

COMBATTING CLIMATE CHANGE WITH SUSTAINABLE MEASURES: A CASE STUDY OF MOUSUNI ISLAND, INDIAN SUNDARBANS

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Abstract: Since 1880 earth's temperature has increased by an average of 0.087 degree Celsius which has resulted in increasing frequency of cyclonic occurrences, especially in Bay of Bengal. Coastal islands of Indian Sundarbans have faced the wrath of cyclones like Aila (2009), Bulbul (2019), Amphan (2020) and Yaas (2021) in this scenario of climate change. Rising sea level (3.14 mm/year) has increased the rate of cyclonic occurrences and river dynamics such as tidal surges trigger the breaching of embankment and saline water intrusion. Located in the southern part of Ganges delta facing the Bay of Bengal, Mousuni Island of the Indian part of Sundarbans has also faced the vulnerability of cyclone. It is a home of 3578 people (Census, 2011). Along the western bank of the island about 3.82sqkm land was reduced by coastal erosion between 1979 and 2011. The objective of the study is to assess the suitability of embankments to combat coastal inundation as an effect of sea level rise and/or tropical cyclones which are enhanced by ongoing climate change. To fulfil the objective, the methodology of both quantitative and qualitative approaches was undertaken. Quantitative methods like measuring various parts of the embankments and observation of embankment design (Aila embankment, earthen embankment, and wooden log embankment) were undertaken. A beach profile was done to observe the effects of coastal erosion on the beach with the help of dumpy level. Qualitative study in the form of interview was undertaken on residents (N=10). Based on the study, more preference was given on concrete embankment specially Aila embankment than earthen embankment as it is not able to combat erosion and the vulnerability of cyclone. Incoming saline water as a result of breaching of embankments disrupted the agricultural system for long period increasing the vulnerability of the residents. Cyclone Bulbul followed by Amphan has demolished 80% of island's households. While the north western part of Mousuni has permanent concrete embankment (Aila embankment from Kusumtala to Baliara bazar), the southern part has Earthen embankment covered with geo jute. There is a multipurpose cyclone shelter situated near Baliara but it is not accessible to all during the hazard (verified by locals). In the present scenario, concrete embankments designed as per the norms of Aila embankment along with a mangrove buffer is preferable to be maintained at Baliara.

Keywords: Cyclonic occurrence, sea level rise, embankment, sustainability, capacity building

1. Introduction

Climate change refers to the long-term shifts in temperature patterns. Earth's temperature has risen by an average of 0.08°C per decade since 1880 and the rate of warming is even more than twice as fast (0.18°C) per decade since 1981(www.climate.gov).

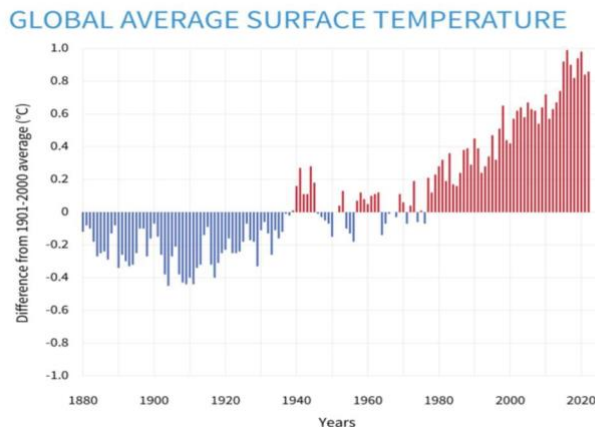


Fig. 1: Yearly surface temperature compared to the 20th century average from 1880-2022.

Source: National centres for Environmental Information

The tremendous heat capacity and size of the global oceans take a massive amount of heat energy to raise Earth's average yearly surface temperature even by a small amount. The heat of the earth surface drives regional and seasonal temperature extremes reducing snow cover and sea ice resulting in sea level rise, intensifying rainfall triggering severe cyclonic disturbances, shift in habitat for plants and animals, and sometimes shrinking of islands along the coasts. (USGCRP,2014)

Coastal disruptions as a response to climate change has also affected marine ecosystem and inundation of coastal ecosystem and elimination of wetlands by the effect of sea level rise as a global change. The rate of relative sea level rise is larger than the global rate wherever the lands are sinking. Parts of Gulf Coast are experiencing faster rates of sea level rise in the United States (US) where lands are sinking. For example, coastal Louisiana has lost 2000sq miles of wetlands (approx.) due to human intervention of Mississippi River which has caused the land to sink and has seen its relative sea level rise by 8" or more in the last 50 years. (CCSP, 2008) The lands of Chesapeake Bay, an estuary in the US is subsiding increasing the risk of flooding in cities, inhabited islands and tidal wetlands. Coastal areas like Gulf of Mexico and Chesapeake Bay are already known as "dead zones", it occurs by pollution based on land contributing to algal blooms. (FEMA,2008).

The word 'sustainable' has been used to specify that the measures taken should be environment friendly by not damaging the island further and to be site specific. The measures implemented should not adversely harm the island, otherwise it would be at stake. In order to make the adaptation process for climate change more sustainable, the 2021 European Union strategy promotes Nature-Based Solutions (NbS) and ecosystem-based approaches as essential measures. Restoring of wetlands and coastal ecosystems have been mainly adopted for coastal areas. Carbon removal benefits offered by restored coastal and marine ecosystem is one the recognised strategies by EU. The policies and instruments relevant for climate change include Integrated Coastal Zone Management (ICZM) and Maritime Spatial Planning (MSP). (climate-adapt.eea.europa.eu)

Indian Sundarbans, West Bengal, India is the world's largest contiguous mangrove forest and is also a designated world heritage site. Due to extreme climate change, Sundarbans and its

adjacent islands are facing several challenges. These coastal islands face the maximum change due to the location of Indian Sundarbans in Bay of Bengal. Due to the rising of sea level of about 8-12mm/year in Mousuni island (www.downtoearth.org.in) which is three to four times more than the global average, this island will slowly disappear and the intrusion of salt water increasing salinity has already threatened the health of forest covers as well as quality of soil with decreasing agriculture and availability of staple crops.

Mousuni island of the Indian Sundarbans is the most threatened by severe cyclonic occurrences and is one of the 10th most vulnerable ocean-confronting islands in South 24 parganas district of West Bengal (WWF India,2010). The extreme climate change and its circumstances have increased the vulnerability of the inhabitants as well as to the island. The rise of sea level has resulted in beach erosion, destruction of agricultural lands by salt water intrusion, increasing tidal surges leading to demolition of embankments, moreover destruction of their homelands and the resorts which was their one of the important sources of income. Some of them has been homeless by the severity of cyclones as a response of climate change. The only way to combat this changing climate is to take precautionary sustainable measures. Mangrove as a buffer is to be used to hold the soil and protecting the island, thus more and more mangroves should be planted across the islands. A change detection map has been provided from the year 1985 to 2022 to detect the accretional and erosional change of the island. The amount of land eroded or added throughout this year indicates the extreme effect of climate change on this island. Increasing global warming has resulted in erosion of most of the parts of Mousuni island. In future, it is predicted that this island might disappear along with the other islands. Thus, it is to be protected by taking sustainable measures mainly by the locals living there and other government bodies by adapting strategies and policies of ICZM by EU and other European countries which will be more beneficial for coastal areas such as Mousuni. (www.rescue.org)

2. Objectives

The objective of the study is to assess the suitability of embankments to combat coastal inundation as an effect of sea level rise and/or tropical cyclones which are enhanced by the ongoing climate change in the island.

3. Methodology

To fulfil the purpose of writing this paper, we have analysed and studied certain literatures and questionnaires were made before visiting the field. Literature available in the public domain including information available on scientific data (researchgate.net) and reports (Bandyopadhyay.et.al, Das,2016), School of Oceanographic Studies, Jadavpur University, Kolkata (2014), websites of several Government agencies have also been analysed for understanding the vulnerability of climate change and the adaptation strategies by this island and its people. The primary data has been collected on field by visiting Mousuni island of Indian Sundarbans and the locals were surveyed to justify the data. During the on-field process, Clinometer and measuring tape were used to measure slope and length of the embankments, GPS (eTrex10) was used to mark the coordinates of the vulnerable and distant places. Vectors were taken from google earth pro and it was digitized with co-ordinate referencing System WGS-84/UTM 45N using QGIS software version 3.14 after the field (post-field). The erosion and accretion map were also done using satellite imagery from google earth and QGIS 3.14 software and analyzed properly. Physical aspects were covered contrasting with our topic and lastly conclusions were made according to the data received.

4. Study area

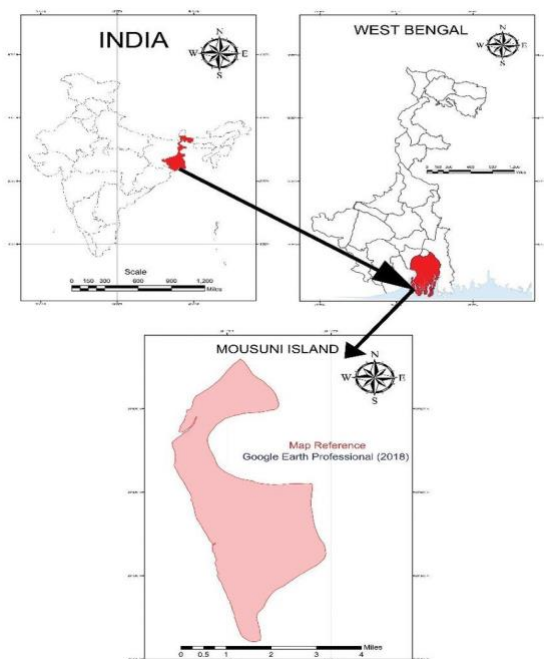


Fig.2: Location map of showing Mousuni island, West Bengal, India
 Source: *Journal of Global Resources, volume6, August,2019-January,2020*

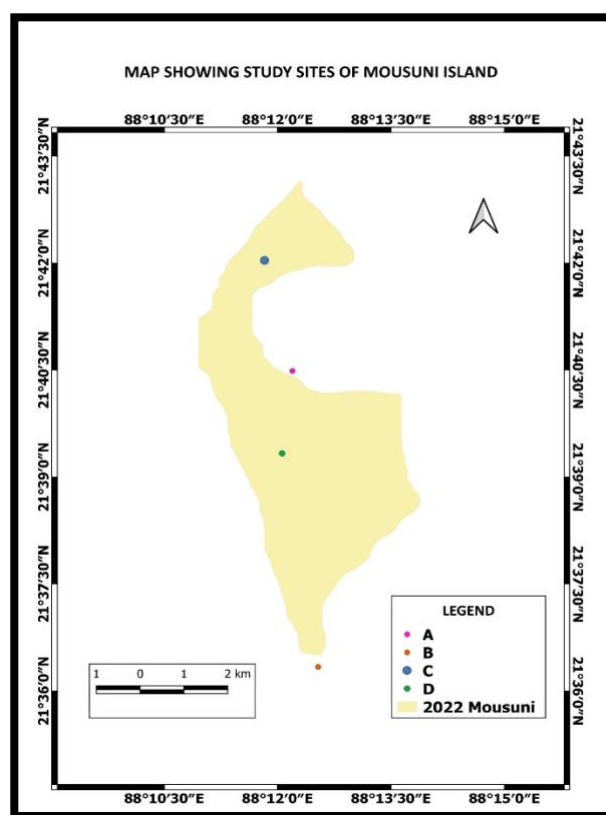


Fig.3: Study area of Mousuni island showing the areas surveyed
 Source: *Prepared by author, 29th August,2023*

Area under study is a part of Indian Sundarbans located in the southern part of Ganges delta, facing the Bay of Bengal, Mousuni island is a home 22073 people (Census 2011). The island covers total area of 27.1 km². It is a deltaic island spread on Bay of Bengal with Muri Ganga River in the western part, eastern part is bounded by Pitt's creek and the southern part is fringed by Bay of Bengal. Mousuni Island lies in Namkhana block in Kakdwip subdivision of South 24 Parganas district of West Bengal, India. Mousuni is one of the seven Gram panchayats of Namkhana Block. Latitudinal extension ranges between 21°39'46"N to 21° 43'30" N and longitudinal extension ranges between 88°12'5"E to 88°15'00" E.

5.RESULTS & DISCUSSION

5.1 Sea level rise

Sundarbans has been identified as one of the vulnerable areas in the climate change context due to its ecological fragility (Jagtap, 2007; Erwin, 2009). A one metre rise in sea level could inundate an estimated 17 per cent of Bangladesh and take the entire Sundarbans with it (Hingorani & Raman, 2009). Global sea level rise is estimated to be just two millimetres a year and the levels in the Sundarbans delta are rising 3.14 by mm. a year (Karmakar,Dey Roy,2022). Mousuni island has 4 villages namely Bagdanga, Kusumtala, Baliara and Mousuni among

which Baliara and Kusumtala are more populated. People living near the coastal areas or the sea facing side which is the southern parts are more effected by the impacts of climate change such as sea level rise, cyclones. The rising sea level, continuous and rapid erosion of the coastline encourage the sinking of the island that have forced the inhabitants of the area to relocate further inland in this fragile island (Karmakar, Dey, Roy, 2020)

5.2 Cyclone scenario

Cyclones are caused by atmospheric disturbances around a low-pressure area distinguished by swift and often destructive air circulation. Cyclones are usually accompanied by violent storms and bad weather. The air circulates inward in an anticlockwise direction in the Northern hemisphere and clockwise in the Southern hemisphere. Cyclones are classified as: (i) extra tropical cyclones (also called temperate cyclones); and (ii) tropical cyclones. (National Disaster

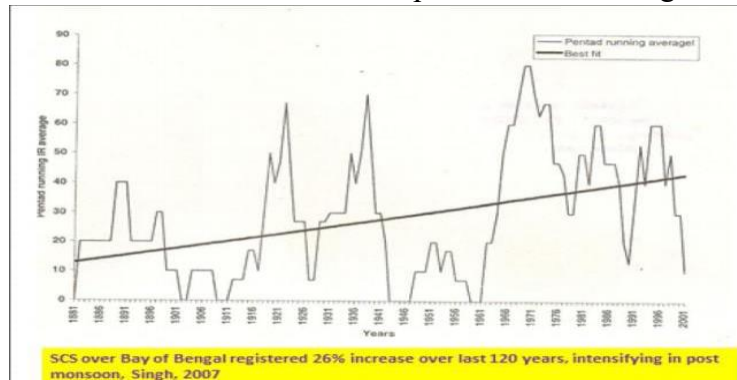


Fig.3: Raise of frequency of severe cyclonic storms over Bay of Bengal
Source: Singh, 2007

management Authority of India) A cyclonic effect is primarily felt through damage to homes and loss of life of the affected area, which can cause disruptions in vital services like healthcare, power, and water supply and sanitation. In addition, cyclones can disrupt transportation systems and damage crops, leading to shortages in food supply. Pre monsoon and post monsoon storms are even stronger than monsoon season. The cyclonic impact is mainly felt in coastal areas of Indian Sundarbans due to warming of Bay of Bengal. According to the study, severe cyclonic storms which are registered over Bay Of Bengal has increased by 26% over last 120 years, specifically during post monsoon (Singh, 2007). Mousuni island, located in the southern part of Ganges delta also face the devastating effect of cyclone along with Sundarban. In recent years, effects of cyclones like, Aila, Bulbul, Amphan and Yaas have been felt by the people of Mousuni island and the adjoining areas.

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CYCLONE	DATE	SPEED	LANDFALL
Bulbul	5 NOV, 2019	130km/hr.	Indian Sundarbans
Amphan	20 th MAY, 2020	175km/hr.	Bakkhali
Yaas	25 th MAY, 2021	140km/hr.	Balasore

Table1: Showing data of respective cyclone in Mousuni Island.

Due to lack of monetary support, the residents cannot rebuild the resources with proper infrastructure. Cyclone Jawad, despite losing steam, was still strong enough to trigger a collapse in an embankment at Mousuni island, sandwiched between Gangasagar and Bakkhali, on the western fringes of the Sundarbans, marooning thousands. (Source: *The telegraph*, 6th December, 2021)



Fig.4: An inundated stretch of Mousuni island on the western end of the Sundarbans
Source: modified by Jayanta das, *Telegraph*, 6th dec., 2021

Heavy downpouring of rain with severe storm has also resulted in breaching of 300m embankment near Baliara and its adjoining areas causing waterlogging in the areas. (Source: *Ei samay newspaper*, 14th August, 20). Not only their houses were disrupted but also agriculture was disrupted due to salt water inundation. The lives of the people are at stake every time during cyclone. A concrete cyclonic shelter was seen at Baliara, but it cannot provide access to the whole of the island during cyclone. Bulbul as well as Amphan consecutively blew off the island living people homeless.

Based on the primary survey, cyclone shelters of this island were also surveyed. A total number of four cyclone shelters are there (according to locals), but only 3 could be surveyed. The multipurpose cyclone shelter is the largest among the three and well-structured with three floors and around 18 rooms in all near Kusumtala. Each and every cyclone shelter is provided with tube wells whereas the electrical system is fully destroyed in spite of having well electrical connections. All cyclone shelters are not accessible by the locals of Mousuni due to its location. The one living near the shelters can access it well while the others cannot during the extreme climatic condition. Cyclone shelter cannot alone combat the vulnerability without people's contribution to adapt strategic policies and mitigation measures. The embankments made for combatting the vulnerability are too weak to protect the island from this monsoonal rainfall. Thus, the tremendous effect of cyclone raises the levels of the sea which continuously erodes them more.

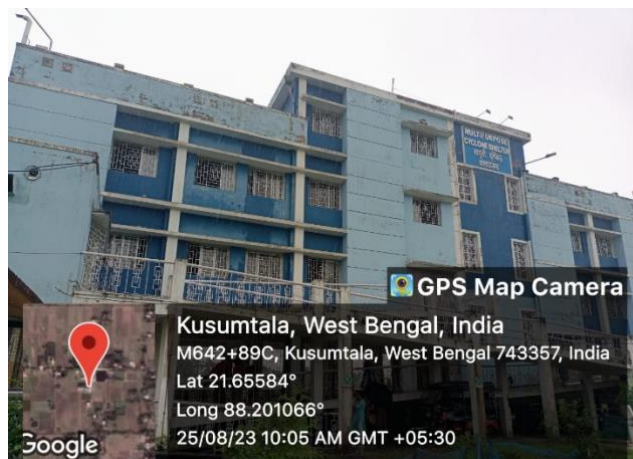


Fig.5: Multipurpose cyclone shelter at Kusumtala
Source: Captured by author, 25th August, 2023

5.3 Embankment: Life line of Indian Sundarbans

Embankment may refer to a levee, an artificial bank raised above the immediately surrounding land to redirect or prevent flooding by a river, lake, or sea. (Das,2016).

Embankment help preventing flood in adjacent areas safe guarding the lives and infrastructure of a particular place by channeling water along designated pathways, embankment mitigate the risk of wide spread inundation, minimizing the adverse impact of flood on communities. Physiography of Indian Sundarbans is active delta intricating networks of rivers and creeks. These networks are affected by tides Most of the land remained under saline water during high tide. To prevent degradation of soil fertility due to intrusion of salt water construction of embankments was done in the tidal creeks thereby protecting the islands and inside water bodies. Considering the low economic status of the population of these regions,

the only source of livelihood is served from the forests, agriculture and the river, creek networks. Agriculture gets widely affected by the saline water intrusion. Thus, embankments are constructed to combat saline water intrusion caused due to tides or cyclones. Thus, embankments are life line of these regions.



Fig.6: Wooden log embankment
Source: Picture captured by author. Date: 7th May 2023

Tabe2: Showing types of embankments in Indian Sundarbans (Das,2016) and those observed in Mousuni island (study area)

INDIAN SUNDARBANS	MOUSUNI ISLAND
Along smaller channel margin (2m height)	Concrete Aila embankment with vertical and horizontal groin structures.
Around the island margin (2.70m height)	Earthen embankment covered with Geojute.
Along wave exposed shorelines and estuary margin (3m height)	Temporary wooden log embankment.

EMBANKMENT TYPE	RIVER SIDE SLOPE (DEGREES)	RIVER SIDE LENGTH (m)	SETTLEMENT SIDE SLOPE (DEGREE)	SETTLEMENT SIDE LENGTH (m)	SUMMIT LENGTH (m)
TEMPORARY GEOJUTE	25	5.06	19	2.1	0.91
AILA BANDH	10	21.48	21	4.2	3.2

Table3: Showing measurements of embankment observed in Mousuni Island.

Through primary field visits the present condition of Aila embankments seems to be not effective. Slab failure and collapse due to improper base construction, structural failure and lack of technology is noticeable. Along with the concrete embankment, Groin structures are also observed. It is a structure extending from the shore into the sea. The main function of a Groyne is catching and trapping part of the sediment moving mainly in a longshore direction (when placed vertically) in the surf zone. As revealed by experiments, groynes partly dissipate energy of water motion (when horizontally placed) during weak and moderate wave conditions, leading to accretion of the updrift shoreline. Both vertical and horizontal

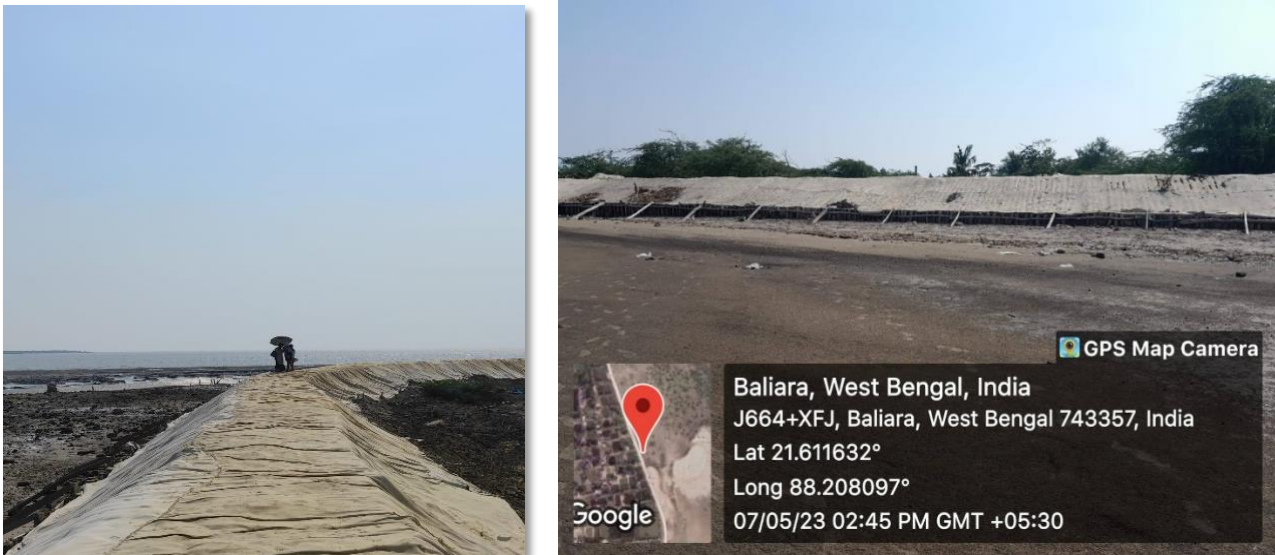


Fig.7: Earthen embankments covered with Geojute.

Source: photographed by author. Date: 7th may, 2023

structures of the groyne is noticed. Though the effectivity of such structure needs further evaluation.

5.4 Embankment breaching

Embankment breaching is a phenomenon when water flows over or through embankment at a heavy rate by eroding the material of the embankment.

Causes of embankments breaching:

Sundarbans are a part of Hugli-Saptamukhi Estuarine Deltaic Complex area and embankment breaching is a problem the causes of which are the following:

The area concerned has high connective tributaries and distributaries, though protected with earthen dykes but in some vulnerable areas due to diurnal tidal phenomena, the sides or the base gets breached, especially in coastal sea facing areas. The weak technological structure is also a major cause of embankments breaching. Because the embankment constructed on the non-cohesive silt that cannot resist the tidal surges in the long term. Population pressure is increasing at rapid rate in this area especially unplanned settlements developed in concave sides of the bends of the meandering river course. These are highly unstable due to natural scouring process. The base of the river embankment gradually weakened (Dhara, Paul, 2016). Most of

the embankments needs proper maintenance as they are very old in nature constructed during British period. It is not impossible for a weak cyclonic occurrence or a high tidal bulge to breach the embankment. High velocity tidal wave in the coastal zones of sea facing islands easily breach the earthen embankments. Mangrove forest also protects the embankments but in land reclamation scenario much of these forests are cut or the locals depends on forest resources thereby exploiting the forest.

5.4.1 Impacts of embankment breaching



Fig.8: Demolition of earthen embankments which was covered with Geojute in Mousuni island, Baliara block.
Source: Captured by author, 25th august,2023



Fig.9: Slab collapse due to faulty construction of the concrete embankment in Mousuni island, Kusumtala block.
Source: Photographed by author. Date:25th August,2023.

Intrusion of salt water due to flooding during environment hazards like cyclone which has vastly affected the inhabitants. Coastal erosion by tidal wave is observed in the surveyed area resulting in degrading quality of embankment. Failure of embankment results in quality degradation of agricultural land due to salt water intrusion in the affected areas.

5.4.2 Incidents of embankment breaching

The western side of the embankment near Baliara has been completely breached due to recent heavy monsoon incident. On the south western side of Kusumtala Mouja of Mousuni Island (Namkhana block) there was a primary school. In May, 2003 due to embankment breaching salt water incursion took place. With high tide water level raised high and submerged thekacharoad, making school inaccessible to children. Agricultural field was badly affected. (Dhara, Paul,2016). During September (18-21), 2005MousaniIsland lost a km and a half of embankment due to tidal surge on the western side along Kusumtala and Baliara mouza. 321 families had been homeless during this time. Vast stretches of agricultural land were under water. It killed paddy and betel vine. Fish pond was also affected.

Embankment breaching took place along the bank of Chinai river of Mousuni Island. 12 km



Fig.10: Salt pan formed due to saline water intrusion in Mousuni Island.

Source: photographed by author. Date: 7th May,2023

5.5 Erosion Accretion scenario of the island

Erosion accretion pattern of the study area shows a very Transient character. Rising sea level (3.14mm/year) along with tidal and ocean currents changes is responsible for delta's retrograding nature. Erosion accretion scenario was studied from the year 1985-2022 and was observed that island has gone through changes specifically in the western coast. Erosion all over the island is about 3.82 sq.km area along the coast which have been eroded away due to fluvial erosion and wave action. Accretion was observed in the eastern side of the island due to deposition from the adjacent creek also known as Chinai river. Time velocity asymmetry (ie flood or ebb dominance involves comparatively shorter duration and higher velocity of the flood currents than the ebbs, resulting in net

embankment breached due to high tidal wave during the full moon. Thousands of families been rendered homeless. They took shelter in the tent along the road side. Some places of Muri Ganga and Ghoramara panchayet of Sagar Island embankment breached. Almost 40 km embankment destroyed during this time in the whole Sundarban region (Anandabazar Patrika, 17 July, 2014)

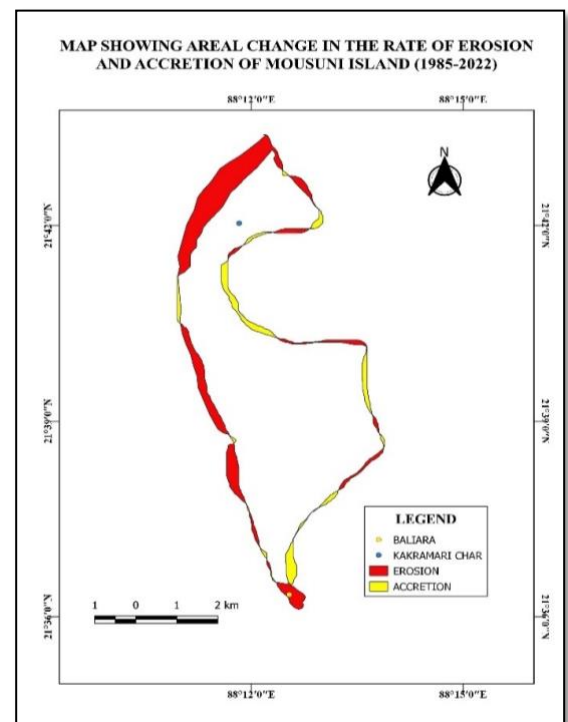


Fig.11: Erosion and accretion scenario of Mousuni island
Source: Prepared by author using QGIS 3.14 version, 29th August, 2023

landward movement of sediments) noticed in the Hooghly estuary is mainly responsible for accretion. Riverine sediments undergo rapid transformation as they enter the estuaries. The bulk of them are carried as colloids, or small charged particles that repel each other. This condition is broken down by the electrolytes and organic matter present in the seawater and the grains start to flocculate and settle. In the still water period at the high-water level of a tidal cycle, individual or groups of flocs settle on the bed of a stream or mudflat and get slowly consolidated during the subsequent slack water period. During the next tidal cycle, velocity of the mid-tide currents may not be sufficient to erode all the materials deposited previously. In the continuous cycles of tidal deposition and erosion, accretion only occurs if a net edge of deposition exists over erosion (Dyer, 1979; Barnes, 1984; Furukawa, et al., 2014). As tidal deposition starts plants communities soon starts to grow there by aggravating the accretion process. At the end of the process, a climax — largely non-mangrove — vegetation community evolves as the land is raised sufficiently above the tidal limits (Chapman, 1976; Thom, 1984) kakramarichar shows similar trend. About 1.07 sq.km area has been accreted between 1985-2022. In the fig10 erosion(red) accretion(yellow) map is shown along with the surveyed area which is kakramarichar in the north and Baliara in the south. Though it is proven that embankments are life line of Indian Sundarbans including our study area, but at the same time these embankments are responsible for dislodging the natural Bi-tidal process of accretion inside the island.

5.6 People’s perception on combatting cyclonic effects with sustainable measures

The people living on the island are the ones to combat cyclonic effects. Most of them have become accustomed with this climate change like their daily lifestyle and have started taking measures accordingly. Some of the locals have made arrangements by themselves to combat cyclonic effects mainly those who cannot access the cyclone shelters.

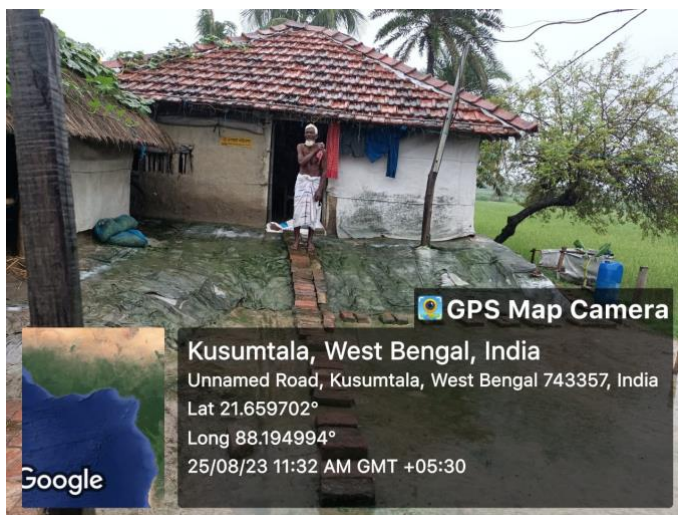


Fig.12: A house of a local protected by using sustainable measures
 Source: Picture captured by author, 25th August, 2023

One of the locals has adopted sustainable measures by lifting his house using certain local materials to combat cyclonic effects and flood. Their main need is a proper embankment around the riverine area and the coastal areas. In fact, most of them are willing to leave the place with help from government. Though some of them are staying as fisherman and are happy to live their livelihood. Most of the youth have migrated to some other places like Kerala in search of job. Schools were also seen near Bagdanga ghat with more

female population. Most of the female are agricultural labourers or work as a cook in the schools. One of the locals near school views that embankment is indeed the basic need to

combat the cyclonic instances but it should be more sustainable and site specific rather than

less reliant. Mangrove buffer is the most sustainable measure according to most of the locals. Active participation of certain NGOs in employing the woman was seen during our survey.

Conclusion

The increasing trend of disastrous events in the present scenario of climate change like frequent cyclones, heavy rainfall, flooding aggravates rapid coastal erosion. Any estuary is extremely responsive to increase in the sea level (Dyer, 1995). Mousuni being a part of the Hugli estuary and being a sea facing island makes it more vulnerable to such events. Under such scenario embankment managements becomes crucial in order to protect the coastline. Regular monitoring of embankments is required along with constant research work. Hydrostatic spill pressure needs to be controlled by allowing wider spill area where ever erosion is constant. Protection of banks with groynes needs to be monitored and carefully observed. Primary field survey and data analysis brings out the embankment breaching scenario. Geojute method of earthen embankment seemed to be a complete failure thus, alternative site-specific techniques need to be studied and implemented. In the extreme south of the islands (Baliara) a mudflat is observed taking advantage of such, mangrove buffer can be created from additional protection of the embankments. Mangroves like *Avicennia marina*, *Avicennia alba* and *Avicennia officinalis* may be planted on the mudflats. Construction of resorts which are restricting beach formations and violating CRZ-1 norms needs to be checked. For construction of a proper embankment settlement needs to retreat towards the central part of the island. Apart from these, capacity building and vulnerability assessments are required. An alternative source of livelihood apart from agriculture is required more to be promoted. Since Mousuni is hazard prone, more cyclone shelters should be produced for easy accessibility of the entire population of the Island.

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