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Impact of Urbanization on Biodiversity Hotspot: A Case of Bhubaneswar City

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Abstract

Urbanization has contributed to pollution and generation of waste heat leading to changes in the urban heat balance thereby influencing its microclimate. Urban regions confront heightened heat wave conditions due to urban heat island (UHI) impact, which is a result of anthropogenic effects on both surface and atmospheric temperature patterns relative to the natural environment. The investigation was carried out in a 20-km radius around the city of Bhubaneswar. The goal of the project was to identify the built-up settlement area and potential causes that may be interfering with wildlife movement and activity in biodiversity hotspots, as well as to investigate the effects of urbanization on biodiversity in the 20 km buffer zone surrounding the city of Bhubaneswar. The remote sensing and geographic information system (GIS) technique is used for the research purpose. Three sets of time series data of the years 2004, 2014, and 2024 have been used to study the status of the study area. The normalized difference vegetation index (NDVI), normalized difference built-up index (NDBI), land use/land cover (LU/LC) analysis showing the vegetation and built up are growing tremendously. Urban expansion was a major driver of forest land loss in Bhubaneswar city region. The maximum NDVI value increased from 0.42 to 0.57 during the period due to plantation program done by the forest department and also the maximum NDBI value increased from 0.23 to 0.58. The biodiversity of the Chandaka and Bharatpur forest area is affected due to the expansion of the built-up area though huge plantation program has done for sustaining the natural resource and also the environment. Both the proportional cover and spatial pattern of developed land significantly affected forest fragmentation in the biodiversity areas.

Keywords: Urban heat island (UHI), normalized difference vegetation index (NDVI), normalized difference built-up index (NDBI), remote sensing, geographic information system (GIS), land use/land cover (LU/LC), time series

INTRODUCTION

In the present day, more than half of the world's population is known to reside in urban areas with the percentage increasing very rapidly, thus leading to rapid urbanization [1]. Increased urbanization is known to result in removal of natural vegetation cover thereby altering the physical properties of surface including spectral albedo, heat capacity, soil moisture and emissivity [2, 3]. Further, urbanization has also led to pollution and generation of waste heat leading to changes in the urban heat balance thus affecting its microclimate [4]. Consequently, urban areas face intensified heat wave conditions due to the urban heat island (UHI) effect, which is a result of anthropogenic changes on both surface and atmospheric temperature patterns relative to the natural environment [5]. On the contrary, the green areas in the city have the potential to help adapt to

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the effects of this microclimate change [6]. India uses a combination of population, density, and employment thresholds in defining "urban" (Government of India, 2011). It classifies an area as urban based on the population of more than 5000; density exceeding 400 persons per square kilometer and where 75% of the male workers are engaged in non-agricultural professions (Census of India, 2011). In this work, "Urbanization" refers to the general demographic processes by which cities are expanding; "Urban area" refers to the amounts of urban land cover, and "urban growth" to the expanded area of urban land cover. Globally, several cities, including Curitiba, Brussels, and Singapore are testing new frameworks to assess the urban-biodiversity linkages [7]. For instance, the City Biodiversity Index or Singapore Index, created under the Convention on Biological Diversity (CBD), includes indicators such as birds, butterflies, mammals, and plants to serve as tools for assessing stressors that deplete biodiversity [8].

In India, most studies on urbanization focus on megacities like Mumbai, Delhi, Chennai, Kolkata, and Bangalore, by mostly focusing on issues related to urban economy, politics, and environmental pollution [9]. However, it is the urbanization of smaller cities and towns, particularly those located in biodiversity-rich areas, that are of serious concern to conservation [10]. Anthropogenic causes like cultivation, formation of rural settlements, poaching, pollution, and urban development have led to habitat loss and fragmentation in Chandaka-Dampara Wildlife Sanctuary (CDWS) [11]. Elephant depredation has increased due to this entire factor giving rise to human-elephant conflict in the nearby areas [11]. Urbanization of Bhubaneswar is growing towards north (Patia to Raghunathpur), south-east (old town to Nathapur and Gangotri Nagar), and south-west (Khandagiri to Patrapada) direction. Entropy measure shows that there is substantial variation in the patterns of urban sprawl among the places of the study area by fitting a second-order polynomial curve, $R^2 = 0.893$ [12]. The city center being already inhabited does not undergo any additional change in its land use/land cover (LULC) pattern. Significantly, observations made from land surface temperature (LST) analysis reveal major changes in land utilization on the outskirts of the city. It can thus be concluded that exploitation of various resources with a fast-growing population in the city has led to severe changes in LULC patterns in the surrounding regions of Bhubaneswar city over the past few years. This has resulted in changing the regional microclimate of Bhubaneswar, with warming being one of the critical parameters [13].

In the current study, changes in LULC and UHI over Odisha's capital city of Bhubaneswar were analyzed as a prelude to evaluating the impact of fast urbanization. Over the past few decades, the city has rapidly become more urbanized, with little focus placed on preserving or growing the amount of open space. The erosion of the current green cover has also been exacerbated by cyclones and storms, which are occurring more frequently [14].

STUDY AREA

The districts of Cuttack to the north, Puri to the east, Nayagarh to the west, and Khordha to the south encircle the city of Bhubaneswar, which is situated in the Khurda district of Odisha. The area under research is 270 square kilometers. The National Highway 5 (NH-5), which connects Chennai and Kolkata, passes through the urban center. It is located 435 km from Howrah and 1215 km from Chennai on the main south eastern railway route. The city is located between latitudes 21° 15' north and longitudes 85° 15'. A buffer zone of 20 km has been created around Bhubaneswar, encompassing the southern region of Cuttack district, the northeastern region of Khordha district, the western region of Jagatsinghpur district, and the northern region of Puri district. Figure 1 shows the study area location.

The flora of Bharatpur Reserve Forest in Bhubaneswar includes a variety of indigenous trees, shrubs, and plants. Some notable species are *sal*, teak, *mahua*, bamboo, neem, mango, and banyan trees. Additionally, you can find medicinal plants like *tulsi* (holy basil), aloe vera, and *brahmi* scattered throughout the forest. The fauna of Bharatpur Reserve Forest in Bhubaneswar includes various species such as spotted deer, wild boar, Indian jackal, mongoose, different types of snakes, and numerous bird species including egrets, herons, kingfishers, and migratory birds like the Asian openbill stork and the white ibis [15].

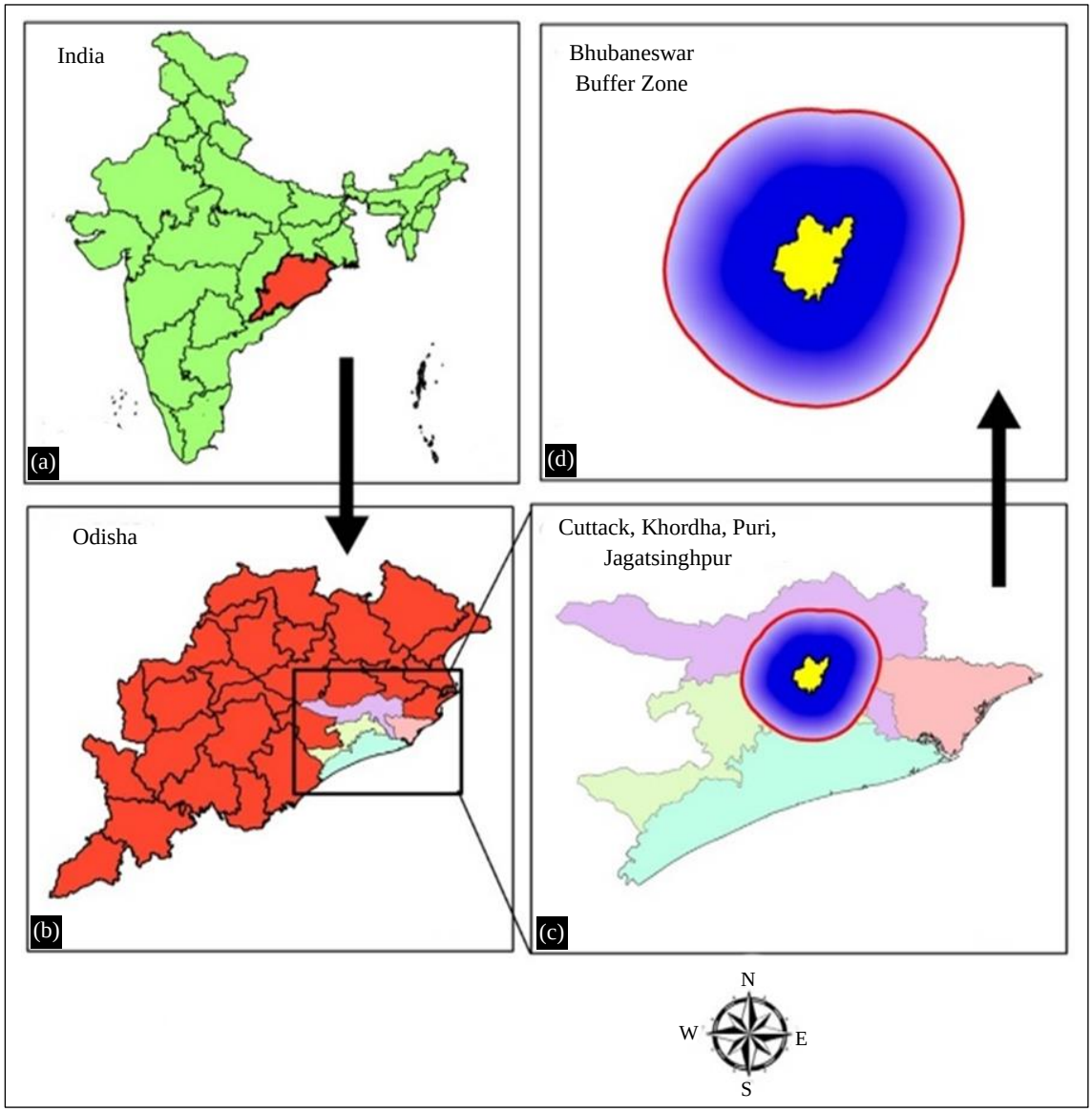

Figure 1. The location map of the study area.

The Chandka sanctuary is home to a diverse range of flora, typical of the Eastern Ghats region. The vegetation includes dry deciduous trees like *sal* (*Shorea robusta*), bamboo, teak, and other species adapted to the current weather conditions [16]. The biodiversity of Chandaka Biodiversity Sanctuary is well-known and includes large populations of deer, elephants, leopards, and many bird species [17]. The sanctuary's diversified habitats give rise to a variety of fauna, which highlights the area's ecological significance.

OBJECTIVE

- To study the impact of urbanization on biodiversity in the 20 km buffer zone of Bhubaneswar city.
- To identify the settlement built-up and the possible reasons disrupting wildlife activities and their movement in biodiversity hotspots.

MATERIAL AND METHOD

For the analysis, normalized difference vegetation index (NDVI), normalized difference built-up index (NDBI), and landuse/landcover (LULC) data from satellites for the period 2004, 2014, and 2024

have been utilized. LULC, NDVI, and NDBI: Landsat 5 and 8 data which were originally derived from the United States Geological Survey (USGS) EarthExplorer for our analysis [18]. Table 1 shows the datasets used in this study.

Formula for Calculating NDVI

NDVI = (NIR – Red) / (NIR + Red) [NIR = near infrared]

For Landsat 5 data, NDVI = (Band 4 –Band 3) / (Band 4 + Band 3)

For Landsat 8 data, NDVI = (Band 5 –Band 4) / (Band 5 + Band 4)

Formula for Calculating NDBI

NDBI = NDBI = (SWIR – NIR) / (SWIR + NIR)

For Landsat 7 data, NDBI = (Band 5 –Band 4) / (Band 5 + Band 4)

For Landsat 8 data, NDBI = (Band 6 –Band 5) / (Band 6 + Band 5)

LULC classification of 2004, 2014 and 2024 were derived from Landsat TM/ETM+ imagery. The Landsat TM/ETM+ images were obtained from the archives of the USGS. The maximum likelihood algorithm was utilized for supervised image classification to carry out the fundamental operations for every image. In order to prepare LULC maps for the temporal satellite data, ground truthing has been conducted for locations that are deemed dubious. Geographic information system (GIS) overlay analysis using Arc-GIS software allowed for the detection of spatiotemporal changes in land use.

Table 1. The materials used for the research work.

Indices	Year	Satellite	Band	Resolution
NDVI	2004	Landsat-5	Band 3 (Red) and Band 4 (NIR)	30 meters
	2014	Landsat-8	Band 4 (Red) and Band 5 (NIR)	30 meters
	2024	Landsat-8	Band 4 (Red) and Band 5 (NIR)	30 meters
NDBI	2004	Landsat-5	Band 4 (NIR) and Band 5 (SWIR)	30 meters
	2014	Landsat-8	Band 5 (NIR) and Band 6 (SWIR)	30 meters
	2024	Landsat-8	Band 5 (NIR) and Band 6 (SWIR)	30 meters
LULC	2004	Landsat-5	All bands	30 meters
	2014	Landsat-8	All bands	30 meters
	2024	Landsat-8	All bands	30 meters

RESULTS AND DISCUSSION

The NDVI map is created using this algorithm, satellite images, and a GIS analysis tool. The NDVI maps of the study area of the year 2004, 2014, and 2024, showing that the density of vegetation has grown by 35.7%, with the NDVI value progressively rising from 0.42 to 0.57 during the year 2004 and 2024. The city's Bharatpur Sanctuary, an elephant corridor and the lungs of Bubaneswar has seen a significant reduction in its vegetation before 2004 but suddenly it has increased which found during the year 2004 and 2014. The number of plants, shrubs, and other greenery has increased as the NDVI value depicts during the year 2014 and 2024. Figure 2 shows the NDVI maps for the study area over the three distinct time period.

Water bodies are represented by an NDBI value that is negative, whereas built-up regions are represented by a larger value. The NDBI maps of the year 2004, 2014, and 2024 depict that the Chandaka and Bharatpur sanctuary area's neighboring areas built-up area has been progressively growing. The core sanctuary area's value increased concurrently with a positive value growth along the sanctuary's perimeter. During the 20 years, the percentage of urban built-up area has grown from 46% to 69%. The NDBI value has increased from 0.23 to 058 from the year 2004 to 2024. The vegetation index showing increase with the built-up index also in increasing trend. The Bhubaneswar city outskirts have increased tremendously as in India, Bhubaneswar is the one of the best cities as perception of the community.

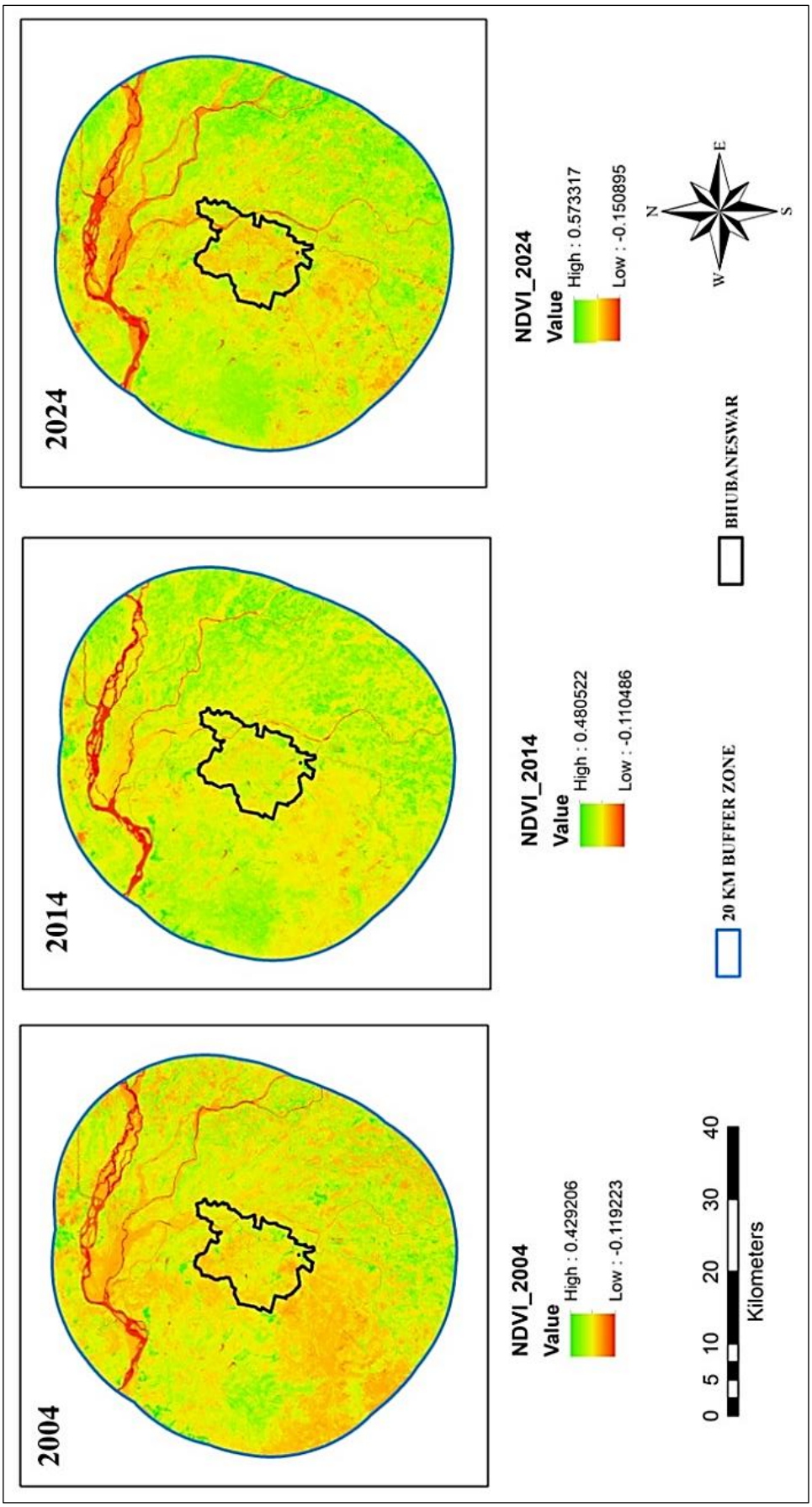

Figure 2. The normalized difference vegetation index (NDVI) maps

Figure 3 shows the NDBI maps for the study area over the three distinct time period. Changes in LULC are crucial to understanding local, regional, and global environmental change. Changes in the land cover are a result of human activity on Earth's surface. The way the Earth system functions is significantly impacted by these changes, including the balance of energy, water, and soil. The LULC classification depicting that the water bodies have decreased and built up has increasing with simultaneously the forest area also increasing. Very interestingly, the dense forest area has increased from 3.40% to 15.74% during the year 2004 to 2024. During 20 years, the open forest area has decreased due to the conversion of the open forest area to dense forest.

Table 2 shows the spatiotemporal dynamic of the LULC. The majority of the empty land has been developed into institutions, residential neighborhoods, and industrial zones. There is also a rise in the transition from open space to developed land. During the years 2004 and 2024, the majority of agricultural, forest, and unoccupied land were converted to residential areas, along with other high-rate categories. Additionally, it has been observed that there is a rise in plantations or degraded vegetation, which is not encouraging given the quantity of degraded vegetated land. The urban LULC has shown a dynamic tendency over time. Urbanization has several effects on changes in land use and cover, including the physiological degradation of the landscape, encroachment of unapproved land, and a reduction in the amount of vegetative cover. Figure 4 shows the LULC maps for the study area over the three distinct time period.

The analysis reveals a positive correlation between LULC and NDVI data with NDBI data. Time series analysis indicates that both vegetation and built-up areas have expanded on the outskirts of Bhubaneswar city.

The Chandaka and Bharatpur forest areas are experiencing biodiversity loss due to encroaching urban development, despite large-scale plantation efforts to conserve natural resources and the environment. Forest loss has primarily resulted from urban expansion in the Bhubaneswar metropolitan area, while forest fragmentation within biodiversity hotspots has been significantly influenced by the spatial distribution and extent of developed land. Increased open forest vegetation density has led to a proportional growth in the Chandaka reserve's forested area. However, the rate of built-up area expansion surpasses that of forest growth.

Over the past decade, Bhubaneswar has undergone rapid spatial growth, nearing the sanctuary boundaries. The city has expanded in seven directions, engulfing nearby communities and protected areas. This has prompted private landowners and businesses to quickly develop residential and commercial properties. Additionally, the number of educational institutions in the region has increased. To address growing land demands, the government has extended land use to the sanctuary's edge. These disruptions to the elephant corridor have intensified human-elephant conflict, especially during harvest seasons. The allocation of land for residential purposes has isolated Bharatpur, formerly connected to Chandaka. Residential plots have been assigned up to the forest's edge, despite Bharatpur being part of an elephant migratory route.

Table 2. Spatiotemporal changes in land use/land cover (LULC).

LULC Category	Area in 2004 (%)	Area in 2014 (%)	Area in 2024 (%)
Water bodies	1.37	1.09	0.7
Dense forest	3.4	6.45	15.74
Open forest	25.21	18.36	7.96
Agricultural land	48.74	45.93	44.56
Built-up area	20.83	22.76	25.29
Barren land	4.63	2.89	1.85

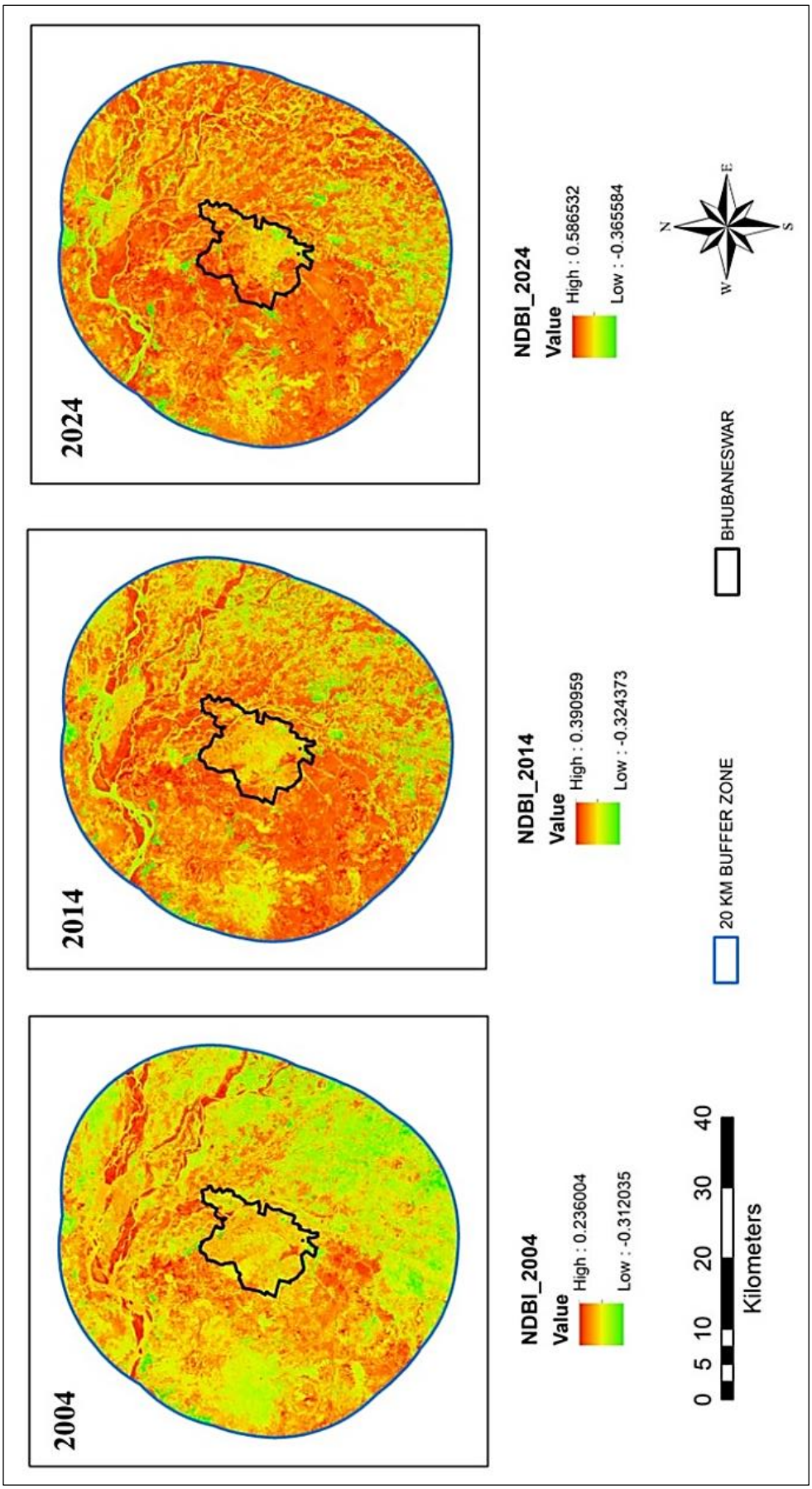

Figure 3. The normalized difference built-up index (NDBI) maps of

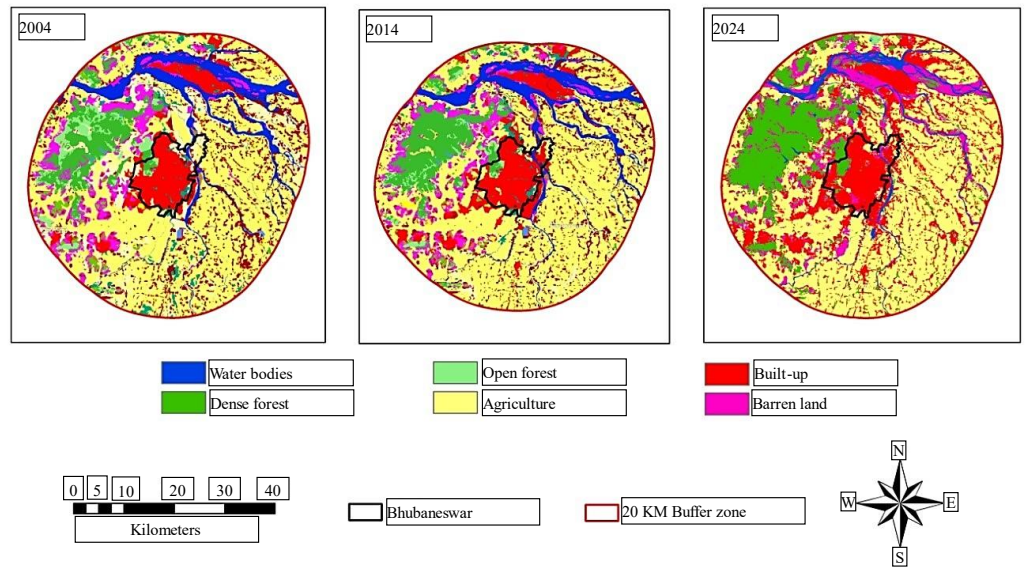

Figure 4. The land use/land cover (LULC) maps of the study area.

CONCLUSION

Ultimately, while urban growth in an Odisha city that is rapidly growing cannot be prevented, it can be controlled and steered in the direction of a healthy city development with the aid of sound planning and administration. The current work thus demonstrates the importance of remote sensing and GIS for the temporal analysis and action of spatial events. The sanctuary and its surroundings have seen spatial changes as a result of Bhubaneswar's development. The 20-km buffer zone surrounding Bhubaneswar has seen habitat loss and fragmentation due to anthropogenic factors such as farming, the establishment of rural villages, poaching, pollution, and urban development. All of these factors have increased biodiversity degradation, which has led to conflict between humans and biodiversity in the surrounding areas. The following are some suggestions for safeguarding and maintaining the hotspots of biodiversity:

The herd as a whole could be tracked in real time by placing a GPS collar on the matriarch of the herd and using the global positioning system (GPS) (Elephant Early Warning System – Helping Communities Live Near Wild Elephants – Wildlife SOS). However, there is a 1- or 2-hour delay when tracking in real time. The overall position of the herd would always be known to the authorities.

The sanctuary authorities need to conduct regular surveys to know the deficiency in the sanctuary in terms of land cover, food, water. Silt can be caused by bank or sheet erosion, which can seriously endanger aquatic life by reducing the photic zone and reservoir life. Important nalas must so have their siltation rates measured; as a result, the authorities must closely monitor these nalas. It is possible to analyze the percentage of precipitation that is lost to runoff and the amount that is held as surface and ground water. In addition, the amount of suspended sediment, organic matter, dissolved salts, and bacteria in the water will all be examined.

Grazing should not be permitted inside the sanctuary. Village people around should be motivated to utilize the forest land around the sanctuary to use as pasture for cattle grazing. For this, they can use different hybrid grass and have a controlled grazing mechanism. The local villagers ought to be incentivized to use the wooded area surrounding the sanctuary as pasture for the cattle. They can employ several hybrid grasses and a regulated grazing mechanism for this. For effective management, a campaign highlighting the values and significance of forests and wildlife must be launched. We could bring up the following issues: (1) As soon as possible, conduct a census to determine the current state of the flora and fauna. (2) To strengthen the forest department, investigate any staffing shortages, step up patrols, and take decisive action against biotic pressures such poaching, wood-cutting, and the

extraction of forest products. (3) Create a new forest corridor connecting the forests of Chandaka and Bharatpur. (4) Put an end to any building projects near the forests.

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