Mapping and impact analysis of vulnerable coastal landscape: Purba Medinipur District, West Bengal

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Abstract: The impacts of human intervention are of particular concern in the coastal regions of tropical countries like India, which are often exposed to different type of natural hazards. Violating the coastal resource zone (CRZ) norms, change in land use practices and increasing growth of built-ups promoting tourism are occurring in the no development zone (NDZ) within the CRZ areas of Purba Medinipur district, West Bengal. To map and analyze the drivers making the coastal tract of this district more susceptible for disaster, encroachments with land use types were mapped and associated impacts were analyzed. GIS and Remote Sensing techniques were used on the downloaded Landsat ETM+ satellite and Google earth images of 2005, 2010 and 2015 to envisage changes in LULC types at every 5 year interval. The combination of moderate and high-resolution data (Landsat ETM and Google earth Image) provided detailed coastal land use maps at a classification accuracy of ≥93% on the 1:25,000 scales for implementing coastal regulation measures. An analysis of the images with the field data revealed 3.41 % area growth in aquaculture ponds, 13.91% area decrease in agricultural land, 1.51 % area decrease in plantation and 5.28 % area growth in the rural built-up. Moreover, 15.34% encroachment of CRZ was found for recreational activities. A negative correlation between cropland and aquaculture influenced increase in aquaculture and decrease in agricultural productivity. Similarly, the negative correlation between rural settlement and agricultural plantation influenced increase in rural settlement and decrease in agricultural plantation. In NDZ areas, massive growth of beach resorts (11% - 69%) was observed and except Digha, perceptions of owners of hoteliers in Sankarpur, Tajpur and Mondermoni on disaster preparedness were evaluated not serious. Thus, high resolution remote sensing data adequately supplemented with field data can be instrumental to quantify the violations in the coastal zone.

Index Terms **- Coastal Regulation Zone (CRZ); Land use/Land cover (LULC); No development Zone (NDZ); GIS; Remote Sensing**

I. INTRODUCTION

Environment management is essential to prevent the natural disaster and for well-being of the humans and other biological organisms. Increasing human demand is the key factor for economic development of a nation that marks the growth and progress of that nation (Twumasi et al. 2006). The ecological smash up causes irreversible reactions on the environment and may cause major threats for survival of flora, fauna and the human community. The rapid growth inhuman curiosity and developments based on the unscientific principles obviously has an adverse effect on the nature's ecological balance. The diverse coastal ecosystems are productive and provide valuable goods and services. They play crucial role in social, political and economic development of many countries. Flooding, erosion, accelerated sea-level rise and increased human induced changes are few observed threats to the coastal environment. Over years, numerous coastal defence structures have been constructed in response to the different threats. These structures brought the dramatic changes to the coastal environment to which the little attention has been paid (Airoldi et al. 2005). The coastal stretch of Bay of Bengal and the adjoining Andaman Sea accounted for more than 60% of all deaths due to storm surges that have occurred already in the low-lying coastal areas. The coastal floods associated with the storm surges cause huge loss to life and property both. Although settlements in the coastal low lands are vulnerable to several natural hazards, yet these areas are growing rapidly and getting densely populated. A global review on the population and urban settlement patterns in the Low Elevation Coastal Zone (LECZ) was done and it was found that it covers 2% of the world's land area, 10% of the world's population and 13% of the world's urban population (Mc Granahan, 2007). For rising tides prevailing risks to the climate change and human settlements in the LECZ, proper understanding on the coastal zone processes and resources is of utmost concern. Over the years, the coastal zones have been exploited greatly by the human for establishment, industry growth, resource extraction, tourism and urbanization. The unsustainable exploitation of the coastal resources in various forms has brought a multitude of negative impacts such as improper industrial and human waste management, accelerated erosion and deposition, eutrophication, destruction of marine life and overall decrease of bio-diversity (Fabbri, 1998). The coastal regulation zone (CRZ) notification issued to conserve and protect coastal stretches, its environment and marine area and promote development activities for ensuring livelihood security to the communities living in the coastal areas on sustainable basis based on the scientific principles by taking in consideration the dangers of natural hazards, restricts setting up and expansion of any industry, operations or processes and manufacture or handling or storage or disposal of hazardous substances. Review of literatures has evidenced that land-use and land-cover changes not only affect the global climate system but also climate at local and regional scales through biogeophysical, biogeochemical and energy exchange processes. Thus, the changes in land-use/ land-cover (LULC) occur due to rapid growth of population, urbanization and tourism developmental activities. These changes increase the demand for land resource such as agriculture, minerals, soil and water, without considering environmental

sustainability (Kaliraj et al. 2017). A large scale strategic level method has been developed to facilitate policymakers for coastal land use management by considering climate change and the implications of sea-level rise in the floodplain areas (Brown, 2006). In India, the human population is increasing rapidly due to which, there is a conspicuous effects on the available natural resources. To investigate the conspicuous effects on the coastal resources in the coastal blocks of Purba Medinipur district, West Bengal, India, the present study discusses the changes occurred in the different land use types, and impacts due to expansion of human settlements, encroachments and conversion of land use types. Additionally efforts were made to analyse the density of built-up developed for tourism purposes in the NDZ within the CRZ areas along with the perception of their owners regarding disaster preparedness. Landsat ETM+ satellite and Google earth images of 2005, 2010 and 2015 were used to perform above said works using the GIS and Remote Sensing techniques. GIS and Remote Sensing is a viable technique for managing, mapping and analyzing the georeferenced satellite data. These systems have ability to provide information on the spatio-temporal structure and relationships of variables in the source data sets. The major advantage of remote sensing data is monitoring of changes that occur in the area periodically. It helps immensely to resolve some of the disputes related to implementation of regulations in the coastal zone. The acceptability of satellite based information on CRZ is by both the executive and judicial authorities. Now, it is almost essential for all the industries, governmental as well as non-governmental agencies to use the satellite-derived information for coastal regulation zone activities. Realising the value of remote-sensing derived information, the state and central agencies responsible for the implementation of CRZ are increasingly adopting remote sensing data for their routine use.

II. Materials and Methods

2.1 Study Area:

The present study includes the coastal block of Purba Medinipur district, West Bengal covering parts of Ramnagar-I & II, Contai-I and Deshopran blocks, extending from 87o28'57"E to 87o53'15"E longitude and 21o36'40"N to 21o53'37"N latitude. The coastal stretch of this district constitutes part of the meso-tidal Balasore-Contai coastal plain characterized by the presence of successive rows of dunes and beach ridge with intervening clayey tidal flats due to the fluctuations in the sea level during the Holocene time (Goswami et al. 1989). The ancient dune belt extending from Paniparul to Contai from west to east indicates the position of the ancient strand line (about 6000 Y.B.P.) in the coastal tract of West Bengal (Chakrabarti, 2010). There are several discrete tidal creeks in the coastal tract of this district viz. Ramnagar Khal, Jhalda Khal, Pichaboni Khal. These tidal creeks physically divide the Medinipur coastal plain (Digha-Junput) into four sectors viz. Digha, Shankarpur-Chandpur, Dadanpatrabar and Junput from west to east (Fig.1). The district experiences a sub-tropical hot and humid climate without any extremities due to its proximity to the sea. In summer, the monthly temperatures rise to a maximum of 39°C (April) while in winter, the temperatures drops to a minimum of approximately 9°C (January) (2014). The average annual rainfall is 1729 mm (2014) (BAES, Govt. of West Bengal 2014) and the wind speed is very high owing its proximity to the coast. The average wind velocity is from 15 to 26 km/hr. The south-westerly wind is dominant from March to September and on the contrary during rest of the year, north and north-easterly wind prevails. The cyclonic storms mainly occur in the coastal areas of the district during the pre and post monsoon seasons. In the low lying areas of the coast traversed by the tidal rivers and creeks, it is necessary to raise embankments called as bheris to keep out the salt water (O'Malley, 1995). In this area, the coastal plain is a predominantly mono-cropped area with double cropping practiced in patches. The betel vines are grown on the black clayish soil in the gardens called 'baraj'. Pisciculture is the main occupation and the people living in the coastal tract are well engaged in fishing and prawn culture. There is enough scope for horticulture by planting cashew and coconut along the banks of the tidal creek in these costal belts. The local specific changes in the LULC pattern may be one of a factor in changing the socio-economic condition and infrastructural development e.g. conversion of cultivable land/salt pan for brackish water fish farming especially for prawn cultivation in the coastal belt. Though this practice fetches easy money, but increases salinity in the surrounding fields and causes long lasting water logging situation during high flood time (Chakrabarti, 2002). There is a lot of human pressure on the coastline due to urbanization, industrialization, aquaculture and agricultural activities. Apart from increase in the salinity of coastal aquifers, changes in the sea level, coastal configurations due to mining activities and impact of the natural calamities like floods, tsunami and earth quake are other problems in this area. Many agricultural lands have been converted to aquaculture and coastal beaches to built-up for recreational activities.

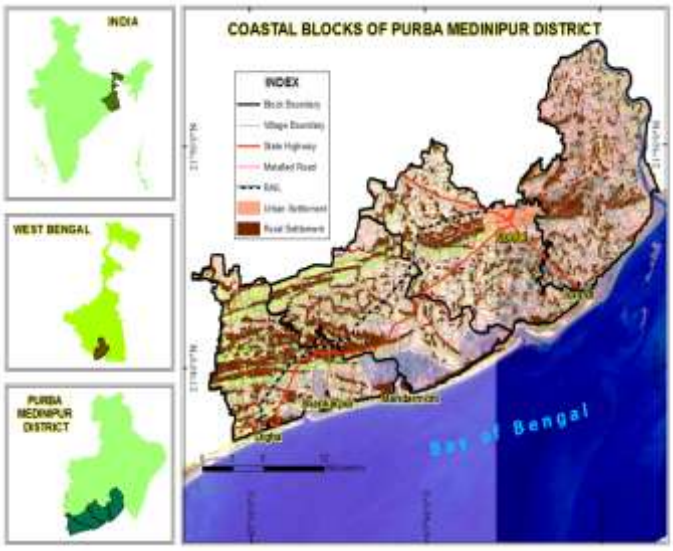

Fig.1. Coastal block of Purba Medinipur district, West Bengal covering parts of Ramnagar-I & II and Contai-I & Deshopran blocks

2.2 Methodology for satellite data analysis

The detailed methodology in the form of flowchart to find the changes in LULC types and assess the impact due to these changes using the different data sources of 2005, 2010 and 2015 years has been well illustrated in Fig.2. The steps as illustrated in this figure are explained below.

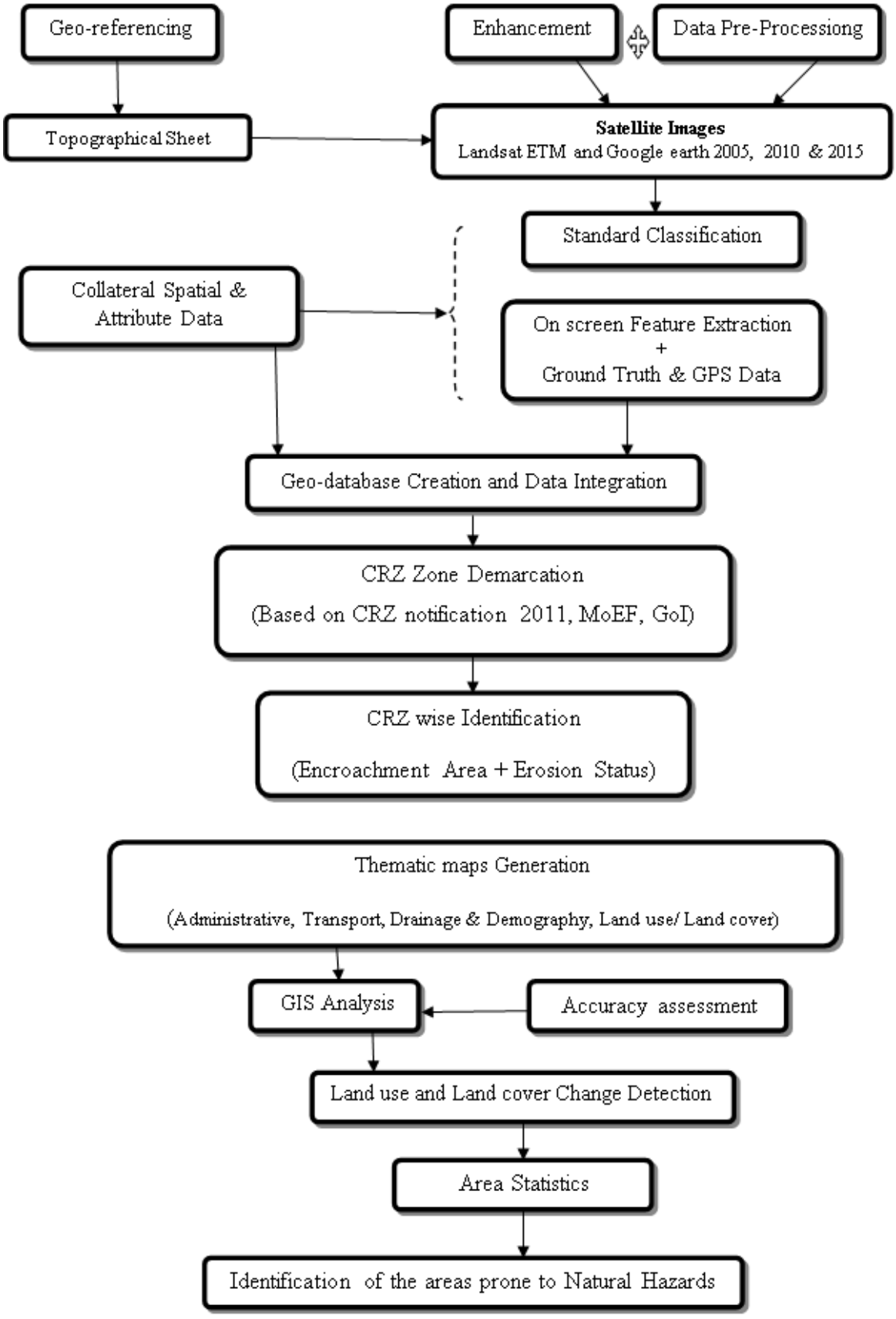

Fig.2. Flowchart of the methodology followed in mapping the drivers of coastal vulnerabilities, Land use/ land cover change detection and identification of areas prone to natural hazards

2.3 Data collection and registration of images

Firstly, toposheets of the study area were collected from Survey of India (SOI), digitized and geo rectified since the accurate geometric corrections and referencing are the indispensible prerequisites to do the change detection analyses using the satellite data. Without this, the results will lose its reliability and analysis will fail to determine the changes accurately (Saha et al. 2005). Thereafter, the geometrically corrected Landsat ETM+ images for 2005, 2010 and 2015 years for the study area were downloaded. The high resolution Google earth images of the study area for 2005, 2010 and 2015 years were used supplementary for interpretation of the Landsat ETM+ images. For image interpretation and observe changes, the Landsat ETM+ images of the above said years were geometrically rectified further using 100 well scattered and distinct GCPs selected from the geo rectified toposheets of the study area. It is worth to mention here that the selection of GCPs was restricted only to the land surface because the water mass cannot be used for GCPs selection. All the transformed images were projected in Universal Transverse Mercator (UTM) projection (WGS 84, zone: 45 North).

2.4 Digitization and preparation of vector layers

ArcGIS desktop environment was used to digitise the sharp shorelines and LULC features in the polygon feature class (Mitra et al. 2013). The multi date shorelines representing LULC layers for 2005, 2010 and 2015 years were prepared. To do this, the on screen feature extraction was used, which is still one of the most widely used methods for detecting, identifying and characterizing the spatial features on an image since human brain is a good interpreter of images. The satellite data of 2005, 2010 and 2015 years were interpreted to identify the changes in LULC based on the visual interpretation keys and Google earth images of these years. All the interpretations were finally verified with the ground truth survey done using GPS. After field survey, the pre field data was updated and collated with the field data. The different thematic maps were generated using pre field and field survey data both.

2.5 Accuracy assessment

The number of reference pixels is one of an important factor in determining the accuracy of the classification. Accuracy assessment for 2015 thematic map for the study area was done using 150 ground truth points recorded during the seven day field visit in September 2016. To assess the classification accuracy, a standard error matrix was created using the data from the output map as rows and the reference data (ground truth points) as columns. To measure the improvement in the classification over a random assignment of pixels, the Kappa and Tau coefficients with 95% confidence intervals were calculated for assessing the significant differences.

2.6 Change detection analysis

An increasingly common application of remotely sensed data is the change detection. Change detection is a process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). Change detection is an important process in monitoring and managing natural resources and urban development because it provides quantitative analysis of the spatial distribution of the population of interest. Change detection is useful in diverse applications such as land use change analysis, monitoring shifting cultivation, assessment of deforestation, study of changes in vegetation cover, seasonal changes in pasture production, damage assessment, crop stress detection, disaster monitoring, day/night analysis of thermal characteristics as well as other environmental changes (Singh, 1989). Thus, all the generated thematic maps of LULC types of 2005, 2010 and 2015 years were converted to raster and change detection analysis was done by using these raster maps in the ArcGIS environment (Santhiya et al. 2010).

III. RESULTS

3.1 Categorization of CRZ and NDZ

CRZ notification first introduced in 1991 using the provision of the Environment Protection Act (EPA), 1986 changed throughout several times and finally reintroduced in 2011 named as Coastal Regulation Zone (CRZ) notification, 2011categorizes CRZ into four categories based on the coastal environmental and ecological sensitivity to regulate development activities in the coastal areas. According to the data obtained from Digha Shankarpur Development Authority (DSDA) for Old Digha, New Digha and Shankarpur most of the hotels, commercial sectors, hospitals, other public offices and waterworks fall under CRZ III category (Fig.2). New Digha, Old Digha, Shankarpur and Tajpur are the tourist hubs and these places are the NDZ areas in the Ramnagar – I coastal block categorized as CRZ III area. Mandermoni is again the NDZ area in the coastal block of Ramnagar –II coastal block categorized as CRZ III area promoting the tourism hub (Fig.3).

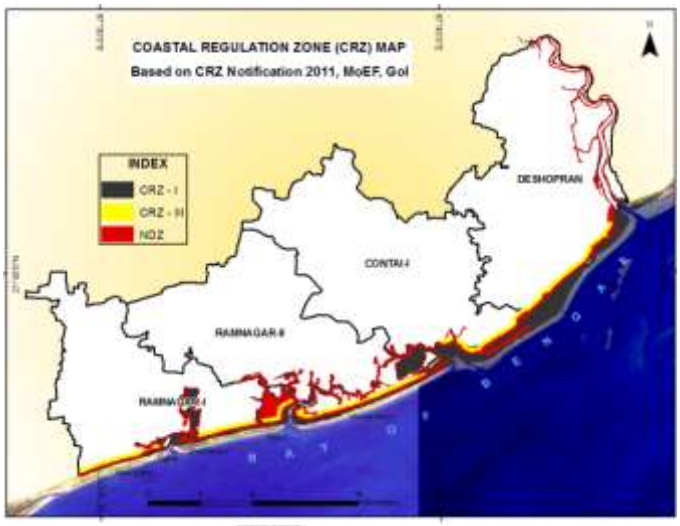

Fig.3. CRZ and NDZ areas in the coastal blocks of Purba Medinipur district

3.2 Human population growth analysis

To analyse the human population growth in the coastal blocks of Purba Medinipur, the census data published by Government of India from 2001 to 2011 was used, digitised, mapped and analysed in the ArcGIS environment. The different clusters of population were created to represent the population index from low to high and during these periods, an appreciable growth in all the four coastal blocks of this district categorised already as CRZ-III areas was found (Fig.4).

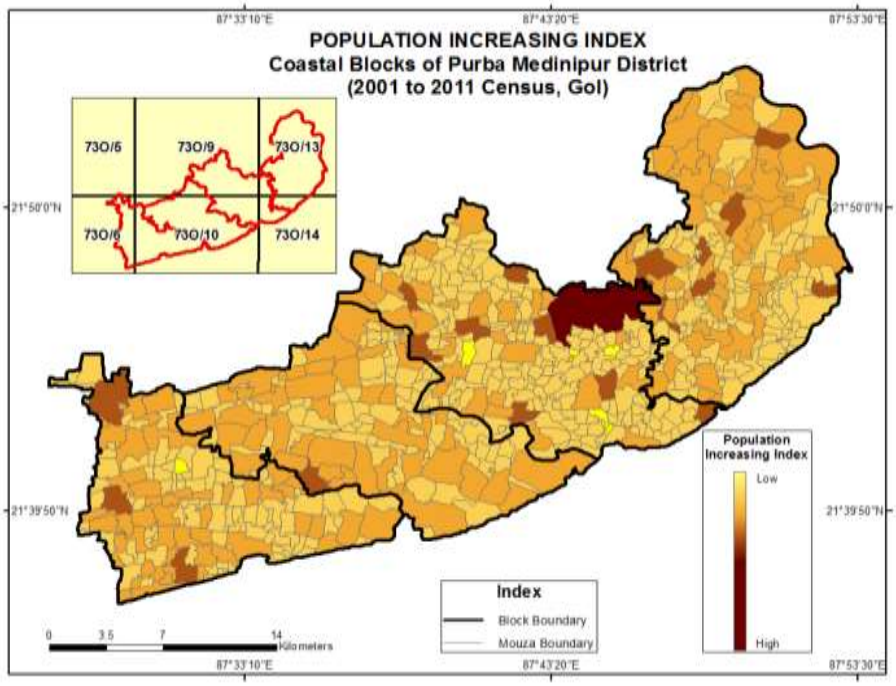

Fig.4. Population index map of the coastal blocks of Purba Medinipur district

3.3 Aquaculture growth analysis

To assess the aquaculture growth activities in the coastal blocks of Purba Medinipur, the polygon feature vector layers of 2005, 2010 and 2015 years representing the aquaculture areas were overlaid and analyzed in the ArcGIS environment. An appreciable growth in the aquaculture practices was observed over the years in all the four coastal blocks categorized already as CRZ- III areas. It was found that more number of culture areas in different locations have come up to promote the aquaculture activity (Fig.5).

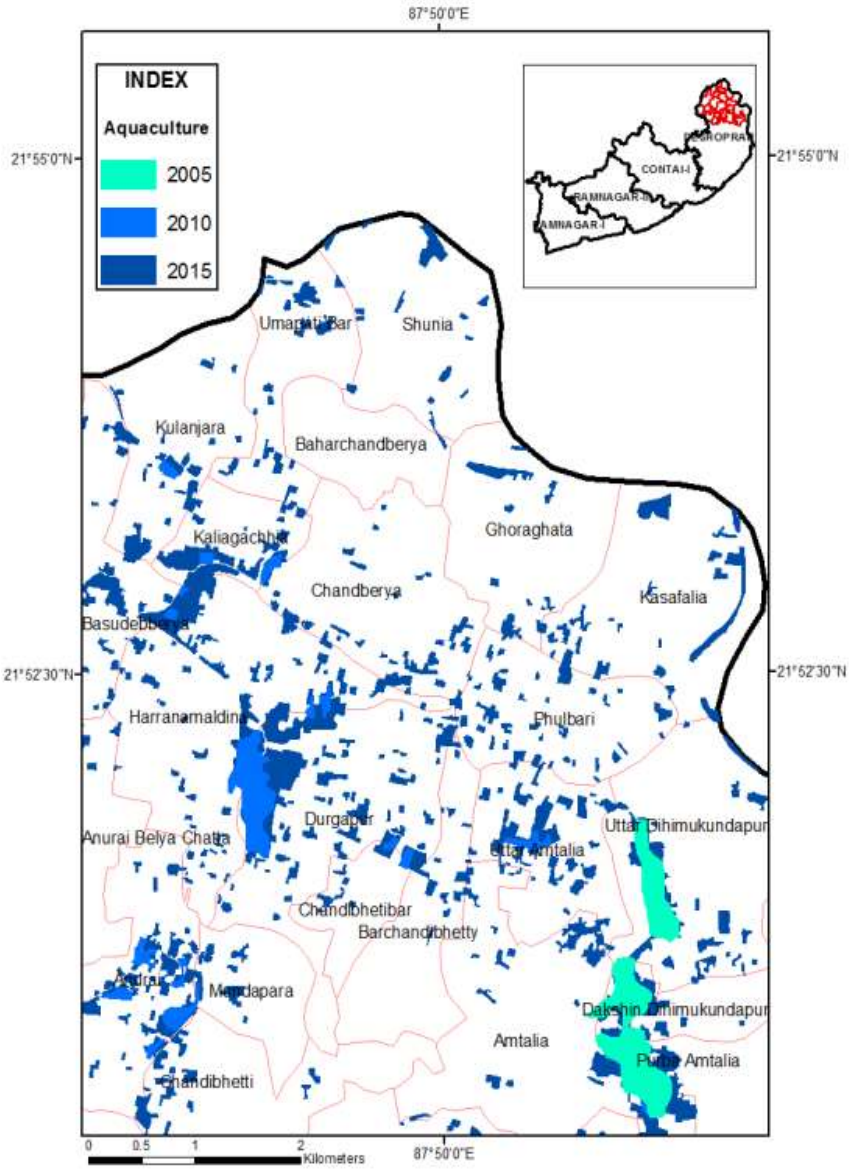

Fig.5. Aquaculture growth map for the coastal blocks of Purba Medinipur district

3.4 Status and implications of encroachments and erosions:

The sea beaches adjacent to Digha categorized as NDZ are gradually developing as tourist spots and the sea beach erosion is causing retreat of shoreline gradually. As a result of which the people and place both are in danger. In the sixties of the last century, the sea beach at Digha was surveyed by River Research Institute (RRI), West Bengal. According to RRI, comparison between the past and the recent survey (2008-09) revealed the considerable change due to imbalance between erosion and deposition during this period. However, some coastal protection works were undertaken but in some parts, this protection failed. Encroachment in the CRZ of the study area was found for different activities. Almost 15.34% encroachment of CRZ was found for recreational activities. Tourism and environment are two interactive components in this area and between them, there is a complex interaction. Tourism has large impacts on the environment, which can be positive or negative. The vast expansion in the tourism activities creates the complexities in the environment. The uncontrolled conventional tourism growth often leads to the deterioration in the environment due to impose of enormous pressure. Environmental issues affecting the coastal ecosystems in the study area is an important consideration in resource planning decisions. Geological Survey of India reported that Digha coastal belt is suffering from an active process of erosion and accretion often accelerated by man-made interventions, removal of sand dunes, mushrooming construction near the coast, continuous dumping of solid wastes and raw sewage in the coastal water. The beach from Digha to Dadanpatrabar is under severe erosional threat due to cyclonic storms, waves, tides, long shore drifts and by human activities such as construction of hotels, diminishing the sand dune, destruction of dunes for open sea vistas and sand transportation (Hazra et al. 2011; Chakraborty, 2010). The discharge from hotel sewage in the embankment disintegrates the base materials, disrupts stability and thereby creates pollution. Review of literatures have evidenced that in the recent times, because of increasing population growth, scaling and upcoming of various industries, mining, fishing, industrial waste effluents, discharge of municipal sewage and different natural factors, the coastal environment is degrading and leading to the coastal hazards. The various other alarming type impacts of tourism were also noticed. Thus, there is an exigent need to protect the coastal environment and habitat both.

3.5 Standing of LULC

The LULC pattern depends on the human usage in terms of natural and socio-economic development through space and time. In other words, the land use changes have the ability to affect the land cover and vice-versa. The shifting into possible negative impact through land use perspective for social activities is affecting the land cover to change, especially in biodiversity, water and earth radiation, trace gas emission and other processes, which come together to affect the climate and biosphere. These changes are commonly attributed to the population growth in terms of size and pattern. The increasing population growth directly and indirectly contributes to changes in LULC, especially from the perspective of demand for built-up area, agricultural activities and water resources. The ecological expertise is very concerned with LULC changes that impact biodiversity and aquatic ecosystems. LULC pattern of this area has undergone many changes over the past 10 years. These changes may be attributed primarily to the increasing demand for land resources in order to derive maximum economic benefit. For instance, the uncertainties on agricultural productivity due to vagaries of the nature have led many farmers to seek higher returns from other sectors such as aquaculture and pisciculture. This has led to the large scale conversion of fertile agricultural land to aquaculture ponds (Fig.6 and 7). Moreover, presence of numerous tidal creeks, extensive mud flats and canals have favored the recent spurt in aquaculture practices in this region. To investigate the changes in LULC types correctly over years, the accuracy assessment of the generated LULC data set for 14 land use categories was done using the Kappa statistics in the ERDAS Imagine environment. The Kappa coefficient is a measurement of classification accuracy for all elements in the classified image (Yang et al. 2001; Foody, 2010; Coppin and Bauer, 1996; Viera et al. 2005). The accuracy assessment for different land use categories carried out using Landsat ETM+ and Google images of 2005, 2010, 2015 years is presented in Table3.1. From this table, it is evident that the classification accuracy for all the 14 land use categories in 2005, 2010 and 2015 years were more than 90%, which is an appreciable result to justify the changes in different land use types and report on the area statistics of these land use categories over years. Table3.2 presents percentage of area covered by 14 land use categories in 2005, 2010 and 2015 years and present area percentage of crop lands converted for aquaculture practices in these years. From this table, it is evident that the aquaculture practices and settlements in the study area are growing rapidly over the years.

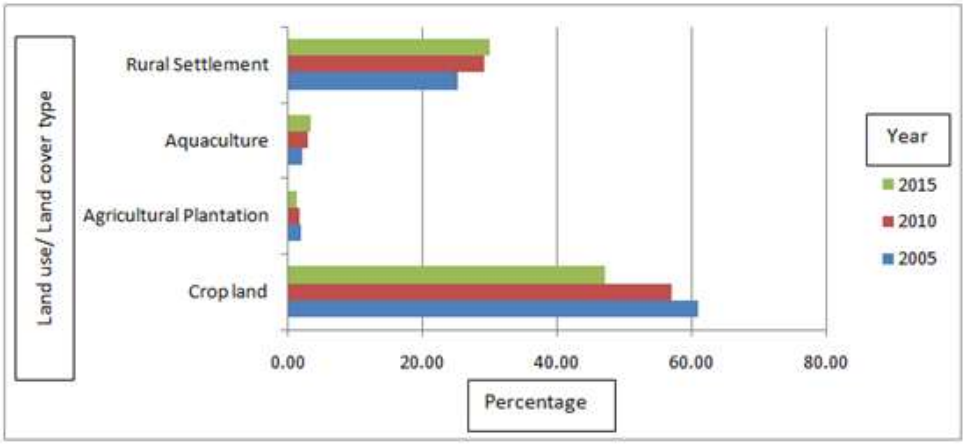

Fig.6. Percentage area covered by rural settlement, aquaculture, agriculture plantation and crop land in 2005, 2010 and 2015

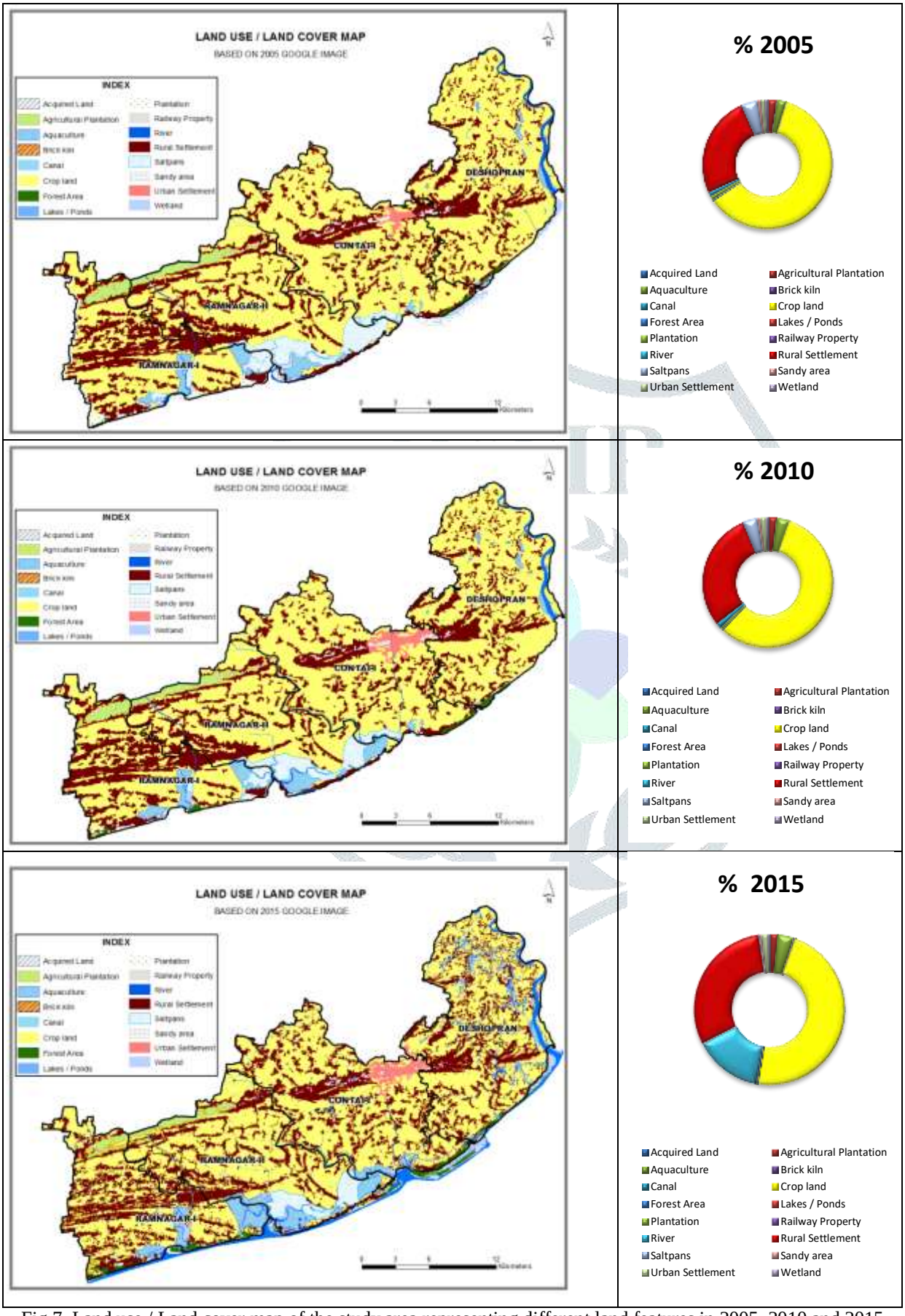

Fig.7. Land use / Land cover map of the study area representing different land features in 2005, 2010 and 2015

Table 3.1 Accuracy assessment result of different land use categories in 2005, 210 and 2015 years

Land use categories	2005 Overall Classification Accuracy	2005 Overall Kappa Statistics	2010 Overall Classification Accuracy	2010 Overall Kappa Statistics	2015 Overall Classification Accuracy	2015 Overall Kappa Statistics
Agricultural Plantation	92.42%	0.9206	92.50%	0.9221	93.33%	0.9151
Aquaculture	93.94%	0.9375	93.94%	0.9375	91.67%	0.8173
Brick kiln	91.18%	0.9077	91.30%	0.9092	90.91%	0.8066
Canal	92.98%	0.9251	91.95%	0.9162	92.00%	0.8879
Crop land	91.80%	0.9130	93.41%	0.9318	94.44%	0.9067
Forest Area	95.56%	0.9236	92.71%	0.9228	93.75%	0.9099
Lakes / Ponds	91.46%	0.9107	91.03%	0.9067	93.48%	0.9303
River	92.86%	0.9172	94.52%	0.9429	91.30%	0.9092
Rural Settlement	91.95%	0.9162	91.67%	0.9060	91.95%	0.9162
Sandy areas	91.46%	0.9103	91.84%	0.9131	90.67%	0.8927
Salt pan	90.91%	0.9050	92.16%	0.9167	93.41%	0.9318

Table3.2 Area in percentage covered by the different land use categories

Land use/ Land cover Categories	% Area 2005	% Area 2010	% Area 2015
Acquired Land	0.16	0.09	0.04
Agricultural Plantation	2.10	1.92	1.51
Aquaculture	2.24	3.10	3.41
Brick kiln	0.10	0.09	0.40
Canal	0.11	0.14	0.14
Crop land	60.97	56.93	47.05
Forest Area	0.27	0.26	0.20
Lakes / Ponds	0.08	0.05	0.03
Plantation	0.96	0.47	0.19
Railway Property	0.01	0.01	0.32
River	1.13	1.42	14.27
Rural Settlement	25.28	29.16	30.07
Saltpans	4.00	3.63	0.19
Sandy area	0.92	0.81	0.40
Urban Settlement	0.94	1.27	1.27
Wetland	0.73	0.65	0.50

3.6 Correlation analysis of LULC

The correlation analysis between cropland and aquaculture and between rural settlement and agricultural plantation showed negative with respect to each other. Increase in the aquaculture practices reduced the agricultural productivity and increase in the rural settlement resulted decrease in the agricultural plantation. Table3.3 presents year wise correlation statistics of 4 land use categories. The natural hazards and changes in LULC have significant impacts on humans around the world and if these two concerns exist together in the coastal area, the consequences for people and the environment may be severe. This study investigated the combined effects of land use changes and natural disasters in the coastal area of Purba Medinipur district, West Bengal.

Table3.3 Year wise correlation statistics of crop land, agriculture plantation, aquaculture and rural settlement land use categories

Year	Crop land	Agricultural Plantation	Aquaculture	Rural Settlement
2005	60.97	2.10	2.24	25.28
2010	56.93	1.92	3.10	29.16
2015	47.05	1.51	3.41	30.07

3.7 Impact assessment and analysis of tourism entrepreneurs

The occurrences of coastal hazards are unpredictable. There are two main categories of coastal hazards *viz.* natural and man-made disaster (Gunasekera, 2004). The human life and properties in the coastal zones are insecure when the coastal hazards arise. The construction in the coastal zone especially in the NDZ areas is extremely detrimental to the devastation by powerful storm and flooding. In recent and past, several powerful storms originated in the Bay of Bengal and directed to the West Bengal coast and Bangladesh coast both. The frequent occurrences of such storms have made the West Bengal coast more vulnerable and a disaster prone zone. A number of newspapers have reported recently about the growth of tourism hubs in the Bengal coastal belt (like Digha, Shankarpur, Tajpur, Mandermoni and Junput) and along the coastal belts of West Bengal (Fig.8). Thus, the development processes along the coastline by violating CRZ norms to promote tourism are in process (Sayanl et al. 2007). To quantify the perception level of the tourism entrepreneurs operating in the NDZ areas *viz.* Digha, Sankarpur, Mandermoni, Tajpur and Junput, an analysis was done. It was found that hoteliers in Shankarpur, Mandermoni and Tajpur are not serious on disaster preparedness while 47.56 % hoteliers in Digha are serious on disaster preparedness. As per Indian Meteorological Department, the east coast of our country is highly prone to cyclones and from 1891 to 2010. The Medinipur district in West Bengal witnessed 22 cyclones of which 10 were severe in nature. Such storm surges are one of the biggest killers during cyclones. The highest storm surge recorded was around 30 meters high. Thus, the entire coastline gets affected by varying frequency and intensity of occurrence of such storm surges.

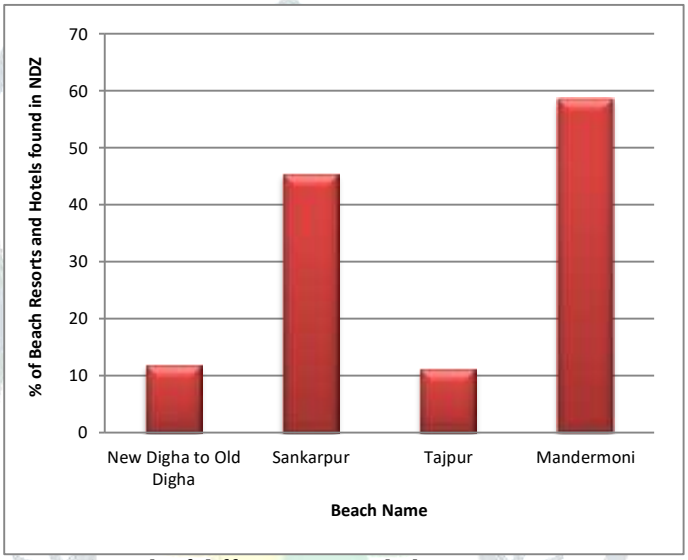

Fig.8. Growth of different tourism hubs in NDZ areas

IV. Discussions

LULC study in the coastal areas is not new in developing countries like India and considerable work has been done. The impacts of climate change and occurrence of natural disasters are of particular concern in the coastal regions. In the present study, the increasing human population, encroachments in the coastal beaches and change in land use practices through conversion of land types are the prime concerns for climate change and occurrence of natural disaster. Worldwide, in many coastal regions, these interventions are also prominent causing widespread environmental problems and thus needs to be mapped and analyzed. In the coastal Regions of Cape Coast and Sekondi, Ghana, analysis of land-use and land-cover indicated that human habitation and increasing activities by human, in this case forest degradation and sand mining were the prime concerns for changes in LULC (Dadson, 2016). This study justifies the work done in the present study because increasing human habitation and different type of interventions by the human beings in the NDZ areas have been noticed as one of the major factor for degradation of coastal environment and services. Further, the Yunlin coastal zone in Taiwan also suffered from substantial land use changes with significant loss of sandy coast on the shoreline due to dramatic increase of industrial and residential area. The study indicated that human induced coastal land use changes do exist in Yunlin and for the last sixteen years, Yunlin shoreline has undergone both erosion and accretion position changes (Lo et al. 2014). The changes in the NDZ areas of different coastal blocks of Purba Medinipur district are also the human induced changes and shorelines in these areas have undergone both erosion and accretion position changes. Later efforts were made to assess the vulnerability of coasts in India at different levels and regions closer to the coastlines were found highly vulnerable regions. Further in the 1940 session of the Indian Science Congress held at Madras, points were raised on the necessity of undertaking the land use survey in India on the district of 24 Parganas, Bengal in 1945. The time series analysis of LULC changes of this area for the period 1986-2009 reveals a virtual disappearance of the mangroves of Namkhana Reserve Forest. This study was conducted to establish the temporal changes of coastline/shoreline and coastal LULC along the coastal tract between the borders of Orissa to the Jaldha mouza of Digha Development Planning Area. Our study provides changes in the coastal LULC part from nature and characteristics of coastal zone of Digha planning area for management and development of tourism activity. Due to increasing population pressure, the construction and development of settlements are growing, which is one of the major reasons of LULC changes. Further the study indicates 3.41 % growth in aquaculture ponds,

13.91% decrease in agricultural land, 1.51 % decrease in plantation, 5.28 % growth in the rural built-up areas and 15.34% encroachment of CRZ for recreational activities, which are quite alarming. In addition to these changes, the shifts into the activities like from agriculture to aquaculture practices and agriculture plantation to settlements are the other major concerns for erosion and shifting of the shoreline in the study area.

Beside changes in LULC patterns due to human induced changes in the study area, the other illegal activities like unauthorised encroachments and constructions were made within reserved forests by the third respondent that violates the provisions of Section 2 of the Forest Conservation Act, 1980. The construction of jetty, bridges and road, leading to the jetty, violates the provisions of the Coastal Regulation Zone Notification dated 19-2-1991, issued under Section 3 of the Environment (Protection) Act, 1986. In spite of following the proper authoritative procedures and norms of the CRZ notification, it is alleged that the 3rd respondent constructed the jetty, bridges and portion of the road, leading to jetty. On these averments, it was prayed that State Government may be restrained from granting any lease or right to the third respondent over lands falling within reserved forests without complying with Section 2 of the Indian Forest Conservation Act, 1980 and to restrain the 3rd respondent from carrying on any construction of the jetty, road or bridge in any portion, which falls within the Coastal Regulation Zone Notification. Besides, massive growth of beach resorts from 11 to 69% in the NDZ areas were detected in the study area. Additionally, the district administrative authorities of Kerala, India detected many instances of encroachment by hotels and restaurants on Samudra, Grove, Eves' and Light House in the Kovalam beach resort of Kerala, India violating the Coastal Regulation Zone (CRZ) norms. Thus, the draft development plan 2034 is not only filled with errors and significant omissions, but also has proposed regularization of encroachments in the eco-sensitive coastal regulation zone-I (CRZ-I) areas. Most of the Mumbai's CRZ-I areas have a massive growth of mangroves which protect the coast from erosion and these mangroves have been declared as forests by the state government.

Occurrences of the coastal hazards are very much unpredictable in the coastal areas. The changes in LULC pattern, encroachments, increasing human population pressure, more demand of natural and bio resources and ineffective regularization of encroachments in the eco-sensitive coastal regulation zone are few concerns for occurrences of coastal hazard in the coastal areas. Therefore, preparedness on coastal hazards is important. Except Digha, the hoteliers in other NDZ areas *viz.* Sankarpur, Mandermoni and Tajpur are not serious on the preparedness from the natural disaster. The beach resorts and hotels came up in the highly disaster prone NDZ areas makes the area much more vulnerable and alarming for disaster. In terms of CRZ violations after Maharashtra with 435 cases, the West Bengal accounted for 151 cases stands second. The Andhra Pradesh accounts for 126 cases, Andaman and Nicobar Islands for 104, Karnataka for 69 and Kerala for 45.

V. Conclusion

Realizing the value of the remote-sensing derived information, the state and central agencies are increasingly adopting remote sensing data and GIS techniques for their routine use in resource planning decisions and management of the natural resources. This study used the same techniques to derive the information on coastal resources and analyze the impact of drivers vulnerable to coastal resources. The use of temporal satellite data for the study areas has provided information on changes that occurred in the coastal areas over a period of time. In the study, efforts were made to document and map the critical habitats, CRZ boundary, land use/land cover, developmental activities (mainly tourism), growth of settlements etc. in the coastal regulation zone to provide the baseline information for planning, monitoring and management of the coastal resources. The combination of moderate and high-resolution data (i.e. Landsat ETM and Google earth Image) provided detailed coastal land use maps at a classification accuracy of ≥93% on the 1:25,000 scales for implementing coastal regulation measures. High spatial resolution satellite data plays an important role in updating and monitoring the developmental activities in the Coastal regulation zone at low cost, manpower and time. The high resolution remote sensing data adequately supplemented with field data can be instrumental to quantify the violations in the coastal zone.

It is well known that the prospect of any tourist area largely depends on the regional inter-connections and efficiency of the tourism related facility system. All the coastal resorts in West Bengal under study are waiting for disaster which is almost inevitable. If the present situation continues, tourism would appear as blight in the long run, particularly with the onset of a disaster in the study area. Finding out the gap area of existing infrastructure extending the facility in well-organized plan is the main solution that can prevent the disaster. Additionally, the Bay of Bengal coast is more prone to cyclonic storms, which probably occurs 2 to 3 times in a year. Any construction in the coastal zone (NDZ areas) based on unscientific principles is extremely detrimental to the devastation by powerful storm and flooding. The study area is occupied by numerous hotels and holiday homes and being used for commercial purposes especially tourism. Almost 15.34% encroachment of CRZ was found for recreational activities. According to CRZ norms 2011, NDZ area is strictly prohibited for any type of development. Satellite image analysis showed vast development in this prohibited zone and vast changes in LULC over a period of 10 years (2005-2015). The regression analysis revealed the relationship between various disasters with changes in land-use/ land-cover and encroachment in the CRZ areas. The rural built-up area increased by 5.28 % due to change in land use activity, is an encouraging result for occurrence of natural disaster. Thus, frequent changes in LULC due to on-going development activities in the prohibited zone based on unscientific principles is making the coastal belt of West Bengal more vulnerable to disaster.

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