Indian Journal of Geo Marine Sciences
Vol. 48 (12), December 2019, pp. 1916-1924

Monitoring Changes in Vegetation Cover of Bhitarkanika Marine National Park Region, Odisha, India Using Vegetation Indices of Multidate Satellite Data

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Received 03 May 2018; revised 20 June 2018

The coast of Odisha extends from Balasore in the north to Ganjam in the south spreading 480 km. It exhibits a depositional terrain formed by the action of fluvio-marine, lacustrine, estuarine and aeolian agents. The river system coupled with marine action help in generating diversified physiographic and dynamic coastal features. Over the period, the coastal tract also witnesses the vagary of nature. Vast alluvial plain, meandering pattern of rivers, low lying swamps and swamp forests, sand dunes, beach ridges, beaches and swales are typical landforms associated with the coastal tract. The Bhitarkanika Marine National Park region, the study area is situated on the northern part of the coast which mostly exhibit swampy habitat due to large fine clastic deposits by riverine action. Mangroves on the swampy region occupy around 18,348 ha and regarded as the second largest mangrove formation in the subcontinent. Besides, the coastal tract also exhibits a congenial place for mass nesting of sea turtles coming from Pacific Ocean. The study area is now under stress due to various natural as well as anthropogenic pressure. The degradation of mangroves is mainly due to human encroachment and reclamation of land for aquaculture practices. It is observed that the occurrence of vegetation cover decreases continuously from 1973 to 2017. Dense vegetation cover is recorded as 35.23 % (1973) which decreased to 22.43 % (2017). On the southern end of the study area lies an all-weather port named Paradeep and on the northern side one emerging new port called Dhamra port. Their activities and impact as well as blooming aquaculture practices have bearing on the ecosystem of the mangroves. The assessment of vegetation vigor of the region portrays the condition of the environment shaped after years of degradation activities due to natural as well as anthropogenic activities induced from 595 villages having 50,6930 population.

The objective of the study is to analyze the changes of vegetation vigor using NDVI from multi date satellite data and record the changes for better monitoring of the area. It may be inferred that the existing conservation measures and protection plans are inadequate to hold the coastal natural resources intact. The community participation and public awareness are not sufficient to abate the brittle coastal environment. Public participation, education programme, awareness initiatives are the foundation of success of any sustainable development in the sensitive coastal region.

[**Keywords:** Geo-Spatial technology, GIS, MNP, NDVI, Vegetative cover]

Introduction

Land cover refers to different features covering the earth's surface including vegetation cover, water bodies, open scrub etc. With the development of Geographic Information System (GIS) and Remote Sensing technologies and its applications, mapping becomes easier and visualization of Land use/land cover (LULC) becomes more efficient. Change detection of land cover is one of the significant techniques, which is widely used for studying temporal changes in land units, inferring causative factors which helps in planning and managing the land. Satellite imagery forms the significant database, which is primarily used in extracting changes in land cover.

Besides land cover assessment, soil moisture measurement, forest type classification, measurement of liquid water content of vegetation etc are also some of the important application areas in studying vegetation. Normalized Difference Vegetation Index (NDVI) is a common and widely used index to study the distribution of greenness in a particular area. It is an important vegetation index, widely applied in research on global environmental and climatic change studies. It is calculated as a ratio between measured canopy reflectance in the red and near infrared bands.

Green vegetation is highly absorptive in the visible part of the spectrum, mostly owing to the presence of chlorophyll. The NDVI algorithm subtracts the red reflectance values from the near infrared and divides it by the sum of near-infrared and red bands[1,2] as given below:

NDVI = NIR-IR /NIR+IR

Satellite remote sensing refers to significant data which is commonly used on extracting change values of land cover[3, 4]. The objective of the present study is to assess the vegetal cover of the area popularly known as Bhitarkanika Marine National Park (MNP). The area is mostly endowed with rich mangrove vegetation, coastal plantations and other vegetation associated with rural settlements. Besides documenting the vegetation health, temporal variation on vegetal pattern is also observed using NDVI approach as the area is witnessing continuous deterioration from 1973 to 2017. The drivers of change are also discussed while stating the land cover features in different periods.

Study Area

The area is situated in the administrative unit of the state called Kendrapara district of Odisha, India. It is a part of the lower deltaic plain of Mahanadi river. It is visited by natural disasters mainly floods and cyclones frequently. It is an ecologically sensitive area as the tract is covered by Bhitarkanika mangrove forest-a RAMSAR site and a sensitive mangrove patch near the Mahanadi estuarine area on the south. Rapid industrialization in Paradeep (southern sector) and Dhamra port (northern sector) areas, increase of aquaculture activities, denudation of coastal sands, rapid degradation of coastal vegetation, salinity ingress in the agricultural land, natural and artificial disturbance on the habitats of sea turtles etc are major concern of the area. Mangroves, which act as a barrier for the coast from any natural disasters is now degrading in a rapid rate which threatens the ecosystem and coastal environment[5].The area is also treated as one of the most vulnerable area of India[6].

The study area lies within 20°17'58.556" to 20°45'55.574"North latitude and 86°42'43.82" to 86°50'32.541"East longitudes and covers a geographical area of 1025 km^2 (Fig. 1). The geographic unit constitute basically combined deltas and flood plains of the Mahanadi river system that is dominated by fluvial action of meandering stream and littoral action of tides, waves and currents. Unconsolidated sediment is the most dominant geological feature of the study area. The soil present in the study area is clayey loam and highly slushy due to the regular inundation through tidal action. Mostly tidal and littoral swamp forests occupy the study area.

It enjoys a tropical wet-dry type of climate which is generally hot with high humidity. The maximum temperature recorded is 45 °C and the minimum is 10 °C during May and January, respectively. The average annual rainfall is about 1300 mm, bulk of which is

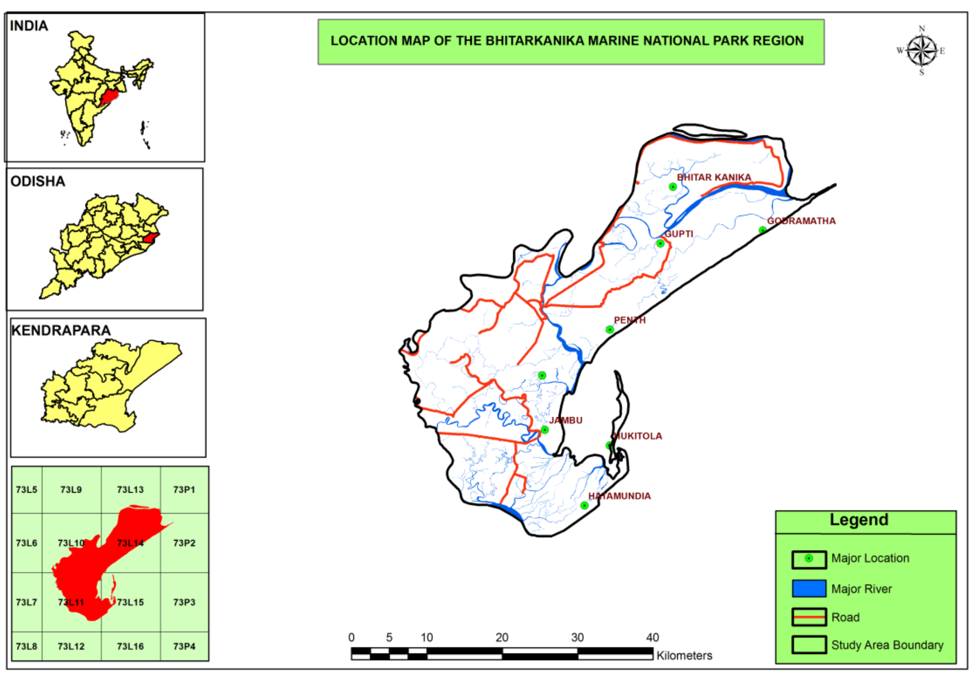

Fig. 1 — Location map of the study area

received during June to mid-October. Mean relative humidity ranges from 70 to 85 % throughout the year[7]. The river system of the area consists of mainly Gobari, Nuna, Patsala and Hansua river.

Bhitarakanika is covered with dense mangrove forests and saline creeks. It was declared as a Sanctuary on 21-04-1975 under the wild life protection act 1972. The sanctuary is bounded by the Dhamra river in the north, the Hansua in the west and the Bay of Bengal in the east and south. It is also declared as a Marine National Park of India and subsequently declared as a Ramsar site. The Bhitarkanika mangroves are home to 55 of India's 58 known mangrove species. Animals like deer, wild boar, monkeys, monitor, python, and king cobra also found here. The mangroves harbor one of the largest population of saltwater crocodiles in India. The role of Mangroves is vital in the coastal ecosystem because of its contribution to coastal fisheries and mitigating coastal erosion. The mangroves are highly vulnerable to cyclone and subjected to strong littoral drift[8,9].The beach is also famous for the world's largest nesting ground for olive ridley sea turtles.

Materials & Methodology

In this investigation, Landsat series of satellite images and IRS -LISS-III data were used for the period of 1973 to 2017. Landsat images are collected from United States Geological Survey (USGS) website, Earth Explorer (http://earthexplorer.usgs.gov/). Landsat images have been registered and geo-corrected from the source. LISS-III data were downloaded from BHUVAN website of ISRO (Table 1).

All satellite images have been registered and geo-corrected from the source. Resampling of satellite images carried out using ERDAS-Imagine 2014 and the resolution is kept at a medium resolution of 40 meter after the re sampling process. Landsat data have different spatial resolution and comparison of different data sets would be erroneous. While Landsat-1 data has 80-meter resolution, Landsat-8 has 30-meter resolution data. Further IRS-LISS-III has products at finer resolution of 23.5 meter. Hence, for bringing to an adjustable and more accurate spatial dataset, all the values of Digital Numbers (DN) are to be moderated and resampled to a common spatial resolution (here it is 40 meter) for better comparison. Using ERDAS imagine s/w the re-sampling has been carried out.

Table 1 — Satellite Data used

Year	Date of acquisition	Path	Row	Sensor
1973	17-Jan-73	149	53	Landsat-1
1985	17-Jan-85	149	46	Landsat-3
1995	14-Nov-95	139	46	LISS-III
2005	19-Feb-05	107	58	Landsat-5
2017	04-Mar-17	139	46	Landsat-8

Normalized Difference Vegetation Indices are generated for each dataset using Arc-Map, 10.2 version. The range of NDVI values (pixel counts) have been reclassified for generating classified units of LULC classes. Then change analysis for the NDVI of different time was brought out.

Results and Discussion

The NDVI for each data set such as 1973, 1985, 1995, 2005 and 2017 have been generated and Land use land cover maps based on NDVI have been prepared. NDVI, an indicator of vegetation growth and coverage, has been widely employed to describe the spatiotemporal characteristics of land use land cover, including percent vegetation coverage[10-12]. The NDVI image enhances the vegetation class in the images and helped in distinguishing it from other non-vegetation classes. Analysis of NDVI index also points out land cover changes due to human activities. The assigned spectral classes which are function of NDVI are evaluated to assign into suitable LULC classes. The study area has been classified as Dense vegetation, Medium vegetation, Low vegetation, Non-vegetation and Water bodies. For each year, individual NDVI based LULC map has been generated and compared with other LULC maps (Figs. 2 to 6). For a detailed study, four regions of the area have been selected namely Bhitarkanika Reserve Forest, Hatamundian Reserve Forest, Kalibhanj Dian Reserve Forest and Satbhaya Reserve Forest. The NDVI for these selected regions is generated for the years 1973, 1985, 1995, 2005 and 2017. The vegetation density has been taken into account and is classified into dense, medium and low.

Significant changes of vegetation cover in the study area are shown in Table 2. A change detection matrix has been prepared for different time period using the NDVI results. Changes between 1973-1985, 1973-1995, 1973-2005, 1973-2017 and 1995-2017 have been studied (Table 3). It is observed that areal extent of water bodies has been increased from 5865.25 ha in 1973 to 6258.27 ha in 1985. The area again decreased to 5835.65 ha (1995) and further to

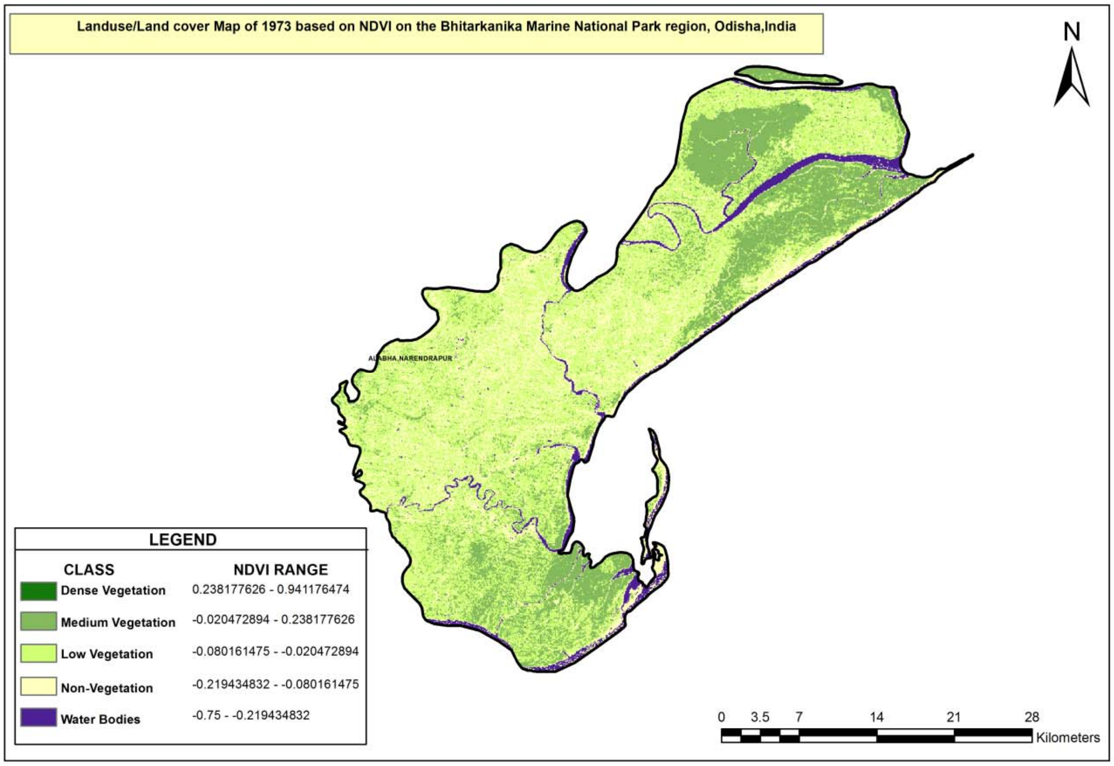

Fig. 2 — LULC Map of 1973

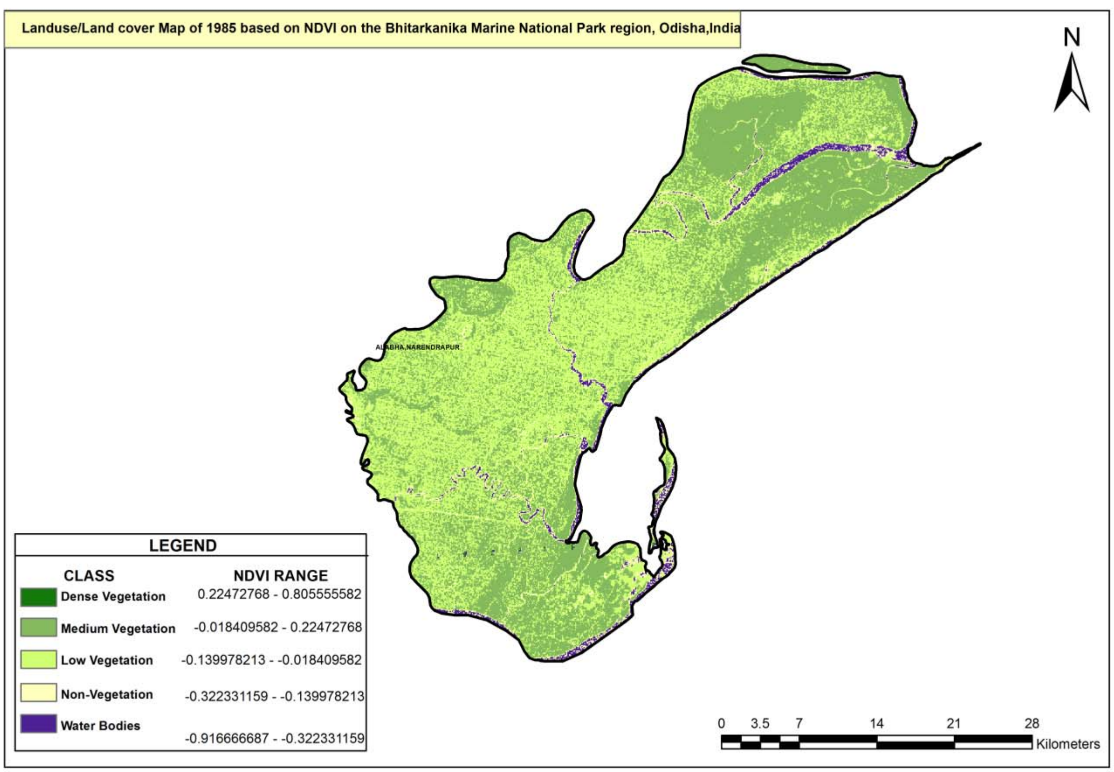

Fig. 3 — LULC Map of 1985

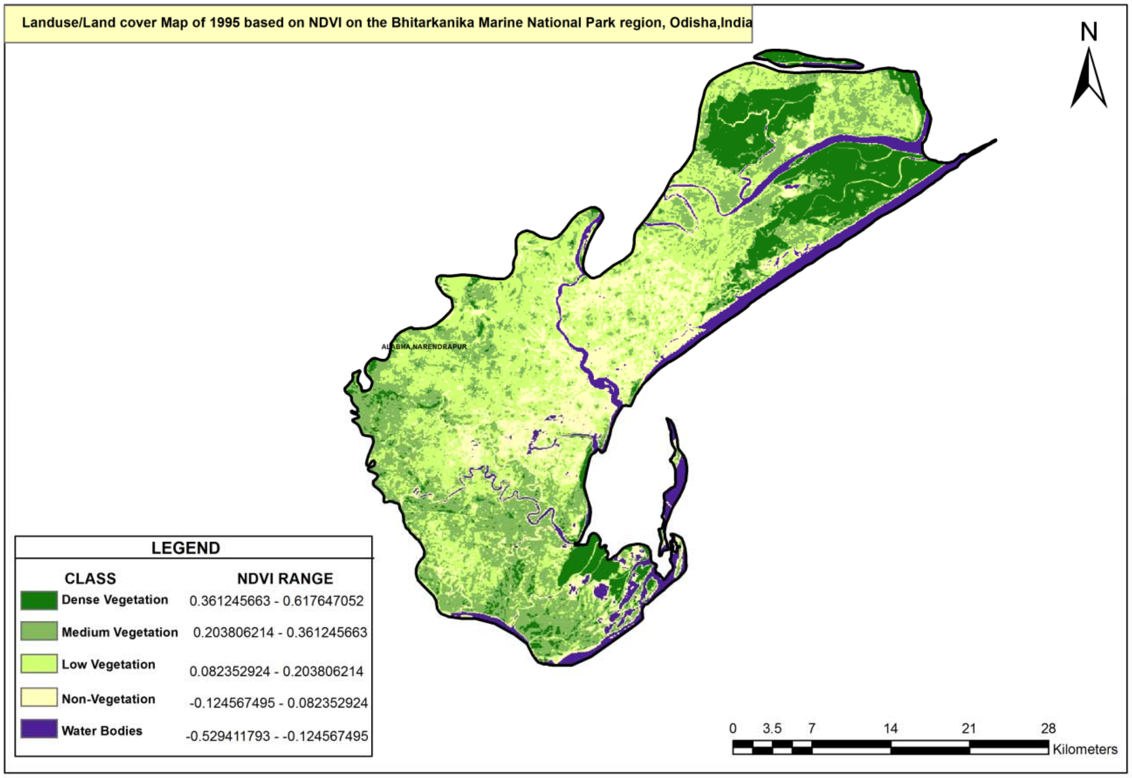

Fig. 4 — LULC Map of 1995

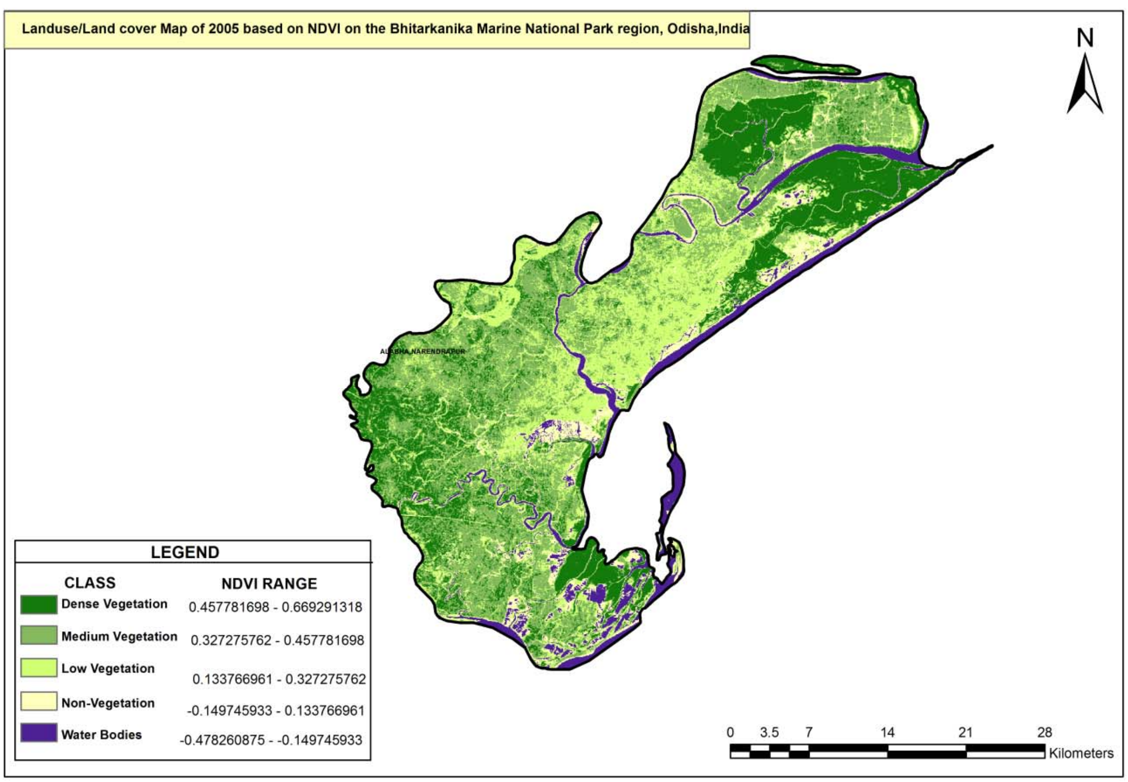

Fig. 5 — LULC Map of 2005

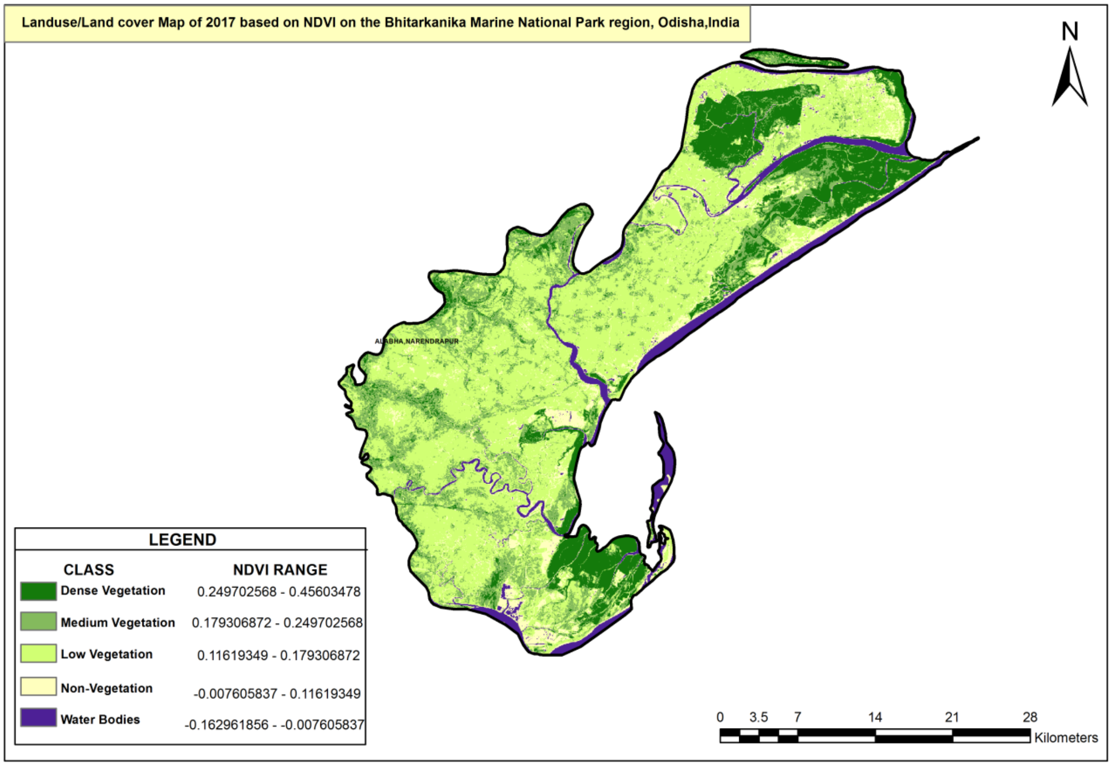

Fig. 6 — LULC Map of 2017

Table — 2 Change Analysis in Individual Years (1973, 1985, 1995, 2005 and 2017

NDVI CHANGE ANALYSIS OF BHITARKANIKA MARINE NATIONAL PARK AREA(1973-2017)

CLASS	WATER BODY	NON-VEGETATION	LOW VEGETATION	MEDIUM VEGETATION	DENSE VEGETATION	TOTAL
			YEAR-1973			
AREA (ha)	5865.25	9858.25	18487.32	24959.35	32185.33	91355.5
Percentage	6.42	10.79	20.24	27.32	35.23	100.00
			YEAR-1985			
AREA (ha)	6258.27	11401.76	20187.25	22487.69	31020.35	91355.32
Percentage	6.85	12.48	22.10	24.62	33.96	100.00
			YEAR-1995			
AREA (ha)	5835.65	15124.57	21953.57	20596.38	27845.35	91355.52
Percentage	6.39	16.56	24.03	22.55	30.48	100.00
			YEAR-2005			
AREA (ha)	6235.65	22556.09	20354.66	18659.54	23549.58	91355.52
Percentage	6.83	24.69	22.28	20.43	25.78	100.00
			YEAR-2017			
AREA (ha)	6352.77	31466.74	16587.35	16457.11	20491.55	91355.52
Percentage	6.95	34.44	18.16	18.01	22.43	100.00

6235.65 ha (2005) and subsequently increased to 6352.77 ha in 2017. The frequent variation in the water extent in the study area may be due to flooding, inundation and seasonal variation as captured at the time of imaging. The non-vegetation area as computed are as follows: 9858.25 ha (1973), 11401.97 ha (1985), 15124.57 ha (1995), 22556.09 ha (2005) and 31466.74 ha (2017). The non-vegetation area includes cropland, wasteland, aquaculture land, settlements and other built-up areas. The drastic increase in non-vegetation area is due to the development activities and impact of settlements surrounding the mangrove vegetation.

Table — 3 NDVI Change analysis in two period

NDVI CHANGE ANALYSIS BETWEEN YEARS

	WATER BODY	NON-VEGETATION	LOW VEGETATION	MEDIUM VEGETATION	DENSE VEGETATION
1973-1985					
Change(ha)	393.02	1543.51	1699.93	-2471.66	-1164.98
Change (%)	6.70	15.66	9.20	-2.71	-1.28
Avg.Change ha/year	30.23	118.73	130.76	-190.13	-89.61
Avg.Change (%)	0.52	1.20	0.71	-0.21	-0.098
1973-1995					
	WATER BODY	NON-VEGETATION	LOW VEGETATION	MEDIUM VEGETATION	DENSE VEGETATION
Change(ha)	-29.6	5266.32	3466.25	-4362.97	-4339.98
Change (%)	-0.50	53.42	18.75	82.5	-13.48
Avg.Change ha/year	17.09	67.11	73.91	-107.46	-50.65
Avg.Change (%)	-0.02	2.32	0.82	3.59	-0.59
1973-2005					
	WATER BODY	NON-VEGETATION	LOW VEGETATION	MEDIUM VEGETATION	DENSE VEGETATION
Change(ha)	370.4	12697.84	1867.34	-6299.81	-8635.75
Change (%)	99.50	153.42	110.10	74.76	73.17
Avg.Change ha/year	11.22	384.78	56.59	-190.90	-261.69
Avg.Change (%)	3.02	4.65	3.34	2.27	2.22
1973-2017					
	WATER BODY	NON-VEGETATION	LOW VEGETATION	MEDIUM VEGETATION	DENSE VEGETATION
Change(ha)	487.52	21608.49	-1899.97	-8502.24	-11693.78
Change (%)	108.31	319.19	89.72	65.94	63.67
Avg.Change ha/year	10.83	480.19	-42.22	-188.94	-259.86
Avg.Change (%)	2.41	7.09	1.99	1.47	1.41
1995-2017					
	WATER BODY	NON-VEGETATION	LOW VEGETATION	MEDIUM VEGETATION	DENSE VEGETATION
Change(ha)	517.12	16342.17	-5366.22	-4139.27	-7353.8
Change (%)	108.86	208.05	75.56	79.90	73.59
Avg.Change ha/year	22.48	710.53	-233.31	-179.97	-319.73
Avg.Change (%)	4.73	9.05	3.29	3.47	3.20

The percentage of areal extent of dense vegetation is reduced from 35.23 % in 1973 to 22.43 % in 2017. While medium vegetation constitutes 27.32 % (1973), 24.62 % (1985), 22.55 % (1995), 20.43 % (2005) and 18.01 % (2017). And the low vegetation covers 20.24 % (1973), 22.10 % (1985), 24.03 % (1995), 22.28 % (2005) and 18.16 % (2017). It is observed that there is drastic change in vegetation cover between different years.

In Bhitarkanika RF alone, dense, medium and low vegetation have been reduced to 13.56 %, 6.97 % and 10.76 %, respectively when data of two dates (1973 and 2017) are compared. This suggests that though the RF is well protected there is a decrease in density of vegetation during a span of 44 years. In the southern part of the study area (Hatamundian RF), dense, medium and low categories have been reduced to 23.58 %, 18.63 % and 16.75 %, respectively. In the channel island (popularly known as Kalibhanj Dian RF), similarly the dense, medium and low categories have been reduced to 44.94 %, 31.95 % and 17.98 %, respectively. In the eastern sector (Satbhaya RF), the changes have been observed as 16.6 %, 17.56 % and 14.97 %, respectively when data of two dates (1973 and 2017) are compared (Table 4).

The drivers of change are of two types: natural and man-made. Tropical cyclones, severe flooding, waterlogging and shoreline changes have bearings on loss of vegetation cover. Manmade activities like construction of aquaculture ponds, settlements on

Table — 4 Region wise and Year-wise vegetation analysis in the Bhitarkanika Marine National Park

YEAR	DENSE VEGETATION(ha)	%	MEDIUM VEGETATION(ha)	%	LOW VEGETATION(ha)	%
BHITARKANIKA R.F						
1973	1421.3	30.77	1325	28.68	1254	27.15
1985	965.44	28.81	1282.35	27.76	1185.35	25.66
1995	962.4	20.83	1235.6	26.75	985.9	21.34
2005	855.68	18.52	1002.87	21.71	854.57	18.50
2017	785.99	17.01	789.35	17.09	757.35	16.39
	4619.4		4619.4		4619.4	
HATAMUNDIAN R.F						
YEAR	DENSE VEGETATION(ha)	%	MEDIUM VEGETATION(ha)	%	LOW VEGETATION(ha)	%
1973	1388.0	53.18	1308.48	50.15	656.32	25.16
1985	1204.2	46.14	1214.35	46.54	606.4	23.24
1995	1001.9	38.53	1124.9	43.12	406.9	15.60
2005	912.58	35.0	987.4	37.84	325.3	12.47
2017	771.25	29.6	822.3	31.52	219.5	8.41
	2609		2609		2609	
KALIBHANJ DIAN R.F						
YEAR	DENSE VEGETATION(ha)	%	MEDIUM VEGETATION(ha)	%	LOW VEGETATION(ha)	%
1973	460.8	68.22	338.7	50.14	177.1	26.22
1985	412.58	61.08	290.4	42.96	145.58	21.55
1995	398.78	59.03	228.8	33.87	101.9	15.08
2005	298.25	44.15	187.7	27.78	88.3	13.06
2017	157.25	23.28	122.9	18.19	55.7	8.24
	675.5		675.5		675.5	
SATBHAYA						
YEAR	DENSE VEGETATION(ha)	%	MEDIUM VEGETATION(ha)	%	LOW VEGETATION(ha)	%
1973	5258.4	62.80	3357.44	40.10	3911.68	46.72
1985	4825.35	57.63	3059.04	36.53	3565.25	42.58
1995	4568.25	54.56	2646.56	31.61	3257.58	38.91
2005	4258.35	50.86	2235.78	26.70	3058.87	36.53
2017	3868.35	46.20	1887.35	22.54	2658.25	31.75
	8373		8373		8373	

reclaimed land, construction of density of vegetation cover. Severe cyclones have been experienced along the coast in the years 1967, port/jetties/embankments also affect the change of 1971, 1980, 1981, 1984, 1999, 2013 and 2014. Due to this the vegetation cover might have denuded. Some destructive floods were also witnessed in the years 1971, 1977, 1980, 1982, 1991, 1992, 1994, 1995, 1999, 2001, 2003, 2005, 2006, 2007, 2008, 2009, 2011 and 2013. Conversion of agricultural land into industrial purpose, and other developmental activities as well as vegetation clearance for settlement activities results into deterioration of the natural vegetation cover.

Conclusion

The coastal vegetation resources and their apparent changes are best studied using NDVI. The observations clearly indicate degradation of vegetation due to natural and anthropogenic factors. Based on the study the area may be divided into planning zones for preservation, conservation and development. Vulnerable areas may be identified and management options may be initiated[13-16]. Community participation programmes are to be taken up more vigorously for the protection of the dwindling coastal environment. Restrictive laws may be enacted for achieving effective conservation goals. In order to achieve a sustainable development in the delicate coastal ecosystem, involvement of all stakeholders at all levels is essential.

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