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Satellite Image-based Land Use/Land Cover Dynamics and Forest Cover Change Analysis (1996-2016) in Odisha, India

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Abstract: Land use/land cover change dealing with the alteration of the land surface and its biotic cover is an important aspect of human-induced global environmental change. The purpose of this study is to monitor long-term changes in LU/LC in Odisha with special emphasis to the forest cover change. LU/LC maps prepared through visual interpretation, indicated a decreasing pattern in percentage forest cover area (40.0%-1996, 39.0%-2006, 37.7%-2016). Conversely, significant increase in built-up area (0.3% in 1996, 0.5% in 2006 and 0.6% in 2016) have been observed. Forest cover maps derived through NDVI thresholding revealed a fluctuating trend of change in dense forest (23%-1996, 24%-2006 and 21%-2016) and increasing trend of moderate vegetation (32%-1996, 34%-2006 and 36%-2016). Vegetation cover change detection through post-classification comparison between NDVI classified images exhibited that 11,543 km^2 and 2662 km^2 under dense forest cover area had been converted to moderate and sparse vegetation cover in 2006 from 1996. Likewise, 10,635 km^2 and 2744 km^2 of dense forest cover area had been converted to moderate vegetation and sparse vegetation cover respectively from 2006 to 2016. Rapid urbanization in Bhubaneshwar and Cuttack was one of the reasons for the change in surrounding land covers and eco-sensitive areas. On the other hand, 10,857 km^2 and 1960 km^2 area which was under moderate and sparse vegetation cover respectively in 1996 had been converted to dense vegetation cover in 2006. Similarly, conversion (12,738 km^2 area of moderate and 4401 km^2 area sparse vegetation cover into dense vegetation) took place from 2006 to 2016. On a positive note, it can be remarked that implementation of plantations, afforestation programmes were found to be useful in saving the forest in Odisha.

Key words: Land use/land cover, forest cover, normalized difference vegetation index, remote sensing, Odisha.

Introduction

"Land cover" (the natural condition of the land, e.g. forest, water bodies) and "Land use" (the modified state of the land after anthropogenic interference to employ the land and its resources, e.g. residential/commercial area) have huge significance in relation to "Land", the most vital and fundamental resource pertaining to overall development of an area (Gupta and Roy, 2012). Worldwide land use/land cover (LU/LC) change as a combined effect of natural phenomena and anthropogenic activities is a matter of huge concern among the research communities because of its wide impact over climate, soil quality, topography, surface water, ground water, plant and animal life over a region. Changes in LU/LC, particularly in the form

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of deforestation, is one of the most prominent reasons for numerous environmental problems ranging from the local to the global scale. Such problem is intense at tropics that supports more than 60% of all known species but represents only 7% Earth's land surface (Dirzo and Raven, 2003).

According to various studies (Laurance and Bierregaard, 1997; Pimm et al., 2001), tropical humid forests are cleared, burnt, logged and fragmented with accelerating rates. In India, despite the ban on clear felling, forest degradation and small-scale deforestation continue for livelihood and commercial purposes (Reddy et al., 2009). Such wide depletion of forest cover affects to degrade the soil, accelerates soil erosion and thereby affects the agricultural production. Moreover, deforestation has its negative impact over carbon sequestration and thereby over the atmosphere. Hence, a detailed periodical assessment of LU/LC change with special attention to the change in tropical forest cover is one of the research interests throughout the world to formulate necessary conservation measures to manage the landscape and protect their biodiversity. Such kind of study is important for carbon budgeting, habitat analysis, land use planning, environmental management, and climate change mitigation (Wasseige et al., 2005; Margono et al., 2012).

For such periodical and long-term assessment of LU/LC change and forest cover analysis, remote sensing is proved to be an important, cost-effective and time-saving technology compared to traditional mapping approaches. The availability of multi-temporal, multi-resolution, multi-spectral satellite imageries have been successfully utilized for temporal assessment of landcover conversion (Jaykumar and Arockiasamy, 2003; Yuan et al., 2005; Halil et al., 2006) and tropical forest cover depletion (Sánchez-Azofeifa et al., 2001; Reddy et al., 2009; Redowan et al., 2014) using both spectral change detection methods and post-classification change detection methods. Landsat 4/5 Thematic (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI) acquire spectral radiance in visible, near-infrared, shortwave-infrared part of the electromagnetic spectrum and provide data with a longer history, free of cost and at regular time interval. Therefore, availability of Landsat images has been proved as a boon for regional scale LU/LC change analysis and assessment of deforestation. Still, long-term study of LU/LC change analysis are few in numbers (Sleeter et al., 2013).

The present study has been carried out in Odisha which is situated in the east coast of India and represents varied tropical vegetation formations. Major changes in the forest cover of this state has occurred during 1935–2010 (mean annual rate of deforestation is 0.69% per year) and resultantly 677 extinct, 1279 critically endangered, 1102 endangered and 1190 vulnerable ecosystems have been reported in a recent study carried out in the state (Reddy et al., 2013, 2014). Moreover, deforestation at a rate of 7.68% has taken place during 1990–2004 in Nawarangpur district of Odisha (Reddy et al., 2009). Land use conversions, expansion of human settlements and agriculture, mining and its allied industrial activities, forest fires, uncontrolled grazing, and bamboo exploitation have been identified as various causes of degradation and change in forest cover in this region (Singh et al., 2010; Reddy et al., 2013; Saranya and Reddy, 2016). Therefore, the present study attempts to monitor long-term (1996-2016) changes in the LU/LC especially the forest cover in Odisha using multi-temporal, freely-available satellite imageries.

Study Area

The area of study (Figure 1) chosen for the current research is Odisha, lying along the east coast of India within latitudes 17°48′ N–22°34′ N and longitude 81°24′ E – 87°29′ E. It is bounded by the states of Jharkhand, Andhra Pradesh, Chhattisgarh, and West Bengal to the north, south, west, and northeast respectively. The Eastern Ghats and Chhotanagpur Plateau make Odisha a rich biodiversity repository, 34.90% of the state's total geographical area is covered with forests. It comprises 6.84% of the India's total forest area (FSI, 2015). Four types of vegetation have been identified in Odisha: (i) Tropical Semi-evergreen forests, (ii) Tropical moist deciduous forests, (iii) Tropical dry-deciduous forests and (iv) Littoral and tidal swamp forests (Champion and Seth, 1968). As larger part of Eastern Ghats of India lies in the state, which has different ecological zones and several biodiversity hotspots, conservation of natural areas and forest cover and maintenance of forest quality is of highest importance.

Data Used and Methodology

Fifteen scenes (Table 1) of Landsat-4/5TM and Landsat-8 Operational Land Imager (OLI) for each year (1996, 2006 and 2016) have been acquired from the United States Geological Survey (USGS) web server. In the trial stage of making LULC maps for three different observation years, misclassification occurred in case of digital classification techniques. Therefore, visual interpretation and digitization is preferred over digital classification techniques as large number of images of medium resolution (30 m) have been used for preparing LULC maps for 1996, 2006 and 2016 in the present research. Moreover, it is worth mentioning that visual interpretation technique has been successfully used for LU/LC detection using medium resolution images in earlier research compared to hard classification techniques (Lee et al., 2002; Ghorbani and Pakravan, 2013). To minimize seasonal and phenological variations, data from same "dry period" was used for each of the three years.

In the level of pre-processing, six bands (Band 1 to Band 5 and Band 7) of TM and six bands (Band 2 to Band 7) of OLI have been stacked. For accurate identification of each LU/LC, the following Eq. (1) proposed by Markham and Barker (1986) has been applied to convert digital numbers (DN) into radiance:

$$L_\lambda = \left(\frac{LMAX_\lambda - LMIN_\lambda}{Q_{calmax} - Q_{calmin}} \right) \left(Q_{cal} - Q_{calmin} \right) + LMIN_\lambda \quad (1)$$

where L_λ = spectral radiance at the sensor's aperture, Q_{cal} = quantized calibrated pixel value [DN], Q_{calmin} = minimum quantized calibrated pixel value, Q_{calmax} = maximum quantized calibrated pixel value, $LMIN_\lambda$ = spectral at-sensor radiance that is scaled to Q_{calmin} and $LMAX_\lambda$ = spectral at-sensor radiance that is scaled to Q_{calmax}.

To remove the atmospheric influences on the amount of electromagnetic energy in the visible and near-infrared parts of the spectrum (Slater et al., 1983), the improved dark object subtraction (DOS) model, proposed by Chavez (1988, 1996) has been used. Finally, the atmospherically corrected radiance of the pixel value has been converted into atmospherically corrected surface spectral reflectance without topographic consideration using Eq. (2) given by Pandya et al. (2002) and Song et al. (2001):

$$R_{\lambda T} = \frac{\pi \times L_{i\lambda} \times d^2}{t_v \left(E_0 \cos\theta_z t_z + E_d \right)} \quad (2)$$

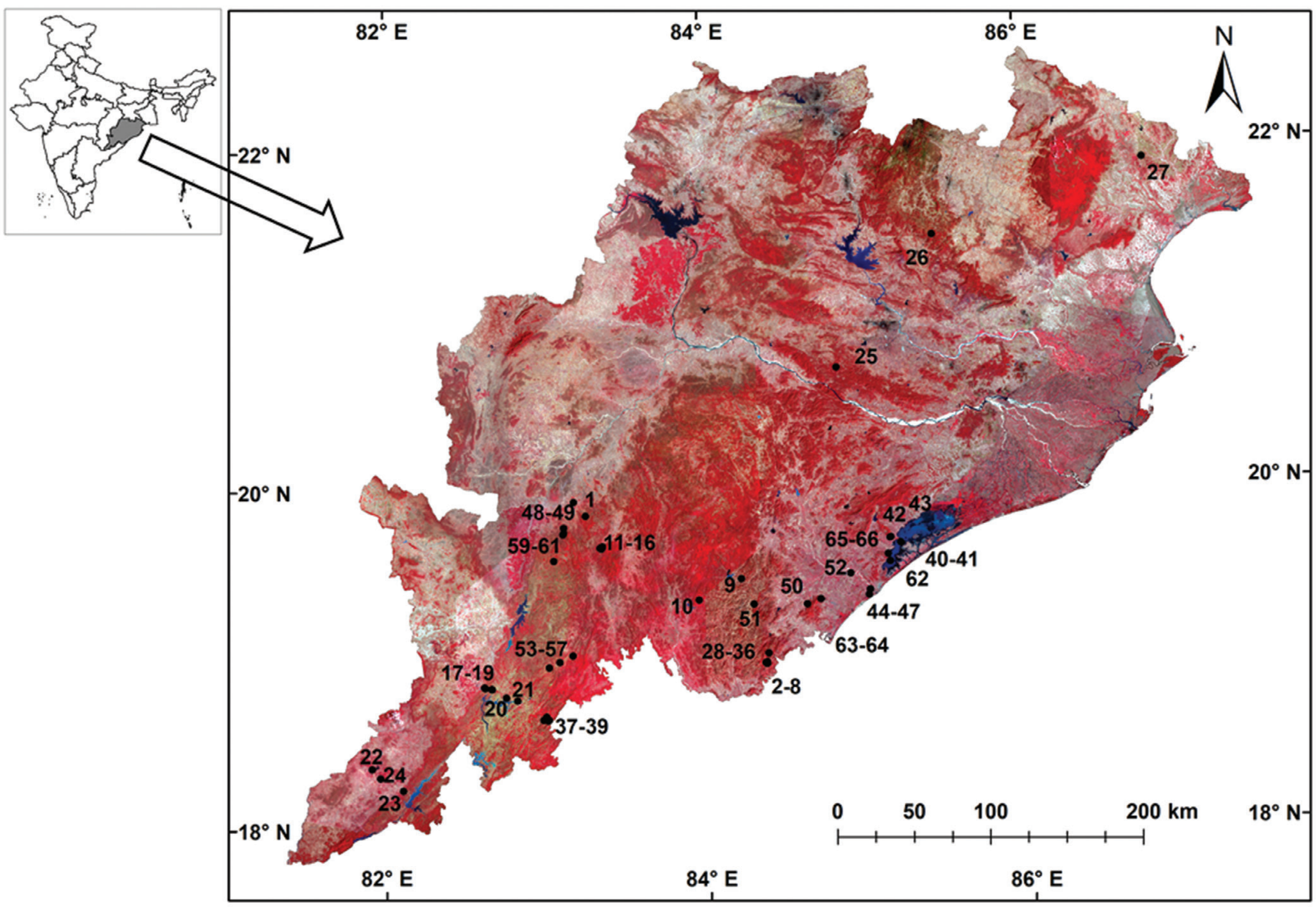

Figure 1: Overview of the study area (as viewed on False Colour Composite with band combination R = Near-Infrared, G = Red, B = Green) with location of field points. Numbers (1-66) indicate code of field points mentioned in Table 3.

Table 1: Specification of data used in the present study

Name of satellite & sensor	*Resolution*		*Date of acquisition*	*Path & row*
	Spatial (m)	*Spectral (µm)*		
Landsat 4-5 (TM)	30	0.45-0.52 0.52-0.60 0.63-0.69 0.76-0.90 1.55-1.75 10.41-12.5 2.08-2.3	10 March 1996	139, 45
			10 March 1996	139, 46
			18 April 1996	140, 44
			18 April 1996	140, 45
			18 April 1996	140, 46
			18 April 1996	140, 47
			24 March 1996	141, 44
			24 March 1996	141, 45
			24 March 1996	141, 46
			24 March 1996	141, 47
			21 February 1996	141, 48
			07 February 1996	142, 45
			15 March 1996	142, 46
			28 February 1996	142, 47
			28 February 1996	142, 48
			23 April 2006	139, 45
			18 February 2006	139, 45
			30 April 2006	140, 44
			25 February 2006	140, 44
			25 February 2006	140, 46
			25 February 2006	140, 47
			16 February 2006	141, 44
			21 April 2006	141, 45
			21 April 2006	141, 46
			21 April 2006	141, 47
			16 February 2006	141, 48
			07 February 2006	142, 45
			28 April 2006	142, 46
			28 April 2006	142, 47
			23 February 2006	142, 48
Landsat 8 OLI	30	0.43-0.45 0.45-0.51 0.53-0.59 0.63-0.67 0.85-0.88 1.57-1.65 2.11-2.29 0.50-0.68 1.36-1.38 10.6-11.19 11.5-12.51	17 March 2016	139, 45
			18 April 2016	139, 45
			24 March 2016	140, 44
			24 March 2016	140, 44
			08 March 2016	140, 46
			08 March 2016	140, 47
			31 March 2016	141, 44
			15 March 2016	141, 45
			31 March 2016	141, 46
			16 April 2016	141, 47
			16 April 2016	141, 48
			22 March 2016	142, 45
			22 March 2016	142, 46
			22 March 2016	142, 47
			22 March 2016	142, 48

Source: USGS, NASA

where $R_{\lambda T}$ = atmospherically corrected true spectral reflectance, $L_{i\lambda}$ = atmospherically corrected radiance of the pixel, d = Earth–Sun distance in astronomical units, E_0 = mean solar exo-atmospheric spectral irradiance (from Chander et al., 2009) (Refer Table 2 for values of E_0 values of different sensor), θ_z = solar zenith angle (calculated based on Kasten (1962) for each pixel of the study area) and $\tau_v(\lambda)$ and $\tau_z(\lambda)$ are equal to 1.0 (ignores atmospheric transmittance), the down welling spectral irradiance is ignored ($E_{down}(\lambda) = 0$)

As different surfaces on the earth possess different spectral response, the preliminary analysis of spectral signature of five broad LU/LC classes (namely, water bodies, forest/vegetation, agricultural land, built up area and barren land) using False Colour Composite (FCC) image with combination of bands, Near-Infrared (NIR), red, green as RGB has formed the basis of further identification and classification of LU/LC. Visual interpretation using image elements like tone, size, shape, pattern, texture followed by manual digitization has been utilized to prepare LU/LC maps of three different years.

To analyse the forest cover/vegetation types and its spatiotemporal change, Normalized Difference Vegetation Index (NDVI) which is a normalized ratio of surface reflectance in red and NIR part of the electromagnetic spectrum has been performed using Eq. (3) (Rouse et al., 1973):

$$NDVI = \frac{NIR - RED}{NIR + RED} \tag{3}$$

To generate the forest/vegetation cover map, four classes have been identified: (a) No vegetation (water, cloud, bare soil, hard rock, built-up land), (b) Sparse vegetation (grassland, agricultural land, shrubland), (c) Moderate vegetation and (d) Dense vegetation using the threshold values for each class. As reported by Weier and Herring (2011), very low NDVI values ($NDVI \leq 0.1$) represents area completely devoid of vegetation, moderate NDVI values ($0.2 \leq NDVI \leq 0.3$) corresponds medium dense vegetation whereas high values ($0.6 \leq NDVI \leq 0.8$) indicate highest density of forest. To select an appropriate threshold value for each forest cover class in the present study area, areas of interest (AOIs) on the desired class have been drawn and the mean NDVI values of those AOIs have been extracted.

Visual inspection of the Landsat-TM/OLI standard FCC, google-earth images and limited field points have been considered for the confirmation of the threshold values in the present study. Although, the threshold value has been changed slightly with time ($NDVI \leq 0$ represents no vegetation in 1996, 2006 and 2016; $0 < NDVI \leq 0.3$ represents sparse vegetation in 1996, 2006 and 2016; $0.3 < NDVI \leq 0.4$ represents moderate vegetation in 1996 and 2006 while $0.3 < NDVI \leq 0.5$ represents moderate vegetation in 2016; $NDVI > 0.4$ represents dense vegetation in 1996, 2006, whereas $NDVI > 0.5$ corresponds dense vegetation in 2016) depending upon the variable health and density of the vegetation, still it can be remarked that threshold value lies within the given ranges reported by Weier and Herring (2011). The forest cover change map during 1996-2006 period has been produced by differencing the forest/vegetation cover map of 1996 (as before image) and 2006 (as after image). Same process has been followed to obtain forest cover change map during 2006-2016 taking forest/vegetation cover map of 2006 (as before image) and 2016 (as after image). A detailed analysis of LU/LC change has been performed within buffer zone of 30 km from region adjoining Bhubaneswar and Cuttack, to evaluate how the urban expansion altered the LU/LC pattern in the surrounding of two urbanized areas of Odisha.

Collection of field points has been carried out during the months of September and October 2016 and January, February, March, May and June, 2017 for each LU/LC classes (Table 3). At the selected field points, latitude and longitude, altitude and LU/LC classes have been recorded using Garmin Map 62S hand-held Global Positioning System (GPS). These field points have

Table 2: Mean solar exo-atmospheric spectral irradiance(E_0) values for different data used

Bands	*Landsat 4 TM*	*Landsat 5 TM*	*Landsat 8 OLI*
1	1958	1958	E_0 values are not required for Landsat 8 data. The Landsat 8 metadata file provides coefficients necessary to compute reflectance from DNs
2	1826	1827	
3	1554	1551	
4	1033	1036	
5	214.7	214.9	
7	80.70	80.65	

Table 3: Details of field points collected at different sites in the study area

Field point code	*Latitude and longitude*	*Altitude (in ft)*	*Attribute*	*Name of place*	*Date of collecting field points*
1	19° 51′ N 83° 15′ E	1502	Stream side forest	Rabandara, Kalahandi	16.06.2017
2	18° 57′ N 84° 22′ E	4354	Mountain forest	Mahendragiri, Gajapati	09.06.2017
3	18° 57′ N 84° 22′ E	4353	Mountain forest	Mahendragiri, Gajapati	09.06.2017
4	18° 57′ N 84° 22′ E	4334	Mountain forest	Mahendragiri, Gajapati	09.06.2017
5	18° 57′ N 84° 22′ E	4330	Mountain and forest	Mahendragiri, Gajapati	09.06.2017
6	18° 57′ N 84° 22′ E	4367	Mountain and forest	Mahendragiri, Gajapati	09.06.2017
7	18° 57′ N 84° 22′ E	4311	Mountain and forest	Mahendragiri, Gajapati	09.06.2017
8	1901°′ N 84° 22′ E	995	Forest	Mahendragiri, Gajapati	09.06.2017
9	1928°′ N 8413°′ E	1456	Forest	Adaba	08.06.2017
10	1920°′ N 8357°′ E	1385	Forest	Gumuda	07.06.2017
11	1940°′ N 8321°′ E	1854	Forest	Niamgiri, Kalahandi	07.06.2017
12	1939°′ N 8320°′ E	1830	Forest	Niamgiri, Kalahandi	06.06.2017
13	1939°′ N 8320°′ E	1737	Forest	Niamgiri, Kalahandi	06.06.2017
14	1939°′ N 8320°′ E	1887	Forest	Niamgiri, Kalahandi	06.06.2017
15	1940°′ N 8321°′ E	1794	Forest	Langigarh	06.06.2017
16	1939°′ N 8320°′ E	1920	Forest	Langigarh	04.06.2017
17	1849°′ N 8239°′ E	3048	Forest	JaypurGhati, Koraput	04.06.2017
18	1850°′ N 8237°′ E	2819	Forest	JaypurGhati, Koraput	28.05.2017
19	1850°′ N 8236°′ E	2554	Forest	JaypurGhati, Koraput	28.05.2017
20	1846°′ N 8244°′ E	2925	Urban area	CUO OLD Campus, Koraput	28.05.2017
21	1845°′ N 8248°′ E	2918	Road side urban area	Sunabeda, Koraput	27.05.2017
22	1814°′ N 8206°′ E	719	Road side area	Balimela Rajlin	27.05.2017
23	1818°′ N 8157°′ E	605	Urban area and side by forest	Malkangiri	26.05.2017
24	1821°′ N 8154°′ E	768	Urban area and side by forest	Malkangiri	26.05.2017
25	2042°′ N 8450°′ E	839	Forest	Tarava	25.05.2017
26	2128°′ N 8527°′ E	2035	Forest	Kangipani Ghati	03.03.2017
27	2153°′ N 8647°′ E	215	Planted forest	Hemchandrapur Baripada	01.03.2017
28	1857°′ N 8422°′ E	4286	Mountain and forest	Mahendragiri, Gajapati	28.02.2017
29	1857°′ N 8422°′ E	4566	Mountain and forest	Mahendragiri, Gajapati	25.02.2017
30	1858°′ N 8421°′ E	3864	Mountain and forest	Mahendragiri, Gajapati	25.02.2017
31	1858°′ N 8421°′ E	4039	Mountain and forest	Mahendragiri, Gajapati	24.02.2017
32	1858°′ N 8422°′ E	4501	Mountain and forest	Mahendragiri, Gajapati	24.02.2017
33	1955°′ N 8310°′ E	922	Hill, temple, some forest	Mahendragiri, Gajapati	24.02.2017
34	1849°′ N 8239°′ E	2986	Road side forest	Mahendragiri, Gajapati	23.02.2017
35	1849°′ N 8239°′ E	3021	Road side forest	Mahendragiri, Gajapati	21.02.2017
36	1849°′ N 8239°′ E	3028	Road side forest	Mahendragiri, Gajapati	21.02.2017
37	1839°′ N 8259°′ E	4822	Mountain with little vegetation	Deomali, Koraput	21.02.2017
38	1838°′ N 8300°′ E	4492	Mountain with little vegetation	Deomali, Koraput	19.02.2017

(*Contd.*)

39	1838°′ N 8300°′ E	4410	Mountain with little vegetation	Deomali, Koraput	19.02.2017
40	1939°′ N 8512°′ E	63	Island on Chillika Lake	Kalijai, Chillika	19.02.2017
41	1935°′ N 8508°′ E	72	Small island in Chillika	Jaleswer, Chillika	28.01.2017
42	1941°′ N 8508°′ E	354	Planted with protected forest	Naraini, Gajapati	27.01.2017
43	1941°′ N 8509°′ E	452	Temple with plants	Naraini, Gajapati	27.01.2017
44	1933°′ N 8508°′ E	63	Scrubland on iceland	Barkud, Chillika	27.01.2017
45	1933°′ N 8508°′ E	14	Scrubland on iceland	Barkud, Chillika	26.01.2017
46	1939°′ N 8512°′ E	90	Scrubland on iceland	Kalijai, Chillika	26.01.2017
47	1939°′ N 8512°′ E	99	Scrubland on iceland	Kalijai, Chillika	25.01.2017
48	1946°′ N 8306°′ E	1014	Forest	Furlijharan, Kalahandi	25.01.2017
49	1935°′ N 8303°′ E	2679	Forest	Gunpur, Kalahandi	09.10.2016
50	1918°′ N 8437°′ E	456	Mountain and patch of forest	Bankeswari, Ganjam	08.10.2016
51	1918°′ N 8417°′ E	2046	Plantation	Chandragiri, Gajapati	30.09.2016
52	1920°′ N 8442°′ E	349	Hill top temple with some vegetation	Kalua Ber, Gajapati	29.09.2016
53	1838°′ N 8300°′ E	3905	Mountain with open forest	Deomali, Koraput	29.09.2016
54	1838°′ N 8258°′ E	3043	Mountain	Deomali, Koraput	28.09.2016
55	1857°′ N 8300°′ E	3071	Forest	Kakriguma	28.09.2016
56	1859°′ N 8304°′ E	3325	Road side forest	Laxmipur, Koraput	28.09.2016
57	1901°′ N 8309°′ E	2687	Road side forest	Laxmipur, Koraput	28.09.2016
58	1944°′ N 8306°′ E	1173	Forest	Jakham, Kalahandi	28.09.2016
59	1944°′ N 8306°′ E	1166	Forest	Jakham, Kalahandi	26.09.2016
60	1944°′ N 8306°′ E	1180	Forest	Jakham, Kalahandi	26.09.2016
61	1945°′ N 8306°′ E	1201	Forest	Karlapat, Kalahandi	26.09.2016
62	1939°′ N 8512°′ E	93	Island scrubland	Chlika, Ganjam	26.09.2016
63	1923°′ N 8501°′ E	126	Hill top temple with some vegetation	Ramchandi, Ganjam	24.09.2016
64	1921°′ N 8500°′ E	74	Urban area	Tampra, Ganjam	22.09.2016
65	1929°′ N 8454°′ E	664	Mountain, temple, some vegetation	Tara Tarini, Ganjam	22.09.2016
66	1929°′ N 8454°′ E	477	Mountain, temple, some vegetation	Tara Tarini, Ganjam	21.09.2016

been used to prepare LU/LC maps of three different years combined with visual interpretation using image interpretation elements. Moreover, for the confirmation of the threshold value for each forest cover class these limited number of field points were helpful along with the visual inspection of the Landsat-TM/OLI standard FCC and the NDVI image.

Results and Discussions

Spectral Signatures of LU/LC Classes

Spectral response curves prepared using twenty-five AOIs for each class (for the years 1996, 2006 and 2016) and their mean reflectance values have been plotted against each wavelength range (Figure 2). For all the three years, the general trend of the spectral response curve for each LU/LC is similar although the reflectance value slightly differs. The spectral reflectance of water bodies has maintained a decreasing trend from visible to infrared region. The reflectance value in the visible is near about 10 percent which has indicated turbidity in the water. Agriculture and forest/vegetation has shown similar reflectance pattern exhibiting peak reflectance in the NIR region maintaining increasing trend of reflectance from visible to NIR and decreasing reflectance pattern beyond NIR region. Such pattern indicated dense to medium dense vegetation in most of the places. Barren and built-up land has maintained an increasing trend from visible to IR region with a peak reflectance in the shortwave-infrared regions.

LU/LC Classification and Change Detection

A quantitative analysis of the spatiotemporal change in the LU/LC pattern of the study area has been performed from 1996 to 2016. LU/LC maps and graphical representation of the area changes for 1996, 2006 and 2016 have been shown in Figure 3a-d. The post-classification change detection exhibited a continuously increasing trend from 1996 to 2006 to 2016 in the area coverage by water bodies, agricultural land, built-up area and barren land whereas a continuously decreasing trend has been observed in forested areas (Table 4). Although, a slight increase in area covering water bodies has been observed from the period of 1996 (1.2%) to 2006 (1.3%) and 2016 (1.4%), which accounts for implementation of major irrigation projects viz. Upper Indravati and Rengali Irrigation Projects in Odisha during the period (Department of Water Resources, Odisha, Activities Report, 2015-2016).

According to Review of Annual Plan of Odisha (2004-05), there were 1166 completed and 2203 ongoing micro watershed projects being implemented in the State under the various centrally sponsored schemes viz. Integrated Wasteland Development Programme (IWDP), Drought Prone Area Programme (DPAP), National Watershed Development Programme in Rainfed Area (NWDPRA), River Valley projects etc. These projects underlay the water availability in the State further by providing more stability to the increasing agricultural practices. A major decrease has been observed in the percentage of forest/vegetation area from 1996 (40.0%) to 2006 (39.0%) to 2016 (37.7%). A major increase in the percentage of barren land from 2006 (0.4%) to 2016 (1.3%) has confirmed the wide clearance of the forest cover. Other studies carried out in Odisha also reported decreasing trend in the areal coverage of forest cover 52.5% (1924–1935), 36.4% (1975), 33.2% (1985), 32% (1995) and 31.3% (2010) (Reddy et al., 2013).

The conversion of forest to agricultural land and built-up zone illustrates the impact of human activities on the dynamics of LU/LC. However, mining operations in many parts of Odisha contributes to the major factor of the deforestation (Singh et al., 2010). A significant increase has been observed in the area percentage of agricultural land from 1996 (58.0%) to 2006 (58.8%) to 2016 (59.1%). In case of built-up zone, although the absolute percentage of area with respect to the total area is less but significant change has taken place in the area percentage from 1996 (0.3%) to 2006 (0.5%) to 2016 (0.6%). The spatial growth of the urban built-up has taken place at the cost of fertile agricultural land and other land having conservation values lying in the fringe area.

Normalized Difference Vegetation Index (NDVI) and Change Detection of Vegetation

NDVI has been successfully applied in many studies to measure and characterize vegetative cover of wide areas (Running et al., 1996; Singh et al., 1986). NDVI value ranges from –1 to +1 indicating areas with no vegetation, sparse vegetation, moderate vegetation and dense vegetation. The vegetation cover map generated through NDVI thresholding method exhibited that negative value of NDVI corresponds to land surfaces with no vegetation such as river/stream and water bodies. Very low values of NDVI correspond to areas with sparse vegetation, mainly the agricultural land and also the grassland, shrubland while moderate to high values correspond moderate to green, healthy dense vegetation (Figure 4a-c). The upper limit of the NDVI value has been decreased from 1996 (0.98) to 2006 (0.78) and 2016 (0.77). However, the area coverage of the vegetation cover class revealed that there is a fluctuating trend of change of dense vegetation (23% in 1996, 24% in 2006 and 21% in 2016) and increasing trend of moderate vegetation (32% in 1996, 34% in 2006 and 36% in 2016) (Figure 4d, Table 5).

To determine quantities of alterations from a specific vegetation cover to another vegetation cover category at a later year and examine the type of the conversions of different vegetation cover classes, post classification matrices (Table 6 a-b) based on post classification comparison (Figure 5 a-b) have been obtained. It has been observed that although 24,238 km^2 area which was dense vegetation in 1996 was still dense vegetation cover in 2006, but 11,543 km^2 and 2662 km^2 area had been converted to moderate vegetation and sparse vegetation cover respectively. But at the same time, 10,857 km^2 and 1960 km^2 area which was under moderate and sparse vegetation cover respectively in 1996 had been converted to dense vegetation cover in 2006.

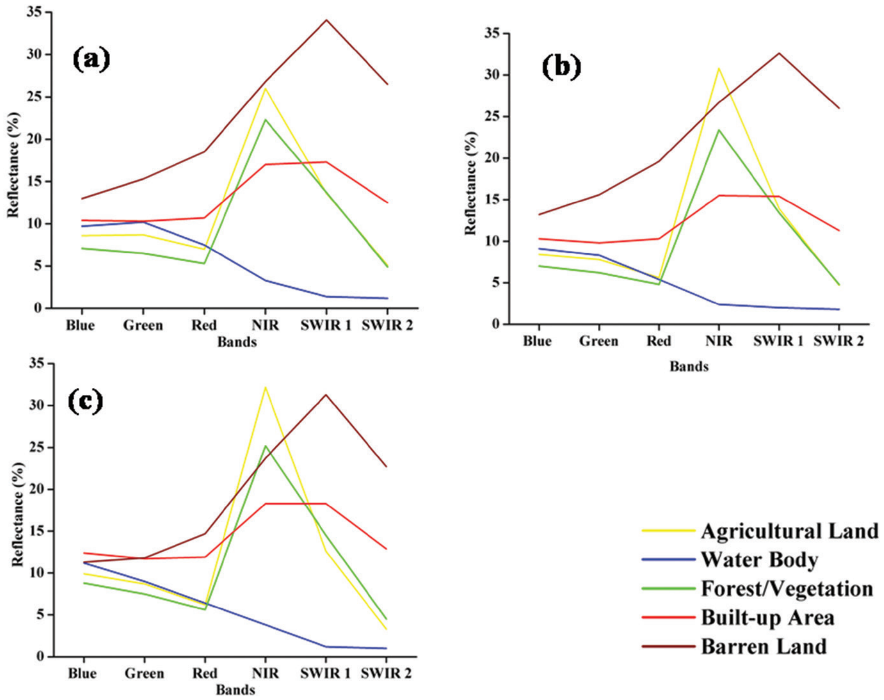

Figure 2: Spectral reflectance curves for LU/LC classes of (a) 1996, (b) 2006, and (c) 2016 derived from TM and OLI images respectively.

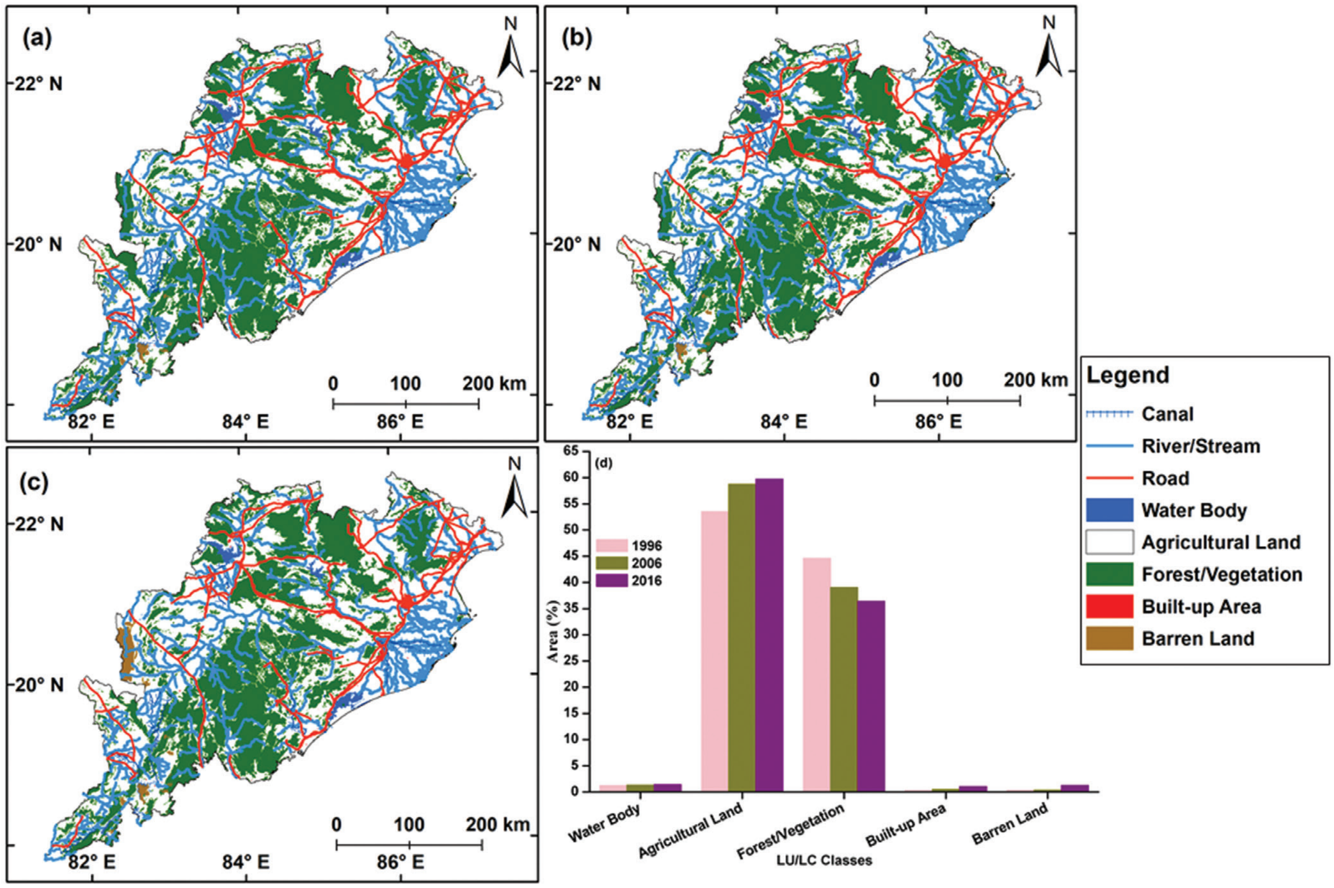

Figure 3: LU/LC maps of (a) 1996, (b) 2006, (c) 2016 derived from visual interpretation and (d) graphical representation of change percentage in area occupied by different LU/LC in the observation periods.

Several plantation and afforestation programmes which are under operation in the state can be the probable reason for that which are helping in saving the forest cover to a much extent and, therefore, helping biodiversity in a secured habitat. Similarly, 21,367 km^2 area which was dense vegetation in 2006 was still dense vegetation cover in 2016, but 10,635 km^2 and 2744 km^2 area had been converted to moderate vegetation and sparse vegetation cover respectively. Even though during the same period, 12,738 km^2 and 4401 km^2 area which was under moderate and sparse vegetation cover respectively in 2006 had been converted to dense vegetation cover in 2016. It is worth to mention that for past two decades, the health and density of vegetation cover has reduced but not with higher intensity. According to Indian State Forest Report (2015), forest cover changes from 2013 to 2015 was positive. Several conservation strategies in mangrove areas and several plantation activities have been implemented in the State. Eastern parts of the study area are under rapid

Table 4: Area of LU/LC classes resulted from visual interpretation

LU/LC classes	*Observation years*					
	1996		*2006*		*2016*	
	Area (km^2)	*Area (%)*	*Area (km^2)*	*Area (%)*	*Area (km^2)*	*Area (%)*
Water body	1940	1.2	2046	1.3	2046	1.3
Agricultural Land	90460	58.0	91640	58.8	92162	59.1
Forest/Vegetation	62494	40.0	60823	39.0	58779	37.7
Built-up Land	479	0.3	813	0.5	909	0.6
Barren Land	501	0.3	552	0.4	1978	1.3

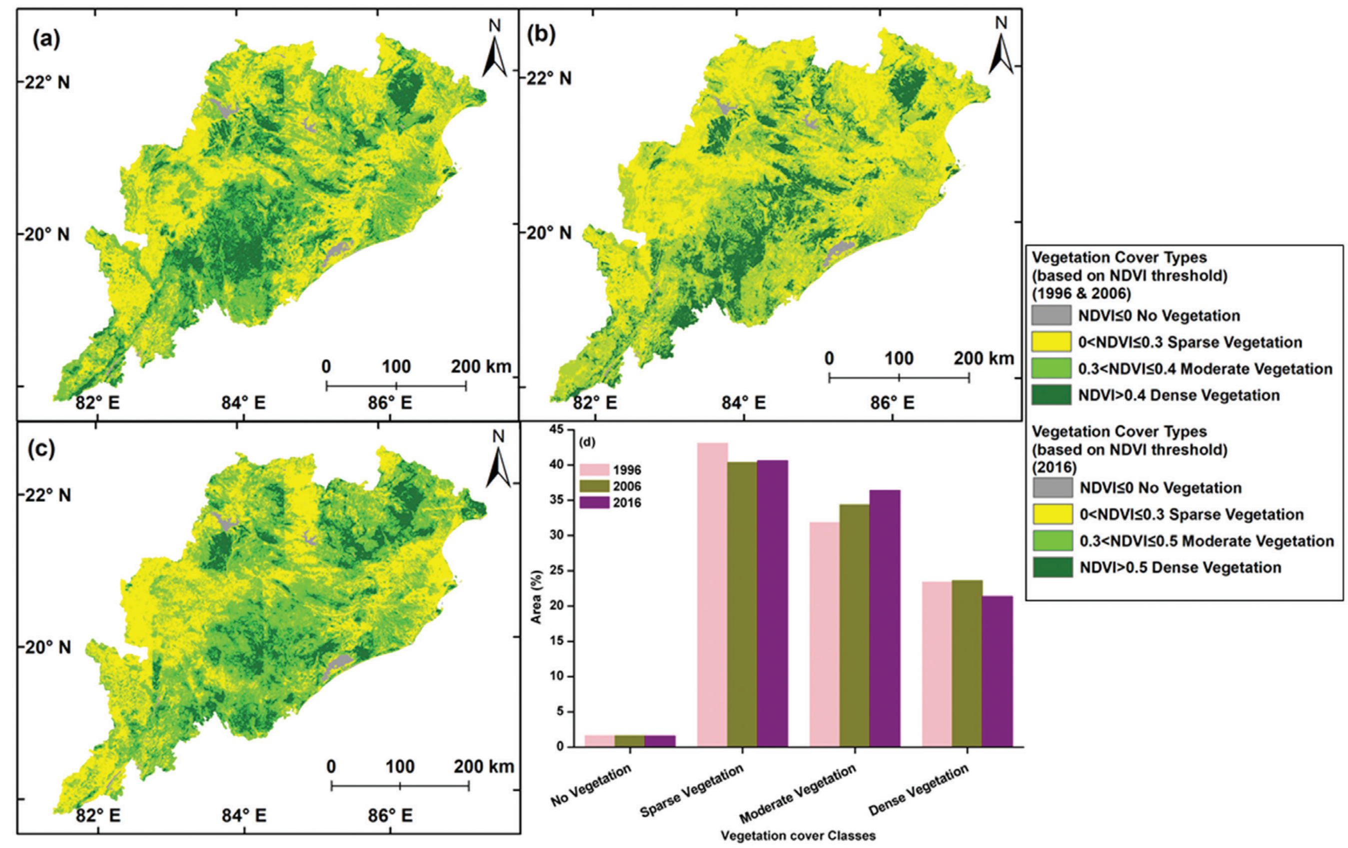

Figure 4: Vegetation cover maps of (a) 1996, (b) 2006, (c) 2016 derived from NDVI thresholding and (d) Graphical representation of change percentage in area occupied by different forest covers in the observation periods.

Table 5: Area of forest cover classes resulted from NDVI

Forest cover classes	*Observation years*					
	1996		*2006*		*2016*	
	Area (km^2)	*Area (%)*	*Area (km^2)*	*Area (%)*	*Area (km^2)*	*Area (%)*
No Vegetation	2586	2	2543	2	2504	2
Sparse Vegetation	67138	43	62944	40	63316	41
Moderate Vegetation	49662	32	53570	34	56765	36
Dense Vegetation	36488	23	36817	24	33289	21

Table 6a: Post classification matrix of study area from 1996 to 2006

		Area (km^2) in 2006			
	Forest cover classes	*No vegetation*	*Sparse vegetation*	*Moderate vegetation*	*Dense vegetation*
Area (km^2) in 1996	No vegetation	1884	519	NS	NS
	Sparse vegetation	585	45927	12804	1960
	Moderate vegetation	NS	13605	29049	10857
	Dense vegetation	NS	2662	11543	24238

*NS: Not Significant

Table 6b: Post classification matrix of study area from 2006 to 2016

		Area (km^2) in 2016			
	Forest cover classes	*No vegetation*	*Sparse vegetation*	*Moderate vegetation*	*Dense vegetation*
Area (km^2) in 2006	No vegetation	1976	438	NS	NS
	Sparse vegetation	473	39615	16344	4401
	Moderate vegetation	NS	18591	26603	12738
	Dense vegetation	NS	2744	10635	21367

*NS: Not significant

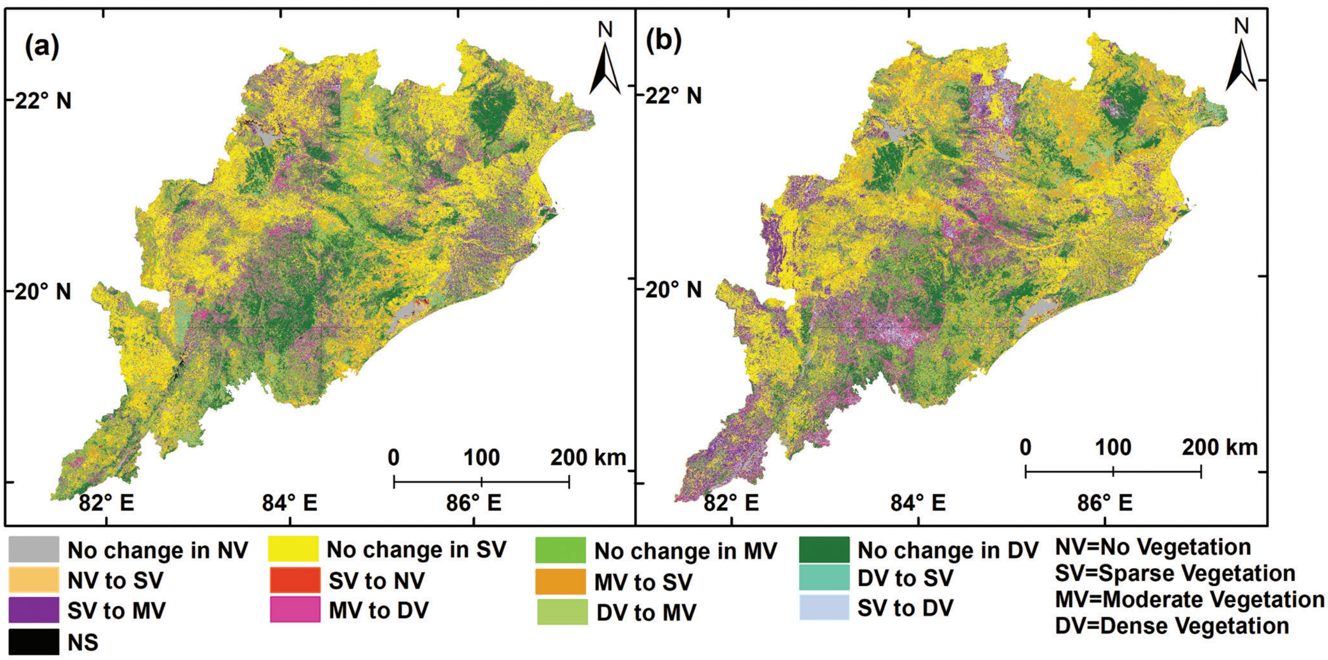

Figure 5: Representation of changes in different vegetation cover classes during (a) 1996-2006, and (b) 2006-2016.

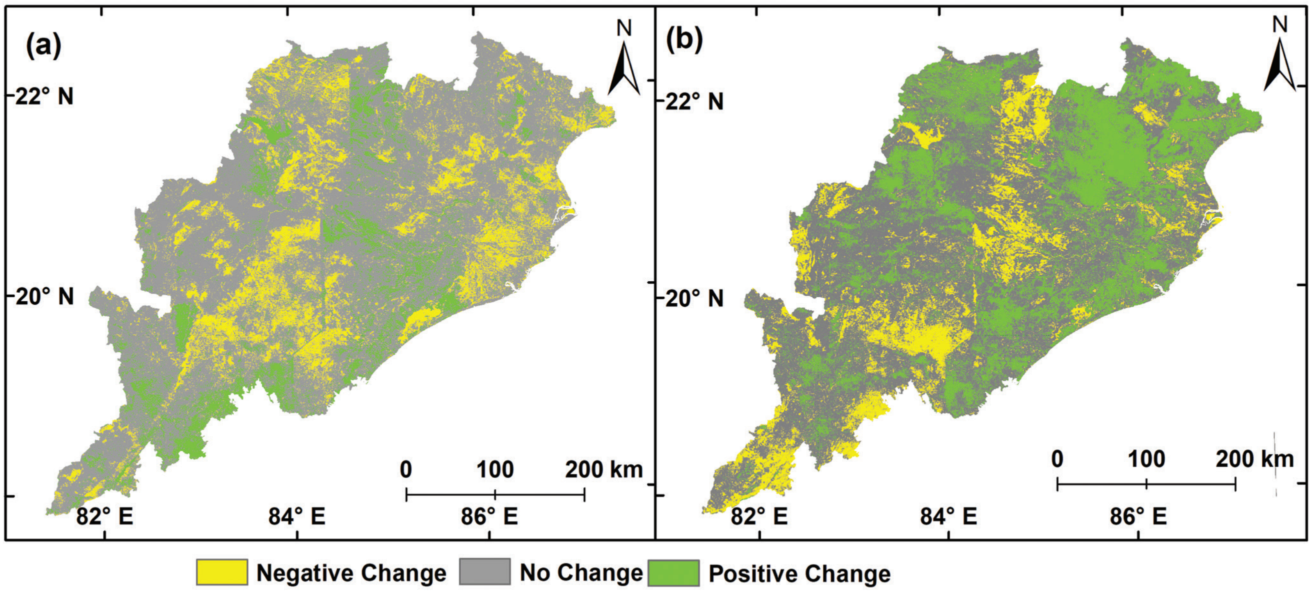

Figure 6: Vegetation cover change/no change maps during (a) 1996-2006 and (b) 2006-2016.

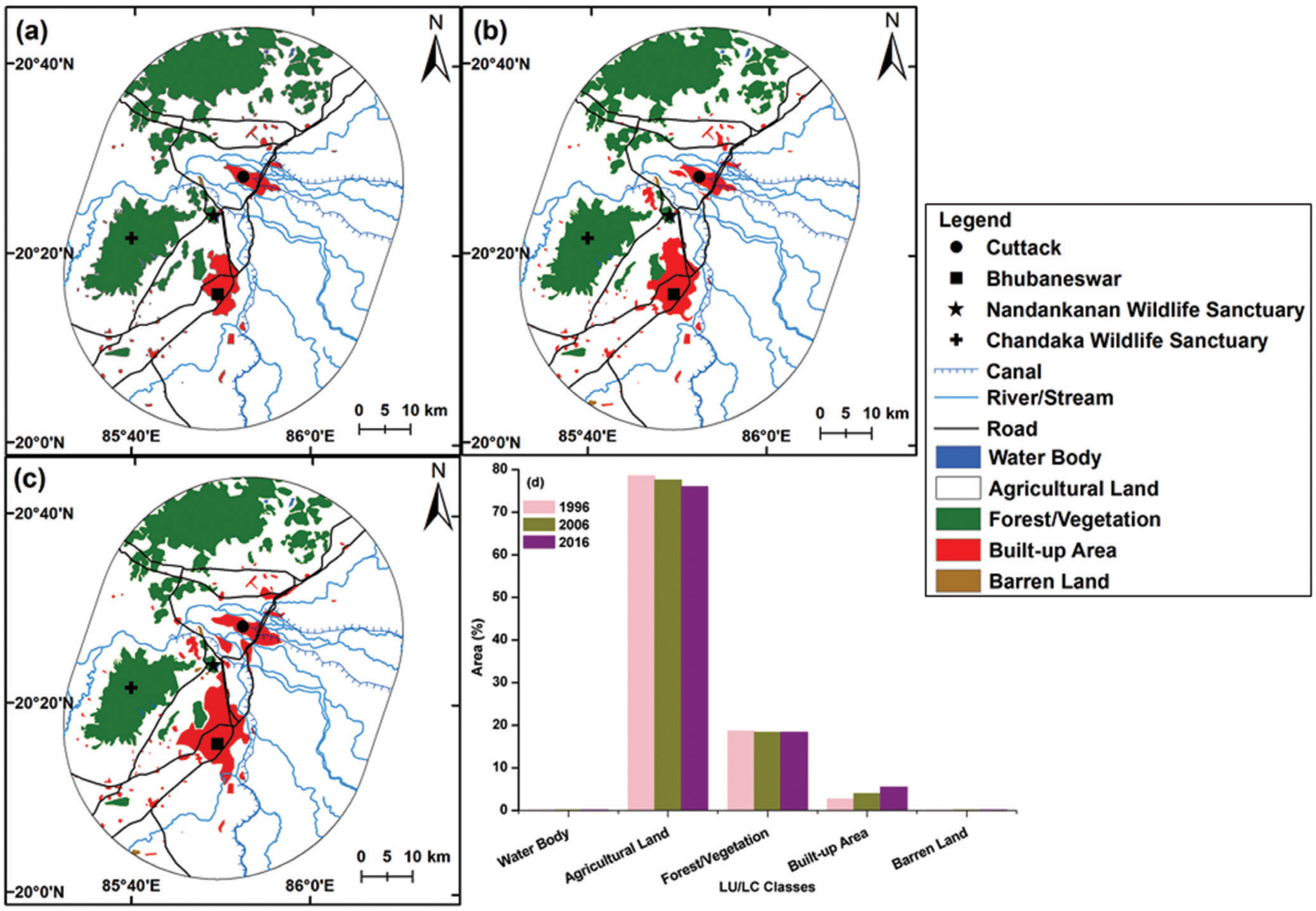

Figure 7: LU/LC within a buffer of 30 km joining Bhubaneswar and Cuttack for the years (a) 1996, (b) 2006, (c) 2016 and (d) graphical representation of change percentage in area occupied by different LU/LC in the observation periods within the buffer zone.

urbanization and therefore holds greater impact over natural resources.

A cell-by-cell subtraction between multi-temporal raster images called Image Differencing technique, is an effective method for vegetation change detection (Nordberg and Evertson 2004, 2005). Change/no change map of vegetation cover have been obtained by performing NDVI differencing (ΔNDVI) between classified NDVI map of 1996 (the previous-image) and 2006 (the after-image) (Figure 6a) and between classified NDVI map of 2006 (the previous-image) and 2016 (the after-image) (Figure 6b) using Eq. (4) (Singh, 1989):

$$\Delta NDVI = NDVI\,(2006) - NDVI\,(1996) \quad (4a)$$

$$\Delta NDVI = NDVI\,(2016) - NDVI\,(2006) \quad (4b)$$

ΔNDVI compares NDVI values by subtracting the NDVI image of previous date from that of the post-date. Regions exhibited positive and negative changes in the NDVI values are assigned green and yellow colour, while grey tone has been used to show the area with no change. The percentage of area experiencing change has been from the first observation period (35% during 1996-2006) to the second observation period (42% during 2006-2016). The main negative change in the NDVI value took place in the fertile agricultural land and dense vegetated areas around the Cuttack and Bhubaneswar city, in the eastern part of the district.

To evaluate the effect of such urbanization over land cover change and resultantly over neighbouring ecosensitive areas, a buffer of 30 km radius has been drawn out from region joining two urbanized areas Bhubaneswar and Cuttack, popularly known as twin cities of Odisha (Figure 7 a-c). The fringe areas of Bhubaneswar are comprised of heritage sites, temples, wildlife sanctuaries and fertile agricultural land. However, though its growth and development as a big city owes a very recent past, it experienced a very rapid spatial as well as temporal unsustainable growth. The spatial growth of both the cities have experienced the conversion of fertile agricultural land and other land having conservation values lying in the fringe area to residential and other urban utility purposes. The ecologically sensitive areas viz. Chandaka Wildlife Sanctuary in the heart of Bhubaneswar city and Nandan Kanan Wildlife Sanctuary under the influence of expansions of surrounding urban regions of both Bhubaneswar and Cuttack cities have also been influenced by this process of urban growth of the twin cities and consequent changes in LU/LC pattern.

According to the analysis, built-up area has been drastically increased from 1996 (107 km^2 - 2.7%) to 2006 (159 km^2 - 3.9%) to 2016 (220 km^2 - 5.5%). Resultantly, a decreasing trend has been observed in the area coverage of agricultural land area from 1996 (3134 km^2 - 78%) to 2006 (3094 km^2 - 77%) to 2016 (3032 km^2 - 75%). Similar decreasing trend has been observed in the area coverage of forest/vegetation area from 1996 (744 km^2 - 18.6%) to 2006 (732 km^2 - 18.3%). But rate of change has become stable from 2006 to 2016 (Figure 7d, Table 7). Such stability has been achieved because of the right implementation of the afforestation programme and forest conservation measures. The results are in accordance with Thandar (2012), that reveals with the increased urban population, most of the land use changes in Bhubaneswar city have occurred in relation to the location of urban centres as well as to the spatial extent of land dedicated to urban uses. It can be remarked that, such analysis can be a contribution towards the recommendation made by Reddy et al. (2013) to consider the ecosensitive areas like Protected Areas for detailed analysis of forest cover or LU/LC changes for a large area like Odisha.

Increasing urbanization, agricultural land expansion and expanding villages near the fringe of Chandaka Wildlife Sanctuary and Nandan Kanan Wildlife

Table 7: Area of LU/LC classes within the buffer zone around Bhubaneswar and Cuttack

LU/LC classes	*Observation years*					
	1996		*2006*		*2016*	
	Area (km^2)	*Area (%)*	*Area (km^2)*	*Area (%)*	*Area (km^2)*	*Area (%)*
Water body	2.5	0.06	2.5	0.06	2.5	0.06
Agricultural land	3134	78.0	3094	77.0	3032	75
Forest/Vegetation	744	18.6	732	18.3	732	18.3
Built-up land	108	2.7	159	3.9	220	5.5
Barren land	1.2	0.3	2.5	0.6	3.4	0.9

Sanctuaries has negatively affected the biodiversity inhabiting this area. Chandaka was once connected to the Kapilash forests in north, Mahanadi river to the west, extended towards Narsinghpur and into what is today the Satkosia Tiger Reserve and Mahanadi Elephant Reserve. Once the elephants traversed this entire landscape. Chandaka Wildlife Sanctuary was formed in 1982 to protect elephants and to serve as Bhubaneswar's green lungs. Rapid growth and ill-expansion of the city is transforming the area into an urban conglomerate that have sprouted and now decimating and engulfing the surrounding forests. This encroachment and other mismanagement practices in the Sanctuary has led to human-elephant conflict (Bindra, 2017).

Conclusion

Effective land use plan and its execution, reforestation, biodiversity protection and thereby sustainable growth and development should be encouraged for preservation of natural habitats and ecosystems. To make effective land use plan, the information regarding the LU/LC change over a long-time within a particular area is important. With this view, the present research has attempted LU/LC change detection with special reference to forest cover in Odisha. Present research successfully mapped the major LU/LC with freely available satellite images and exhibited the changes in the area coverage of different LU/LC classes with detailed analysis of the forest cover change. Although mapping such a large area with so much complex LU/LC classes and accumulating large number of satellite images is difficult. Despite of being time-consuming and labour-intensive, visual interpretation and manual digitization is proved as successful and effective tool for mapping such heterogeneous LU/LC classes with mixed spectral signatures.

The results of the present study highlighted the declining pattern of the area coverage by forest with a decrease of its health and density. Nevertheless, it is worth mentioning that various operating plantation and afforestation schemes in the state are helping to save and conserve the forest. The detailed study concentrating on the periphery areas of the urban development around twin city of Bhubaneswar and Cuttack discovered the negative impact of the unplanned urban expansion over ecosensitive areas. Such analysis can be useful for formulating effective conservation and management policies for forest, wildlife and other natural resources in the state. Bhubaneswar city is under progress to be developed as first Indian smart city and in this direction results of the present study will be also useful for future planning of the city.

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