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Monitoring the Mangrove Forest Cover Change of Bhitarkanika National Park using GIS and Remote Sensing Technique

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Abstract- **− Increasing anthropogenic activities and intense biotic pressure poses a serious impact on coastal environment, especially mangrove ecosystem and Bhitarkanika mangrove ecosystem is no exception to it. Remote Sensing and GIS serves as important tool to provide up-to date information which is the primary requirement for conservation, planning and restoration of mangroves. The present study deals with periodic assessment and monitoring of the mangroves of Bhitarkanika National Park, Orissa, India. Satellite data of Landsat ETM$^+$ for year 2000, IRS R2 LISS III for both the years 2006 and 2015 respectively were used along with other spatial and non-spatial data to find out the changes that occurred in mangrove forest and other land cover categories. It was found that the National Park occupied 73.29 % of mangrove forest, 14.80% of agricultural land, 1.02% of aquaculture ponds, 0.76% of settlement, 0.34% of roadways, 5.83% of drainage, 3.38% of scrub forest and 0.58% of grassland. The data were verified through ground truth data collected through random field sampling. It was inferred from the study that there is a loss of 64.40 ha (1.52%) of mangrove forest and 112.28 ha of mudflats (30.6%) during the study period. An increase in aquaculture pond area of 34.84 ha (56.47%), settlements of 18.86 ha (40.83 %) and scrub forest of 80.29 ha (64. 39%) is observed during the study over the last 15 years. This clearly depicts that increase in anthropogenic activities by local villagers and other anthropogenic causes have led to the LULC changes over the study period. An immediate step should be taken by the State Forest Department, NGO'S and policy makers, to monitor the status of mangrove vegetation and LULC pattern so as to conserve the floral and faunal biodiversity of Bhitarkanika mangrove ecosystem.**

Keywords: Mangrove; LULC; Floristic Composition; Bhitarkanika National Park

I. INTRODUCTION

Mangrove forests are among the most productive and biologically important ecosystems of the world because they provide important and unique ecosystem goods and services to human society. The forests help stabilizing shorelines and reduce the devastating impact of natural disasters such as tsunamis and hurricanes. They also provide breeding and nursing grounds for marine and pelagic species, and food, medicine, fuel and building materials for local communities. Mangroves, including associated soils, could sequester approximately 22.8 million metric tons of carbon each year. Covering only 0.1% of the earth's continental surface, the forests account for 11% of the total input of terrestrial carbon into the ocean [1] and 10% of the terrestrial dissolved organic carbon (DOC) exported to the ocean [2]. The total mangrove area of the world has been assessed to be approximately 18.15 million hectares. India's mangrove wetlands range from 6,81,000 ha [3] to 5,00,000 ha [4]. The distribution of mangrove forest in India and Orissa is given in Table1.

TABLE 1: MANGROVES COVER DATA OF INDIA AND ORISSA (Km^2)

Places	**Years**							
	1997	1999	2001	2003	2005	2009	2011	2013
India	4737	4871	4482	4448	4581	4639	4663	4628
Orissa	211	213	215	207	203	221	222	213
Balasore	3	3	3	4	4	3	4	2
Bhadrak	17	18	19	21	20	23	23	21
Jagatsinghpur	10	10	5	8	4	7	7	7
Kendrapara	181	184	192	180	175	187	187	183
Source-state Forest Report, FSI :(1997-2013)								

The mangrove forests of Bhitarkanika mangrove ecosystem, located in the state of Orissa are the second largest mangrove forest of mainland India [5]. Developmental activities such as construction of jetties, roads, and defence structures, missile testing site, inshore fisheries by mechanized vessels and the proposal of a major port threaten the existence of this unique ecosystem [6,7]. Spatial characteristics and extent of anthropogenic disturbances (Table 2) affecting the mangrove forests of Bhitarkanika situated along the east coast of Odisha, India was examined by using remotely sensed data and GIS, supplemented with socio-economic surveys which shows that 30% of the major forest classes to be under high to very high levels of disturbance especially at easy access points [8].

TABLE 2: RESOURCE USE AND DEPENDENCY OF LOCAL PEOPLE IN VILLAGES LOCATED IN BHITARKANIKA CONSERVATION AREA, INDIA (N = 324 HOUSEHOLDS)

Resource Use		**Mean Quantity (kg/hhld/annum)**
Fuel wood	Total consumption of fuel	2205.0 +104.2
	Fuel wood from Park	312.0 +32.2
	Fuel wood from homesteads	21.0 +2.35
	Cow dung, farm refuse, others	1949.0 +375.0
Fish	Fish caught from the Park	98.0 +28.3
Timber	Used as rafters	343.0 +36.9
	As roof supports	27.0 +4.3
Non Wood Forest product	Honey	525.0 +239.7
	Thatching materials (*Phoenix paludosa*)	49.0 +8.7

Source: Ambastha et al., (2010)

The satellite remote sensing applications in forestry offer great advantages and can lead to better monitoring, planning and management of forest resources in the country. Synoptic coverage, imaging access to inaccessible areas, concurrently temporal viewings enables to holistically understand and monitor forest environment. It also assists, in determining forested area, forest health, afforestation or deforestation activities and overall impacts. The mangrove ecosystem is both dynamic and complex in nature. The conventional field surveys are extremely difficult to carry out in swampy areas. Hence, cost effective and accurate mapping techniques are required for timely monitoring of mangroves [9]. Remote sensing technology serves as a valuable tool for gathering accurate information with time and cost effectiveness [10].
Land use/land cover (LULC) changes are key elements of the global environmental change processes [11,12]. Remote sensing technique is emerging as increasingly important tool for mapping and timely monitoring the mangroves [9]. Application of remote sensing has now made it possible to study the changes in land cover in less time, at low cost and with better accuracy [13]. In this background, the present paper aims to monitor the changes in the LULC pattern of Bhitarkanika National Park over time in order to pinpoint the causes of such change.

II. MATERIALS AND METHODS

A. Description of study site

The mangrove forests of Bhitarkanika National Park are found largely within Bhitarkanika Wildlife Sanctuary (BWS) between 86^0 45′ E to 87^0 50′ E longitudes and 20^0 40′ N to 20^0 48′ N latitudes in the lower reaches of the Dhamra-Pathsala-Maipura Rivers (Fig. 1).

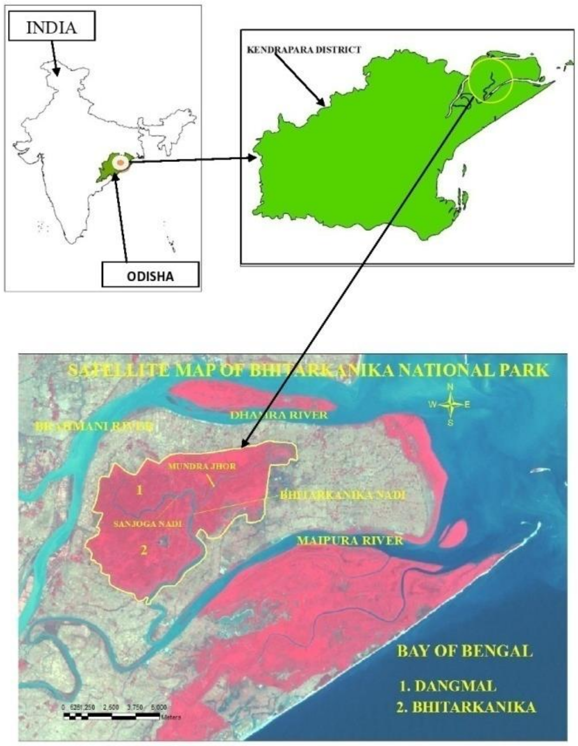

Fig. 1. Location map

The climate in this area is tropical and annual rainfall averages 1670 mm with the main rainfall occurring during the months of August and September. The temperature ranges from 30^0 C in summer to 15^0C in winter [14]. In 1988, an area of 672 km^2 of these forests was declared as a Wildlife Sanctuary with a core area of 145 km^2 that was designated as National Park. Floral and faunal diversity of the area includes more than 300 plant species [15] of mangroves and non-mangroves, 31 species of mammals representing 25 genera and 14 families [5], 29 species of reptiles with four species of turtles and 174 species of birds [16]. It is a critical habitat of the endangered Saltwater Crocodile (*Crocodylus porosus*) and the nesting ground of the Olive Ridley Sea Turtles (*Lepidochelys olivacea*) [17]. Considering its ecological and social value the area has been identified as a Ramsar Site [18]. The tree flora is primarily confined to a few families such as *Apocynaceae, Avicenniaceae, Sonneratiaceae, Tamaricaceae, Bignoniaceae, Euphorbiaceae, Leguminosae, Meliaceae, Plumbaginaceae, Rhizophoraceae* etc. Air breathing roots or pneumatophores are seen dominantly only in *Avicennia, Lumnitzera and Sonneratia apetala* where it is sharply pointed, vertical and woody. Vertically flattened roots are seen in *Heritiera* and *Xylocarpus* where the surface roots are vertically flattened and look finger like projections. In most of the mangroves, leaves are thick and fleshy which possess aqueous tissues, mucilage and stone cells and have shrunken stomata.

B. Analysis of data

Landsat L7 ETM+ satellite image having resolution 30 m of December 2000 and Indian Remote Sensing Satellite (IRS-Resourcesat-2, LISS-III) satellite images having spatial resolution of 23.5 m of February 2006 and April 2015 were used respectively for image interpretation in the entire study. These data were procured from NRSC (National Remote Sensing Centre), Hyderabad (IRS-R2) and Earth Explorer image harnessing site (Landsat L7 ETM+). Survey of India toposheet (SOI, 1979) was also used for georectification of data. Reference map of ORSAC (Orissa Space Application Centre) was used for image interpretation. Digital image processing technique has been adopted for classification of LULC classes occurring in Bhitarkanika National Park. Procured raw images of three different years were taken for band composition and generation of FCC (False Colour Composites) images and then georegistered to UTM (Universal Transverse Mercator) projection of WGS (World Geodetic System) 84 datum.

Georeferencing of the images have been done by using the existing georeferenced satellite imagery of ORSAC. All the satellite images were interpreted in visual interpretation method. In this method, field truth collected from mangrove area was taken into consideration and the tones, textures of the images were also taken into consideration for interpretation. River, island and other land parts of estuarine area were also interpreted visually. The interpreted layers were stored in GIS platform and all these items were also separated through non-spatial value like land use category. Through this process land use and land cover maps of three different years have been created using ArcGIS 10.1 software (Fig.2). The georectified images were classified into 50 classes. The Unsupervised Classification Maps and False Colour Composite maps were verified by ground truth verification of land use and vegetation types.

III. RESULTS AND DISCUSSION

Bhitarkanika mangrove ecosystem flourishes in the deltaic region, formed by the rich alluvial deposits of Brahmani and Baitarani River. Brahmani has a drainage basin of 8570 km^2, length of 365 km and peak discharge of 14,150 m^3/s, while Baitarni River has drainage basin of 8570 km^2 lengths of 365 km and peak discharge of 14,150 m^3/s [19]. It receives inputs of untreated domestic and industrial wastes (including organic matter, oil and heavy metal). These mangroves received attention for it floristic and faunistic diversity. The present study was undertaken to understand the prevailing situation of the inputs due to anthropogenic pressure on these mangrove dominated estuarine ecosystem.

The area statistics of forest and land cover types as interpreted from satellite imagery is given in (Table 3).

TABLE 3: CHANGE PATTERN OF AREA (HA) OF LULC CLASSES OF BHITARKANIKA NATIONAL PARK FROM 2000 TO 2015

SL. no.	LULC classes	2000	2006	2015	Change in Area 2000-2006	Change in Area 2006-2015	Change in Area 2000-2015	% of change from 2000-2015
1	Agricultural Land	970.157	939.392	893.127	-30.76	-46.26	-77.03	-7.94 %
2	Aquaculture Pond	26.85	24.991	61.691	-1.85	+36.7	+34.84	+ 56.47%
3	Drainage	345.135	350.391	351.761	+5.25	+1.37	+6.62	+1 .882%
4	Grass Land	33.18	35.298	35.129	+2.11	-0.16	+1.94	5.52%
5	Mangrove Forest	4489.076	4545.914	4421.685	+56.83	-124.22	-64.40	- 1.52%
6	Road	18.673	20.525	20.525	+1.85	0	+1.85	+9.9%
7	Scrub Forest	123.533	79.404	203.823	-44.12	+124.41	+80.29	+ 64. 39 %
8	Settlement	27.328	38.017	46.191	+10.68	+8.17	+18.86	+ 40.83 %

The landscape comprises of 73.29% of forest land (mangrove) and 20.29% of matrix comprising private agricultural land, sand-barren land, mud-flat, aquaculture pond and trees. Interspersed grasslands and water bodies occupied 0.58 % and 5.83 % area of the landscape respectively. Thus, the landscape represents a complex of forest- grassland and wetland interspersed with agriculture. Two forest classes were identified namely **mangrove forest** (*Heritiera fomes*, *Excoecaria agallocha*, *Avicennia* sp. *Rhizophora* sp. etc) occurring in the fringe area of the National Park and **scrub forest** are dominated *by (Thespesia populneoides, Salicornia brachiata, Lumnitzera racemosa*. *Cynometra ramiflora, Acanthus ilicifolius, Porteresia coarctata, Suaeda nudiflora, Suaeda maritima*). The different land use patterns and the change in land use from the year 2000 to 2015 is represented in Fig. 2.

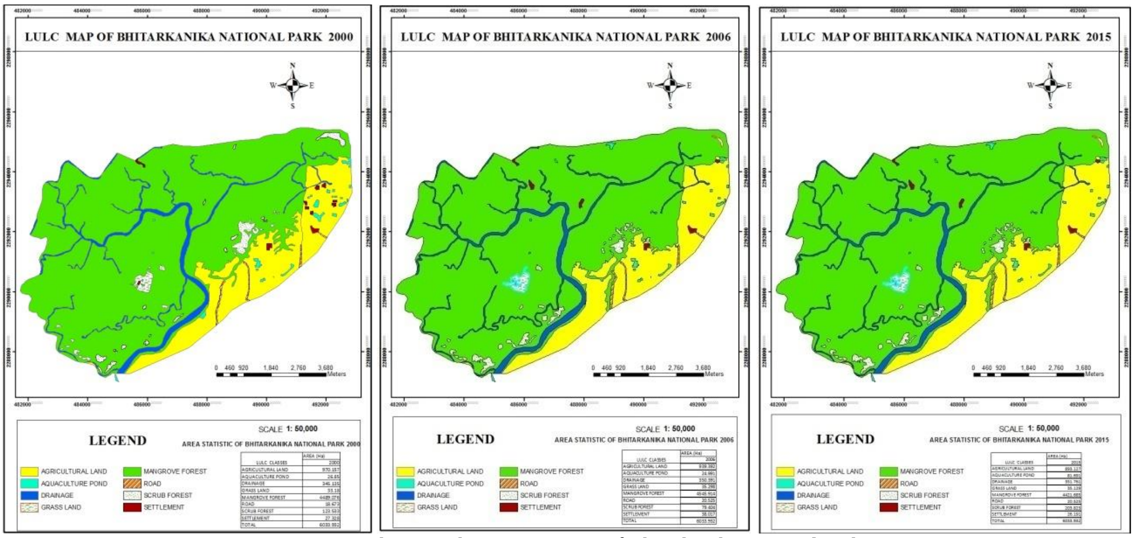

Fig. 2. Map showing changes in LULC of Bhitarkanika National Park

Despite the protected status and a ban on resource extraction, local extractions from the Park are considerable. In average 14% of the total fuel wood consumed in each of the household *i.e*. around 312 kg come from the forests in the form of dead or felled wood collected during the dry season which are used for house construction, non wood forest product (NWFP), fisheries, fodder and on much smaller scales for construction of jetties, forest pathways, small gap bridges, boats, fish traps, and mooring poles (Table 2).

From Table 3, it is clear that most of the landscapes are occupied by mangrove forests whose area has been increased from 2000 to 2006 but gradually decreased from 2006 to 2015. The most important activity carried out in Bhitarkanika National Park is agriculture where as aquaculture, roadways construction and settlement is negligible. However, there is an increasing trend of settlements, roadways and development of aquaculture ponds over the years from 2000 to 2015 which is an alarming signal for sustainability of mangrove forests. To understand the trend of change in the Land Use and Land Cover (LULC) pattern in different categories, maps have been prepared taking the data of fifteen years (2000-2015) as represented in Fig.2, which is also supported by the ANOVA analysis at 1% level of significance (Table 4).

Agriculture is the most important source of income for Orissa; two thirds of the state budget is produced by agriculture which employs 80% of the population. The agricultural land has gradually decreased from 970.16 ha to 939.39 ha (3.17%) and 939.93 ha to 893.13 ha (4.92 %) during 2000-2006 and 2006-2015 respectively showing a total decrease of 7.94% during the period of fifteen years which may be due to the conversion of the agricultural land to the aquacultural pond for the purpose of shrimp culture. There has been a great hike in aquaculture pond area from 26.85 ha to 61.69 ha (129.76 %) as shown in Table 3. The decrease in the agricultural land and increase in the aquacultural pond area are also confirmed through ANOVA ($p<0.01$) during 2000-2006 and 2006-2015 respectively (Table 4).

All the rapid developments and manmade activities are making a great impact on the coastal ecosystem of this area [20]. Due to the pressure posed by the increasing population in the National Park the huge increase in the settlement areas from 27.33 ha to 46.19 ha during this tenure of fifteen years which accounted for 69 %. This may be considered as one of the prime reasons for the decrease in the agricultural land as well as a threat to the mangrove ecosystem and its biodiversity. The settlement area gradually increased from 27.33 ha to 38.01 ha (39.07 %) during the period 2000-2006 and 38.01 ha to 46.19 ha during the period 2006-2015 (Table 3), which is also supported by the ANOVA values ($p<0.01$) (Table 4).

SL.No.	LULC CLASSES	ANOVA VALUES		
		F_{cal}	F_{crit}	P value
1	Agricultural Land	20.14	5.14	<0.01
2	Aquaculture Pond	8.55	5.14	<0.01
3	Drainage	0.2	5.14	<0.01
4	Grass Land	0.11	5.14	<0.01
5	Mangrove Forest	32.15	5.14	<0.01
6	Road	0.79	5.14	<0.01
7	Scrub Forest	40.84	5.14	<0.01
8	Settlement	19.31	5.14	<0.01

The roadways inside the National Park have also shown a slight increase in their numbers which is necessary to support the increasing population of the area. They occupy an area of 20.53 ha which has not changed from 2006 and the total change in the area under roads is 1.85 ha (9.90 %) during 2000-2015 of the total area of Bhitarkanika National Park. The natural drainage pattern in the National Park has not been affected significantly showing a minor increase from 345.14 ha to 350.39 ha (1.52 %) and 350.39 ha to 351.76 ha (0.39 %) during the periods 2000-2006 and 2006-2015 respectively which gives around 1.92% of increase in total (Table 3). The changes in the road and the drainage area has also been confirmed through the ANOVA values (p<0.01) (Table 4).

The mangrove forests in the coastal regions are the barriers, which protects the coastal ecosystems from the severe impacts of natural calamities like cyclones, storms and tsunamis. During the period 2000-2006 the mangrove forest has shown an increase of about 56.84 ha which accounts for 1.26 %. This may be attributed to the increase in the afforestation programmes, natural germination and other reformation practices like plantation in the fringe areas of the National Park after the Super Cyclone, 1999 which struck the Orissa coast. But, the forest areas have shown a significant decrease during the period 2006-2015 from 4545.91 ha to 4421.69 ha which accounts for 124.22 ha (2.73 %) due to the increase in anthropogenic activities inside the National Park like cutting of trees for fuel wood as well as for the enhancement of their economic status (Table 3). Natural causes like increase in sedimentation are also responsible for the decrease in the mangrove forest area. This result has also been supported by the highly significant ANOVA value (p<0.01) (Table 4).

The grassland area occupies an area of about 35.12 ha which has increased from 33.18 ha accounting for 1.94 ha (5.87 %) increase in total in the study area. The decrease in grassland area including mudflats from 35.23 ha to 35.13 ha during 2006-2015 (Table 3) shows the general trend of erosion in the area. This is also due to the loss of the mangroves forests as well as decrease in the agricultural land during these 15 years. Increasing scrub forests is one of the major concerns of the National Park and its biodiversity. The scrub forests witnessed a decreasing order during 2000-2006 (35.72%) and has showing an increasing trend during 2006-2015 (156.70 %) accounted for an area of 124.41 ha. The scrub forests/scrublands showed a total increase of 64.39 % (123.32 ha to 203.82 ha) during these 15 years. The trends of change in grasslands and scrub forests has also been verified using ANOVA values (p<0.01) (Table 4).

The degree and distribution of resource extraction (Table 2) shows the dependency of the local villages and the villagers on the availability of forest products. Although Bhitarkanika National Park is a protected mangrove forest, still the anthropogenic disturbances depend on the availability of alternatives, ease of accessibility, levels of protection, roads, agriculture, aquaculture and forest composition. Nevertheless, the restrictions enforced by forest department have ensured low use of fuel wood consumption [21] with crop residues meeting majority of the energy demands (78%). The intermediate settlement located inside the National Park enjoys the substantial and commercial benefits of mangroves as accessibility to roads enable them to market of mangrove products. This cumulative effect disturbs both human-induced and natural effects that shape the forest system by influencing their composition, structure and functional processes. This also has been confirmed by Ambastha *et al.*[8] and Sahu *et al.*[22].

In the present study the geospatial analysis has helped in revealing distinctive resources use patterns over 15 years. Since the people are poor and depend heavily on the mangrove forest to meet their basic subsistence needs they were often not in a position to be selective in terms of species and size, instead, extract what is most readily available to them [23]. From the map generated a period of 15 years clearly it reveals that most part of the Bhitarkanika National Park is exposed to anthropogenic impact like agriculture, aquaculture, human settlement etc. Our results have also proved the loss of mangrove area in Bhitarkanika over the year is mainly due to human interference and reclamation of land for agriculture [24] and unsustainable resources use practices such as aquaculture activities. The socio-economic condition of people around Bhitarkanika National Park being poor and income restricted to only seasonal agriculture, has laid to production in agricultural land and increasing aquacultural pond area. Recent development activities such as construction of roads, jetties, forest pathways etc. have exaggerated this problem.

Anthropogenic activities due to population explosion including tourism, discharge of effluent, municipal sewage, aquaculture, agriculture etc. possess adverse effect on coastal environment. Understanding rate of land use changes in time and space will help us to find out the reason behind such changes and is very useful in preparing models for regional and spatial pattern of the area as well as future prediction of implication of such changes can be done. Constant monitoring of this area (Bhitarkanika National Park) will help us verifying the present findings and allow us to develop models for land use patterns in the area with advancement of remote sensing in terms of sensor resolution (from 1 km to 1m spatial resolution) and with supporting systems like GIS we can have a better understanding of land use land cover changes.

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