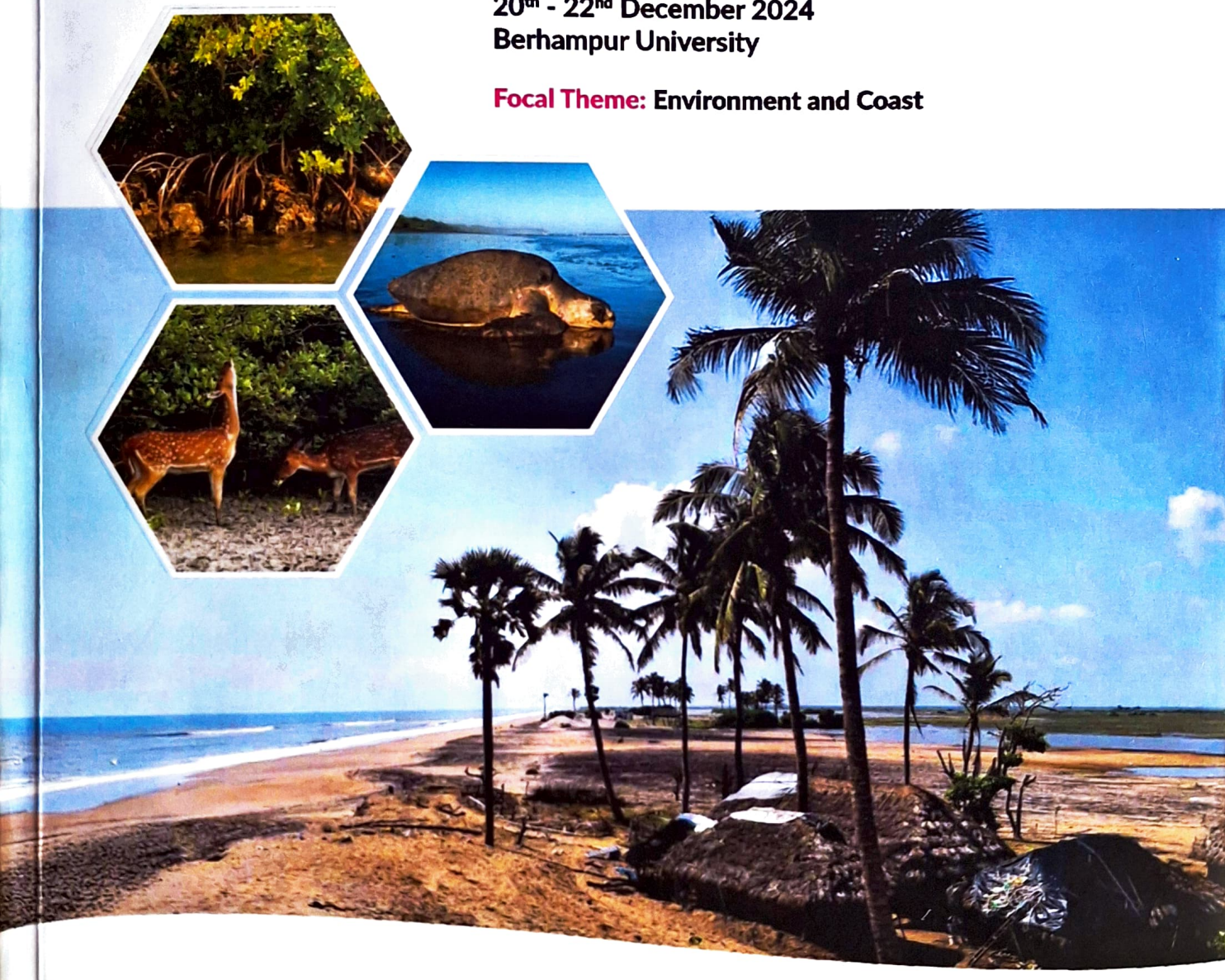
Proceedings

ODISHA ENVIRONMENT CONGRESS 2024

20th - 22nd December 2024
Berhampur University

Focal Theme: Environment and Coast



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Proceedings of the
Odisha Environment Congress - 2024

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Human Development Foundation-cDAR
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Regional Museum of Natural History
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Publisher : Pakhighara Prakashani
32, Madhusudan Nagar
Bhubaneswar-1, Odisha, India.
Ph. +91 94385 59778
e-mail : pakshighara02@gmail.com

Design & Pre-press
Godfrey's Graphics
Sasthamangalam, Thiruvananthapuram

ISBN : 978-81-19327-52-2
Price : ₹895.00

Impact of Tropical Cyclones on Livelihood: A Case Study of G-Plot, Patharpratima, Indian Sundarbans

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ABSTRACT

The G-Plot Island is a part of the Sundarban Deltaic Complex (SDC) located in the Saptamukhi River estuary of the Ganga Delta. It is one of the 54 reclaimed islands of the 102 islands of the Sundarbans and belongs to the Patharpratima subdistrict of South 24 Parganas District, West Bengal. This densely populated island, with an approximate population density of 715.85 persons/ km^2, has been facing erosion along the shoreline. The study aims to find the areal evolution of the island in the past 20 years and to study the effects of climatic calamities; majorly cyclones, on the island's residents. The southern section of the island has been much focussed, including Buraburi Tat and Gobardhanpur, which are highly impacted by the coastal floods, and Chandmari Ghat in the northeastern portion, which is highly impacted by the riverine floods. This study used Landsat images to determine the areal evolution of the island and track erosion and accretion zones. A primary field survey in the form of interviews was conducted with the residents of the islands regarding their perception of the region's climatic vulnerabilities. This island, exposed to repeated climatic calamities has impacted its residents in storms and cyclones. The major findings of the survey reveal a large loss of land and property due to cyclonic activity causing embankment failures, notably the Aila, Amphan, and

Yaas cyclones from the last 20 years. Moreover, the effects of flooding surpass from just waterlogging to water stagnancy due to the concrete embankments trapping the water inland. Such trapping of saline water in the agricultural fields causes increased soil salinity and transfers the land use from agriculture to aquaculture. The survey revealed that the residents mentioned the plantation of mangroves to decrease the rates of erosion, which are increasingly high.

Keywords: cyclone, erosion and accretion, livelihood, Sundarbans

INTRODUCTION

South Asia is said to be among the most affected regions by climate change. The main impacts of climate change, as given by the IPCC Fourth Assessment Report, are increased frequency of floods and drought, which negatively affect the production, sea level rise, which increasingly exposes the coast to phenomena such as coastal erosion and glacial melting of the Himalayas causing rock avalanches (Poncelet et al., 2010). Out of 102 islands of the Indian Sundarbans, 48 islands are under the Sundarban Reserve Forest (SRF). In comparison, the remaining 54 islands are inhabited by around 4.5 million people, which started almost two centuries ago (Ghosh and Roy, 2022). The shoreline profiles and their salinity are greatly impacted by rising sea levels along with natural phenomena and human intervention (Sreelekshmi et al., 2023).

A bimodal distribution of tropical cyclones is found in the Bay of Bengal, which occur between October and December and between April and June, where an increase in the frequency of severe annual cyclones has been recorded between 1891 and 2019 (Mandal et al., 2024). The coastal inhabitants are exposed to climate hazards, which include fluvio-tidal floods, tropical cyclones, which are accompanied by storm surges, riverbank erosion, salinity intrusion, and arsenic contamination of groundwater. A rapid increase in population is seen during the Anthropocene period in the combined GBM Delta. It has been accompanied by changes in the land use of the region, although it is one of the most underdeveloped regions of India and Bangladesh. The population of this region is mainly engaged in primary activities, including mono-crop cultivation of paddy (Aman) and fishing, crab collection, honey collection, and others (Rahman et al., 2020). In the present century, almost 7% of the world's population lives in deltas (Ericson et al., 2006; Safra de Campos et al., 2020).

The first mangrove forest of the Indian subcontinent was found approximately 9 crore years ago (Baksi, 1972). 2 crore years ago, the coastline was situated near Durgapur to the west, and at the foothills of Bhutan, Darjeeling to the north (Bera et al., 1995). Fossil studies and carbon dating of rock samples have proven that sea level has changed in phases.

It has been found that prior to the Pleistocene ice age, Sundarban was located near Canning, and the sea level was located near Garhbeta of Midnapore. 14,460 ybp (years before present), Sundarban was located near Swatch of no ground, and 7000-6500 years before present, flooding due to Flandrian Transgression led to the flooding of Kolkata, Dumdum, Kolaghat, Barrackpore (Banerjee et al, 1984), The coastline including Sundarban was protruded up to Kolkata, Dumdum Kolaghat and Barrackpore. Later, sedimentation by the Ganges led to regression, and Sundarban prograded southwards. At approximately 3000 ybp, the shoreline stabilised near Namkhana.

Sufficient evidence of ancient human settlement has been found and recovered from the Sundarbans, even though the muddy portion of the Sundarbans is presently not conducive enough for human habitation. Finding of ancient artifacts deep inside the Sundarbans, West Bengal, indicate the presence of human settlements to be as early as the 3rd century BC, found during exploration in Gobardhanpur and Uttar Surendraganj, South 24 Parganas, by the Directorate of Archaeology and Museums, Government of West Bengal. The evidences reveal the existence of settlements from the ancient period till the early medieval period. However, Neolithic evidence is insufficient to prove the existence of settlements during that period. Ancient evidences are found in the earliest archaeological sites of the southwestern Sundarbans, including Mandirtala, Sapkhali, and Pakurtala, including Neolithic Celt, non-Aryan Matrika (Mother Goddess) sculptures, CORRIE, and thousands of stone beads.

Numerous archaeological pieces of evidence were found in Gobardhanpur and Buraburir Tat during phases of low tide, which is surprising in such a mangrove-dominated environment. Fishermen Biswajit Sahu and Bimal Sahu of Gobardhanpur are engaged in collecting and preserving these artifacts, including potsherds and terracotta figurines. These findings prove the evolution of cultural history as well as the physical landscape of the Sundarban deltaic surface over the geological periods. The deltaic plains of southwest Sundarbans, which were separated by larger tidal rivers, with gradual accretion and accumulation of fluvio-tidal sediments, were agglomerated, modifying the rivers into narrow channels. Initial settlements during the early historic periods were made in the northern southwest Sundarbans about 4000 years ago, which gradually shifted southwards with the maturity of the delta region (Saren and Paul, 2023).

Land reclamation during the British Period and after of the Indian Sundarbans were made in 5 phases. Phase 1 occurred in 1770, when reclaimed areas were Haroa, Bhangar, Kulpi, Hasnabad, Canning, Baruipur, Jaynagar, and Patharpratima. Phase 2 occurred during 1770- 1873, which reclaimed Hasnabad, Haroa, Bhangar, Kulpi, Minakhan, Canning, Jaynagar, Mathurapur

and Sagar. Phase 3, during 1873-1939 reclaimed the whole of Sandeshkhali, Kakdwip, residual portions of Sagar and Canning, greater parts of Namkhana, Patharpratima, Basanti, Mathurapur, Kultali, Hingalganj and Gosaba. Phase 4, during 1945-51 witnessed additional settlements in Hingalganj, Gosaba, Basanti, Kultali, Mathurapur, Patharpratima, and Namkhana; and rehabilitation of East Pakistan refugees occurred in portions of Hingalganj, Gosaba, Satjelia, Kultali, Patharpratima, Namkhana, Sagar, Mousuni Island, and Jharkhali (Basanti). The last phase which occurred after 1951, reclaimed Satjelia Island, Marichjhanpi (restored mangrove forest, 1979) (Das and Das, 2023).

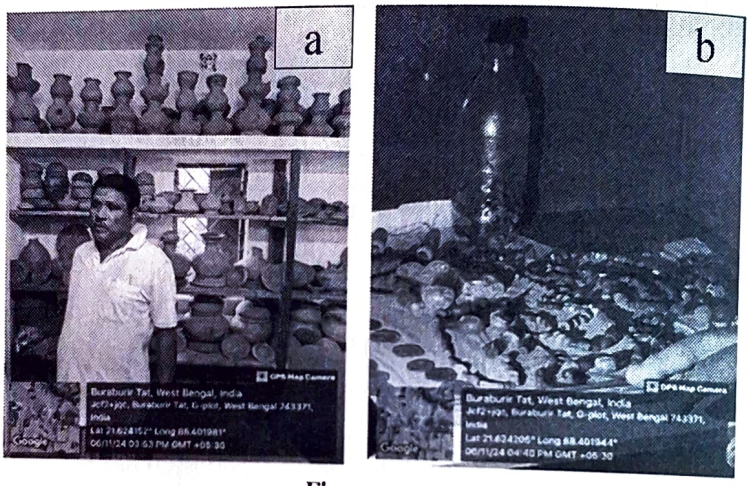

Figure 1.
(a) Biswajit Sahu displaying ancient potteries and terracottas, found in Gobardhanpur, (b) Beads and stone ornaments of the ancient period (before the discovery of precious metals) (right)

Settlements have been found to decrease in the southern portion of the G- Plot Island of the Sundarbans, and increase in settlements have been found in the northern portion which indicate the vulnerability of cyclonic events (Paul et al., 2021).

This study aims to explore the areal evolution of the island since 2001, thus tracking the shoreline changes. The island is located in a cyclonic vulnerable region and thus this study again aims to study the effect of climatic calamities; majorly cyclones on the residents of the area, emphasising on the perspectives of the local residents on their perception of cyclonic events and socio-economic distress.

MATERIALS AND METHODS

Study Area

The Sundarbans cover a stretch of 453 km and covers parts of districts North 24 Parganas and South 24 Parganas of the state of West Bengal in India and Khulna

and Bakhergunj in Bangladesh. In West Bengal, the Sundarbans consists of 19 Development Blocks of which 13 blocks are under South 24 Parganas and 6 are under North 24 Parganas (Mandal, 2003). G-Plot Island (Figure 2) is a part of the Patharpratima subdistrict of district South 24 Parganas. Located in the western bank of the Saptamukhi river, the G-Plot Island is an inhabitated island with a population of about 28992 (Census, 2011); contrary to the Dhanchi forest, located in the eastern bank of the river. The Buraburir Tat and Gobardhanpur villages have been selected for the study, owing to active erosion taking place in these locations. Special emphasis has been given to Bisweswar Point, which is the last tip of this island, from where the Bay of Bengal starts. The Chandmari Ghat has also been studied for its riverine location, and it being the main communication source to the mainland.

The remote location of the island, with an average elevation of 4 m above m.s.l. (mean sea level) adds to its vulnerability where the only mode of transport to reach the mainland include ferries and boats; high tide is suitable for the ferris to reach Sitarampur Ghat of the island while ferris cannot travel beyond Chandmari during low tide. All materials for livelihood need to be transported by the ferries, such as oil drums, vegetables and even vehicles such as bikes. The Chandmari Ghat is concrete and consists of a local market, which is the only source of communication between the island people and the mainland. Most of the embankments are noted to be unstable and prone to severe erosion. Embankments are in a better condition where the mangroves have grown in front of them; thus, acting as a shield.

Data Sources

Satellite images have been collected from USGS Earth Explorer of missions Landsat 4-5 and Landsat 8-9 as per the temporal setting of the study between 2001 and 2024, for study of the areal evolution of the G-Plot Island Table 1 and Figure 2).

Table 1
Detailed Description of the Satellite Images used

Sl. No	Image ID	Date	Area Covered	Spatial Resolution
1	LT05_L1TP_138045_20010112_20200906_02_T1	12/01/2001	G-Plot Island	30m
2	LT05_L1TP_138045_20041104_20200903_02_T1	04/11/2004	G-Plot Island	30m
3	LT05_L1TP_138045_20100121_20200825_02_T1	21/01/2010	G-Plot Island	30m

4	LC08_L1TP_138045_20200406_20200822_02_T1	06/04/2020	G-Plot Island	30m
5	LC09_L1TP_138045_20221216_20230317_02_T1	16/12/2022	G-Plot Island	30m
6	LC09_L1TP_138045_20240425_20240425_02_T1	25/04/2024	G-Plot Island	30m

Interview schedules were prepared for field interaction with the local respondents, during field visits in April and November, where households from the villages of Buraburir Tat and Gobardhanpur Village have been surveyed, regarding their general perception of cyclonic phenomena affecting their locality and about the impacts of the recent cyclone Dana, which took place on October 24th, 2024. Simple random sampling was used for the selection of the respondents after interacting with some of the older generation population of the villages beyond the age of 60, for their experience of past events in the island. The sample population consisted of both males and females and people from diverse occupations, from farming to business.

Data Analysis

The collected satellite images have been processed and vectorised for the calculation of the areal changes in the island using QGIS software. Since land use changes are important in the study of evolution, land use changes in the past 20 years have been studied, comparing the images of years 2004 and 2024, using QGIS classification. The data collected through sample survey have been analysed using cartograms such as pie and bar diagrams, which include mostly perception of the respondents and losses incurred by them due to cyclonic phenomena.

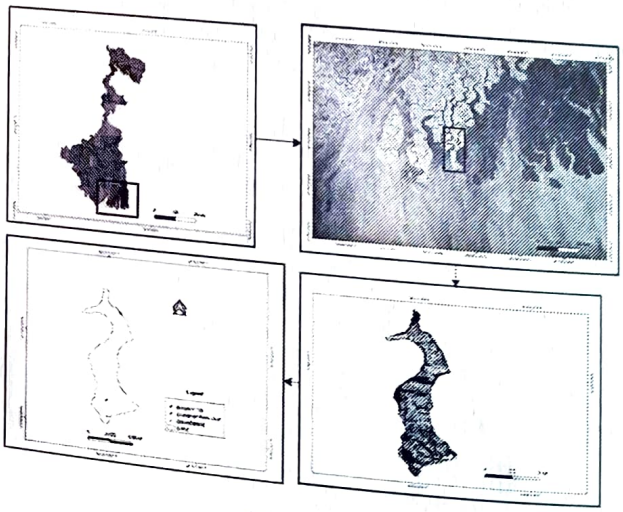

Figure 2
Location Map of G-Plot Island

Results

Areal Evolution of G-Plot Island: As found from the study of literatures, the G-Plot Island (Figure 2) has experienced erosion greater than accretion, which has resulted the island to reduce in areal extent. The 2001 image depicted the area of the island to be approximately 41.681 km², which has reduced to 40.921 km² in 2024. Over the years, the erosion rates have been 0.104 km²/ year, while the accretion rates have been 0.071 km²/ year. From Figure 3 it can be found that much erosion has occurred only in the southern portion of the island, especially in Buraburir Tat, Gobardhanpur and Sitarampur. The changes in the shoreline of G-Plot Island have been studied, where major change is found in the southern portion, followed by the northeastern portion, marked by erosion. Accretion has been found smoothly along both the eastern and western banks of the island, with major deposition in the south-western portion (Figure 3).

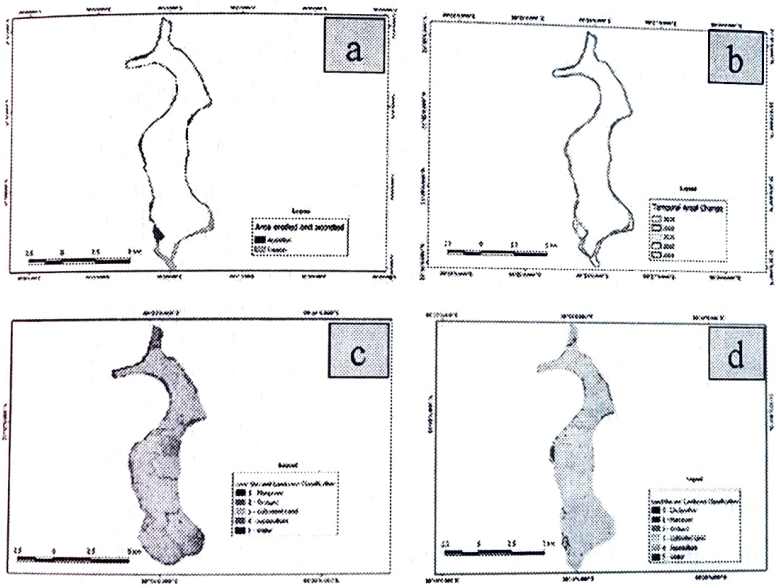

Figure. 3
(a) Erosion and Accretion of G-Plot Island, (b) Areal Evolution of the G-Plot Island, Change in Land Use and Landcover, 2004 (c), 2024 (d)

Changes in Land Use and Landcover: Land use and land cover changes on the island have been studied for 20 years, from 2004- 2024. The major changes in land use and land cover in these years include the clearing of land and an increase in aquaculture, which are high in the southern section of the island. As per the residents, the increase in salinity of the crop fields leads them to transfer the croplands to aquaculture ponds.

Perception Analysis of Cyclones: A total of 25 households have been surveyed regarding their perception of the impact of cyclones on the island, where emphasis has been given to interaction with the older generation due to their

longer exposure in the region. The perception survey revealed the perception of the residents on the impacts of cyclonic phenomena and their preparedness.

Socio-Economic Profile of the Respondents: The socio-economic profiles of the respondents have been recorded to assess their vulnerability to cyclones. It has been found that 44% of the respondents are less satisfied with their current financial condition, while 56% have average satisfaction with their financial conditions (Figure 4 a). The respondents were classified according to their occupation (Figure 4 b), where most of the respondents (32%) were engaged in transportation, such as photos and van driving.

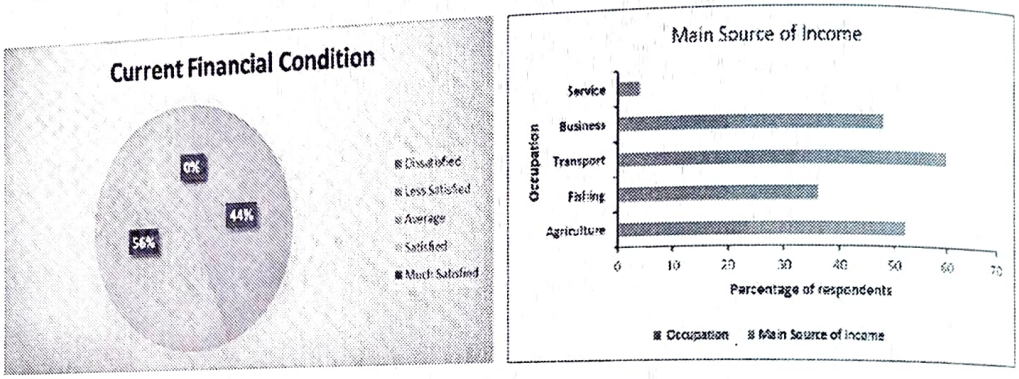

Figure 4

(a) Financial condition of the people, (b) Main Sources of Income

However, the major source of household income remains agriculture, as well as transportation and business. Fishing remains another major occupation, where common varieties include "boal" fish (*Wallago attu)* and "bhetki" fish *(Lates calcarifer)*. Almost all houses have ponds for aquaculture, which are for subsistent consumption. Agriculture in this island mainly grows paddy with numerous betel leaf nurseries. Spices such as chili are grown for home consumption, and vegetables such as bottle gourds, bitter gourd, and brinjal are also grown plentily for home consumption. This indicates still high dependence on natural phenomena for income sources; however, shifting of income sources has started, which indicates a coping mechanism to the ongoing situation, such as engaging in business and transportation.

General Perception of Respondents regarding ongoing natural phenomena: The residents were interviewed on their perceptions regarding the severity of the cyclones and how they have changed over the years, embankment conditions, and erosion. It has been found that all respondents agreed to an increase in the severity of the cyclonic events over the years. Mention was made of Bulbul (2019), Amphan (2020), and other cyclones that hit the region.

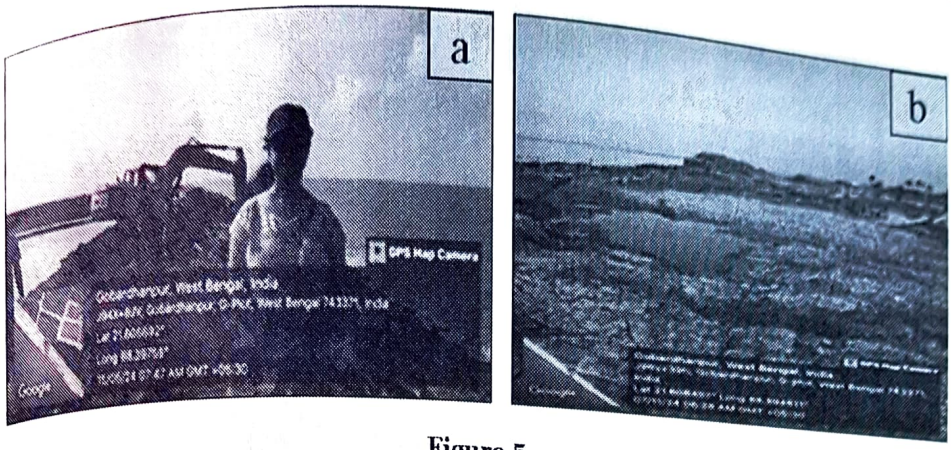

Figure 5
Condition of embankment in April (left) and November (right), 2024

The condition of the embankments has deteriorated in the past 5 years, and the erosion rates have severely increased (Figure 5). Local respondents informed us about the decrease in the area of Gobardhanpur village from 6000 bighas to 1200 bighas over 60 years, which indicates high erosion. The people were informed about moderate preparedness to meet natural calamities, with two functioning cyclone shelters in Indrapur and Daspur villages, respectively. Hospital facilities are only found in Indrapur village, and all the villages have local doctors.

While the majority of the respondents faced lesser damage to their houses due to cyclones, people living near the river had faced severe damage to their houses (Figure 5a). Complete loss of livelihood due to past cyclones were less reported amongst the respondents due to involvement in multiple occupations in each family. All of the respondents had lost their agricultural fields in cyclones, either by erosion and land loss or by an increase in salinity. However, their involvement in other sectors didn't lead to a complete loss of livelihood.

Perception and Impact of Cyclone Dana

Cyclone Dana, originating in the Bay of Bengal, landed between Balasore and Paradeep on 24 October 2024, with an average windspeed of 120 km/hr. Although the southern West Bengal was not affected much, the southern sections of the deltaic complex of the Sundarbans were affected by the cyclone.

Cyclone warnings were given well in advance to the residents where the respondents received information through various sources like television, newspaper, radio, and announcements. The less severe nature of the cyclone, as opined by the respondents, caused less damage to the island and most of the respondents claimed to have lost nothing in this recent cyclone. Houses near the Bisweswar Point were affected by the cyclone *Figure 6 a and b) and embankments of aquaculture ponds got severely affected (Figure 6 c).

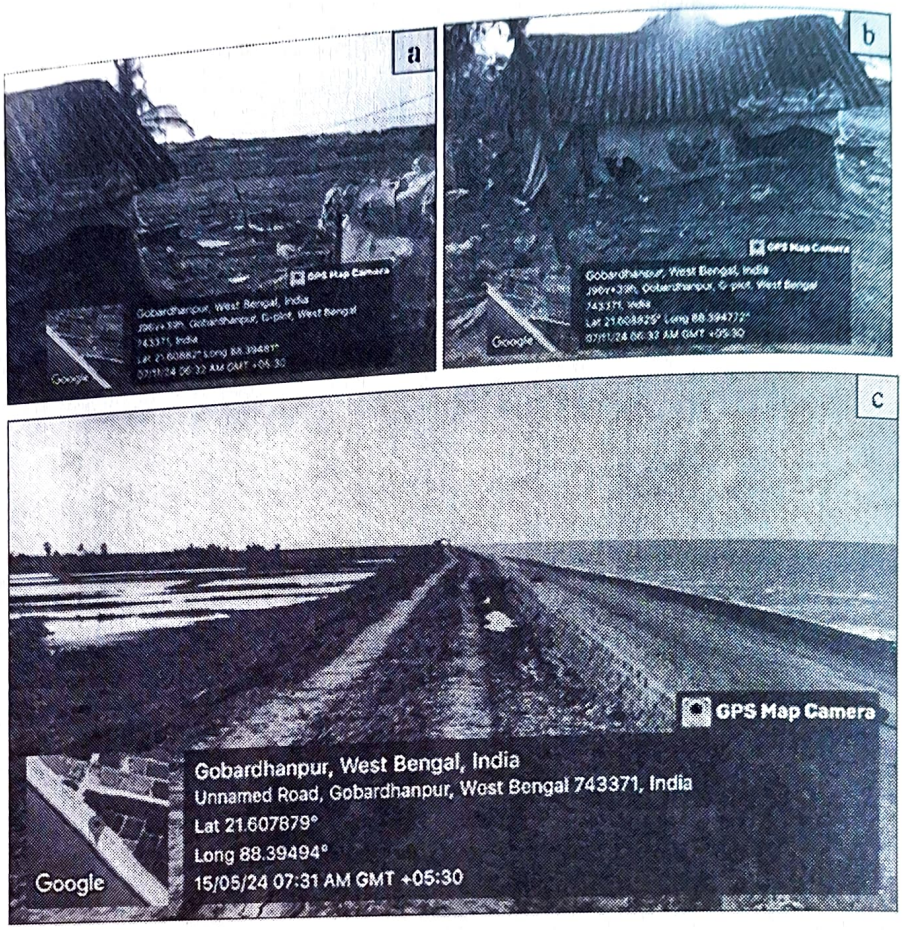

Figure 6
a and b. Cyclone Dana affected house, Bisweswar Point,
c. Aquaculture ponds near to the eroded embankments at Gobardhanapur

Discussion

The G-Plot Island, located on the Bay of Bengal at the confluence of the Saptamukhi Estuary with the Bay of Bengal in the south, is vulnerable to climatic phenomena, including cyclones and thunderstorms. High tide levels lead to submergence of the island's shoreline, with a mean tidal range greater than 4 m, and upto as high as 6.7m during Spring Tides.

People from Buraburi Tat, Gobardanpur and Chandmari reported the increased frequency of cyclones, which have affected their households, especially the Kachha houses. The surpassing of water beyond the embankments and consistent waterlogging have often resulted in the transformation of agricultural lands to aquaculture ponds, due to increased moisture and salinity (Plate. 4). The Gobardhanpur village, previously noted for salt production, has stopped production due to competition from the industrial market, with the production of refined salt. Loss of land have also transformed the major occupation of

the people, which was previously agriculture to fishery or other services. The younger generation often migrates to the mainland for better opportunities.

Conclusion

The people are affected by cyclones and heavy rainfall when the river water surpasses the embankments and enters the agricultural lands and fisheries. The constructed earthen embankments are regularly broken and repaired. Transportation, both internal and external, is a problem for the residents. Lack of civic amenities such as health care facilities worsens the situation during climatic calamities or even at night when the only means of transport include ferry services and local boats to reach the mainland. The people wish for the construction of bridges connecting the islands to the mainland for ease of travel. It can be said that this region, being located in a cyclone-vulnerable area, will always be vulnerable to erosion and flooding. However, such incidents can be reduced by plantation of mangroves.

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