e-planet **19** (1): 88-98 (June 2021)

Geo-spatial analysis of land use and land cover in Bhitarkanika Wildlife Sanctuary, Odisha

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Date of receipt : 15.11.2020 Date of acceptance : 22.05.2021

ABSTRACT

Mapping and monitoring of land use land cover (LULC) changes is vital for sustainable development, planning and management. Based on Remote Sensing (RS) and Geographic Information System (GIS) techniques, the study is an attempt to monitor the changes in LULC patterns of Bhitarkanika Wildlife Sanctuary in Kendrapara District of Odisha for the period of 30 years from 1990 to 2020. The total area of the Bhitarkanika Sanctuary is taken under study with an area of 672 km^2. This study aimed to calculate changes in LULC within the period of 30 years with an interval of 10 years respectively i.e. 1990-2000, 2000-2010 and 2010-2020 and satellite data were used to identify the change. The use of geo-informatics has enabled us to assign spatial connotations to land use land cover changes namely, population pressure, climate, terrain, etc., which drive these changes. This has helped scientists to quantify these tools and to predict various scenarios. However, Landsat Satellite images adequately aided to detect changes brought down by man or nature in due course of time in three decades which was analysed for the study area. The study aims to detect the change in different land use land cover categories within the Bhitarkanika Wildlife Sanctuary. Ancillary data and local expert knowledge were necessary to expose long-term trends and formulate explanations in a region that surrounds and includes a sanctuary which have been largely devoid of significant direct anthropogenic impact. The reasons for such changes could generally be explained with detailed field-based data sets and such information does not exist at the requisite spatial and temporal scales. Remote sensing datasets, e.g., Landsat imagery, provided the only feasible method to enumerate the trends in land use and land cover in the spatially extensive study area. The changes in the pre and post classification maps were performed by comparison of area based on different land use classes and using change matrix analysis. The result highlighted the changes in the spatial extent of the mangroves and other land use categories in the study areas as a result in due course of time. The present study also deals with periodic assessment and monitoring of the mangroves of Bhitarkanika Sanctuary.

Key words: GIS, land use and land cover, mangroves, mud flat, remote sensing, satellite imageries

INTRODUCTION

Land use and land cover changes, apart from changing the physical dimension of the spatial extent of the land use and land cover classes, also influence many of the secondary processes which lead to the eventual degradation of the ecosystems of the earth (Dregne and Chow, 1992). Land cover refers to the physical and biological cover over the surface of land, including water, vegetation, bare soil and/or artificial structures (Ellis et al., 2007). Land-use/cover is largely determined by the ecological conditions, altitudes, geological structure and slope along with technological, socio-economic and institutional set-up, which also influences the land-use pattern (Rai et al., 1994). Changes in the condition and composition of land-cover affects climate, bio-geochemical cycles, energy fluxes and livelihoods of people (Vitousek et al., 1997; Duong et al., 2016; Gashaw et al., 2018). With the increase in population and urbanization, large areas of forest covers are being converted into other land use categories.

MATERIALS AND METHODS

Bhitarkanika in Odisha is the deltaic region formed by the alluvial deposits of sacred river Brahmani, Baitarani and Dhamra and happens to be a unique habitat with mangrove vegetation on the sides of meandering creeks and tidal mudflats (Fig. 1). The mangrove forests of Bhitarkanika Wildlife Sanctuary constitute and are largely confined between 86° 45′ E to 87° 50′ E longitudes and 20° 40′ N to 20° 48′ N latitudes. In the year 1975, Bhitarkanika was declared as a Wildlife Sanctuary under the Wildlife (Protection) Act, 1972 with an area of 672 km^2. Considering the ecological, faunal, floral, geomorphological and zoological importance and for the purpose of protecting, propagating and developing wildlife and its environment, Govt. of Odisha declared Bhitarkanika as a National Park on 3rd October 1988 with an area of 145 km^2. Average annual rainfall is around 1600 mm. Temperature varies from a minimum of 10°-15° C in December-January to maximum 40°-45° C in May-June. It is one of the largest mangrove ecosystems of India. Bhitarkanika is the home to diverse flora and fauna out of which some are endemic. It is the ideal habitat for the reptiles like estuarine crocodile, water monitor lizard, king cobra and python (Chadha and Kar, 1999). Important avifauna includes the kingfishers, storks, ibises, waders and varieties of migratory ducks like bar headed goose, brahminy duck, gadwall, pintail, etc. Fauna such as leopard cat (*Prionailurus bengalensis*), fishing cat (*Prionailurus viverrinus*), jungle cat (*Felis chaus*), hyeana (*Hyaena hyaena*), jackal (*Canis aureus*), sambar (*Rusa unicolour*), cheetal (*Axis axis*), rhesus macaque (*Macaca mulatta*), wild pig (*Sus scrofa*), small indian civet (*Viverricula indica*), rattel (*Mellivora capensis*), porcupine (*Hystrix indica*), water monitor lizard (*Varanus salvator*) smooth coated otter (*Lutrogale perspicillata*), etc. were also recorded from this study area (Mohanty et al., 2004).

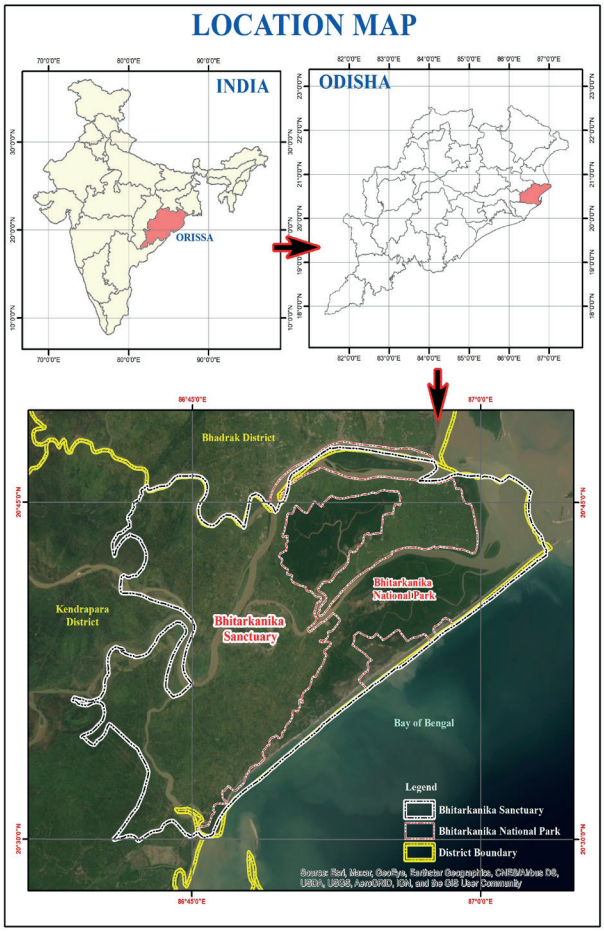


Fig. 1. Location map of Bhitarkanika Wildlife Sanctuary, Odisha, India

Analysis of data

Multi-resolution satellite data over the study area, such as Landsat MSS, Landsat TM, Landsat ETM+ and Landsat OLI were acquired from USGS Earth Explorer portal for the period 1990 to 2020. Four different years data starting from 1990, 2000, 2010 and 2020 were taken into account for the analysis. The dates were chosen in the long dry season in order to use images that were sensed in similar conditions and similar time for a coherent data analysis (Konko et al., 2020). Level 1 product of Landsat archive of USGS was downloaded. All images are ortho-rectified and the details regarding satellites, their acquisition dates and times are listed in Table 1.

Table 1. The satellite data showing year, date, time and resolution

Year	Satellite	Date of pass	Time (UTC)	Resolution	Path/row
1990	Landsat 4 TM	18-Dec-1990	03:54	30 m	139/046
2000	Landsat 7 ETM+	29-Mar-2000	04:30	30 m	139/046
2010	Landsat 7 ETM+	20-Jan-2010	04:29	30 m	139/046
2020	Landsat 8 OLI	28-Mar-2020	04:38	30 m	139/046

The requirement of the study defines the scale at which the mapping is to be done so that details can be extracted from the remote sensing data (Nayak and Bahuguna, 2001). For the current study, Landsat data of 30 mts. Resolution has been taken of four time periods starting from 1990 to 2020, with a span of 30 years having an interval of ten year each. Landsat Thematic Mapper 1990 has been used as the base map for the classification. All the satellite images were taken in the dry season to get the same landscape of the study area throughout the time period. Also getting satellite images of same seasons is considered to be ideal to avoid confusion while mapping. It is well known that season wise, the satellite images change and the landscape also gives different signature on colour, tone, texture of the same feature. The data set obtained for all the four years were first geometrically corrected. Digital image processing technique has been adopted for classification of land use and land cover classes occurring in Bhitarkanika Wildlife Sanctuary area. Raw Landsat images of four different years were taken for band composition and generation of FCC (False Colour Composites) images.

Survey of India toposheets was also geo-rectified and mosaiced to study the land use change detection and then geo-registered to UTM (Universal Transverse Mercator) projection of WGS (World Geodetic System) 84 datum. Re-sampling of satellite images were carried out using ERDAS IMAGINE 2013. The resolution was kept in the re-sampling process at 30 meter for analysis. The visual image interpretation technique was adopted to classify the land use and land cover.

All the database was then exported so as to be used in ERDAS IMAGINE 2013 for layer stacking after which the FCC (False Colour Composite) of each images are generated. After which each geo referenced satellite images are exported and was used in ARC GIS 10.7 for further land use analysis. The satellite images of all the time period were mosaiced on top of the base data and the boundary of Bhitarkanika Wildlife Sanctuary was manually digitized from the Survey of India Toposheets (OSM Series) with UTM WGS 84 projection to get the study area. As it is to be mentioned that the total area of Bhitarkanika Wildlife Sanctuary is 672 km^2 as per Govt. of Odisha vide the notification No. 6958/FFAH Dt. 22.4.1975, to be declared as Bhitarkanika Wildlife Sanctuary and an area of 145 km^2 was declared as a National Park Vide Notification No.19686 / Forest and Environment Deptt./ Dated 16.9.98 to be declared as Bhitarkanika National Park which is the core area of the existing Sanctuary (Chadha and Kar, 1999).

All the Landsat images are provided with ortho- rectification with UTM projection and WGS 84 datum by USGS. Therefore, the existing

geo-rectification of all the images are used and not re-rectified for this study. Landsat collections Level-1 data products consists of quantized and calibrated scaled Digital Numbers (DN) representing the multispectral image data. The Digital Numbers (DN) of each Landsat images were rescaled to top of atmosphere (TOA). To discriminate of aquatic and terrestrial areas from satellite imagery, Normalized difference water index (NDWI) was used because if its efficiency and convenience. NDWI is computed according to the Equation

$$\text{NDWI} = \frac{\text{Green} - \text{Near Infra Red } (^{*}\text{NIR})}{\text{Green} + \text{Near Infra Red } (^{*}\text{NIR})}$$

*NIR = Near Infra Red, Green band.

NDWI seeks to maximize reflectance if water using green wave lengths, minimize the low reflectance of NIR by water features and finally, take advantage if high reflectance of NIR by both the vegetation and soil. Typically, as a result water has a positive value while soil and vegetation have either nil or negative values.

Field verification was first carried out in order to know the ground truth. The visual interpretation of the satellite data is difficult without the field verification and training data sets which is later matched with the remote sensing image to do the final classified maps. The images were carefully classified and interpreted on the basis of tone, texture, colour, pattern, etc. The current classification is done using ArcGIS 10.7, a supervised classification was run. The analysis was again refined by coding through visual interpretation to generate the required 9 classes. The references for verification were SOI Toposheets, High resolution satellite imagery

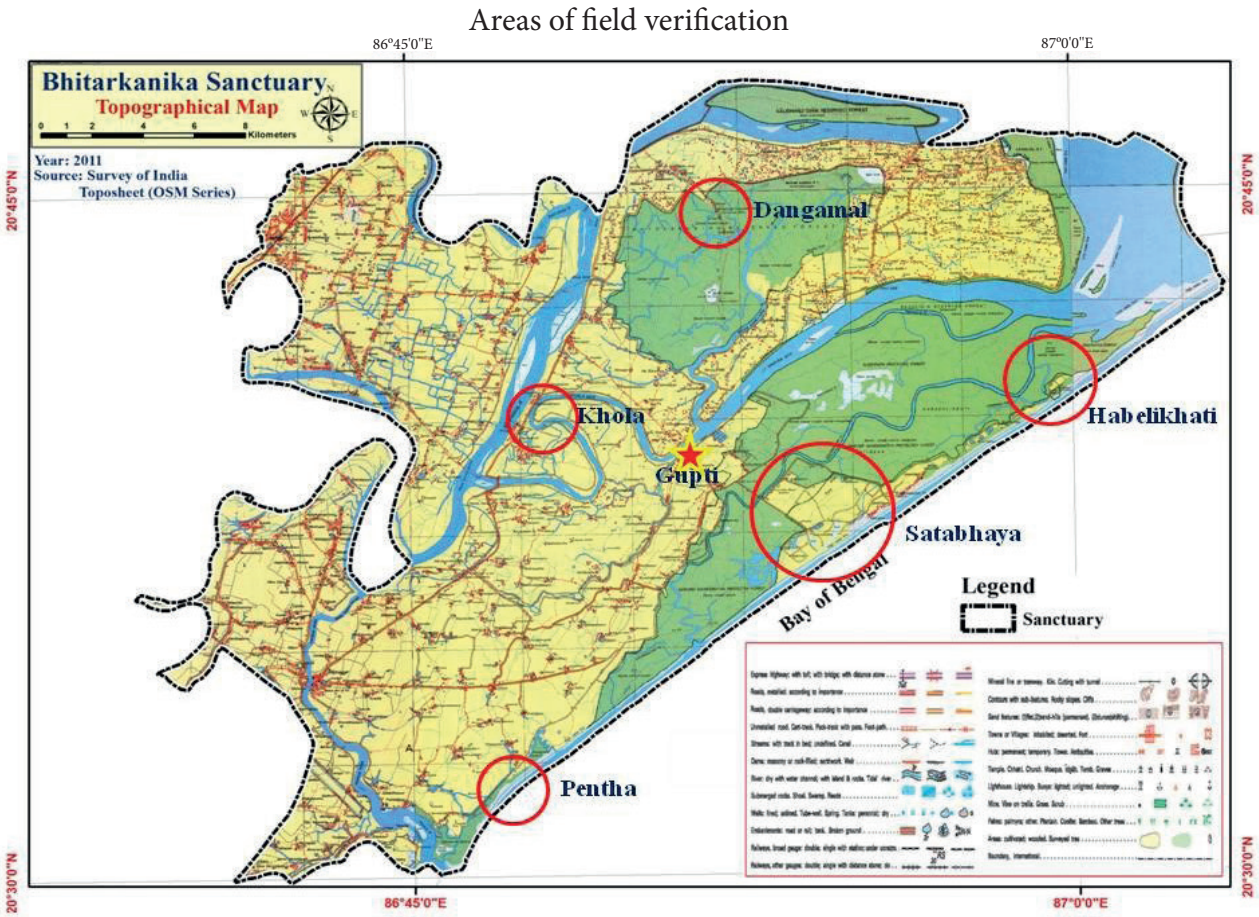


Fig. 2. Areas of field verification in Bhitarkanika Wildlife Sanctuary, Odisha

from online ArcGIS, Google Pro and dedicated field survey. The field verification was basically conducted to know the actual ground reality.

In the process of land use and land cover analysis, the Ground Control Points (GCPs) identified for field verification where the ground truth was conducted, the field truth collected from sanctuary area was taken in account and the colour, tones, textures of the images were also considered for interpretation. River, Mudflats, Sandy areas, Inter Tidal Zones, Island and other land parts of estuarine area were also interpreted visually. Google Earth mobile App and Avenga Map Mobile App were used in the field for locating the ground truth areas and to correlate and verify the ground information with satellite images. For further accuracy Geo Tagged photos were used to correlate the map data with ground data. These images were taken at the time of field ground truth which helped to reveal the true interpretation and investigation on land use land cover features in ground. A proper planning with the help of map (Fig. 2) was prepared for the field investigation. Centered at Gupti, the field investigation started with considering the vital and essential parameters required for all categories of land use classification. The places were taken East, West, North and South of Gupti and the places as identified for the cross checking with the satellite image and topographical sheet are Habelikhati in East, Khola in West, Dangamal in the North and Pentha in the South.

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 four different years have been created using ArcGIS 10.7 software. The Unsupervised Classification Maps and False Colour Composite maps were verified by ground truth verification of land use and vegetation types. In a broader sense the interpretation of satellite images was done for 9 major classes like (a) agriculture (b) dense mangroves (c) water (waterbody of all types which includes rivers and creeks within the PA) (d) open mangroves (e) inter tidal zone (f) mudflats (g) plantations/vegetation (including village and near plantations other than mangroves) (h) sand and (i) aquaculture. Finally the statistical analysis was carried out for each year to figure out the change matrix, percentage change, individual graphs and pie charts of these referenced years.

LAND USE LAND COVER CHANGE ANALYSIS

There is change in forest cover with addition of newly formed forests in Odisha. Mangrove cover in Kandrapara district also witnessed an increase in the Mangrove cover as compared to 2017 (FSI, 2019). A detailed study of land use and land cover (LULC) of Bhitarkanika Wildlife Sanctuary for nine categories was carried out for a period of 30 years details of which are presented in Table 2.

Table 2. Change in area (km^2) of land use and land cover classes of Bhitarkanika Wildlife Sanctuary from 1990 to 2020

SL NO	Category	1990		2000		2010		2020	
		Area (km^2)	Area in %	Area (km^2)	Area in %	Area (km^2)	Area in %	Area (km^2)	Area in %
1	Agriculture	338.2	50.3	350.0	52.0	317.8	47.3	311.4	46.3
2	Dense Mangroves	118.2	17.6	122.0	18.1	122.9	18.3	101.4	15.1
3	Waterbody	82.1	12.2	80.0	11.9	80.1	11.9	75.0	11.2
4	Open Mangroves	37.2	5.5	29.8	4.4	42.0	6.2	49.5	7.4
5	Inter tidal zone	13.6	2.0	16.2	2.4	18.8	2.8	22.9	3.4
6	Mud Flats/ Swamps	47.9	7.1	33.9	5.0	42.4	6.3	48.7	7.2
7	Plantation/ Other vegetation	27.8	4.1	34.3	5.1	36.4	5.4	36.9	5.5
8	Sand	6.6	1.0	5.9	0.9	9.5	1.4	6.8	1.0
9	Aquaculture	0.4	0.1	0.6	0.1	2.4	0.4	19.5	2.9

The changes within the time period of three decades were analyzed for classes like (a) dense mangroves (b) open mangroves (c) agriculture (d) plantations / vegetation (including village and near plantations other than mangroves) (e) water (water body of all types which includes rivers and creeks within the pa) (f) mudflats (g) sand (h) inter tidal zone and (i) aquaculture (Table 3).

Table 3. Change matrix of different land use and land cover classes in Bhitarkanika Wildlife Sanctuary

Sl. No.	Category	1990	2020	Change matrix
1	Agriculture	338.2	311.36	-26.8
2	Dense mangroves	118.2	101.41	-16.8
3	Waterbody	82.1	75.01	-7.1
4	Open mangroves	37.2	49.49	12.3
5	Inter tidal zone	13.6	22.94	9.4
6	Mud flats/ swamps	47.9	48.72	0.8
7	Plantation/ Other vegetation	27.8	36.90	9.1
8	Sand	6.6	6.83	0.2
9	Aquaculture	0.4	19.45	19.0

The final land use and land cover maps were prepared after prior interpretation of individual Land sat satellite imagery of 1990, 2000, 2010 and 2020 (Fig. 3).

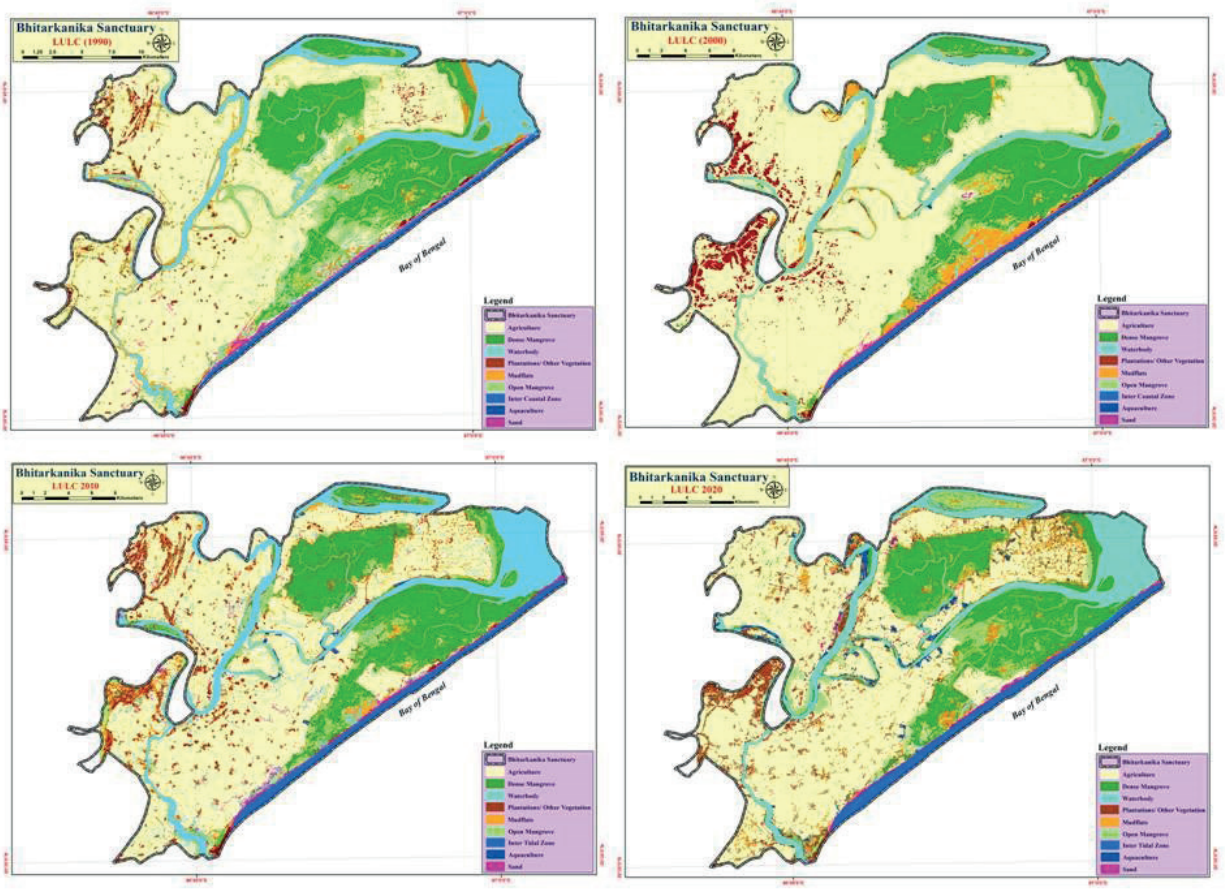


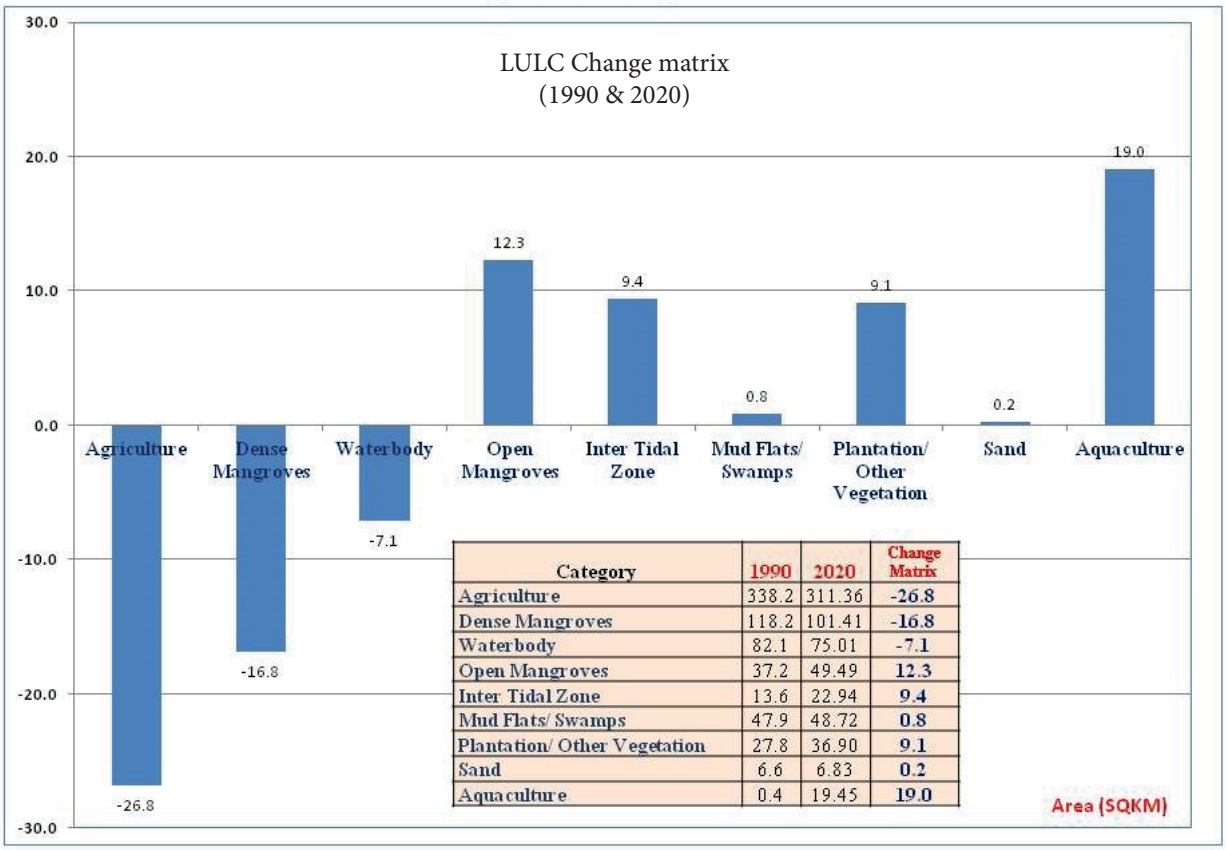
Fig. 3. Land use/cover change of different categories during years 1990, 2000, 2010 and 2020 of Bhitarkanika Wildlife Sanctuary

The analysis further continued with the study of net change area for each decade and finally the overall change in area was calculated from 1990 - 2020 (Table 4).

Table 4. Land use changes in each period in Bhitarkanika Wildlife Sanctuary (km^2)

Sl. No.	Category	Net change in 1990–2000	Net change in 2000–2010	Net change in 2010-2020	Over all Change 1990–2020
1	Agriculture	11.8	-32.2	-6.4	-26.8
2	Dense mangroves	3.8	0.9	-21.5	-16.8
3	Waterbody	-2.1	0.2	-5.1	-7.1
4	Open mangroves	-7.4	12.2	7.5	12.3
5	Inter tidal zone	2.6	2.6	4.1	9.4
6	Mud flats/ swamps	-14.0	8.5	6.3	0.8
7	Plantation/ other vegetation	6.5	2.0	0.5	9.1
8	Sand	-0.7	3.5	-2.6	0.2
9	Aquaculture	0.2	1.8	17.1	19.0

Basing on the study area analysis, considering all the four years with 3 decades time period, a change matrix was prepared (Fig. 4).



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Plantation/ Other Vegetation	27.8	36.90	9.1
Sand	6.6	6.83	0.2
Aquaculture	0.4	19.45	19.0

Fig. 4. An overview of change matrix (1990–2020) in Bhitarkanika Wildlife Sanctuary

Land use of agriculture

It is a fact from above figures that Agriculture is the predominated Land use category of all and is practiced in a major portion of the study area. But this study analysis shows that a land transformation from agricultural to aquaculture in recent years. As it was observed that during 1990, 338.2 km^2 area with 50.3% of the total area was under agriculture was increased to 350.0 km^2 with 52% in 2000. This change added some more areas under Agriculture where rice/ paddy being the major in agricultural crops. This trend declined to 317.8 km^2 in 2010 with 47.3 per cent to further to 311.4 km^2 having 46.3 per cent in 2020. The rate of decline as revealed in the study has a significant impact on Agriculture as a result of introduction of aquaculture farms within the sanctuary area. The aquaculture firms require saline water which are transformed to the aquaculture ponds through inlet channels. Actually these in turn are the carrier of irrigation water for the agricultural fields and add salinity to the fertile soil of the region which indicates possibilities of decrease in rice yield with the increasing salinity in the area. Such an enhanced salinity of the soil is expected to impart adverse effects on local economy. Several other studies on exploration of possibilities in yield reduction due to saline water intrusion have also confirmed that salinisation and subsequent acidification of agricultural soil renders considerable reduction in rice yield (White et al., 1996). Even with moderately saline water irrigation, the yield has been found affected (Asch et al., 2000). In addition, as it has been reported earlier that, a shift in highest rainfall months from June and October during 1980-84 and August to October during 1995-99, is noticed (Mitra and Hazra, 2003). Since 1988-89 the monsoon rainfall excluding the super cyclone year has been found to decline rapidly. Among other factors, climate plays most vital role in agricultural productivity. Alike other coastal zones, Bhitarkanika too, cannot depend on the irrigation water for agricultural practices, as the estuarine water may make the soil saline, if irrigated. Timely and the desired level of rainfall thus are very critical for the region.

Land use of dense mangroves

In particular to the Bhitarkanika Wildlife Sanctuary, the mangrove plays a major role in land use classification. The wetland supports one of the largest mangrove ecosystems after Sundarbans, Gujarat and Andhra Pradesh in the Indian mainland. It has more than 300 numbers of plant species, which include mangroves, mangrove associates and non mangroves. The floral diversity of Bhitarkanika wetland is known to be largest and the most productive ecosystems in India. It adds to the coastal fishery production. The rivers and creeks in the wetland are a major source of variety of indigenous fish. In addition, the local people depend on the mangrove vegetation for collection of honey, wax and medicinal plants as these dense mangroves provide valuable services to them.

The land use study in Bhitarkanika Wildlife Sanctuary shows a declining trend in Dense Mangroves since the early 90s. In 1990 only 118.2 km^2 area comprising 17.6% of the total area of the sanctuary was under Dense Mangroves category, whereas the trend continued to decline to 122.0 km^2 in 2000, 122.9 km^2 in 2010 and 101.4 km^2 in 2020 respectively with 18.1% in 2000, 18.3% 2010 and 15.1% in 2020. This study reveals the reduction in the area of dense mangroves caused by endogenic and exogenic forces which are act as an alternative landuse elements like aquaculture, agriculture and tourism which possess high level of threat to this mangrove class.

Land use of open mangroves

This is mostly found along the fringes of defunct creeks, in small islands and forest peripheries where the vegetation density is less than 40% canopy cover. The trend in change in the open mangrove cover increase, being 37.2 km^2 in 1990 with 5.5%, 29.8 km^2 in 2000 with 4.4% , 42.0 km^2 with 6.2 km^2 in 2010 and 2020 the figures rose up to 49.5 km^2 with 7.4% increase in total. This kind of vegetation is found as large patches inside the Satabhaya coast, Suneirupei forests, Gopalpur P.F. and Bhitarkanika R.F.

Land use of water body

The sanctuary is bounded by Dhamara river in the north, the Hansua in the west and the Bay of Bengal in the east and south. The river Dhamara (the confluence of Brahmani and Baitarani) in combination with Maipura, the tributary of Brahmani, constitutes the delta developed by creeks and channels in Odisha coast. The water body category includes all the rivers, creeks, channals, ponds etc. now the land use study shows decline of area under water body.This can be a change drawn between the high tides and low tides. Some portions of this water get in to the feeding channel which supply water to the aquaculture ponds. The trend chart of water body shows that 82.1 km^2 having 12.2% of area in 1990 was under this category, whereas in 2020 the land use under water body category decreased and went down to 75.0 km^2 with 11.2% decrease in area under water body. The overall change in waterbody category is found to be 7.1 km^2 less as compared to the area under water body in 1990.

Land use of inter tidal zone

The Inter Tidal Zone is the area between the sea and the shore line. As it is clearly indicative that the inter tidal zone is increasing in due course of time. Every decade some more area is added to the inter tidal zone. The direct agents acting in this scenario is the sea current and the tidal effect of the Bay of Bengal. The area under tidal zone in 1990 was 13.6 km^2 with 2% of the total area and increased on to 16.2 km^2 in 2000 with 2.4%. The increase further continued with 18.8 km^2 totaling to 2.8% of area in 2010, finally contributed 22.9 km^2 with 3.4% area under this land use category. The change in the inter tidal zone as reflected in the analysis shows an increase net change area with 2.6 km^2 in 1990–2000, similarly same area was under this category of land use in the next decade i.e. 2.6 km^2 in 2000–2010. The area increased to 4.1 km^2 in 2010-2020 making an overall net change of 9.4 km^2 from 1990 to 2020.

Land use of mud flats/ swamps

The mudflats extensive and wide salty marshy land main consists of clay and silt. Presently the mudflats contribute to 48.7 km^2 of area. They are usually submerged in the saline waters due to the effect of high tides and low tides. These mudflats usually are formed due to the deposition of sediments from river outflow from the Bhitarkanika drainage catchment area and are found in the Maipura and Dhamra estuaries which act as major inlet river in the sanctuary. The mudflats had only 47.9 km^2 contributing to 7.1% of the total area in 1990. But it the change in land use was major in the year 2000 with 33.9 km^2 and 5% area with a decrease of 14.0 km^2 area as compared to 1990. The sanctuary again had an increase of area in mudflat category figuring to 42.4 km^2 with 6.3% in 2010, it added an area of 8.5 km^2 to the net change as compared to the year 2000. Finally the mudflats contributed 0.8 km^2 area as an overall change in respect to 1990 compare with 2020.

Land use of plantation/ other vegetation

Overall plantation in the sanctuary area was taken in account for 3 decades. This category included all the vegetation and plantations other than mangrove species. This category of the land use witnessed an overall increase in area with increasing trend in all decades. With 27.8 km^2 area having 4.1 per cent area under this category in 1990, it started an onward trend in subsequent years. It noticed a change in area in 2000 with 5.1 per cent having 34.3 km^2 area with an increase of 6.5 km^2 area as compared to 1990. In the year 2010 plantation category increased to 36.4 km^2 with 5.4 per cent and finally reached to 36.9 km^2 having 5.5 per cent area under it. The overall change in area as compared to 1990 with 2020, 9.1 km^2 of area contributed to this category. There is a marginal change in area which is due to other plantation activities done by the village people and the roadside plantation/ conservation activity of the government.

Land use of sand

This land use category is confined to the coastal areas along the Gahirmatha Marine Sanctuary coast adjacent to the inter tidal zone.

The area along the Gahirmatha coast is found suitable for the Olive Ridley sea turtles which come for mass nesting and egg laying process every year. Along this coast some Casuarina plantation was observed near Habelikhatti, Sathbhaya, Kanhupur and Barunai. The sand category had a marginal influence in area as compared to all 3 decades. It had only 6.6 km^2 area with 1.0 per cent in 1990 and in 2020 it was observed with an area of 6.8 km^2 having 1.0 per cent under this landuse category. It observed only 0.2 km^2 increase in area from 1990 to 2020 in its overall change area.

Land use of aquaculture

In and around the site, a large chunk of the agriculture land adjacent to rivers and creeks have been converted to prawn farms. The existing population pressure and mass unemployment has invited a large number of people residing nearby and from outside the area have purchased private land along the coast as well as along the rivers and the creeks, converting the same to aquaculture farms. They are discharging the untreated effluents from the farm to nearby rivers and creeks and thereby affecting the aquatic fauna and the mangroves. As these farms are in close proximity to the mangroves of these region they impact factor is very high in degrading the mangroves. The rate in increase of aquacultural farms has a direct impact on the declining rate on agricultural lands and associated activities. Moreover the inlet to these ponds which acts as feeder channels are usually rivers and creeks passes through mangroves and agricultural fields. Due to this salinity of the area increases which results in decrease in rice and paddy yield. As it is clearly confirmed from the study that in 1990 only 0.4 km^2 with 0.1 per cent area was under aquaculture and the nature was scattered type. The rate of increase was marginal in the two decades up to 2010 as the area under this category was 0.6 km^2 in 2000 and 2.4 km^2 in 2010 with 0.6 per cent and 0.4 per cent of the total area. Gradually the rate and the area under aquaculture started to increase, in 2020 the aquaculture farms/ponds had steep increase with 19.5 km^2 areas totaling to 2.9 per cent. This sudden spike in aquaculture was because it is a very profitable business as the local price of aquacultural products is quite high in comparison to other fishery items. The rapid commercialization of this business has added to the existing precarious situation of mangroves in the study area. The aquacultural farms directly affect the process of degradation of mangroves in the area by blocking or diverting the stream channels towards their farms.

RESULTS AND DISCUSSION

Mangrove forests in the Bhitarkanika Wildlife Sanctuary are getting degraded due to intense anthropogenic activities (Misra et al., 2018). People do have associated activities on the mangroves and extract them for economic and medicinal purposes. The increase of aquaculture ponds and the daily discharge of effluents from these ponds to the rivers and creeks have got severe impact on degradation of dense mangroves. The daily need and dependency on mangrove forests by these people are depleting the density of mangroves which are disappearing at an alarming rate. Many of the mangroves or associated species which have their economic importance have become threatened because of there over use and exploitation due to various human activities. It is observed that, government has taken some initiatives for the sustainable development in the study area. Some degraded areas are now under plantation. The settlement distribution is rapidly increased which is adding tremendous pressure in the dynamic coastal environment. The government and the forest department should take adequate steps for realising all these pressures on mangroves by ensuring different *in-situ* and *ex-situ* conservation activities. The managers of the sanctuary and mangrove areas should come up with some alternative ideas and projects which will help the local people dependent on mangroves and associated species that makes their livelihood different to reduce such pressures on the mangroves.

ACKNOWLEDGEMENT

The authors express sincere thanks to the PCCF (WL) and CWLW (Odisha), Chief Executive, Chilika Development Authority, DFO, Rajnagar and Wildlife Warden, Bhitarkanika Wildlife Sanctuary, Kendrapada, Odisha, Dr. G. Rastogy and Dr. P. Muduli, Scientists, CDA for providing permission and facilities to undertake the study in the sanctuary.

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