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Rapid land use and land cover changes in response to environmental variables: A study on Namkhana Abad of Indian Sundarban

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Abstract
Estuarine morphology discusses the impact of transition zone between fluvial environment and marine environment. The dynamic change of the morphological relationship with environmental variables throw light to Namkhana Abad as selected study area of the south-west part of Sundarban, India. The Namkhana area is very prone to cyclone attack and has been affected by devastated activities of high magnitude cyclones (particularly Aila Cyclone of 2009) along the shoreline for its vulnerable characteristics in the previous decades. The rapid change has been observed in Land Use & Land Cover and Drainage area for understanding the spatial changes due to the cyclone effect. The drainage map has been generated on the basis of ASTER DEM of two years 2005 & 2010 for the comparative analysis of drainage degradations. The Land Use and Land Cover change have been generated using supervised classification techniques with the geospatial data of 2005 & 2010 and ground truth verification. These temporal changes helped the present study to observe the Aila cyclone effect with comparative analysis of two years for the establishment of the relationship between drainage and LULC as environmental variables. The above study reveals that the coastal fringed paddy fields and mangrove forests are heavily degraded by salt water encroachment and erosion with the impact on the local people of the study area forcing them to modify their land use conversions. Today the salt affected paddy fields are converted into land for aquacultural practices by the local people as rapid adjustment with the environmental variables.

Keywords: drainage map; environmental variables; estuarine morphology; land use and land cover (LULC); supervised classification, vulnerable

Introduction

In the micro-tidal environment of deltaic lowland tracts, tidal currents enter the distributary channels during tidal flood stage, spreading over the channel banks and submerging the flood basin of inter distributary area. Before the release of water at the ebb stage the high tide water's used to store temporarily at the lowland of the area. Thus, the lower distributary courses or the lower reaches of estuaries are dominated by tidal currents, and large intertidal flats are produced in the inter distributary areas of the lower deltaic plain. Tidally influenced distributary channels of the present delta plain are flared up and are funnel shaped with a high width depth ratio, and having a low sinuosity index (Paul *et al*., 2012, Du je *et al*. 2018; Black KP *et al*., 2017) [13, 7, 3]. In the Ganga delta of this, western sector, the tide dominated distributaries (Hughli, Saptamukhi, Thakuran, Matla & Rai mangal-Haria bhanga) range in depth from 10 to 26 m, among the distributary channels, only the Hughli, Muri ganga, Sapta mukhi dissect the beach ridge barrier shoreline of the Sundarban. Various bed forms (dunes, sand waves, mega ripples) predominated over the channel margin study shoals and channel bottom sand beds by strong tidal current drift, however, the complex inner deltas are dominated by the occurrences of sand bars and mud flats at the distributary channel confluences (Richards, J. F., 1990; Wolanski E, *et al*, 1998) [14, 19]. At the Hughli channel, sediment load is deposited in a large portion as it flares at the confluences below Diamond harbor and fluvial currents are also impounded by incoming tidal currents in this lower reach. Mud flats are extensive along the channel banks.

Tidal distributary channels of the delta plain are less prone to switching and abandonment under micro-tidal environment. Bank erosion and lateral migration are however, maintaining a balance with channel bed deposition and bar surface or island surface accretion (Ghosh, *et al*. 2016) [9]. Large scale channel bank slumping is an important features of Ichhamati, Saptamukhi, Muriganga and Hughli river as they often have fine grained cohesive bank materials. The tidal dominated delta plain of tropical climate along with high proportion of fine grained sediment comprises organic rich mud with plant debris largely derived from mangrove vegetations (Paul et. al., 2012, Becherer J *et al*. 2016 Rogers *et al*. 2016) [13, 1, 16]. The banks of rivers and tidal channels are usually higher (3-4.7 m) than the interior parts of the islands, due to levee deposits by repeated submergence. For this reason every high tide cannot reach the interior parts of some islands. However, during the spring high tides, the interior of island marshes or swamps contributes silts to the island edges by the current network of tidal channels at the ebb tides.

In the lower part of the tidally influenced reaches of distributary channels, flow-aligned bar occur in the central channel section. Such features of the Ganga delta are known as linear tidal current ridges (Coleman; 1669 Coleman and wright, 1975) [4, 5]. Many bars have emerged as islands with the colonization of saltmarshes and mangroves and their sediment trapping abilities in the tidal stages. These linear shaped islands are 8-9 km long and 1.5 to 4 km wide as the

function of the size and form of the channels. Tidal distributary channels of the delta plain are less prone to switching and abandonment under micro-tidal environment. Bank erosion and lateral migration are however, maintaining a balance with channel bed deposition and bar surface or island surface accretion (Felsenstein *et al*., 2014) [8]. Large scale channel bank slumping is an important features of Ichhamati, Saptamukhi, Muriganga and Hughli river as they often have fine grained cohesive bank materials.

Inter distributary areas of tidal floodplains include a maze of smaller and larger tidal creeks of anastomosing pattern, extensive intertidal and supratidal flats which are sensitive to the tropical climate. Over a large tract (about 4264 km2 areas) of the lower delta plain, the inter distributary areas are dominated by mangrove swamps and dissected by a complex pattern of meandering tidal creeks. Lateral migration of point bars in the tidal creeks, development of sand ridge and swales, and clay plugs of in filled channels represent a complex depositional facies of swampy surface in the sundarban. Inter distributary areas of the sundarban tidal flats are isolated into different island units by crisscross channels of tidal influence (Pargiter, F. E, 14. Chakrabarti 1991) [12, 6]. The tidal dominated delta plain of tropical climate along with high proportion of fine grained sediment comprises organic rich muds with plant debris largely derived from mangrove vegetations.

Study Area

The Namkhana Abad of Kakdwip subdivision is geographically located in Sundarban deltaic region, which is a part of the Ganga-Brahmaputra-Meghna basin area. Namkhana is located at 21^0 45’ 59.99” N 88^0 13’ 60.00” E which covers an area of 370.6 square kilometer, surrounded by Patharpratima, Kakdwip, and two rivers i.e. Saptamukhi and Muriganga. Namkhana block consists of 7 Gram Panchayat (GP) with 32 villages (Fig.1). The river network is a major transport system of this block. People of this block are also dependent on river for their livelihood (basically fishing) purpose. There are innumerable tidal creeks and khals are spread over that area between the large estuaries and rivers. The rivers are tidal in nature due to its location in deltaic region, the area is tide dominated being geomorphology is very active and environment is very sensitive. Breaching of embankments, river bank erosion very common phenomenon over here. Due to its location of southern part of Sundarban its makes the area cyclone prone where the depression forms over the Bay of Bengal and affects the nearby coastal area.

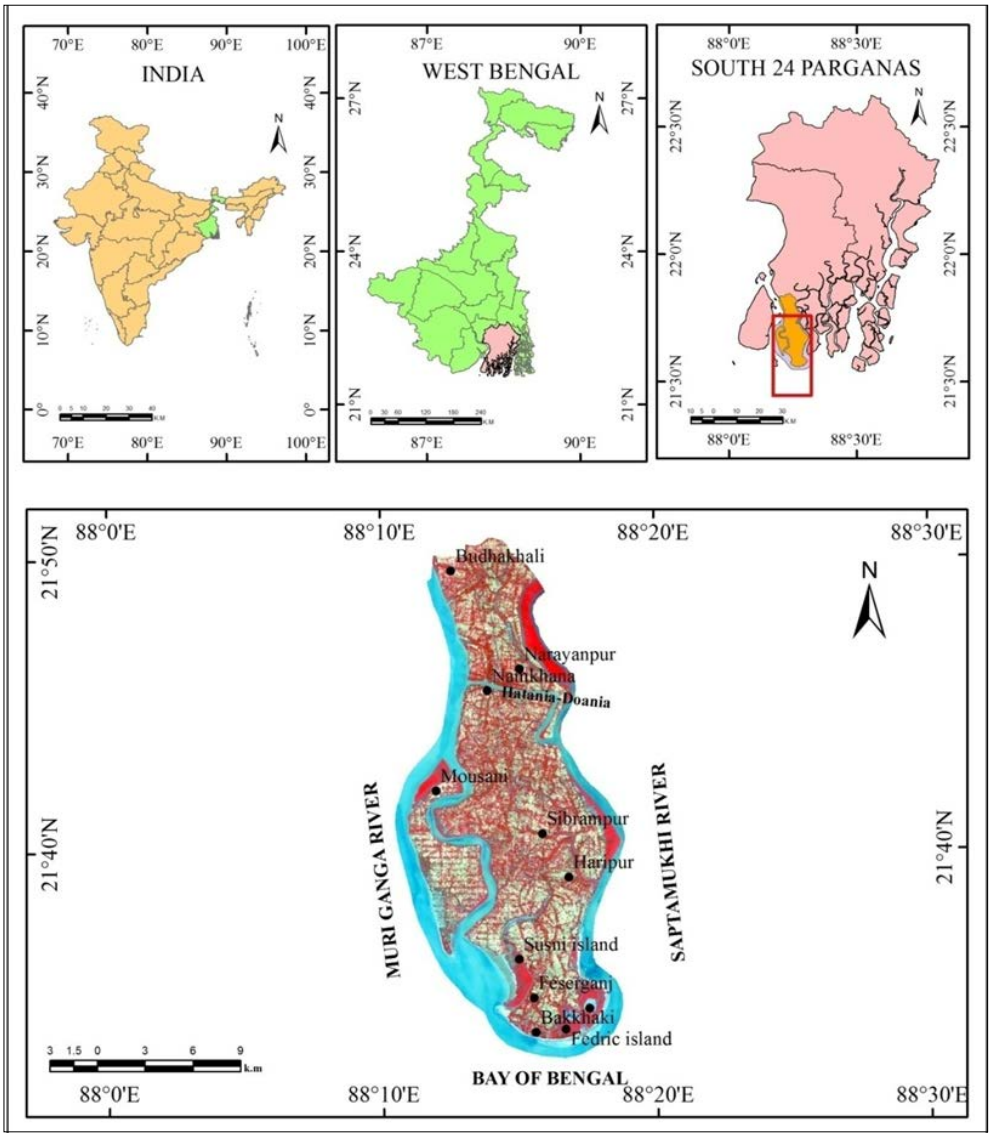

Fig 1: Location Map of the Study Area

Materials and Methods

The data collection plays an important role in the part of enhancement of analysis for research work. The methodology can only be established depending on the basis of data availability and acquirement. The present study discusses about the use of geo-spatial techniques for the study of dynamic changes. The Landsat 5 TM and Landsat 7 ET M+ images are collected from USGS for the land use and land cover change using supervised classification. The drainage map is generated on the basis of ASTER Global DEM (Digital Elevation Model). The geological records have been collected from GSI (Geological Survey of India) and the soil datas are collected from NBSS &LUP (National Bureau of Soil Survey and Land use Planning). SOI (Survey of India) toposheet are also used for the change detection of analysis (Fig.2). Field survey and GPS data collection played a vital role for the assessment of rapid changes of Land use and Land cover map.

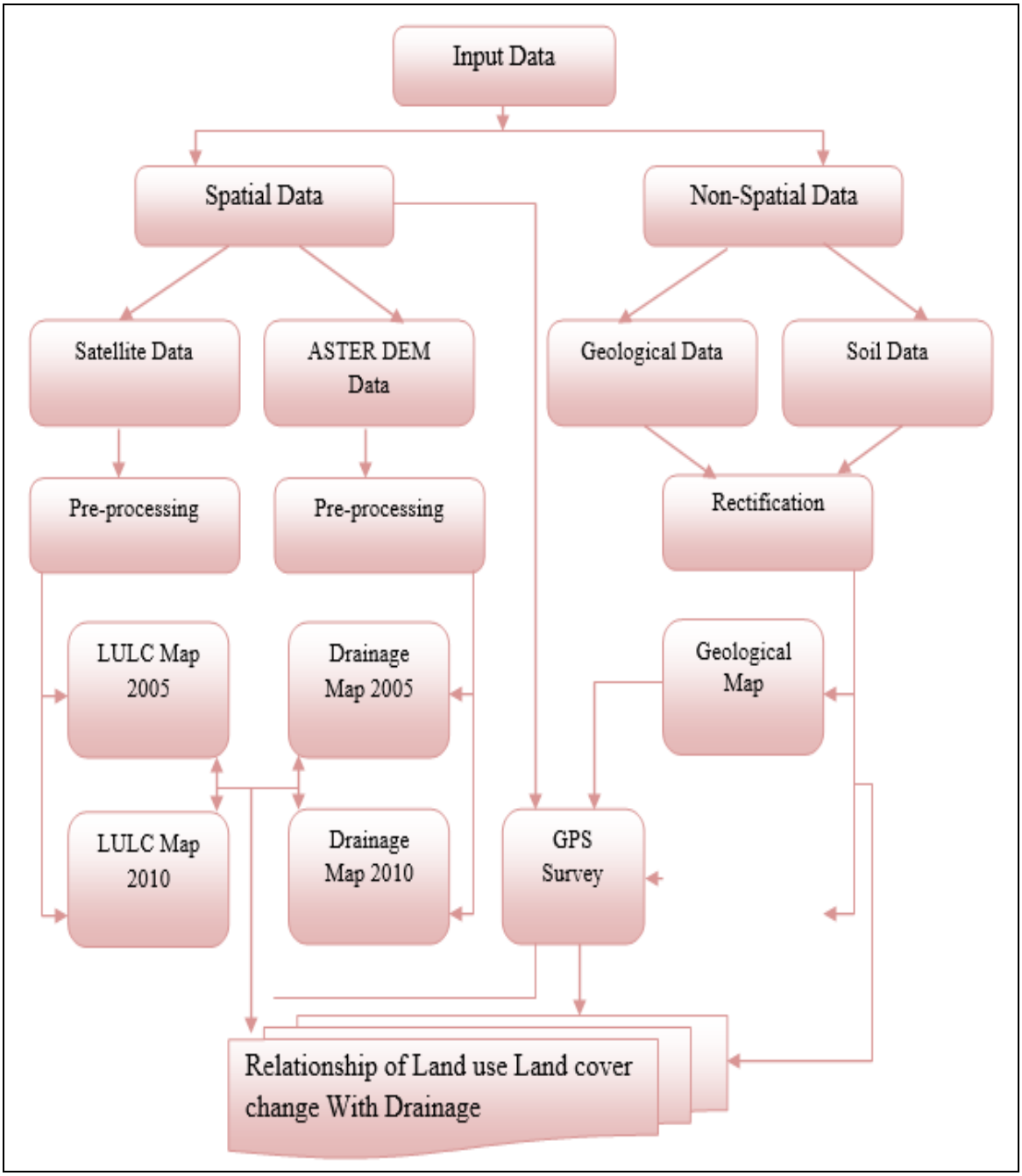

Fig 2: Flow Chart of the Study Area

Results and Discussion

Geology

Geology means the study of Earth and the processes acting upon them includes the study of organism inhabited in the planet. Rock units or strata are shown by color or symbols to indicate where they are exposed at the surface. Bedding planes and structural features such as faults, folds, foliation, and lineation are shown with strike and dip or trend and plunge symbols which give these features three dimensional orientation. The geological information indicates the marine transition of Bay of Bengal shelf occurred locally during Cretaceous and widely Eocene. During Miocene only the eastern part of Bengal self was dominated under arise influence

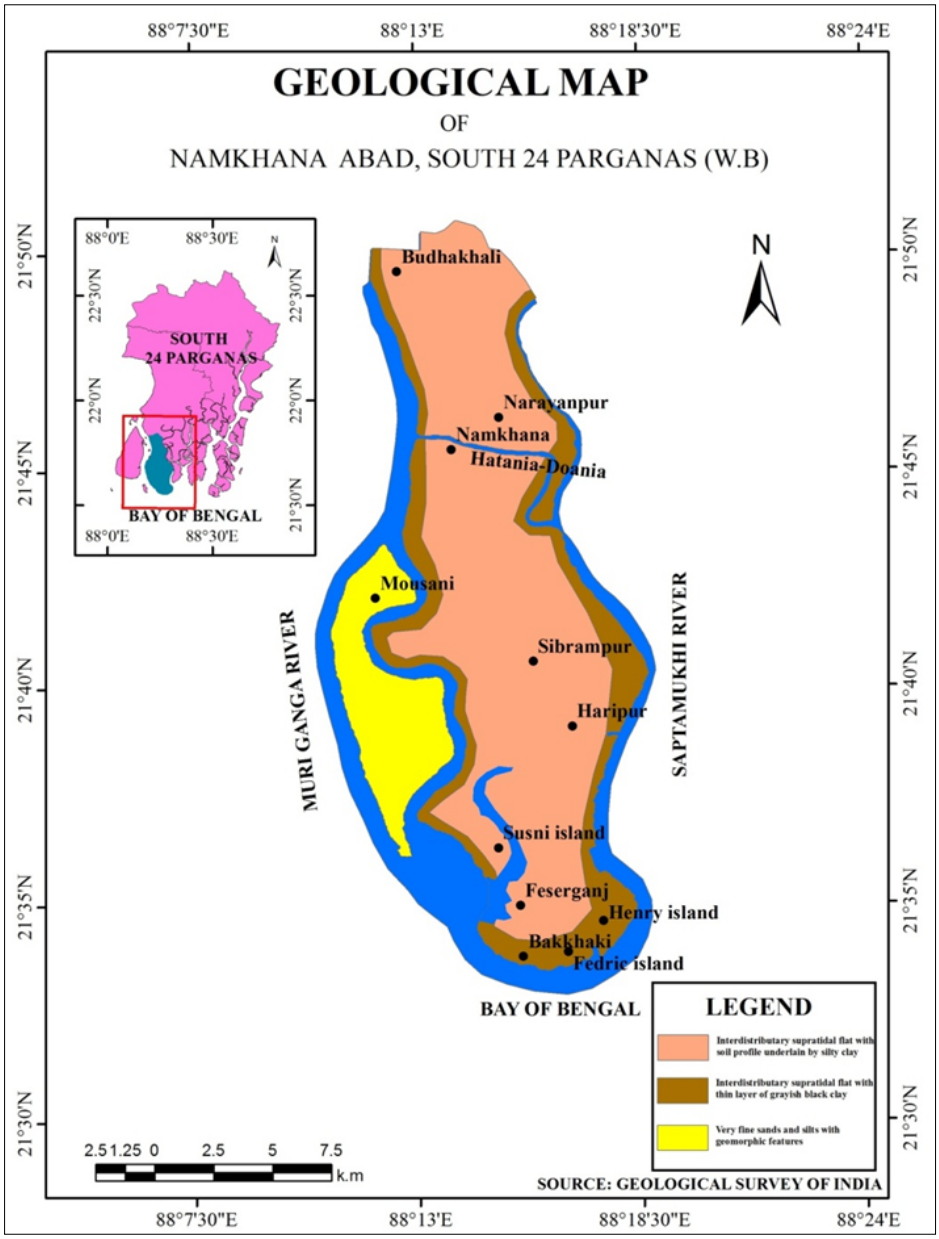

Fig 3: Geological map of Namkhana Abad

The majority and the central part of the Namkhana cover the inter distributary supratidal flat with soil profile. The area under Maisani region covers the part under very fine sand and silt with geomorphological features. The southern part of the Namkhana Abad that are Bakkhali, Fredrick Island, Fraserganj Island, Henry Island, and parts of south Chandanpiri, north Chandanpiri covers with inter distributary supratidal flat with very thick and fine silt and clay. The geology of the study area discusses about the deltaic environment of the area. The total area of Namkhana Abad lies under the deltaic alluvial plain and the lower part of theblock lies under the coastal alluvial plain. Geologically, the seaward part of Ganga delta adjacent to the administrative block of Namkhana Abad separated by Muriganga River and Saptamukhi River can be categorized into three stages of formation (Fig.3). They are known as;

1. Upper Holocene delta plain (11,700-4,300 ybp)
2. Middle Holocene formation of delta plain (8,300-4,200 ybp)
3. Late Holocene formation of younger delta plain (4,200 ybp present day)

However, this part of the delta is geologically dated by Allison & Goodbrid (2016), and according to their study, it is named as Hugli deltaic lobe and dated as 5,700 ybp. The Upper Holocene delta plain alluviums are mostly made up of Hugli- Saptamukhi systems with flood plain alleviation. This particular layer is dominated by fine sands with alternate clay layers. Over this layer of flood plain origin, the middle Holocene delta plain deposition took place with fluvio-tidal deposits. The alluvium of this category is dominated by channel deposition of loamy sands and clays and lag deposits. The final stage of formation known as late Holocene deposition which took place by tidal and marine alluviums. They are dominated by silty clay, muddy alluviums fine sands at the sea surface. The above description of geological formations is established on the available information from Geological Survey of India (GSI) records.

Drainage Features

The source of all the rivers of distributary channels in the western Sundarban are being progressively silted up leaving

hardly any passage for freshwater. Thus, the rivers are getting more salty and shallower year after year. Ichhamati, Piyali, Bidyadhari and upper part of Saptamukhi River are chocked with rapid siltation. The banks of rivers and tidal channels are usually higher (3-4.7m) than the interior part of the islands, due to levee deposits by repeated submergence. For this reason every high tide cannot reach the interior parts of some islands. However, during the spring high tides, the interiors of island marshes or swamps contribute silts to the island edges by the current network of tidal channels at the ebb tides. This continual scouring without compensatory silting during the flood tends to Ebb tide concentration has developed (by repeated scouring) innumerable small creeks when draining out the water which reaches inlands and flow to nearby rivers or estuaries.

In the study area Namkhana Abad surrounded by two major rivers i.e., Muri-Ganga River and Saptamukhi River. This area is basically an estuarine part of Sundarban where a river meets with Bay of Bengal. The drainage system of that area is based on tidal processes. A very few tidal creeks or inlets are spread over the study area. Tidal creeks & tidal channels with intricate channel patterns are dominating in the deltaic landscape of Namkhana administrative block. These are different types of drainage features in the present area. Among them; i.e. i. Two major tidal river mouths (Saptamukhi & Muriganga) ii.Inland tidal channels dominated by tide water inflows (Hatania-Doania, Pitts's creek, Ed wards creek) and iii.Smaller tidal creeks within the land masses (Fig.4).

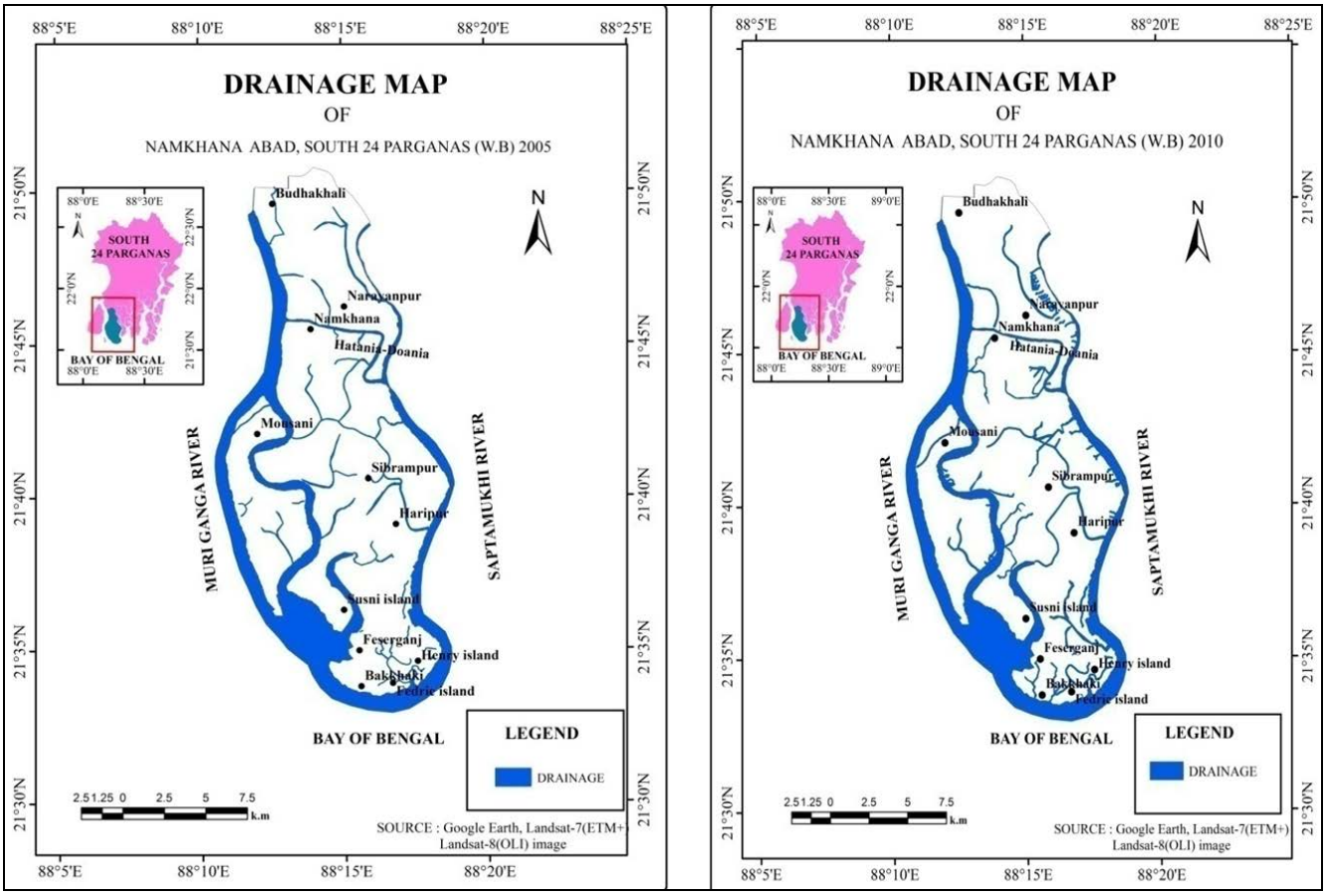

Fig 4: Comparative Analysis of Drainage Map of Namkhana Abad (2005 & 2010)

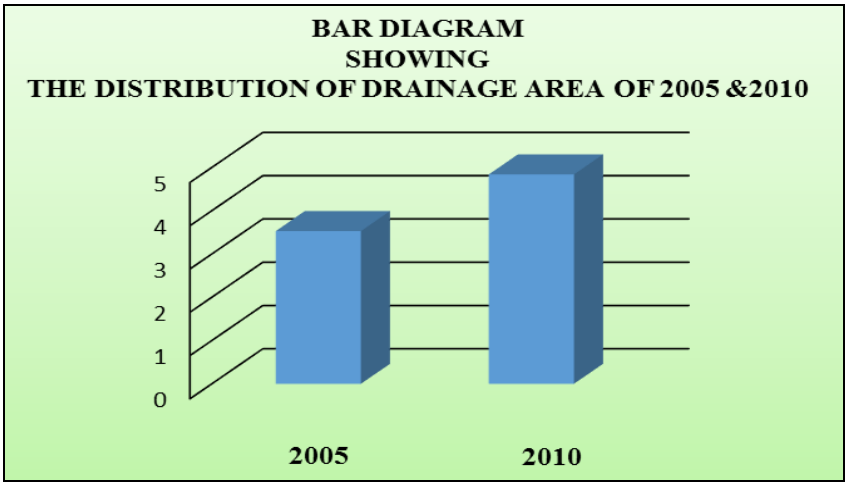

Fig 5: Distribution of Drainage Area of Namkhana Abad (2005 & 2010)

The larger tidal rivers are filled up with tidal shoals and sandbars and getting wider by their bank margin retreats due to the pressure of tidal prisms. The sea face is strongly influenced by long shore currents and wave induced currents which deposited huge volume of fine sands into the mouth of inland tidal channels in the present study area. However, the tidal drainage loss in significant in the inner part of mangrove dominated islands (Henry, Fredrick, Bakkhali & Patibhunia etc) due to the maturity of the upper part of mangrove swamp by bio-tidal accretion and storm deposits.

After overlaying the Google earth image, satellite image and toposheet the drainage mapping has been done with the consideration of two years mainly 2005 and 2010. The year 2005 shows 3.5264 square kilometer area is occupied the drainage system of the study area. Basically the area is an estuarine area so tidal creek is a common physical feature of that area. An increase of drainage basin area is observed in the year 2010. To analysis the change of the drainage basin area, these two years images are used particularly because of the 2009 25th May's devastating Aila cyclone. In 2010 the drainage area increased 4.3888 square kilometer. Cyclones and floods have affected the drainage system of an area and Namkhana Abad is a cyclone and flood prone area (Fig.5).

Soil

Soil map is a map which gives the geographically representation showing the diversity of soil type and soil properties like (soil ph, texture, organic matter, depth of horizon) soil map is commonly used for land evaluation, environmental protection. The study area shows the soil differing from other inland soil.

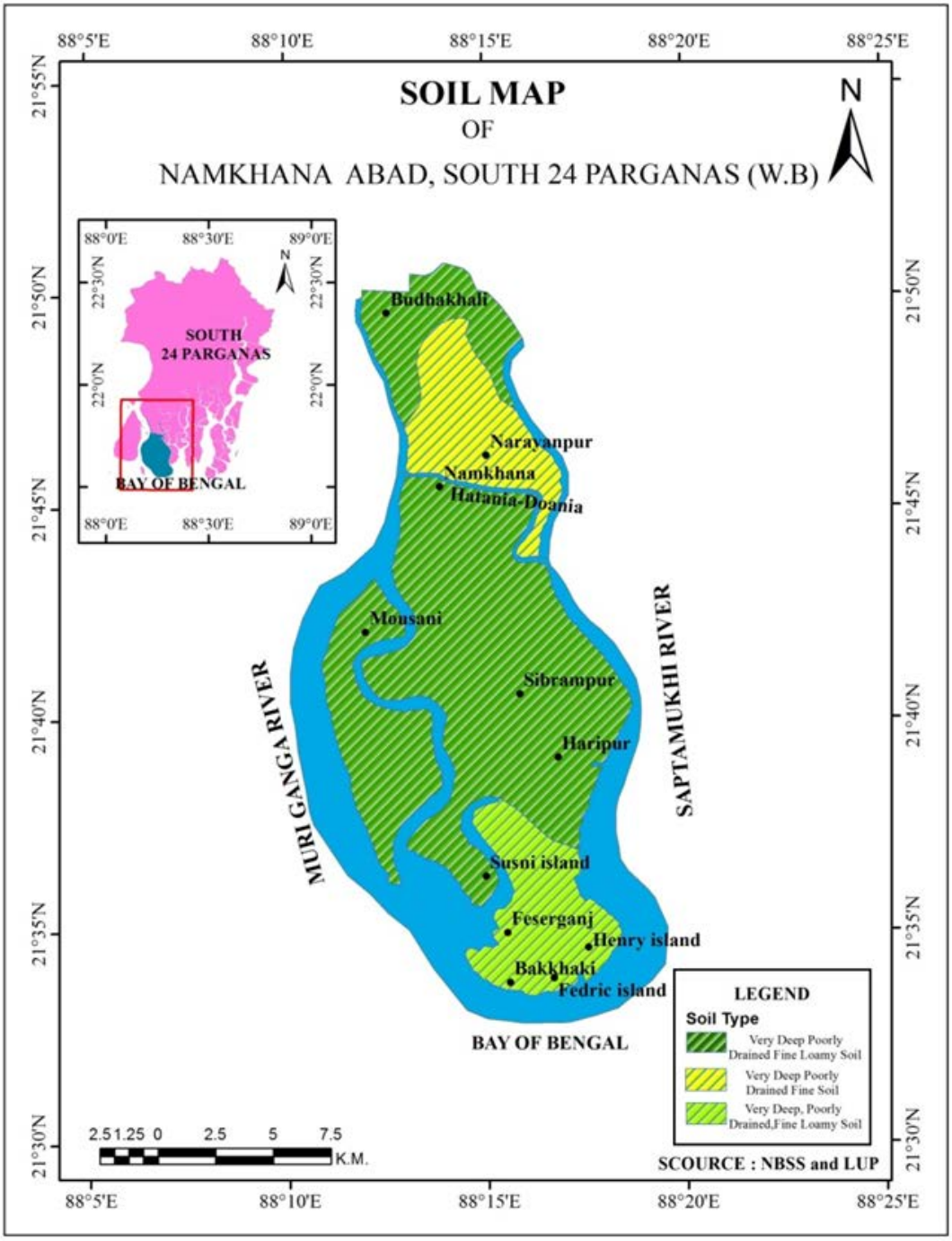

Fig 6: Soil Map of Namkhana Abad

Alluvial types of soil are mostly seen in the study area. The soil are deep to very deep. Sundarban soils are locally known as “Nonamati”. The soil of the study area developed mainly on tertiary sediments with the elements like sand, silt and clay. The deltaic soil of Sundarban mainly comprises of saline alluvial soil consisting clay, silt, fine sand, and coarser sand particles. Soil of upper deltaic plain found are fine loamy in texture and neutral to salinity alkaline (ph 7 – 7.8) and in lower delta region is found fine texture an acidic to alkaline (ph 5 – 8) while soil of marshes area can be found fine in texture and shows acidic to neutral reaction (ph 5.6 – 7.5). Namkhana, Narayanpur, Ishwarpur region shows very deep poorly drained but fine soil. The area of Bakkhali, Fraserganj, Fredrick Island and Henry Island shows fine loamy soil. The other majority portion is covered by very fine loamy soil (Fig.6).

Land Use and Land Cover

Land use and land cover describes the two terms often being used interchangeably where land use indicates how people utilize the land with socio-economic activity like road, settlement, embankments etc. and land cover indicates the surface cover on the ground like vegetation, river, salt pan, tidal creek etc (Hassan. Z *et al*, 2016; Rahaman *et al*., 2012; Shalaby *et al*, 2007) [10, 15, 17].

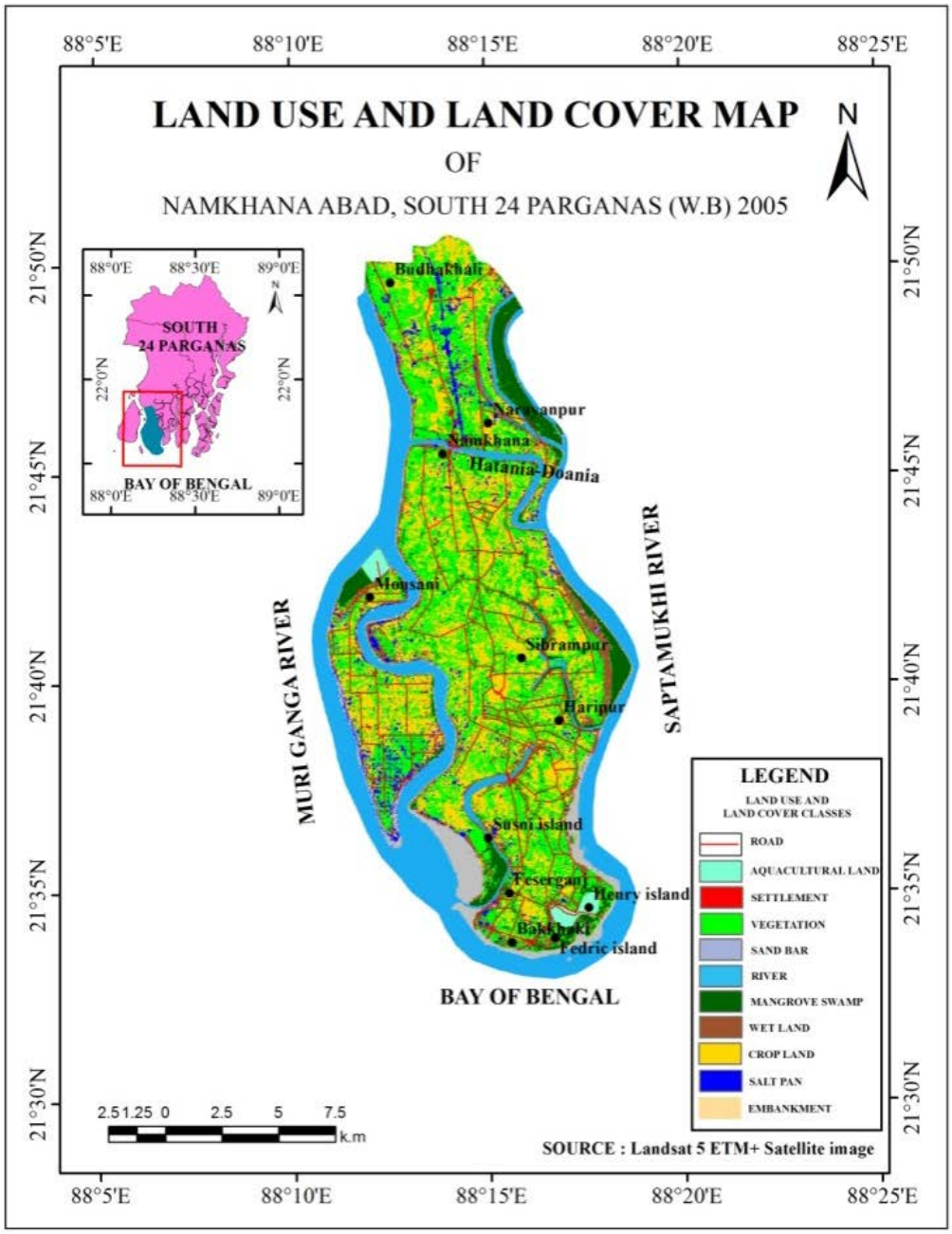

Fig 7: Land Use and Land Cover Map of Namkhana Abad, 2005

Mangrove swamp is major vegetation which are found in coastal wetlands of tropical and subtropical regions. Mangrove swamp is spread over the steady area of Namkhana Abad covering 1587.24 hec consisting of 5.31% of the total area. The block also covers natural vegetation which is called open forest that are identified by light red tone (Mandal RN.et.al 2019; Banerjee K et.al.2017; Thakur S et.al; 2021) [11, 2, 18]. Vegetation is occupied by 8000.28 hec consisting of 26.77%. A tidal creek, tidal channel, or estuary is the portion of a stream that is affected by ebb and

flow of ocean tides. Tidal creeks are found in side of mangrove swamp and some channel is found in all over the part of the area. In the area Namkhana a few numbers of tidal creeks are found. The area covered by the tidal creek is 1283.21 hec consisting of 4.83% of the total area. Sand dune accumulation of sand grains is shaped by the wind under the influence of gravity. Some sand dunes are observed covering the area of 485.1 hec consisting of 0.34% of the total area. Mud flats are formed due to sediment deposition by the nearby rivers. Basically mud flats are found in sheltered areas like bay, estuaries. The study area Namkhana abad is situated in an alluvial plain near to the coast. Very few river and estuaries are found over there due to mud flats in that area. The area covered by mud flats is 1049.85 hec consisting 3.51% of the total area. Sand beach is basically consisting of sand (Fig.7 & 8).

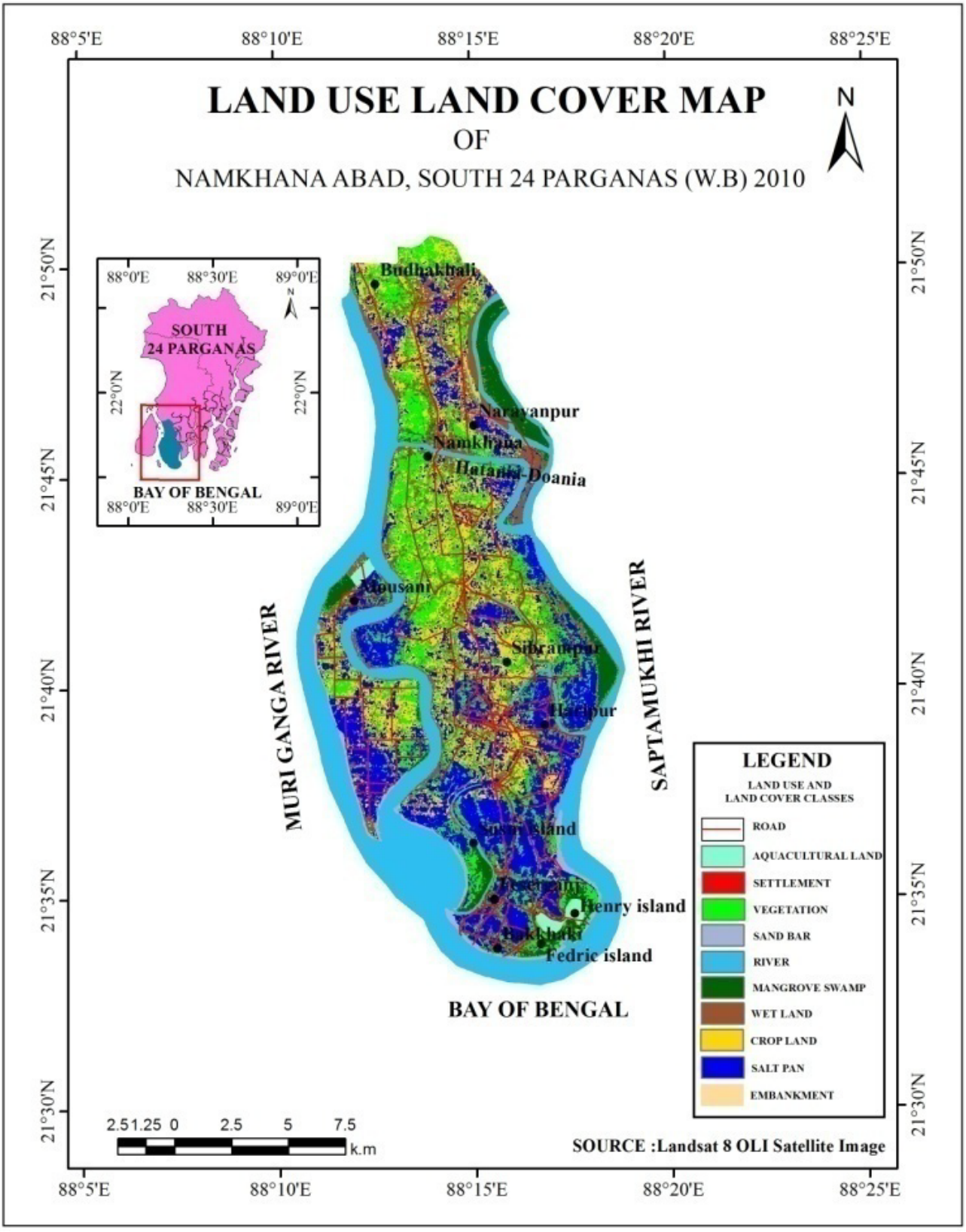

Fig 8: Land Use and Land Cover Map of Namkhana Abad, 2010

Namkhana is a coastal belt area so beaches are identified nearby the ocean. The total area covered by sand beach is 560.52 hec consisting 1.88% of the area. Now days of that particular area the agricultural land converted into pisi cultural land so increased the aquacultural land. The block Namkhana surrounded by Saptamukhi River and Muri Ganga River and it falls in to Bay of Bengal. In the study area, the area of the river is 7166.07 hec consisting with 23% of the total area. The terrain analysis and classification (Chakrabarti 1991) reveals that development of soil profile is very poor in estuarine part of Hooghly River. The inter-distributary terrain is used for cultivation. The area covers 8620.2 hec of crop land consisting of 28.85% of the total area. The area covered 477.72 hec under fallow land consisting 1.59% of the total area. The land use/land cover map is spatial information of the natural, cultural, anthropogenic cover types on the existing scenario. The analysis of land use and land cover of the study area for the years 2005 and 2010 were done in order to detect the changes that has taken place in the various categories. In 2005 the total area is divided in some categories i.e. River, Vegetation, Mangrove swamp, Sand, Wet land, Crop land, Salt pan, Aquaculture land, Settlement, Embankments (Table.1 & Fig.10).

Table 1: Comparative Analysis between the LULC Changes 2005 & 2010 with help of Change Detection of areas

LULC Classes	Year(2005)	Area in percentage	Year(2010)	Area in percentage
River	6647.63	23.54186788	7804.35	25.40502498
Vegetations	8128.3	28.78550171	6415.28	20.88327006
Mangrove Swamps	1777.81	6.29592323	1273.3	4.144895899
Sand bar	1480.57	5.243279685	1098.27	3.574252491
Wet Land	1648.67	5.838587786	2803	9.124435094
Crop Land	6757.02	23.92926082	4380.19	14.25856559
Saltpan	1138.79	4.032902512	5575.51	18.14795778
Aquaculture Land	253.17	0.896574372	550.23	1.790381485
Settlements	317.993	1.126138066	700.59	2.280587935
Embankments	87.526	0.309963931	120.0	0.390628688
Total	28237.479	100	30719.71	100

Change Detection Analysis

The change analysis reveals that there has been a considerable change in the land use/land cover status of Namkhana area from 2005 to 2010(Fig.11 &12). The area which has been lost under one land use/land cover category has converted to other land use/land cover category thereby showing an increase in the respective categories:

1. Namkhana is a coastal plain so that sand bar is a major land cover of that area which has shown a remarkable change. It has decreased from 1098.27 hec (3.57%) in 2010 to 1480.57hac (5%) in 2005. Because of particularly Aila cyclone the sand bars are eroded away.
2. The total area and percentage under salt pan 5575.51 hec (18.47%) in 2010 that increased from 2005 the area under 1138.79 (4.03%). During the Aila cyclone 2009 the sea water entered towards the land area. So that the salts are consolidated on the land and the salt pan is increased.
3. Mangrove swamps is the main species of the Sundarban area. The mangrove swamps covered land has shown a net decreased 2.02% from 2005 to 2010. The total area under mangrove swamp 1777.81 (6%) in 2005 decreased the area 1273.3 hec (4%).that area is poorly cyclone prone area. So mangrove degradation is a major problem of that area.
4. The area vegetation in 2005 covered 8128.3hec (28%) that decreased the area covered 6415.28hec (20%). The vegetation land cover shown a net decreased 8.17%. Salt pan increased in 2010 so the vegetation cover is decreased.
5. The cropland has decreased to 4380.19 hec (14.25%) in 2010 from 6757.02 hec. in 2005 due to Aila Cyclone and flooding so the local people converted the agricultural lands to aquacultural lands.
6. The Aquacultural land increased to 550.23 (1.79%) in 2010 from 253.17 (0.896%) in 2005.
7. The area under wet land 2005 covered 3803.9 (12.22%) that increased in 2010 covered 1648.67 (5.83%) because of cyclone disaster.

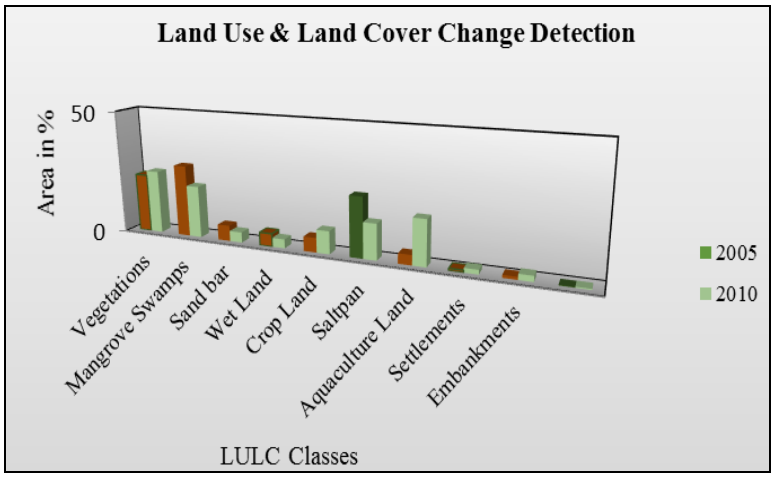

Fig 9: Land Use & Land Cover Change rate of Namkhana Abad (2005 & 2010)

Fig 10: Photographic document shows the different types of Land Use & Land Cover features, i.e. Tidal Creek of Haripur; Edward Creek; Hatania- Doania Creek; Tidal Creek of Narayanpur; Mud Flat; Agricultural land; & Sand Beach

Conclusion

The following conclusions may be drawn on the basis of above study. Geologically the deltaic islands of the present study area younger and modern deposits of fluvial, fluvio-tidal and fluvio-marine. Effect of the saltwater encroachment is reflected on the land use conversion by the local people. The sea faces are significantly affected by beach erosion. Advancement of the over washes sand for lobes and hyper saline patches. The conservation of mangrove forests is urgently needed by developing new plots of mangrove forests in the emerging sand bars and tidal flats in the present area. The rate and types of land use land cover changes is direct indicator of environment changes and predicted sea level rise in the study area. Increased drainage area in compare with 2005 & 2010 particularly by the impact of Aila cyclones (25th May, 2009). The shore faces and the bank margins are effected by over wash sand deposits, bank erosion and extension of salt pans or salt flats. The mangrove vegetations particularly are to some extent degraded in the sea face of the islands by erosion, over wash sand deposits & tidal drainage loss. However some areas in the tidal river sites are showing the nearly developed mangrove forest by plantation and in the inner parts of islands through afforestation continued but they were affected due to the development of hyper saline environment. The land use changes are also recorded in the present study in the four of land conversion from paddy land to fishery land by the farmers particularly after the incidence of Aila cyclone and marine influences during the current decade. The agriculture land in the form of paddy farm plots are also decreased in compare to the year 2005 due to continuous conversion of the reclaimed portion of the delta for infrastructural development & expansion of settlement areas. The agriculture land in the form of paddy farm plots are also decreased in compare to the year 2005 due to continuous conversion of the reclaimed portion of the delta for infrastructural development and expansion of settlement areas. The area under aquaculture ponds is also increased in the inner part of landmass and along the banks of tidal creeks and channels due to the rapid adjustment of the people to combat with the impact of salt water influences into the margins of the islands.

Fig 11: Field Photographic documents in the Namkhana Abad

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