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"MAPPING BEACH RIDGES COMPLEX WITH GEOSPATIAL TECHNIQUES, JATADHAR MUHAN CREEK, ODISHA, INDIA"

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Abstract:

The beach ridges around Jatadhar Muhan Creek (JMC)are recently in news because the POSCO wants to acquire nearly 4000 acres of land near nearby (a place where nine rivers' of the district debouch in to the sea, and a place which provides foods and earning to nearly 10,000 fishermen) to build captive port for export of minerals. These beach ridges are prolonged accumulation of littoral deposits parallel to shoreline created by the combined action of storms, waves, currents and tides. There is a need for analyzing and assessing these geomorphic landforms before these are transferred for construction of built environment. The purpose of this paper is to map, interpret the coastal geomorphic landforms and also analyze the character and conditions of beach ridges around Jatadhar Muhan Creek. The methodology used is field survey using Trimble Pro-XT DGPS, detailed mapping of coastal landforms using visual interpretation of satellite imagery and cross validation using ancillary data and post filed surveys. The map analysis and the field observations show that the zone of beach ridge complex morphology were reworked by coastal processes in short span of time. These transformations were in form of set of inner beach ridges and swales with parallel alignment to coastline showing signature of progradation process in old frontal system.

Key Words: ***Beach Ridge Complex, Prograding Coast, Swales, Jatadhar Muhan Creek and Sand spit.***

Introduction

The Odhisha coast, known for its long coast line and diverse biological and natural resource is at risk from a wide range of environmental and human induced hazards. Natural hazards such as cyclones, floods and droughts have caused widespread environmental degradation and human deaths. Besides, burgeoning population stress, environmental conflicts and increased agricultural and industrial activities have led to depletion of natural vegetation cover, over exploitation of ground water, erosion of bio-diversity and salinization of soil in the coastal zone. The lack of adequate reference to other user groups has led to many cases of conflicts between different sectors. As each user group has already under intense pressure, but by adopting artificial boundaries lead to conflicts between these groups into more bitter and intractable conflicts. The coastal processes in this region play major role in transformation of the local configuration of this transition zone. These transition zones between land and sea is highly complicated phenomena with beach ridge, beach ridge plain, relict foredune and plain, cheniers and other shore parallel/ sub-parallel ridge features resulted from processes at different time and space (Larson and Kraus, 1995; Taylor and Stone, 1996; Hesp, 2005). These ecological sensitive coastal features are under development pressures require in depth understanding of morphodynamics of geomorphic feature in the region. Therefore, study of the transition zone arising out of interaction of physical processes and the socio-economic fabric demands an integrated and interdisciplinary approach to the direction of change. The scientific knowledge that that coastal resource are diminishing force the need to compile inventories and information systems that will able provide sustainable solution to manage the fragile resources (Kempka et al., 1991; Trotter, 1991; Welch et al., 1992; Ji et al., 1992b; Nagamani & Ramachandran, 2003). The geospatial techniques are effective and popular methods for analyzing and interpreting decadal coastal change studies in regional scale (Ehlers et al, 1991; Jensen et al., 1991; Johannessen et al., 1993; Schwartz, 2005; Maiti, & Bhattacharya,

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2009). These techniques integrated with field surveys can be modeling inputs for environmental sensitivity mapping, geological exploration, natural resource inventory, and urban development in coastal regions. Though great stride has been made in geospatial technology and field survey with Pro-XT DGPS but the cost of operation still remain quite high. Satellite imagery has created a possibility of reducing the initial data cost and help in creating digital information for coastal planner and manager. These integrated technique built on knowledge from geography, geology, computer science, cartography and mathematics offer possibility to support analysis, problem solving, planning, decision-making, and management of the coastal processes required to pursue integrated coastal zone management.

The geomorphic landforms which are signature of coastal processes around JMC are under stress of built environment may be the cause of erosive processes in coastal zone of Odhisha. The beach ridge complexes around JMC are formed by the hydrodynamic forces from both the creek and sea side's resulting to degradation and deposition in the region (Vaidyanadhan, 1991; NIO Report, 1998). These beaches are generally defined as broad barriers consisting of a series of intertidal ridges or bars alternating with low swales, which may number between 2 to 20 in a ridge set. The purpose of the study is to diagnose, model and manage of the dynamic zone of beach ridges around JMC using integrated geospatial technology.

Geologic and geomorphic setting of the study area

The Jatadharmuhan creek located between Mahanadi and Devi Rivers is a tidal creek having orientation in the NE-SW direction and situated south of Paradip port along east coast of India (Fig 1). It is surrounded by number of linear to curvy sand ridges on both sides with an orientation more or less parallel to the present shoreline. This portion can be interpreted as remnant of beach ridges where strong deposition has occurred with adjustment to the energy supplied by storms, wave tide and currents. The beach ridge complexes are surrounded by smaller tidal inlets which are built of silt and clayey sediments with a steep gradient (NIO Report, 1999). The steep gradient might be caused by erosional environment due to heavy wave breaking inside JMC. The coastal plains of Orissa are predominantly occupied by the Tertiary and recent alluvium.

The study area consists of plains made of Tertiary and Quaternary sediments deposited under fluvial, sea marginal and marine and aeolian environment. The various features observed are: wide extensive alluvial flood plains, natural levees, paleo-channels, active channels, recent and paleo-beach and beach ridges, tidal flats, mangrove swamps, spit bars and lakes **(**Mahalik, 1984). The area covered by different geomorphic features along the Orissa coastal plains studied by the Space Application Center (1992) is shown in Figure 2.

Data Sources

Topographic sheets of Survey of India No, 73L/8, and 73 L/12 (Table-1) on 1:50000 scale and LANDSAT-ETM (Enhanced Thematic Mapper) image acquired on November 21, 2001 have been used as database for the present analysis**.** Ancillary data were aided for analysis and updating the information. In particular, topographical maps, field surveys and also existing geomorphic maps formed the basis for annotating various built up features. The Survey of India topographical sheets have also been used as the reference point for geomorphic mapping.

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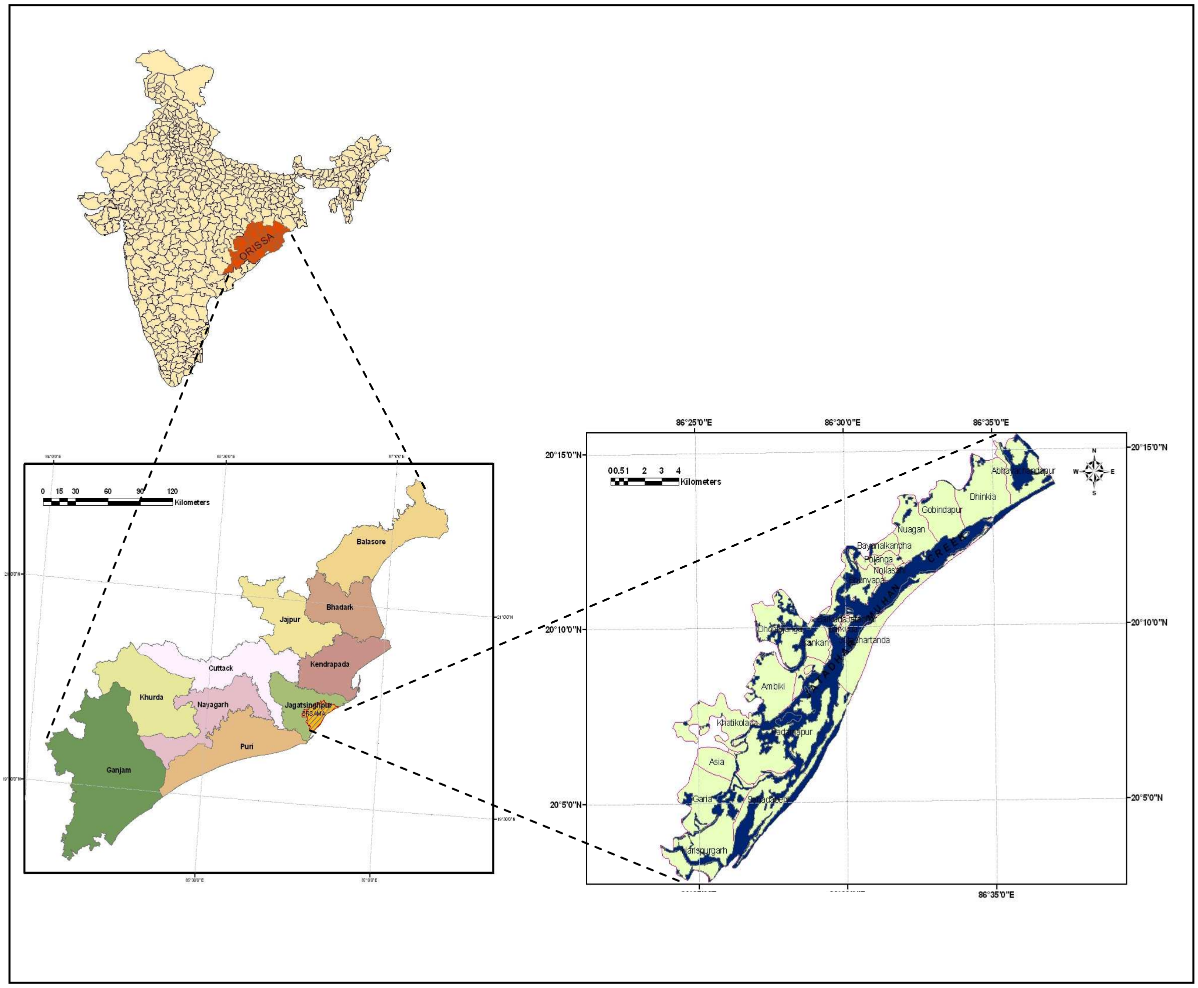

Figure 1 – Location of the Study area

Table 1 – Data source

Toposheet	Year of publications	Scale	Source
74 L/8	1973	1:50,000	Survey of India
76 L/12	1973	1:50,000	Survey of India
LANDSAT ETM	2001	WRS-2, Path-139, Row-46	Global Land Cover Facilities Website

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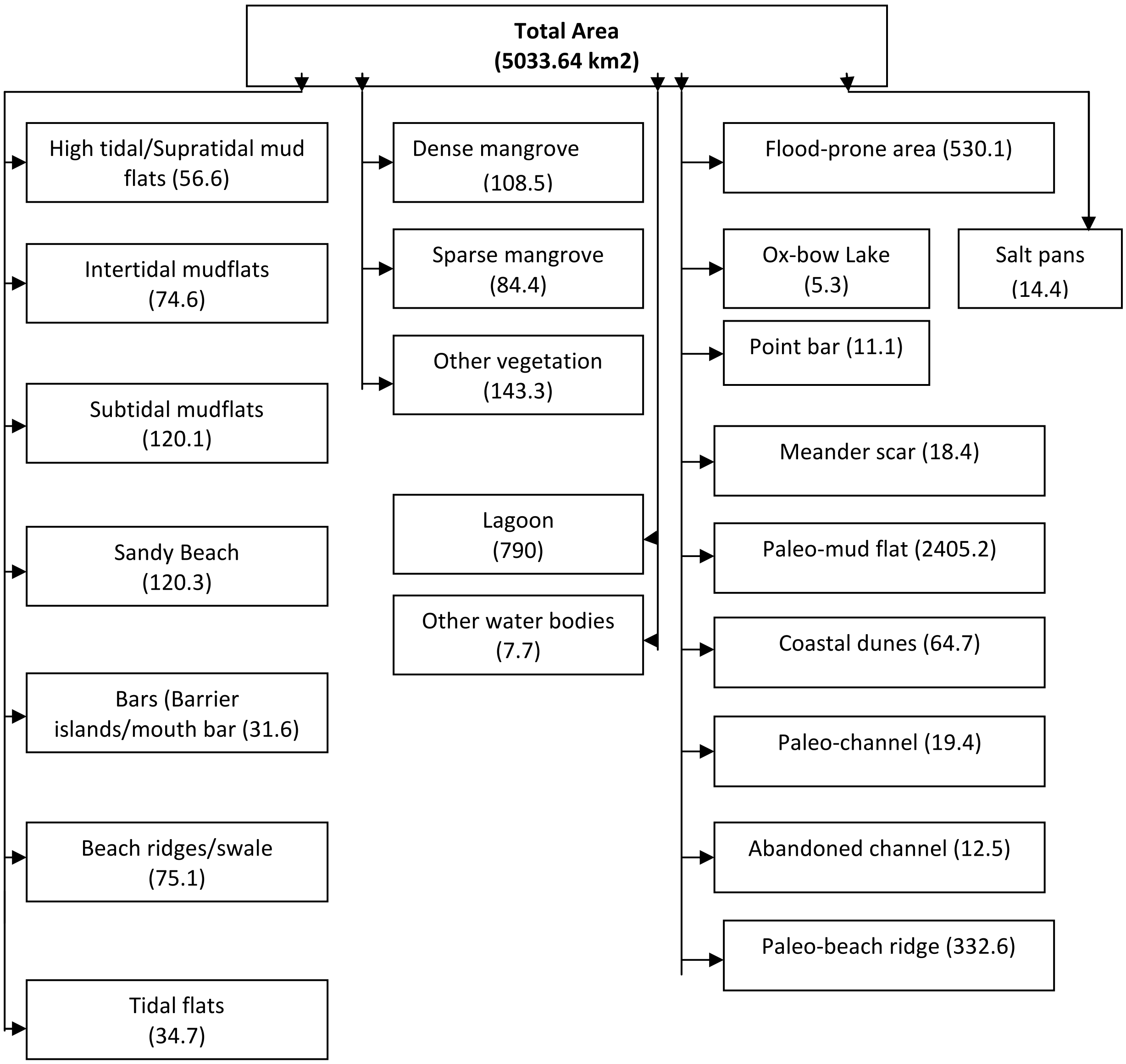

Figure 2 Area (km^2) coastal features along the Orissa coast (complied from SAC, 1992 & Mohanty et al, 2008)

The elevation survey was carried out using Trimble Pro-XT DGPS in the study area. Ancillary data like elevation of Survey of India reference point and public work department points have also been incorporated for present mapping. The surveys include the base station foundation and onshore transects.

Methodology

Quantification of coastal landforms in the study area were accomplished in three parts

i) Field survey and ground truthing using DGPS,

ii) Scanning and Geo-referencing of topographic sheets and satellite imagery,

iii) Visual interpretation and on-screen digitations,

iv) processing and analysis at GIS platforms.

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i) Field survey and ground truthing using DGPS

The field survey were carried out using Trimble Pro-XT DGPS is an advanced instrument and directly linked with satellite, geological position and produces all data like latitude, longitude, elevation height, and date and time of the survey. It consists of two units. One unit was used serving as the reference receiver, or base station, and the other serving as serving as the rover. It has a quoted accuracy of 10 mm+1 ppm. At first instance the mapping of contour and drainage system of the study area done. Then sampling of 50 profiles perpendicular to shoreline were undertaken and record of soil moisture and morphological forms of each sample point in the study area were written in field book. The elevation data and geographic co-ordinates were collected by the receiver (base) in geodesic landmarks. The elevation values are not related to the sea level, they correspond to the altitude relative to the geodesic landmark. The distance between the points of the same profile was determined by the variation of ground characteristics, what means that, if there was a beach ridges it was taken a point on the base of the dune, one at the top and another on the posterior base. The ground turthing on study area were carried to collect more accurate information from field and followed by interview of local population. A number of photographs were also taken of the study site using a digital camera in order to capture the area's current appearance.

ii) **Scanning and Geo-referencing of topographic sheets and satellite imagery**

The Landsat ETM image and Survey of India Toposheet having scale 1:50,000 were scanned at 500 dpi using a HP Scan Jet 3300C scanner. The resulting scanned photographs were saved in Tagged Image File Format (TIFF) before geo-referencing. This image was again rectified using 50 ground control points (GCPs) evenly distributed across the entire image. The GCPs selected included road-intersections, structure corners and field boundaries. The mosaic image processing software then semi-automatically, rectifies hundreds of images at a time, applying bundle block adjustment, and joins them into a large geo-referenced and orthorectified mosaic. All the rectified images were projected to the **UTM system, Spheroid GRS 1980, Zone 45 North, and Datum GRS 1980**. After projection, the image was clipped to match the boundary of the study area and "stacked" into a 7-band image file.

iii) **Visual interpretation and on-screen digitations**

Multi image enhancement technique was carried out to improve the interpretability of the Landsat ETM data in order to highlight the geomorphic features. In addition to data obtained by the visual interpretation of analogue satellite data, Principal Component Analysis (PCA) of the Multi Image Enhancement techniques and false color composite (FCC) were also used for highlighting the coastal geomorphologic features. The principal component analysis (PCA) originally known as Karhunen-Loeve transformation (KL-transformation) is used to compress multi-spectral data sets by calculating a new co-ordinate system (Jenson, 1996) that reduces the data redundancy. Principal component images

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were prepared for the three ETM visible and three reflected infrared bands of the available Ersama LANDSAT- 5/ETM sub-scene. The first three PC images (PC 1, 2, 3) contain 97% of the variation of the original six ETM bands, which is a significant compression of data. The last three PC images (PC 4, 5, 6) account for only 2.6% of the original variation (Sabins, 1987). PC1 contains maximum information but the landforms are better interpreted in the PC 2 image. An FCC image is arguably the most effective means of visual presentation of multi-channel multi-band image and survey data. A decision has to be made about the information content of the final color composite as a fraction of the total information available. Normally, researchers choose three original bands in red, green, and blue RGB. A standard FCC image contains 73% of the available image variance, whereas, the principal composite image contains 97% (Canas and Barnett, 1985). Since all the classes are submerged in similar tone, two different combinations viz. FCC of PC1, PC2, PC3 and FCC of PC3, PC2, PC1 are generated in order to highlight different coastal geomorphic landforms in fragile coastal ecosystem of villages around JMC. An in-depth analysis of the classification scheme and features are analyzed in terms of concept, nomenclature and content to arrive at a meaningful schema of reference into which the existing legends can be translated to cater the needs of a wide range of user community. A level method balancing the specificity of the geomorphic features which we believed could be classified with reasonable accuracy by adopting reasonable accuracy (Table 2).

Table 2 Classification scheme for geomorphic features (NRSA Scheme)

GEOMCODE	UNIT
90100	Old Coastal Plain
90101	Paleo - Beach Ridge
90102	Paleo - Beach Ridge Complex
90103	Swale
90108	Coastal Sand Sheet
90200	Young Coastal Plain
90201	Beach Ridge
90202	Beach Ridge Complex
90203	Swale
90204	Young Mud Flats
90210	Beach Young Coastal Plain
90211	Spit

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iv) **Processing and analysis at GIS platforms**

The elevation data generated from field survey were used in GIS platform to construct digital elevation model using triangulation weighted average of Z-values. This surface model applies a weight inversely proportional to the distance of the center of the quad cell from the three vertices of the plane in the Triangular Irregular Network. There is small altimetric variation (0.62 to 10.85m) resulted restriction to 10 classes of elevation and this spatial data converted to raster format with spatial resolution of 5.4 meters. The thematic map generated from visual interpretation was integrated with raster data of elevation in GIS platform to generate the final geomorphic landforms of the study area.

Result and Observation

The structures of costal features of the study area are originated from the interaction of land-sea-climate mainly the movement of sediments brought by current from the south of Bay of Bengal. Some part of the littoral drifts help in depositing the sediment at mouth of JMC because of obstruction of hydraulic barrier of the coastline. The sediments are deposited in form beach ridges which are linear alongshore, triangular to convex ridges, formed of sand, gravel or shelly sediments (Hesp, 1999). These features are formed by wave swash process during beach progradation, by storm wave/swash process or combination of both (Taylor and Stone, 1996). The successive low ridges built by constructive waves parallel to coastlines and below the level of high spring tides are known as beach ridges. The persistence of beach ridge depends on overall progradation of the coastline and its separation from earlier ridge is often an outcome of the phase of erosion. There are numerous roughly parallel beach ridge complexes acting like barrier to the sea, each marking a former coastline. The elevation map generated from DEM shows that the highest altitude of the study area are portion of beach ridges parallel to coastline located at system of beach ridges of inner ridges (Fig 3). The elevation diminish with proximity mouth of JMC, the portion which inside the creek. The geomorphic landforms interpreted from integrated geospatial technique can be classified into three zones: frontal dune ridge fields, inner beach ridge complex and Swampy areas (Fig 4). The first zone having physical contact with sea having more morphological transformation occur because of availability of sediment and reworked several time by waves, storms and current in short period of time. The second zone represents a set older inner ridge complex with parallel alignment to the coastline and geological record of shoreline changes on progradational process. The third zone is swampy areas constantly flooded along the study area. The height and spacing of parallel beach ridge is determined but the rate of progradation (i.e. the rate of supply of sand and shingle) depending on the available source and pattern of sediment flow, the incidence of cut and fill and the upper swash limit of the waves that built them, which is modified by changes in relative level of land and sea (Taylor and Stone, 1996). From the elevation map (Fig. 3) and geomorphic map it can concluded that the beach ridges found in south–eastern part of study area contain swales, but the north–eastern part evolved due to progradation; or that, the growth is still continuing to the north–eastern direction. Progradations of beach is often indicated by the formation of successive beach ridges of sand or shingle built above high-tide level (Bird, 2000)**.** The southern eastern part of JMC having parallel beach ridge (1-10) is separated from earlier ridges by swales. There can be possibility of process that the phase of deposition is followed by a phase of erosion. The direction of progradation is south west– south east direction. The south east part of Jatadhar Muhan Creek having portion of beach young coastal plain proves that progradation still continues, i.e.

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accretion of sediment in the newly formed beach is still in progress. The central part of the JMC contains beach ridges without swale. The deposition (ridge No 11, 12, 13, 14 and 15) interrupted after the formation of ridge No 16 (Fig 4). The possible cause may be the change in direction of wind or current. Ridge No 16 acted as a barrier and stopped the coastal ingression like wave, tide and storm which was earlier helping in the formation of beach ridges in this zone. This beach ridge has changed the direction of progradation from south west –south east to south east–north east direction. Progradation still continues on the end of spit in the JMC with sign transgressive ridges but also show development of intermediate regressive ridges (beach ridges) and laterally accreted ridges in its different phase of development. Hence integrated geospatial method can be be useful on the analysis of the land forms, indicating the presence and orientation of smaller ridges, not visible on the digital elevation model. Further these geomorphic landforms mapped could be used by coastal managers to determine the direction changes happened in coastal process in very broad regional scale by extrapolating and simulating signature of change from very short historical time series.

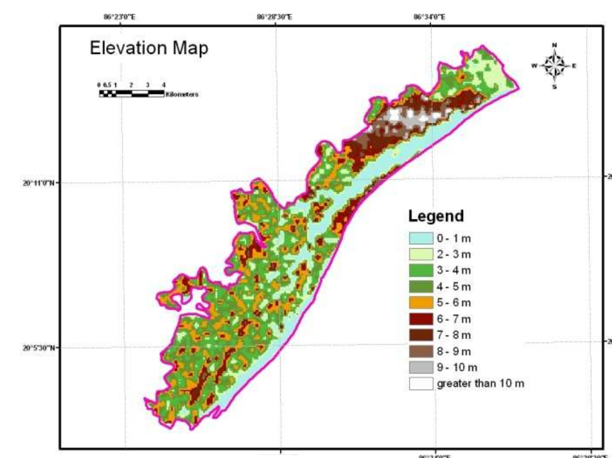

Figure 3

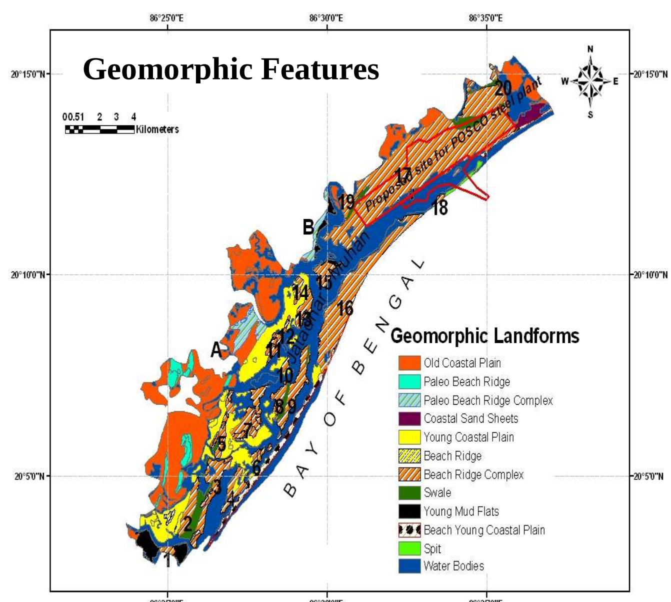

Figure 4

Conclusion

Coastal processes play a major role in decisive the coastal configuration of this area. In spite of the big irregularity of the relief, the relative altimetry values, the integrated geospatial technique can be potential methods to diagnose and analysis the coastal landforms. LANDSAT-ETM image coupled with extensive ground survey has helped in zoning the geomorphological landforms: frontal dune ridge fields, inner beach ridge complex and Swampy areas (Old coastal plain, Young coastal plain, Beach ridge, Beach ridge complex, Young mud flats, Beach young coastal plain and Water bodies). The result of this study can be integrated with dataset of land use patterns, hydrological data, human activities and other coastal processes to monitor changes around JMC. The result can also be shared with relevant stakeholders like coastal managers, coastal planners, the public, policy makers, researchers and other scientists, for use in decision-making on such issues as land use planning, development of set-back lines and identification of low-cost methods which could be used in the context of integrated coastal zone management.

Future studies can be done in the study area for sustainable management before leasing the site for POSCO steel plant as follows:

(a) Sediment budget calculation

(b) Bathymetry and configuration of JMC

(c) Temporal dynamism of geomorphic landforms

(d) Basic process controlling the morphological changes

e) The direction and rate of mobility of landforms

(f) Physical vulnerability mapping

(f) Land suitability mapping of the area and

(g) Institutional arrangement for periodic monitoring of these geomorphic landforms.

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