land birth and processes of erosion (Emran et al., 2017). The sediment composition of the Meghna Estuary bed primarily comprises silt and fine sand, with a median grain size of the bed material in which, approximately, one-fifth to one-third of the original supply of 1100 million tons are retained which play an important role providing the material for land formation in the central part of the coast and ultimately influence the hydrology of surroundings (Emran et al., 2017). Sandwip is a significant offshore island located in the Meghna estuary along the south-eastern coast of Bangladesh, specifically within the Chittagong Division. The distinctive attributes of the subject can be ascribed to its hydro-geomorphic environment. The island has experienced a gradual reduction in size over the course of the last two centuries. Based on historical data, it can be observed that the island's total area experienced a notable change over the course of a century. In 1780, the island encompassed approximately 480 km^2. However, by 1880, the area had expanded to 502 km^2 as a result of land reclamation efforts. In 1979, the area experienced a significant reduction to 290 km^2 as a result of extensive bank erosion (Rob, 1997) Based on the data collected between 1978 and 1989, it can be observed that approximately 19 km^2 of land was lost, while only 4.1 km^2 experienced accretion. Approximately 40% of the eastern island experienced erosion from 1984 to 2007 (Brammer, 2014). The last three decades, indicating that various sections of the island exhibit distinct patterns in coastline changes linked to hydrological dynamics (Emran et al., 2017). Sandwip Island displays a cyclical pattern of accretion and erosion across its various regions. Due to this erosion across different regions land cover changes in Sandwip over time. Similarly, one study utilizes time-series satellite imagery analysis to examine coastal erosion-accretion and its correlation with land cover changes in Kuakata over 31 years (1989-2020), identifying areas prone to erosion and suggesting implications for policymaking in coastal zoning and protective measures (Aishi et al., 2022). The erosion and accretion of the island are the outcomes of both natural and human-induced factors. The physical causes of the phenomenon include river discharge in the Meghna estuary originating from the upstream Ganges-Brahmaputra-Meghna Rivers, sediment load, tide, wave, water current, and bank configuration. Furthermore, it is important to acknowledge that human activities have a significant impact on both shoreline dynamics and the hydrology of the channel. The ocean depth around the island reacts similarly to coastline erosion and accretion. Coastal morphology modification and erosion-accretion history of this offshore island are frequently linked. Modern remote sensing and GIS have become essential tools for coastal change investigations. Such studies serve as crucial input for crafting policies related to the rehabilitation and resettlement of erosion victims, aiding in the formulation and update of long-term delta and coastal zone policies. (Ahmed et al., 2018) Compared to conventional approaches, this technology is reliable, cost-effective, and covers broad areas. The objective of this study is to identify and examine the alterations in the coastline and hydrological conditions in the Sandwip region, as well as to find a stakeholder engagement and how they can response towards the changes?

2. METHODOLOGY

Prior to commencing research studies, it is fundamental to begin with an in-depth review of previous research attempts and articles. This indicates the very first phase in the research process. To successfully carry out this method of study, a thorough review and analysis of previously published articles and literature is essential. The objective is to gather, evaluate, and incorporate pertinent knowledge, theories, methodologies, and discoveries in order to determine the prior condition of erosion and accretion. After doing a thorough research assessment, secondary data was gathered from BWDB, Google Earth, BIWTA, and BMD. Satellite images was gathered using Google Earth Pro, AcrGIS, and the United States of Geological Survey. After the data collection process was finished, Landsat images from the years 1990, 2000, 2011, and 2020 were obtained and examined. A scrutiny of the satellite image was conducted using Google Earth Pro. ArcGIS 10.8 was chosen to generate a visual depiction of the historical assessment of erosion and accretion. The study presented the corresponding findings and outcomes, in addition recommendations and suggested measures were prescribed.

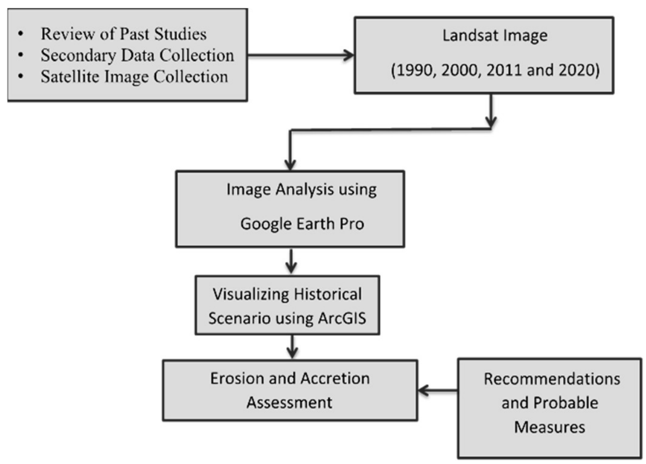

Figure 1: Flow Diagram of Methodology

2.1 Data Collection by Gathering Satellite Images

All information about Sandwip Island have been collected from Chittagong Divisional Websites and other relevant secondary sources. Geographic co-ordinates have been collected from GPS Navigation System. Geographical Map and Satellite Images (Figure 1) have processed from Google Earth Pro and ArcGIS.

2.2 Digitizing Historical Images from Google Earth Pro

The process of digitizing historical images enables to discern the trends of accretion and erosion over time, providing insights into the extent of these phenomena. This allows to analyze and quantify the occurrences of erosion and accretion throughout the historical period under consideration.

2.3 Visualizing Historical Scenario of Sandwip Island

Landsat images have been collected from Google Earth. From the availability of satellite images, 1990, 2000, 2011 and 2020 images have been selected for analysis. All the images have been digitized from Google Earth. Then the historical 40 years changes have been visualized using ArcGIS.

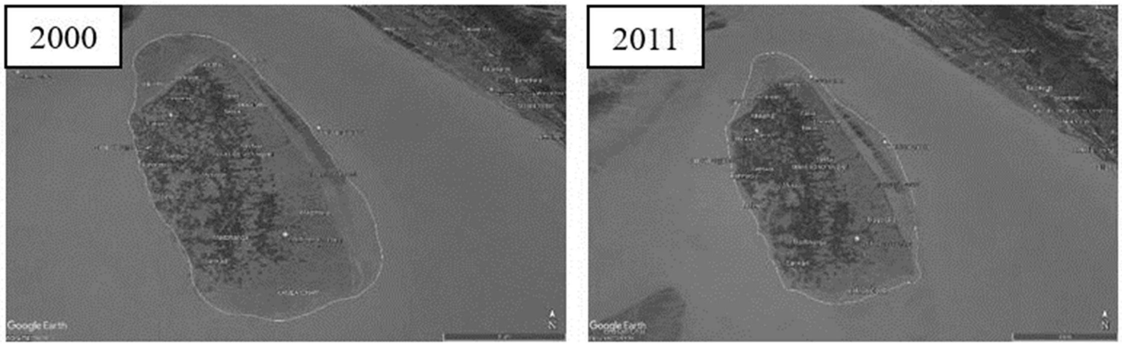

Figure 2: Satellite Images Collected from Google Earth

2.4 Assessment of Erosion and Accretion using ArcGIS 10.8

After collecting the images, erosion and accretion have been determined using ArcGIS (Figure 3). At first, two images of different years have been overlapped on each other. Then erase tool is used to identify the eroded and accreted area. After determining the erosion and accretion rate, a risk assessment has been conducted based on the erosion rate.

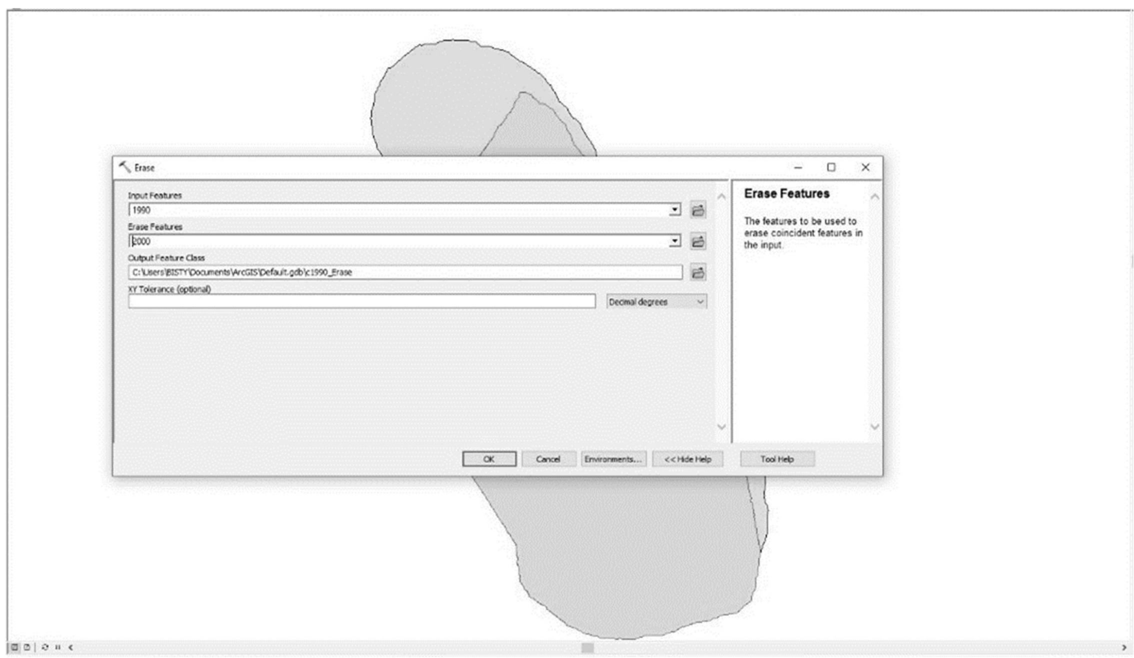

Figure 3: Determination of Erosion and Accretion Rate

3. RESULT & DISCUSSION

The graphic below displays images collected from the years 1990, 2000, 2011, and 2020 used in this case study.

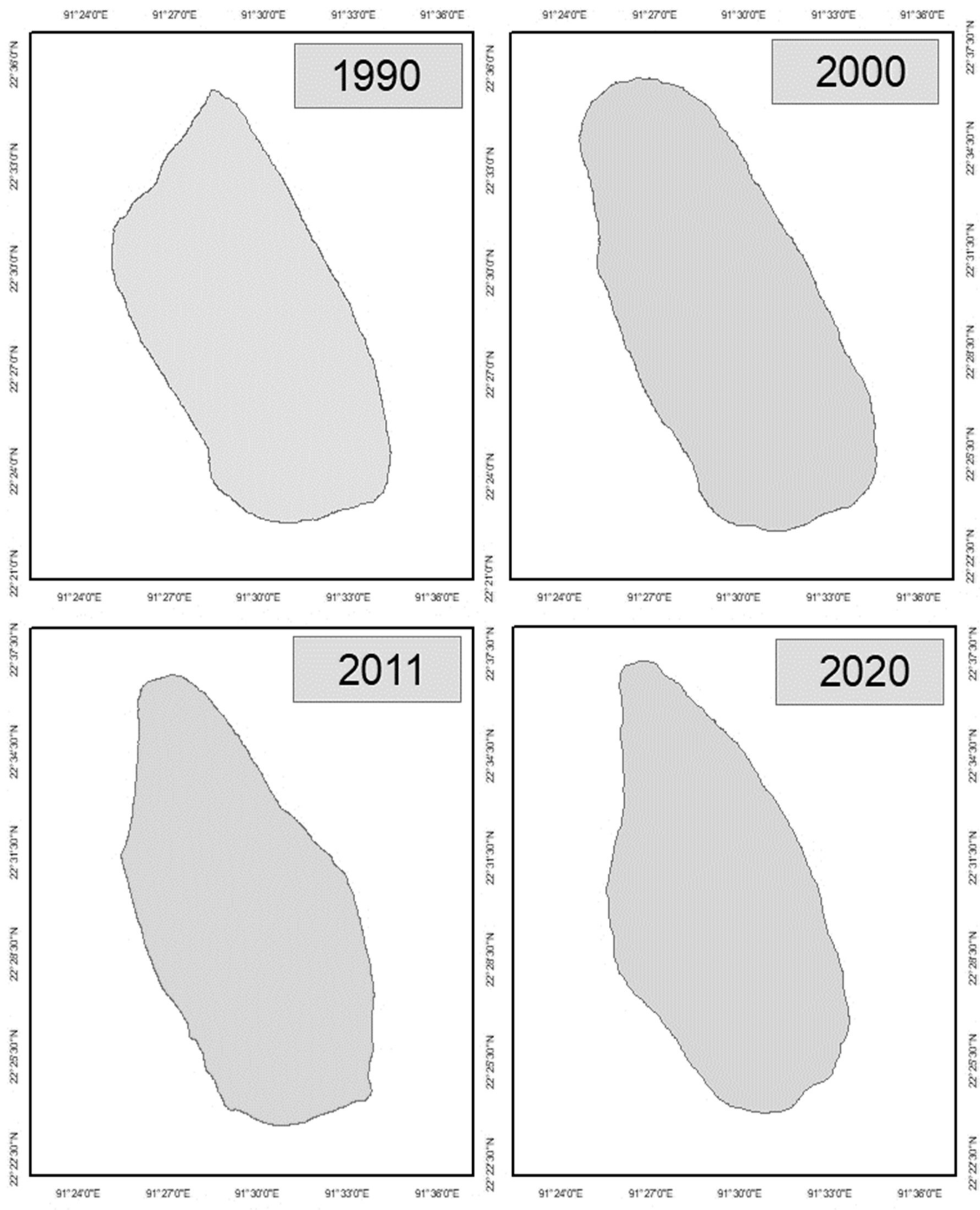

Figure 4: Historical Images for the Study Area

The images endured scrutiny, and the erosion and accretion that were observed during the study were determined using ArcGIS. After completing a thorough historical analysis over a period of thirty years, it was determined that there was a consistent pattern of enhanced land stability (Figure 4). The proportion of stable land increased from 73% in 2000 to 86% in 2020. After analysing these findings, it has been determined that 2011 had the most substantial erosion, leading to the loss of around 3200 hectares of land. Conversely, the greatest increase in land area has been recorded since 2000, amounting to approximately 5000 hectares. The southern portion of the research area has been identified as the region most susceptible to erosion. Both mapping and graphical representation have been used to depict the erosion and accretion scenarios.

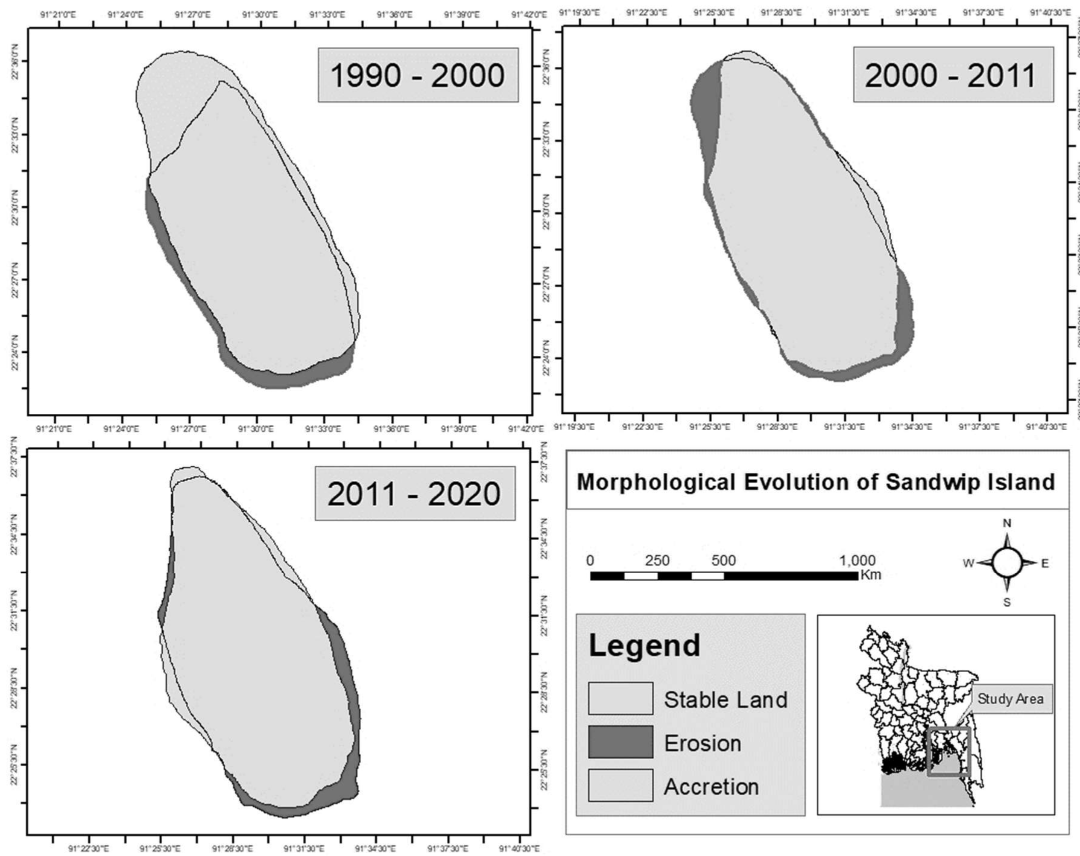

Figure 5: Erosion and Accretion Assessment the Study Area

In Figure 5 a comprehensive analysis reveals the morphological evolution of Sandwip Island over three distinct time intervals: 1990-2000, 2000-2011, and 2011-2020. Each map within the figure portrays landforms through color-coded representations of stable land, erosion, and accretion, accompanied by scales indicating distances in kilometres. Notably, during 1990-2000, substantial erosion is evident along the southwestern and eastern coasts, with pockets of accretion. In the subsequent decade (2000-2011), erosion rates appear to diminish, while accretion persists in northern and eastern areas. The period from 2011-2020 sees a resurgence of erosion along the southwestern coast, with persistent accretion in the northern and eastern regions. These observations suggest a dynamic interplay of erosion and accretion processes, emphasizing the vulnerability of the southwestern coast to erosion and the propensity for accretion in the northern and eastern zones.

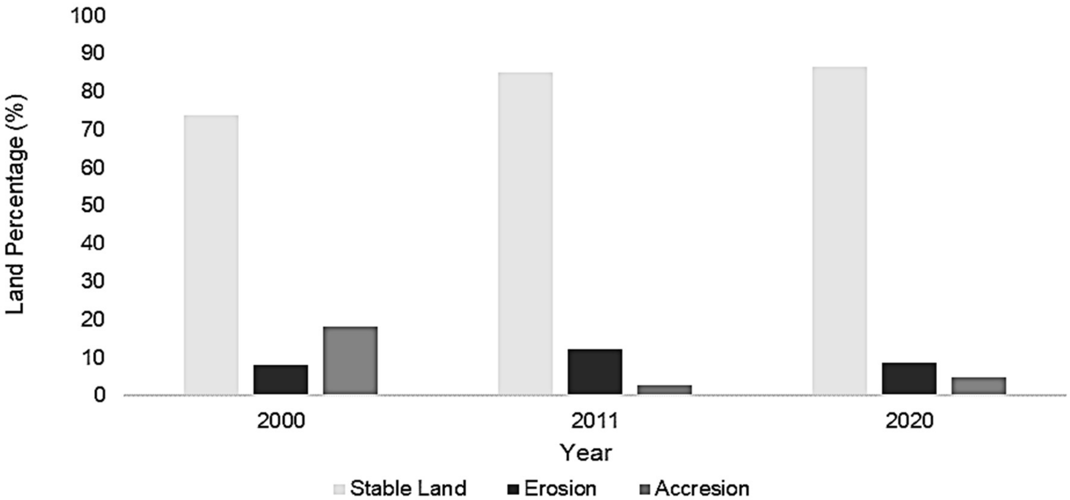

Figure 6: Graphical Representation of Erosion and Accretion Assessment

Figure 6 depicts the distribution of land cover percentages across three categories: stable land, erosion, and accretion. The analysis indicates that stable land cover consistently ranges between 80% and 85%, exhibiting minimal yearly fluctuations. Erosion shows a slight upward trend from 10% in 2000 to 15% in 2020, with varying yearly increases suggesting potential disparities in erosion rates. Conversely, accretion displays a gradual decline from 10% in 2000 to 5% in 2020, with yearly decreases potentially following non-uniform patterns. While the overall land cover remains relatively stable, a nuanced shift is observable, subtly favouring erosion over accretion. This insight contributes to the understanding of the dynamic coastal processes reflected in the presented data.

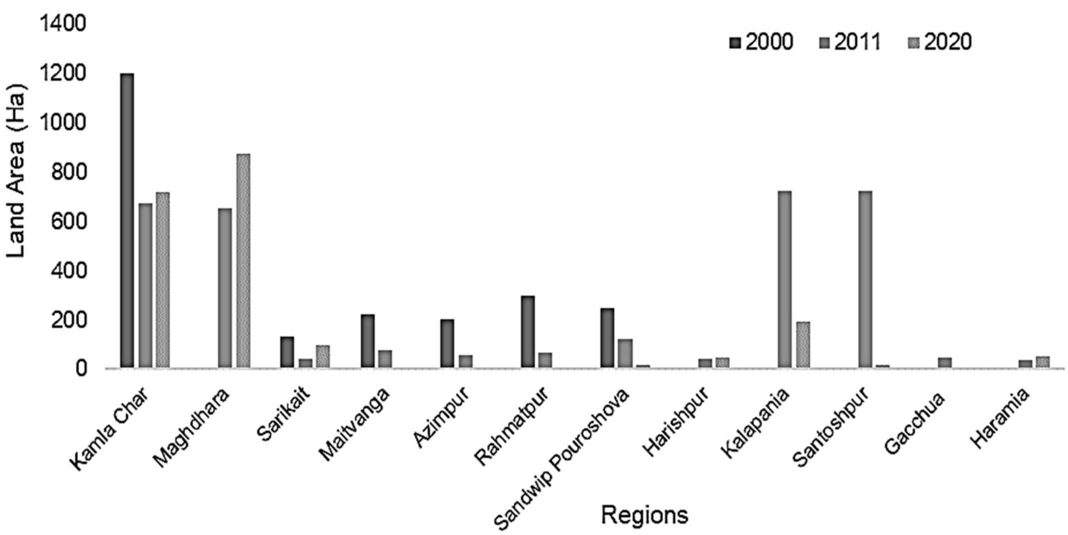

Figure 7: Graphical Representation of Erosion Rate of the Regions

The erosion and accretion assessment have identified the region in the study area that is currently at significant risk of erosion (Figure 7). Notably, out of the twelve regions that were studied, Kamla Char has been identified as the most susceptible to erosion. Based on the graph, it can be noted that Kamla Char is experiencing ongoing erosion. A total of 867 hectares of land have been degraded over a period of 30 years. Maghdhara has been identified as the second location with a high risk of erosion. The erosion rate in Maghdhara has been determined to be an average of 510 hectares during a period of 30 years. Erosion rates have been categorised into three distinct levels: low, medium, and high. The classification has been depicted in the table. Santoshpur and Kalapania have been categorised as areas with a moderate risk of erosion based on their classification. Approximately 20% of the regions on Sandwip Island are classified as very prone to erosion, while 60% are categorised as having a low risk of erosion (Figure 8). The remaining sections fall into the medium risk category.

Table 1: Adopted Classification of the Erosion Rate

Class	**Land Area (Ha)**
Low	0 – 250
Medium	250 – 500
High	>500

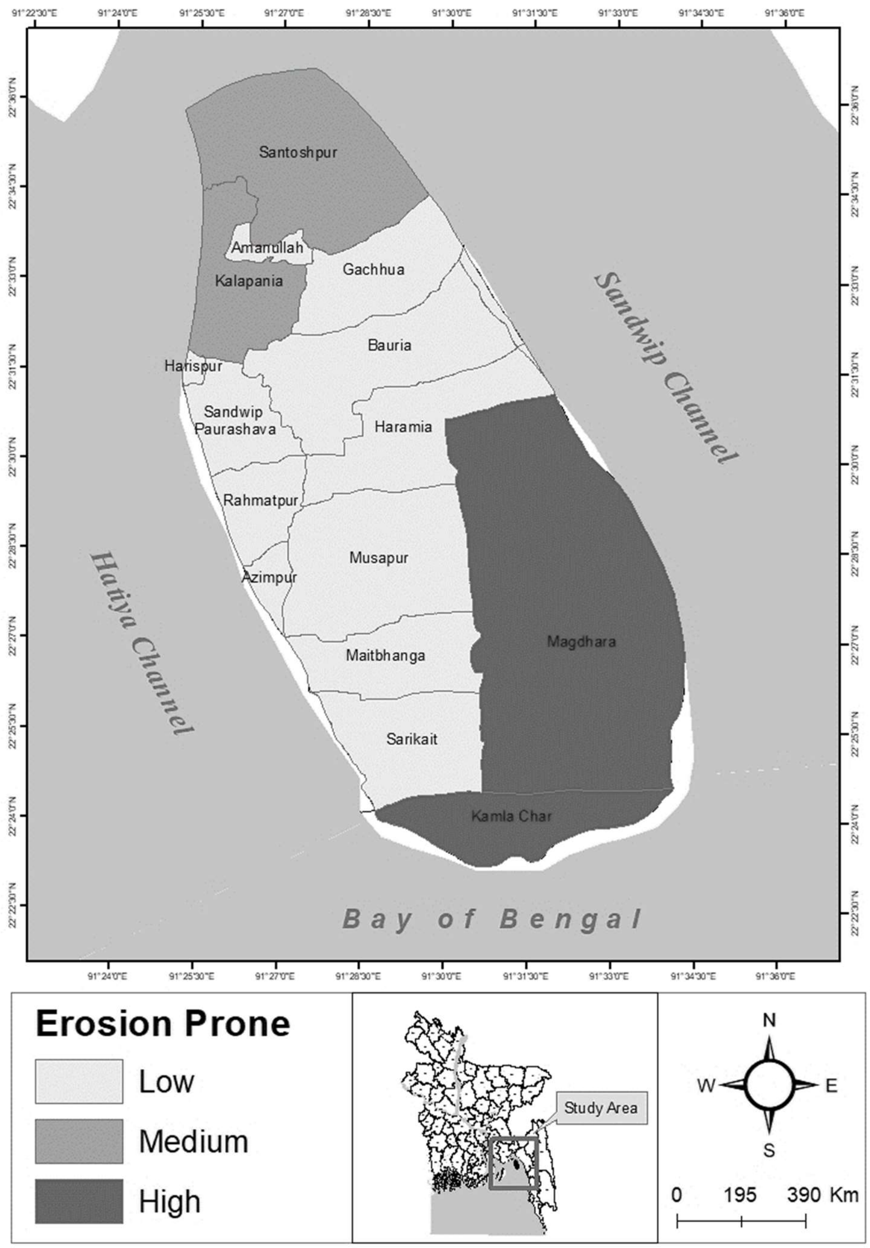

Figure 8: Erosion Risk Assessment of Sandwip Island

In one study, diverse hydro-morphological dynamics were observed on the island between 1980 and 2010, with increased water depth causing erosion in the western and southern regions and decreased water depth facilitating accretion in the northern and north-eastern parts (Emran et al., 2017). This study aligns with these findings, contributing to a comprehensive understanding of Sandwip Island's erosion and accretion dynamics.

Coastal erosion is influenced by several variables, including the presence of powerful waves and strong currents, the occurrence of severe weather events like storm surges and flooding, a reduction in sediment availability, and the combined impact of natural and human-driven climate change (Hoque et al., 2019).

4. CONCLUSIONS

According to the study, out of the twelve studied regions, Kamla Char stands out as the most erosion-susceptible, experiencing ongoing erosion. Over 30 years, a total of 867 hectares of land have degraded. Maghdhara follows closely as the second high-risk erosion location, with an average erosion rate of 510 hectares during the same period. The regions that are most susceptible is Maghdhara, and Kamla char which indicated as black in Figure 8. Infrequent events occur due to the tidal effect and natural disasters. Additionally, the bank's location, which is sea-surrounded, presents stabilisation difficulties. When implementing any project in this area, it is important to take safeguarding issues into account. These may include a gender action plan, environmental and social grid analysis, resettling action plan, the introduction of climate resilience infrastructure, and the introduction of wash facilities.
The study's results offer valuable insights for various stakeholders, including government officials, NGOs, and donors, providing a basis for targeted disaster mitigation projects. By aligning with the Standing Orders on Disaster (SOD, 2019), community-led programs can be strategically implemented, prioritizing areas based on their vulnerability. This approach streamlines policymaking, enabling the effective identification and categorization of zones from most to least vulnerable, thus facilitating the successful implementation of safeguarding measures and cost-effective, climate-resilient coastal vegetation or infrastructure projects.

ACKNOWLEDGEMENTS

I would like to express my profound appreciation to Md. Amin-Uzz-Zaman Madani and Md. Ayman Azad for their invaluable contributions and unflinching support during this journey. Ayman's indispensable contributions and Madani's ability to generate ideas while writing effectively have played a crucial role in creating and improving this work, resulting in a remarkable demonstration of collaborative greatness.

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