*Article*

# Ecological significance of core, buffer and transition boundaries in biosphere reserve: A remote sensing study in Similipal, Odisha, India

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**Abstract**

Protected areas and national parks need periodic assessment and monitoring for evaluating natural resources, effectiveness of management and studying the effects of global climate change. The present work has been undertaken to prepare the multi-date vegetation density maps in terms of Normalised vegetation index (NDVI) and to monitor the changes in and around the areas close to transition, buffer and core boundaries of Similipal Biosphere Reserve (SBR) using digital remote sensing and GIS techniques.Time series Landsat images covering a period of 30 years are used for change detection studies.

**Keywords** biosphere; reserve; similipal; core; buffer; transition; Remote Sensing; GIS; NDVI; vegetation density.

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## 1 Introduction

Biosphere Reserve (BR) is an international designation attributed by UNESCO for representative parts of natural and cultural landscapes that extends over a large area of terrestrial or coastal/marine ecosystems or a combination thereof. BRs are thus special environments where human beings and nature can co-exist respecting each others' needs. In order to carry out complementary activities of biodiversity conservation and for sustainable management aspects, Biosphere Reserves are demarcated into three inter-related zones. These are (I) natural or core zone (ii) manipulation or buffer zone and (iii) A transition zone outside the buffer zone. A core zone secures legal protection and allows management and research activities that do not affect natural processes and wildlife and this core zone is to be kept free from all human pressures external to the system. In the Buffer Zone, which adjoins or surrounds core zone where uses and activities such as recreation, tourism, fishing and grazing are permitted to an limited extent. The Transition Zone is the outermost part of a Biosphere Reserve that is usually not delimited one and is a zone of cooperation where conservation, knowledge and management skills are applied together. This area includes settlements, crop lands, managed forests and area for intensive recreation, and other economic activities that is prevalent in the region.

Changes in land use/ land cover due to natural and anthropogenic activities can be observed using recent and archived remotely sensed data. One of the major advantages of remote sensing technique is its capability for repetitive coverage, which is necessary for change detection studies at global and regional scales. Change detection of in land use/ land cover involves use of at least two period data sets. Multi date satellite images are useful for both visual assessments of dynamics of forest ecosystems occurring at a particular time and space as well as quantitative evaluation of LULC changes overtime (Tekle and Hedlund 2000; Gautam et al. 2003). Vegetation mapping is very important application of remotely sensed data. Spectral profiles of vegetation clearly show that the peak reflectance can be found in the near-infrared wavelengths mainly because of the internal structure of ‘‘green’’ leaves, and the greatest absorption is in the red wavelengths because of the presence of chlorophyll pigments.The normalized difference vegetation index (NDVI) is one of most successfully used vegetation indices for land cover classification (Brown et al., 1993; Evans et al., 1993; Loveland et al., 1991; Townshend et al., 1994). It is also used as an environmental indicator to monitor temporal and spatial variation in vegetation density as well as the health and viability of plant cover (Fung et al., 2000; Jiang et al., 2008; Wang et al., 2001; Weng et al., 2004; Ioannis and Meliadis, 2011; Ballestores and Qiu, 2012), for the derivation of vegetation biophysical properties (Asrar et al., 1992; Goward and Huemmrich, 1992; Sellers et al., 1994) and for estimation of net primary production (Prince, 1991; Running and Nemani, 1988; Tucker and Sellers, 1986). The NDVI is correlated with many biophysical properties of the vegetation canopy such as leaf area index (LAI), fractional vegetation cover, vegetation condition, and biomass. The NDVI is used in several studies to estimate vegetation biomass, greenness, primary production, fraction of absorbed photosynthetically active radiation (fAPAR) (e.g., Gropal et al., 1999; Kawamura et al., 2005; Koide et al., 1998; Myneni and Williams, 1994; North, 2002; Telesca et al., 2006). The NDVI values increase as green cover density increases (Lo, 1997); the values are calculated from red and near infrared reflection values (Fung and Siu, 2000; Jiang et al., 2008; Myeong, Nowak, and Duggin, 2006), that has a wide range used in vegetation indices (Coops et al., 2008). The NDVI is a potential ecological indicator for successfully monitoring temporal and spatial variation in vegetation density as well as the health and viability of plant cover (Fung and Siu, 2000; Jiang et al., 2008; Wang et al., 2001; Weng et al. 2004).

Vegetated landscapes typically have NDVI values ranging from 0.1 in the desert to 0.8 in dense tropical rain forest (Hassani, Benabadji, and Belbachir, 2006). Sobrino and Raissouni (2000) demonstrated that when NDVI values are between 0.0 and 0.2, the pixel is considered bare soil; for NDVI values greater than 0.5, the pixel is considered fully vegetated.

Protected areas and national parks need periodic assessment and monitoring for evaluating natural resources, effectiveness of management and studying the effects of global climate change. The present work has been undertaken to prepare the multi-date vegetation density maps in terms of Normalised vegetation index and to monitor the changes in and around the areas close to transition, buffer and core boundaries of Similipal Biosphere Reserve (SBR) using digital remote sensing techniques.

## 2 Study Area

The Similipal is a densely forested hill-range in the heart of Mayurbhanj district of Orissa in the eastern India, lying close to the eastern-most end of the Easternghats. Located in the Mahanadian Biogeographical Region and within the Biotic Province of Chhotanagpur Plateau, it is located between 20°17' and 22° 34' North latitude and 85°40' - 87°10' East longitude. The total area of Similipal Biosphere Reserve (SBR) is 5569 Sq Km. Similipal is unique in many respects, notable among which are its flora, fauna, forests, landscapes, waterfalls and native tribal population. The landscape is beautifully scattered with numerous small and high hills densely covered with vegetation. The highest mountain is the peak is Khairiburu which is approximately 1168 mts. above the sea level. Similipal is the richest watershed in the state of Orissa giving rise to many perennial rivers. Natural colour composite of the SBR along with core, buffer and transition boundaries are presented in Fig.1. People residing in the Reserve area are largely tribal. Due to low level of skills, lower educational levels, socio-culture traits, they are mainly dependent on local resources. There are four villages inside the core namely, Kabatghai, Jenabil, Jamunagarh and Bakua. There are 61 villages in the buffer. The climate of the area is monsoonal and divisible into three seasons; summer (March-June), rainy (July- October) and winter (November-February). Pre-monsoon showers are received during May and June. Post monsoon showers are received during November and December. The natural vegetation is moist deciduous type (Champion and Seth, 1968) and is dominated by *Shorea robusta*, *Anogeissus latifolia*, *Buchnania lanzan*, *Dillenia pentagyna*, *Syzygium cumini* and *Terminalia alata*. The area and status of SBR since 1979 is presented in table 1. Similipal was declared as a biosphere reserve by Government of India on 22nd June 1994 due to its rich biodiversity and natural heritage. There are 1076 plants recorded from the area including 60 species of ferns, 92 species of orchids and two gymnosperms (Saxena and Brahmam, 1989; Misra, 2004).

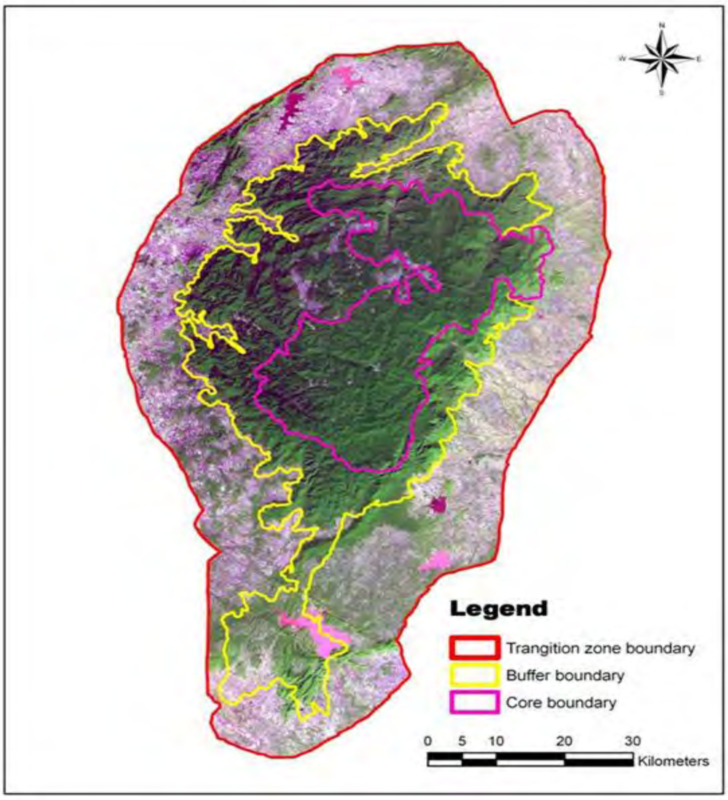


**Fig. 1** Natural colour composite of the SBR along with core, buffer and transition boundaries.

## 3 Data Source and Materials

We used time series Landsat images as the primary data source for derivation of generalized land-cover information. Landsat images provide multispectral data from the early 1970s to the present. the spatial resolution of Landsat data was appropriate to provide a general landscape characterization and change analysis instead of detailed vegetation and resource mapping, As the intent of this study was to reveal the general trends of land-cover change and landscape context, the difference in spatial resolution between MSS and TM/ETM+ images was not a concern as long as we obtained areas of different vegetation density classes. All the landsat images were obtained from Global Land Cover Facility (GLCF) used to classify vegetation density in terms of NDVI in the study area. The details of the images used are given in table 2. All the landsat images were acquired during the dry season, which enables us to ensure that the images are completely cloud free, and also allow us to differentiate forest from nonforest areas, with a greater degree of accuracy. All image processing was carried out using the ERDAS Imagine image processing software. The biosphere was delineated in to core, buffer and transition zones as per the map provided by the state forest department. The ancillary information was collected by Anthropological Survey of India, Kolkota. Digital topographic maps digitized from hardcopy Survey of India topographic maps with scale of 1:50,000 were used mainly for geometric correction of the satellite images and for some ground truth information.

**3.1 Geometric correction**

After atmospheric correction and elimination of offset value of satellite data, in order to prepare two or more satellite images for an accurate change detection comparison, it is imperative to geometrically rectify the imagery.Geo referenced to the UTM map and WGS84 datum using 40–45 ground control points (GCPs) with a root mean square error not exceed 0.5 pixels (Lunetta and Elvidge, 1998) for accurate registration of the different time periods images. Accordingly, the 2005 image was used as the bases image to more precisely geo-reference the other scenes. The correction were made using first order polynomial transformation model and nearest neighbor method for re-sampling. The geo-referenced images were then clipped with vector masks for transition, buffer and core boundary to generate the areas of interest.

**3.2 Generation of NDVI image**

NDVI is based on the spectral properties of green vegetation contrasting with its soil background. This index has been found to provide a strong vegetation signal and good spectral contrast from most background materials. NDVI is a measure derived by dividing the difference between near-infrared and red reflectance measurements by their sum. NDVI provides an effective measure of photosynthetically active biomass (Tucker and Sellers, 1986). For its measurement scientists use satellite sensors that observe the distinct wavelengths of visible and near infrared sunlight which is absorbed and reflected by the plants, then the ratio of visible and near-infrared light reflected back up to the sensor is calculated. The ratio gives a number from minus one (−1) to plus one (+1). An NDVI value of zero means no green vegetation and close to +1 (0.8–0.9) indicates the highest possible density of green leaves. The ‘normalized difference vegetation index’ is calculated by the formula: NDVI = (IR−R)/(IR + R), where IR = infrared light and R = red light (Lellesand and Kiefer, 1994). The group of pixels having NDVI values from 0 to 0.2 were categories under canopy density class of <10%, 0.2-0.4 as canopy density class of 10-40%, and, the group of pixels having NDVI value > 0.4 were kept under the canopy density class of 40%.Normalized difference vegetation index NDVI was used to prepare a forest density map that was categorized into three canopy density classes: <10% (non forest), 10-40% (open), > 40% (medium/ high/ very high depending on the NDVI value . Image elements like tone, texture, shape, size, shadow, location and association were also evaluated to aid in the class delineations.

There are many change detection techniques from visual comparison to detailed quantitative approaches (Howarth and Wickware,1981).The fact that sums and differences of bands are used in the NDVI rather than absolute values will make the NDVI more appropriate for use in studies where comparisons over time for a single area are involved, since the NDVI might be expected to be influenced to a lesser extent by variation in atmospheric conditions. An assessment of vegetation cover change in terms NDVI between 1975,1990 and 2005 was conducted using post classification change detection analysis and the results are as follows.

**Table 1** Area and status

| Zone | Area (sq Km) | status |
|---|---|---|
| Core | 845 | Sanctuary from 1979<br>National Park (1980/1986) |
| Buffer | 2129 | Sanctuary from 1979 |
| Transition | 2595 | Reserved Forest |

**Table 2** Details of the Landsat images used in the study

| Satellite/Sensor | Path/row | Date | Spatial resolution |
|---|---|---|---|
| Landsat MSS | 150 045 | 19 November 1975 | 56 |
| Landsat TM | 139 045 | 21November 1990 | 30 |
| Landsat TM | 139 045 | 14 November 2005 | 30 |

## 4 Results and Discussion

### 4.1 Transition zone

It is observed from Table 3 and Fig. 2, the area under < 0.2 class has increased significantly over the years in the transition zone whereas the area under NDVI class 0.2- 0.4 has not undergone much change. During the same period, the area under > 0.4 NDVI class has increased by 20,000 hectare. It is observed from Table 4 and Fig. 3, the area under < 0.2 class has increased significantly over the years in the 5 km buffer area surrounding the transition boundary whereas the area under NDVI class 0.2- 0.4 has not undergone much change. During the same period, the area under > 0.4 NDVI class has also increased .This shows that less dense forest area has undergone deforestation to a greater extent where as marginal reforestation occurred in the high dense forest area.

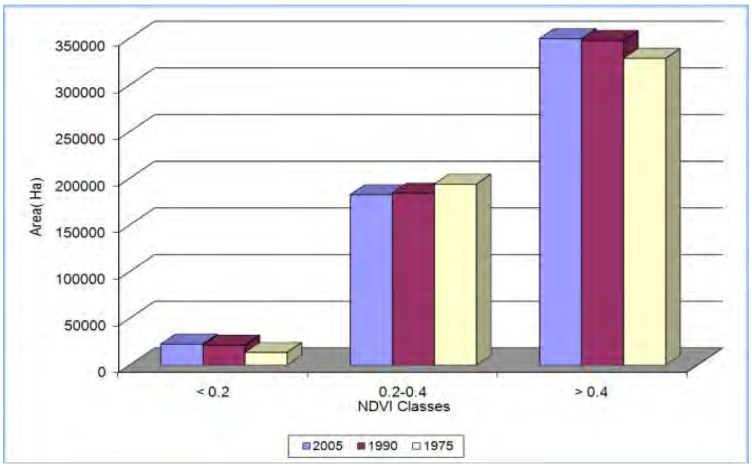


**Fig. 2** Area (ha) occupied by different NDVI classes in the transition zone in SBR.

### 4.2 Buffer zone

It is observed from Table 5, Figs 3 and 4, the area under < 0.2 class has increased significantly over the years in the buffer zone whereas the area under NDVI class 0.2- 0.4 has decreased significantly. During the same period , the area under > 0.4 NDVI class has increased by 15,300 hectare. As shown in Table 6 and Figs 3 and 4 there is an significant increase in < 0.2 NDVI class in the area surrounding 5 km buffer to buffer boundary of SBR where as in the same area the other two NDVI classes have undergone very less change in area. This shows that less dense and medium dense forest area has undergone deforestation where as reforestation process was witnessed in the high dense forest.

**Table 3** Area (ha) occupied by different NDVI classes in the transition zone in SBR.

| NDVI classes | Transition Zone 2005 | Transition Zone 1990 | Transition Zone 1975 |
|---|---|---|---|
| < 0.2 | 22582.4 | 21400.1 | 13579.2 |
| 0.2-0.4 | 182553 | 184406 | 193954 |
| > 0.4 | 349828 | 347918 | 328659 |

**Table 4** Area (ha) occupied by different NDVI classes in the 5 km buffer area surrounding transition boundary in SBR.

| NDVI classes | area surrounding trans boundary 2005 | area surrounding trans boundary 1990 | area surrounding trans boundary 1975 |
|---|---|---|---|
| < 0.2 | 31442 | 33690.3 | 19678.7 |
| 0.2-0.4 | 281941 | 287845 | 296546 |
| > 0.4 | 407850 | 398168 | 378919 |

**Table 5** Area (ha) occupied by different NDVI classes in the buffer zone in SBR.

| NDVI classes | buffer Zone 2005 | buffer Zone 1990 | buffer Zone 1975 |
|---|---|---|---|
| < 0.2 | 6576.12 | 3664.98 | 4365 |
| 0.2-0.4 | 33793.2 | 24580.2 | 47567.9 |
| > 0.4 | 221881 | 233096 | 206580 |

**Table 6** Area (ha) occupied by different NDVI classes in the 5 km buffer area surrounding buffer boundary in SBR

| NDVI classes | area surrounding buffer boundary 2005 | area surrounding buffer boundary 1990 | area surrounding buffer boundary 1975 |
|---|---|---|---|
| < 0.2 | 15967.8 | 13825 | 10645.9 |
| 0.2-0.4 | 120593 | 117671 | 132041 |
| > 0.4 | 302390 | 306474 | 283494 |

### 4.3 Core zone

It is observed from Table 7 and Fig. 5 the area under < 0.2 and 0.2- 0.4 NDVI classes has decreased significantly over the years in the core zone whereas the area under NDVI class > 0.4 has increased significantly. Though the area under 0.2-0.4 NDVI class has decreased to a large extent but the concurrent increase in other two classes corroborates that reforestation process occurred throughout the core zone that very much in agreement with the core zone concept of a biosphere reserve.

**Table 7** Area (ha) occupied by different NDVI classes in the core zone in SBR.

| NDVI classes | core Zone 2005 | core Zone 1990 | core Zone 1975 |
|---|---|---|---|
| < 0.2 | 21.6 | 10.98 | 329.76 |
| 0.2-0.4 | 3821.76 | 1733.04 | 14252.8 |
| > 0.4 | 93539.2 | 95293.6 | 81992.5 |

**Table 8** Area (ha) occupied by different NDVI classes in the transition zone excluding buffer in SBR.

| NDVI class | trans minus buff_05 | trans minus buff_90 | trans minus buff_75 |
|---|---|---|---|
| < 0.2 | 16279.9 | 17850.9 | 9330.12 |
| 0.2-0.4 | 149676 | 160335 | 147316 |
| > 0.4 | 129923 | 115747 | 124064 |

**Table 9** Area (ha) occupied by different NDVI classes in the buffer zone excluding core in SBR.

| NDVI class | buff minus core_05 | buff minus core_90 | buff minus core_75 |
|---|---|---|---|
| < 0.2 | 6499.08 | 3639.78 | 4057.56 |
| 0.2-0.4 | 30088.1 | 22869.7 | 33540.5 |
| > 0.4 | 129428 | 138401 | 125482 |

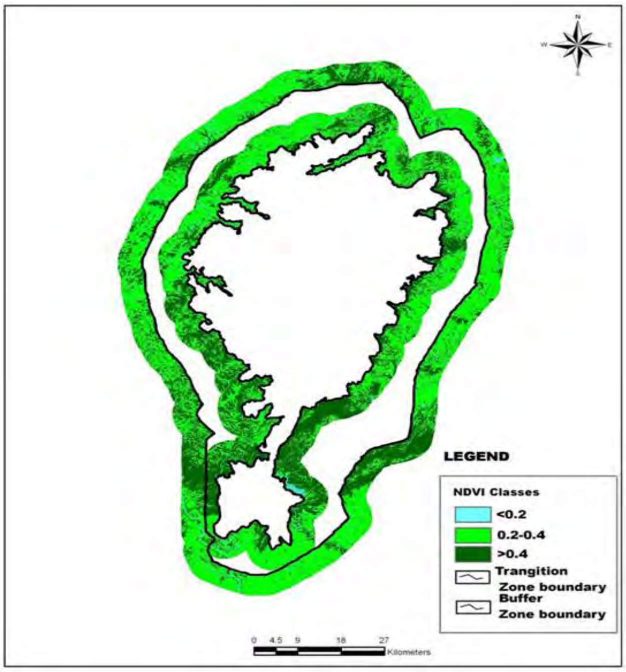


**Fig. 3** Vegetation density map in the 5 km outer buffer of transition and buffer bounaries in SBR in 1975.

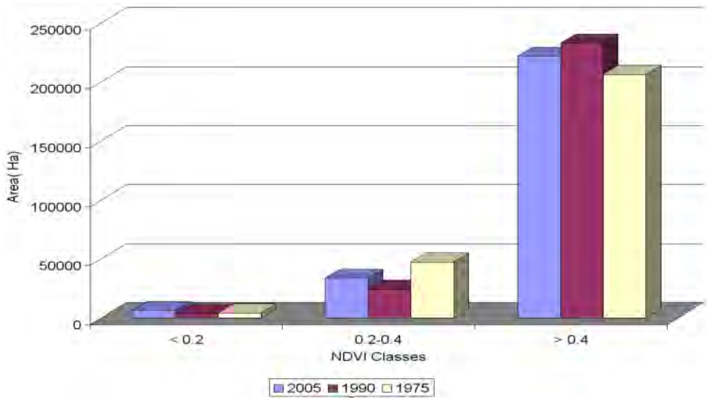


**Fig. 4** Area (ha) occupied by different NDVI classes in the buffer zone in SBR.

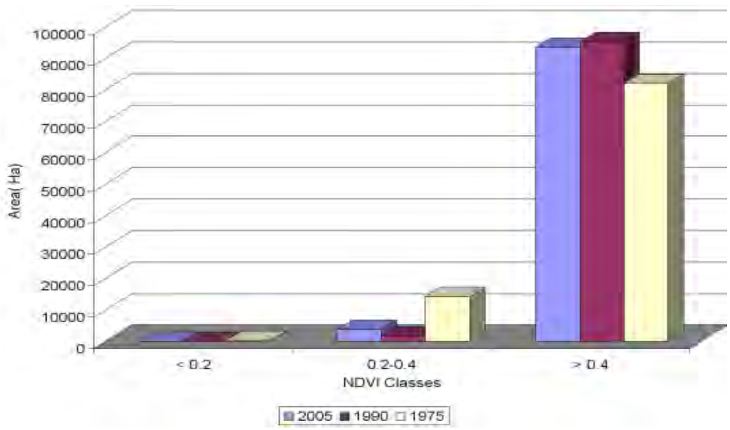


**Fig. 5** Area (ha) occupied by different NDVI classes in the core zone in SBR.

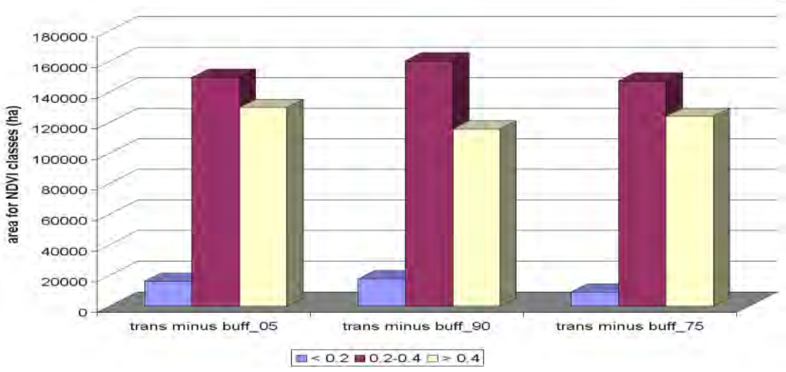


**Fig. 6** Area (ha) occupied by different NDVI classes in the transition zone excluding buffer zone in SBR.

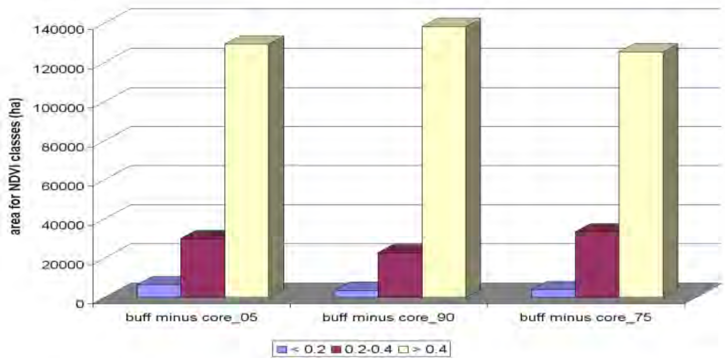


**Fig. 7** Area (ha) occupied by different NDVI classes in the buffer zone excluding core in SBR.

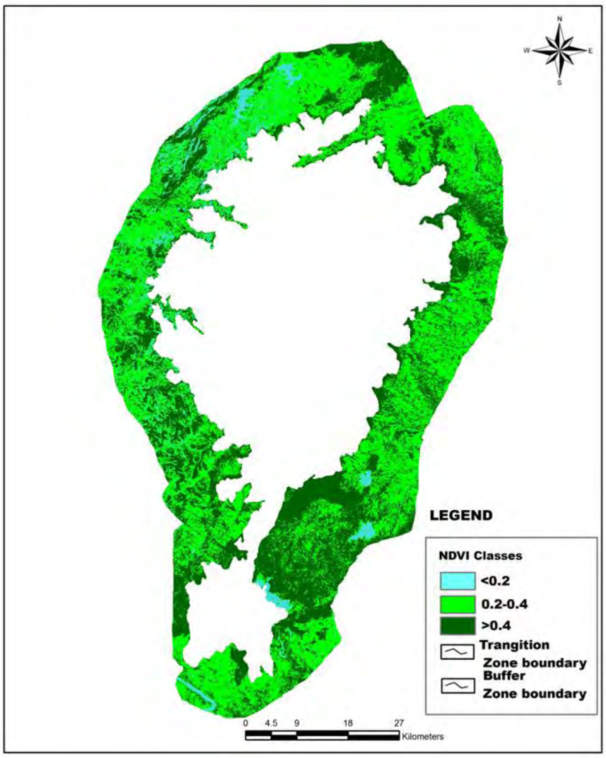


**Fig. 8** Vegetation density map in terms of NDVI classes of the transition excluding buffer zone for the year 2005.

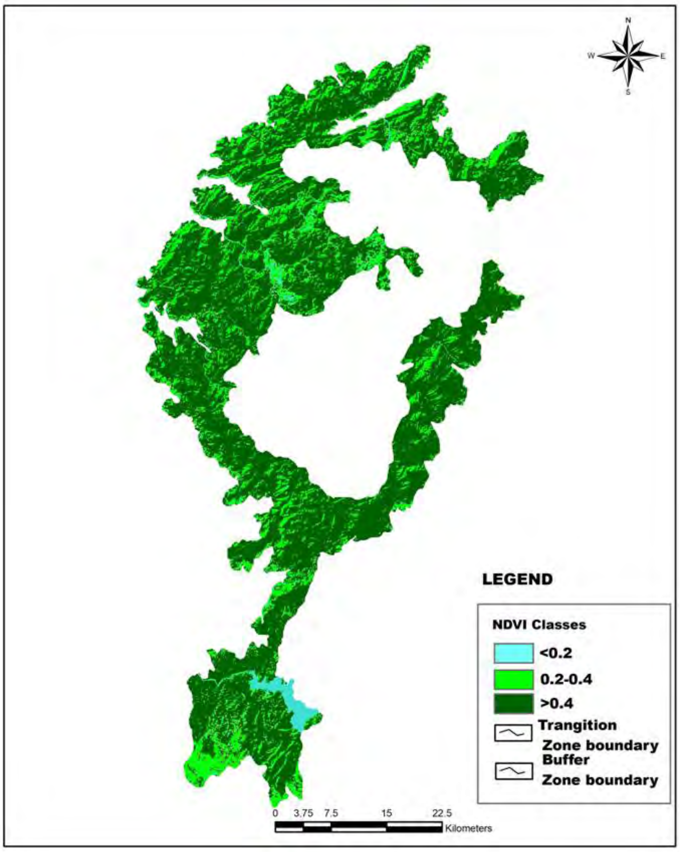


**Fig. 9** Vegetation density map in terms of NDVI classes of the buffer excluding core zone of SBR for the year 2005.

**4.4 Transition zone excluding buffer zone**

It is evident from the Table 8 and Figs 6 and 8 that the transition excluding buffer area in SBR is mostly occupied by the medium dense forest with NDVI value 0f 0.2 to 04 throughout the time period from 1975 to 2005.There was a mariginal increase in 0.2- 0.4 NDVI class from 1975 to 1990 but again followed by a decrease to the same extent. The area under the high dense forest cover has changed a little. In this zone deforestation occurred in less dense forest cover as the area under < 0.2 NDVI class increased significantly.

**4.5 Buffer zone excluding core zone**

It is observed from Table 9 and Figs 7 and 9 the area under < 0.2 class has increased significantly over the years in the buffer zone whereas the area under NDVI class 0.2- 0.4 has undergone significant decrease. During the same period the area under > 0.4 NDVI class has increased by 20,000 hectare. This shows that less dense vegetation forest area has undergone deforestation to a greater extent than the very dense vegetation area.

**5 Conclusion**

The results presented above are based on preliminary assessment from time series image analysis. Extensive field work and survey has to be conducted to verify the results. In general it was observed that the high dense forest in the core zone is conserved and highest reforestation has also occurred in this zone of SBR. Over the years, forest density in terms of NDVI as evidenced from the time series Landsat images has increased as the area under > 0.4 NDVI class has shown a positive trend throughout the zones of analysis.

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