



Symbiosis of Urban Agglomeration vs. Natures Deterioration with Anthropocene; Odisha

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Bhubaneswar, the city set up with Anthropocene; is suffering from forest losses, UHI upshot after the golden spike period (1980 onwards). It is associated with environmental, ecological and social challenges with population/economic growth. The symbiosis of urban agglomeration vs. natures deterioration is well felt from fag end of 20th century. Re-greening of Bhubaneswar smart city with involvement of about 1100K stakeholders in 2021 from about 15k in 1950. The research uses the remote sensing big data through GIS technology and using ERDAS software to construct the land use and land cover (LULC) change maps of the study years 1990, 2000, and 2020. The NDVI for the year 2000 and 2020 along with the land surface temperature on winter and summer days are calculated. There is abrupt changes in built up and afforestation areas at the cost of barren land and water bodies. Reconstruction of green corridor along with building the smart city urges for vertical expansion of the city along with zero slum with uncontrolled migration and population rise.

Keywords: *Bhubaneswar; LULC; NDVI; plantation; vertical expansion; zero slum.*

1. INTRODUCTION

Homo sapiens are datable in history since last 200kYBP (years before present) that is a very small fraction to other species available in abundance. The Hominids were the hunter-gatherers of Stone Age. With freeze cold environment, the hominids became the survival of the fittest and started dominating over all the other species until the end of the late glacial and early Holocene (Greenlandian period) after Pleistocene- Holocene boundary, which was 11700YBP. The hardship of haunting and steady weather during Northgrippian period encouraged the Hominids to develop agriculture, community living, engineering advancements, Khandelwal et al., [1] ; Rockstorm et al., [2], Weaver [3], Stringer et al., [4], Mishra, et al., [5], Rowan e al., [6].

The invitation to the Anthropocene since the Industrial revolution during 18th century, but the new epoch entered the gates after first atomic explosion from 1946 at Bikini Atoll. However, the working group on Anthropocene has decided the entry year from 1950 and accepted by International Union of Geological Sciences (IUGS), and Global Standard Stratigraphic Age (GSSA), Zalasiewicz et al., [7], Mishra S. P., [8].

Proxy annals divulge that about 200kYBP (post glacial maxima) Bay of Bengal strand lines (coastal front) withdrew $\approx 60-100\text{m}$ offshore in comparison to present MSL. Later during early Northgrippian boundary brought week Indian summer monsoon (ISM) during pre-epoch, which surge up during 9000 to 6000YBP (Lake level rise, green India and cultivation). Later in Northgrippian phase occurred from 5000 to 3500YBP until present days, the dry period is

continuing with Interim Ice Age. The greater Chilika was a gulf then and its west bank extended up to present Bhubaneswar city. The downsizing of Chilika lagoon, northerly shift of the River Kathajodi, formation of Rajua loop, Alaka-Prachi-Ratnachira system old, and southern shift of east flowing Paleo Rivers and formation of barrier spit from south with conversion of the Chilika to a lagoon are the geomorphic changes, (Mahalik et al, [9], Mohanty et al., [10], Mishra et al., [11]). All hydrologic changes have occurred around the present Bhubaneswar city and made the area ecologically a paradise.

The megacities were the cynosure for the high growth potential. Incidentally, with independence of India, few new capital cities, Bhubaneswar of Odisha and Chandigarh (Haryana and Punjab) were initiated their building with the start of Anthropocene during 1950's. Bhubaneswar declared as new capital of Odisha, shifted from the old city Cuttack. The Bhubaneswar was a city encompassed by the river Kuakhai and the Daya towards NE to SE, and by Chandaka hills range.

The historic core temple city have glimpses from 3000YBP with conglomeration of sculptural remains of the large number of old temple with Lingaraj temple at center, Hati-gumpha with Ashoka's ethics, Khandagiri with ancient caves and the Sisupal Garh (Pandava caves). Otto Koneigsberger the German architect, designed the initial city with a dwelling for about settlements 20k government officials and government offices accommodated within 10km^2 . However towards early 60's, found inadequate to accommodate the rising population, deplaning of the pre-independent novice city has been raised 200K residents within 135Km^2 Fig. 1.

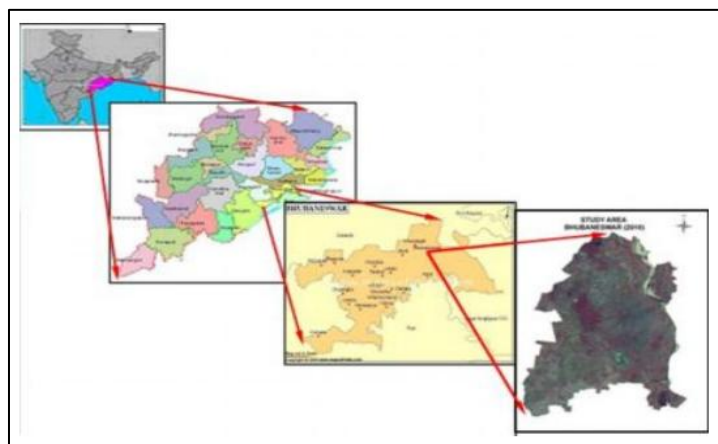


Fig. 1. The index map of Bhubaneswar, capital of Odisha, a part of Khordha district

2. REVIEW OF LITERATURE

The 11700years old Holocene epoch has made good by welcoming the Anthropocene epoch from 1950 well accepted by the scientists, thinkers and geologist as man has conquered the geo-bio-hydro sphere including the atmosphere. The Global Boundary Stratotype Sections and Points (GSSPs) and Global Boundary Stratotype Section and Point (GSSP) accepted the age of humans (Anthropocene) in top of geological time scale on earth. The industry, urbanization, agriculture, mining and use of fossil fuel have surged the atmospheric carbon dioxide (CO₂) concentration surged its highest level that has not happened for millions of years. Concurrently increased solar insolation, global warming, Green House Gases surging, mineralization, carbon sequestration, chemical, hydrologic cycles distraction. The human stress have brought sixth mass extinction, climate change and leading global transformation to the earth system and its sustainability, Cruzen [12], Zalasiewicz, et al., [13], Ellis et al., [14], Lewis et al., [15], Mishra, [16], Baur et al., [17].

Neolithic period has encouraged nomadic homosapiens to shift from hunter-gatherers and cave dwellers to agriculture (Fertile Crescent). Permanent settlements, living in villages and towns in India from Northgrippian period with intense monsoonal activities. As per bio-stratigraphic records, ≈5.0KYBP the humans have constructed planned towns or cities ancient Mesopotamia, (Nile Valley), Yangtze Valley (Nubia) and the Indus valley, (Mahenzodaro and Harappa) in Indian subcontinent and later in Ganges flood plains (Mahajanapadas), were well time-honored, technically developed, politically sound and culturally distinctive.

During Meghalayan period (4.2KYBP), the technological advances, bio-stratigraphic and physio-chemical changes with human impact has altered the nature and life of the humans among industries, cosmopolis and socio-political environment, Kathayat et al., [18], Mishra et al, [19], Elmqvist et al., [20]. Since last two centuries, the global human population has mounted from ≈ 1 billion, to 7.9 billion by 2022. The consequences of population explosion is conglomeration and urbanization in the globe. Tim Dyson's evaluation of India's population were 4-6 million ≈4.0KYBP, growing to 35 mi, 169 mi, and 1380 mi during 2.0KYBP, 220YBP and at present (2020) respectively Desai S [21].

Various researchers have studied the Land use and Land cover (LULC) changes with variation in surface air temperature (SAT), covering wildlife and forest corridors, mining areas, valley vegetation in western Himalayas, urban agglomeration and spatial growth, Kayet. .et al., [22], Taloor et al., et. al., [23], Gadrani et al., [24], Banerjee, et al. [25], Somvanshi, et al. [26], Mishra et al., [27].

Geographic information system (GIS) and Remote sensing (RS) methodology is an efficient tool for assessing the Land use and land cover of an area. The agglomeration of a city not only changes the climate of the area but also make it an urban heat island (UHI). LULC changes accompanied by rise of temperature, expansion of urban landscape with the concomitant surge in anthropogenic accomplishments, down surge of water-bodies have changed the pleasant microclimate of the Bhubaneswar city, Gogol et al., [28], Das et al., [29].

Present study involves the gradual changes in Bhubaneswar Township in demography, LULC, temperature, rainfall, demography, geohydrology during the Anthropocene epoch that started synchronous to the formation of the capital.

3. METHODOLOGY

The dominant delinquent problems of the deterioration of greenness in the urban areas is snowballing due to surge in surface temperature as the vegetated cover on the earth surface is diminishing gradually due to anthropogenic rise and exploitation of nature surrounding such as forests and green areas. The present study includes downloading the Landsat data from the remote sensing big data of the cloud platform Arc GIS-10.4. Geo-referencing has been in use along with confirmation by ground trothing. Using ERDAS IMAGINE 2014 software all the maps generated and studied for the purpose. The methodology employed are (Fig. 2).

3.1 Objectives of the Study

Present study is to prepare the land use/ land cover (LU/LC) maps of Bhubaneswar City from Remote-Sensing data and to get LU/LC changes for last three decades considering from Jungle to modern settlements. The investigation also covers the changes in temperature, and changes in anastomosed drains to settlements, slums and mainly habitations. The methodology adopted in the research is in Fig. 2.

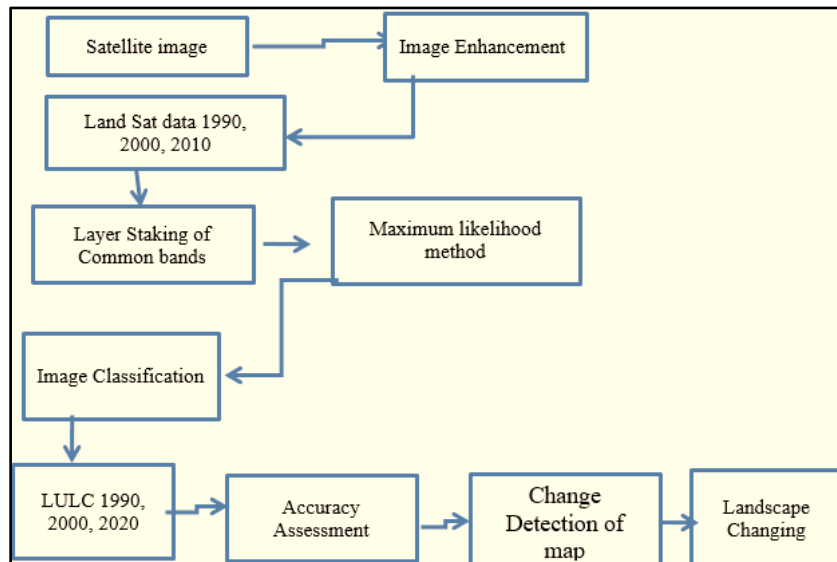


Fig. 2. The methodology adopted for finding landscape changes of Bhubaneswar

3.2 Climate

The average annual rainfall, minimum and maximum temperature of Bhubaneswar is 1498 mm (IMD) of BBSR are 27°C to 41°C respectively. The area housed in the tropics with similar Savanna climate as per Koppell- Geiger (AW) classification. The necessary potential environmental requirements are satisfied satisfactorily in the city like topography, communication, drainage, water supply, soil, air quality and ambient noise. The population grew from 13k to 110k within 70 years around the secretariat explicitly but at the cost of solitary, hilly and tranquil environment with cover of cornfields and Chandaka Jungle.

3.3 Soil

Bhubaneswar is located at 20° 12' N and 20° 23' N latitudes and 85° 44' E and 85° 54' E longitudes .It has an average elevation of 58 meters. It consists of a wide range of soils including mixed red and black soils, red earth, red loamy soils, red sandy soils, red gravelly soils and other alluvial soils. The eastern part of Bhubaneswar, in the banks of riverine zone is alluvium where is rest part is latosols over sandstones. The west region is part to Khandagiri hills range with sparse vegetation.

3.4 Bhubaneswar during Transition

With the decision of shift the old capital from Cuttack to Bhubaneswar during 1948, planned for accommodating a population of about 40k

government employees. The architectural plan instituted by Otto. H. Konigsberger, German Architect in 1946. The new settlement was towards the northern direction of the Lingaraj Temple with six units (I, II, III ...VI) with market building and Hat as the center. The healthy climate, ample free space, employment opportunities attracted people to settle at Bhubaneswar from 1970 onwards. Present Bhubaneswar city consists of ≈1.1mi from fast growing city of population of about 15K during 1951.

Initially started with as a Notified Area Committee constituting south of Lingaraj temple on 1.2.1948, developed as Notified area council on 1.10.1952 constituting n area of 25.9km². On 29.03.1979 the NAC was developed as a municipality with population >100k and area 92.91km². Later the municipality was reconstituted as Bhubaneswar Municipal corporation with population >400k comprising of area 135Km², 4 sectors, 64 wards in 1994 [30,31] (Fig 3).

The urban sprawl of Bhubaneswar Town, at the cost of the reserve forests towards the NW part and the flood plains of the rivers Kuakhai in the eastern part, and the Daya towards south. The old rectangular city could not grow as envisioned. The structure of the city today shows more growth towards SW side of the city (Fig. 4).

3.5 GIS/Remote Sensing Applications

GIS with Remote Sensing (RS) enable to detect and monitor the physical characteristics of an

area by measuring its reflected and emitted radiation at a distance. Though attempts made to prepare small-scaled maps (1:2000) by UAV/ drones fitted with special cameras to collect remotely sensed images for better planning yet it is under process. Remote sensing both directly and indirectly informs the construction of viable LULC scenarios through construction of regional

landscape histories, examination of LULC patterns, and exploration of linkages between historical LULC change and socioeconomic and biophysical driving forces. However the use remote sensing methodologies with remote sensing architecture is an easy and convenient tool for it and provide very accurate big data for analysis using cloud technology.

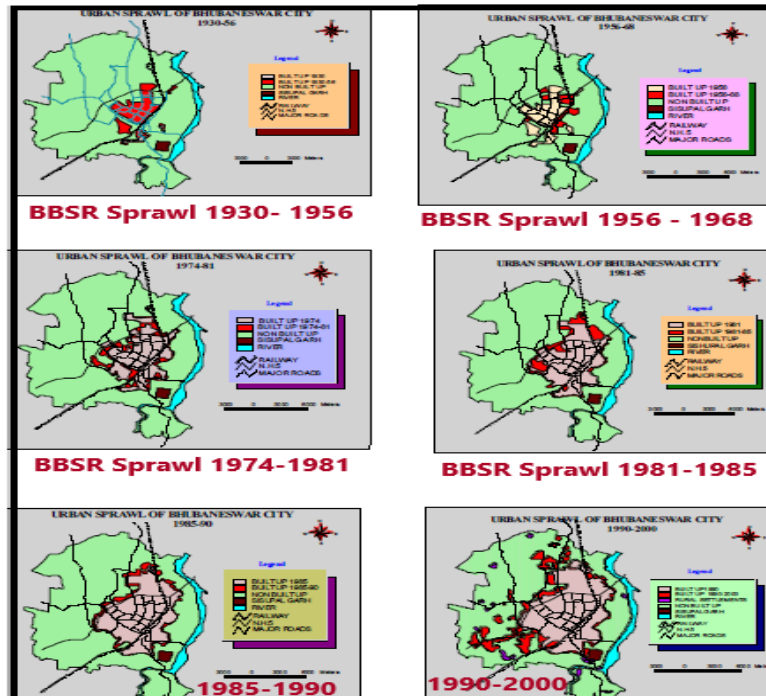


Fig. 3. The Urban agglomeration of Bhubaneswar 1930-2000
 (Source: https://forest.odisha.gov.in/sites/default/files/2020-01/Chap_3)

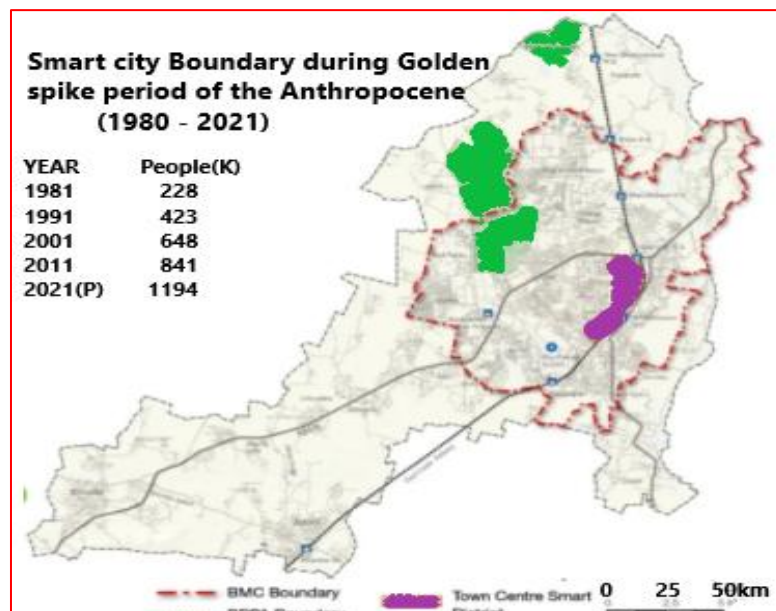


Fig. 4. The Smart city extensions Bhubaneswar during 1980 to 2021

3.6 Land Surface Temperature

Land surface temperature (LST) is one of the most important aspects of the land surface. LST has applications in studying climate change, hydrological and agricultural processes, and urban land use/land cover that has been controlling the most physical, chemical, and biological processes of the Earth. Literature reveals that the cool Bhubaneswar has turned to a Heat Island due to anthropogenic interventions on the land use and land cover.

3.7 Land Use Classification Scheme

Land-use classification schemes includes the most general or aggregated classification (level I level II) comprising of broad land-use categories, such as ‘agriculture’ or ‘urban and built-up’ land. This level of classification is commonly used are (Table 1).

3.8 Data source and Software Used

Data acquired from USGS. Topo sheets and Google Earth Pro used for ground trothing of

data for the field validation. The Soft wares used in the study are GIS software’s (GIS 10.4, ERDAS IMAGINE 2014). The details of acquisition of data are as follows Table 2.

3.9 Supervise Classification Process

Supervised classification uses the spectral signatures obtained from training samples to classify an image. With the assistance of the Image Classification toolbar, you can easily create training samples to represent the classes you want to extract. You can also easily create a signature file from the training samples that uses by the multivariate classification tools to classify the image (Fig. 5 and Table 3).

From supervised classification, the inference is major decrease in bare and fallow lands (50.46%) and converted mainly as settlements i.e. in urban agglomeration by 31.234%. However, the plantation and vegetation areas have increased by 20.834%, (Table 3; Fig. 5).

Table 1. Various levels in land use and land cover classification scheme in GIS

Level I	Level II
Urban or built-up	Residential, Commercial and services, Industrial, Transportation, communication, and utilities, Industrial and commercial complexes, and Mixed urban and built-up land
Agriculture	Cropland and pasture, Orchards, groves, vineyards, nurseries, and ornamental horticulture; Confined feeding operations
Forest land	Deciduous forest land, Evergreen forest land, Mixed forest land
Water	Streams and canals, Lakes, Reservoirs , Bays and estuaries

Table 2. LANDSATs used for data acquired, analysis, their passing dates, and path/rows

SI No.	Satellite Name	Sensor	No. Bands	Date of Acquisition	Path and Row
1	Landsat 5	Operational Land Imager (OLI) & Thermal Infrared Sensor (TIRS)	07	1990-01-28	Path – 140; Row – 47
2	Landsat 8	Operational Land Imager (OLI) & Thermal Infrared Sensor (TIRS)	11	2020-20-04	Path – 140; Row - 47

Table 3. Change in LU/LC areas in core areas of BMC fro, 1990 to 2020

#	Class Name	Area(Ha) [1990]	% of Total	Area(Ha) [2000]	% of Total	Area (Ha) [2020]	% of Total	LULC change %
1	Water Body	528.22	2.88	379.16	2.0697	235.01	1.283	-1.601
2	Urban Area	4122.26	22.5	6403.54	34.953	9844.83	53.736	31.234
3	Bare Land	11586.97	63.25	6867.37	37.484	2343.12	12.789	-50.459
4	Plantation	2082.22	11.37	4670.62	25.494	5899.297	32.200	20.834
		18319.7	100	18320.69	100	18322.257	100	

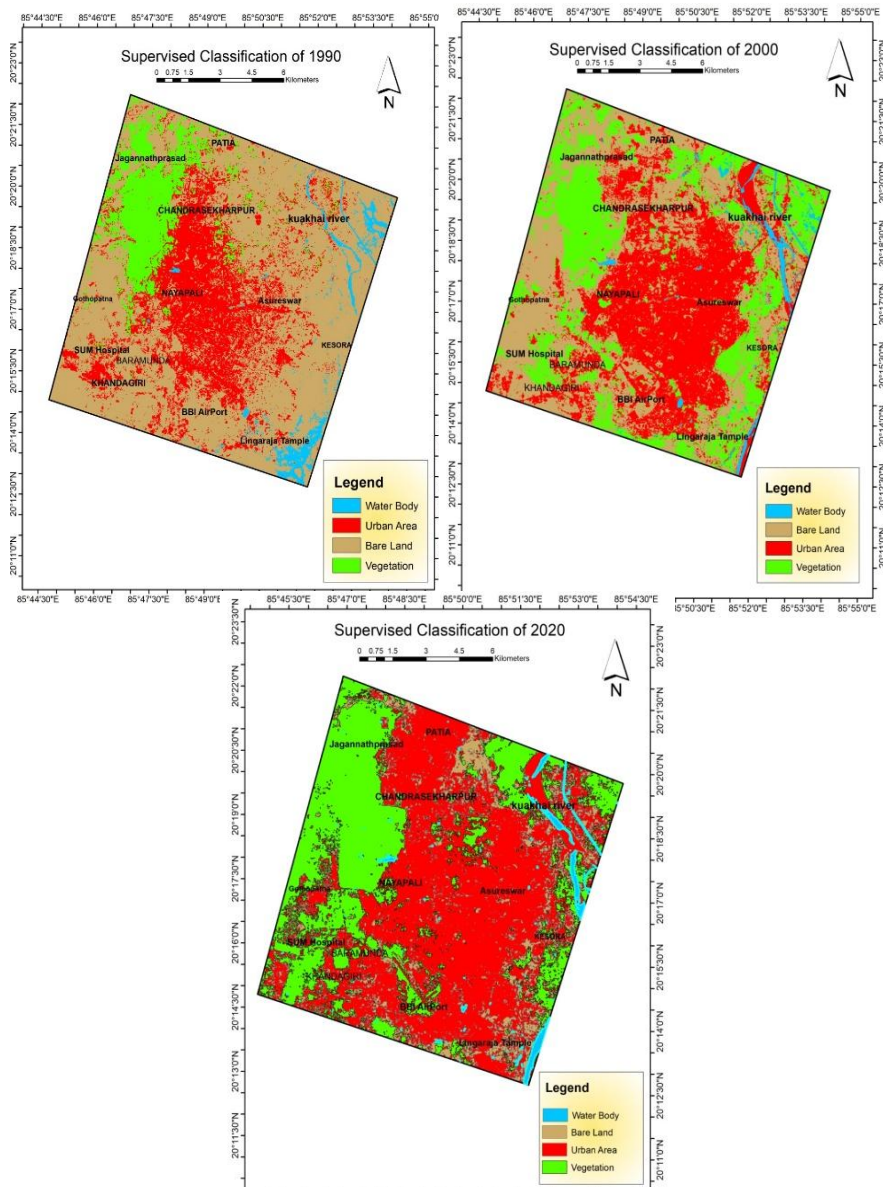


Fig. 4. The supervised classification of BMC area during 1990, 2000 and 2020

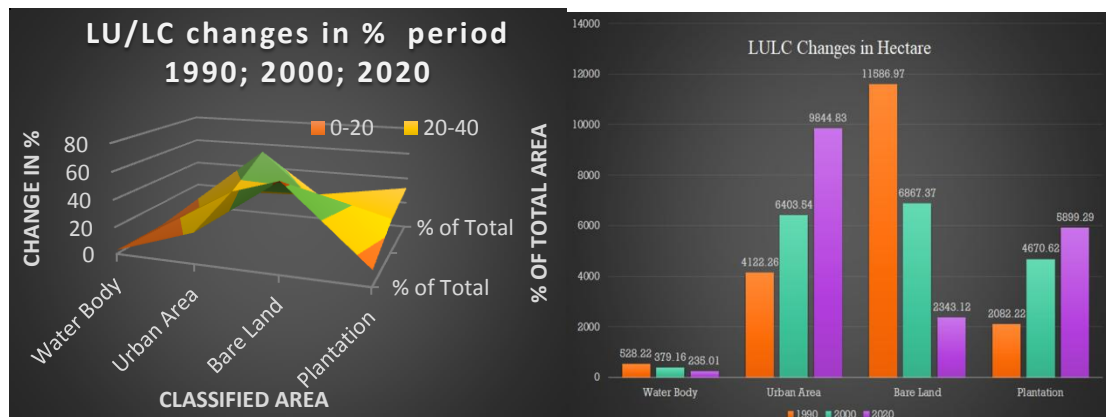


Fig. 5. LU/LC changes in %, and hectare during 1990; 2000; 2020

3.10 Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) quantifies vegetation by measuring the difference between near infrared (which vegetation strongly reflects) and red light (which vegetation absorbs).

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)} \quad \text{Eq-1}$$

Where Red = DN values from the Red band, and NIR= DN value from Near-Infrared band. The notion is that a healthy and luxuriant plant with plenty of chlorophyll and cells absorbs red light and reflects NIR and vice versa. NDVI is a good indicator of drought and clearly indicate the status of agriculture, forestry, vegetation and land degradation. The proportion of vegetation (PV) is:

$$PV = \frac{(NDVI - NDVI_{min})}{(NDVI_{max} - NDVI_{min})} \quad \text{Eq-2}$$

Where NDVI_{max} and NDVI_{min} are maximum and minimum NDVI values. NDVI value <0.15 indicate a ploughed land, dead vegetation. When the low NDVI value 0.15 to 0.2, signifies winter vegetation before tilling early germination/ leaf formation stage. Values obtained if of range 0.2 - 0.3 specify good growing vegetation whereas values 0.3 – 0.5, the land has a good Vegetative cover.

3.11 Land surface Temperature

The study involves NDVI of the populous LULC for the BMC area of about 8143.5Ha (Table 4; Fig. 6).

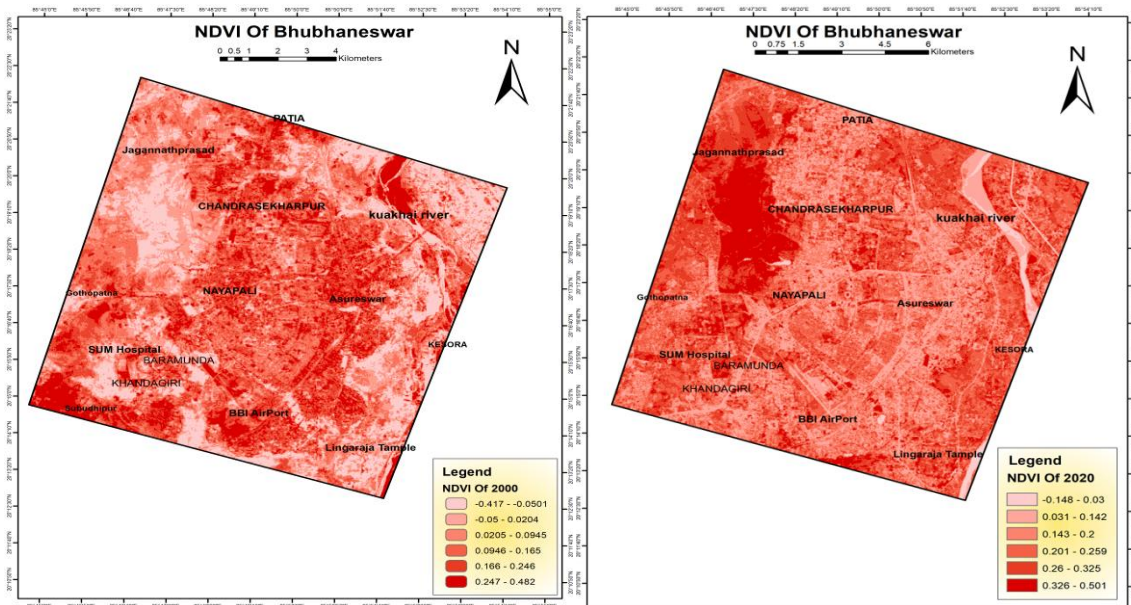


Fig. 6. NDVI; of Bhubaneswar Municipal Corporation area in 2000 and 2020

Table 4. The change in the NDVI in land use and land cover during 2000 to 2020

#	NDVI Value	NDVI classes	Area in Ha(2000)	In %	Area in Ha(2020)	In %	% Changes
1	-0.14 to -0.501	Water Body	811.2	9.97%	134.68	1.66%	8.31
2	-0.05 to -0.0204	Scrubs & Small plants	1462.4	17.95%	1225.6	15.04%	2.91
3	-0.0205 to 0.0945	Roads & Path Way	1750.36	21.49%	1702.44	20.90%	0.59
4	0.0946 to 0.165	Urban Area	1784.6	21.91%	2098.64	25.78%	-3.87
5	0.166 to 0.246	Forest Area	1602.88	19.69%	1969.84	24.19%	-4.5
6	0.247 to 0.482	Bare Land	732.08	8.99%	1012.32	12.43%	-3.44
Total Area=			8143.52	100.00%	8143.52	100.00%	0

3.12 LST Changes

Fast urbanization of urban areas around the world is at the cost of water bodies, Forestland, fallow land, and vegetative covers. The conversion to concrete jungle from natural land have surged the local temperature at a high rate by transforming it to urban heat Island and changing the local seasonal weather abruptly (Das et al, 2002; Kumar e al, 2021; Shukla et al 2021; Liao et al., 2022). Landsat data (Level-1) comprises of quantized with calibrated and scaled Digital Numbers (DN) that denote the multispectral image data. Landsat 8 data picked up by the Operational Land Imager (OLI) + Thermal Infrared Sensor (TIRS) delivered in 16-bit unsigned integer format. Landsat 1-7 products generated from single sensor data and delivered in 8-bit unsigned integer format (City Development Plan Report, [31]; USGS L-1 data use [32]).

Level 1 Data Rescaling: The Satellite imagery of Level 1T down loaded using Landsat 5 TM, Landsat 7 ETM+ and Landsat 8 sensors from USGS website having least cloud cover (<10%) and atmospheric corrections made. Transformation from Landsat 5 TM to Landsat 7 ETM+ the equation applied in eq.-3; Mwangi et al., [33] and <https://www.usgs.gov/landsat-missions/using-usgs-landsat-level-1-data-product>

$$DN_7 = (Slope_{\lambda} * DN_5) + intercept_{\lambda} \quad \text{Eq -3}$$

Top of Atmosphere (TOA) Radiance: Using the radiance-rescaling factor, Thermal Infra-Red Digital Numbers converted to TOA spectral radiance L_{λ} in $m^2 * sr * \mu m$

$$L_{\lambda} = M_L * Q_{cal} + A_L \quad \text{Eq -4}$$

Where: M_L = Radiance multiplicative Band (No.); A_L = Radiance Add Band (No.); Cal = Quantized and calibrated standard product pixel values (DN)

Conversion to TOA Reflectance: The DN's reflective band transformed to TOA reflectance by use of rescaling coefficients in the MTL file i.e.:

$$P_{\lambda}' = M_{\rho} Q_{cal} + A_{\rho} \lambda' = M_{\rho} Q_{cal} + A_{\rho} \quad \text{Eq -5}$$

Where P_{λ}' = TOA planetary reflectance, without correction for sun angle.

M_{ρ} = Multiplicative rescaling factor (Band-specific) from the metadata.

A_{ρ} = Additive rescaling factor (band specific) from the metadata

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

With sun angle correction the TOA reflectance is

$$\rho_{\lambda} = \frac{P_{\lambda}}{\cos(\theta_{SZ})} = \frac{P_{\lambda}}{\sin(\theta_{SE})} \quad \text{Eq -6}$$

Where: ρ_{λ} = Planetary reflectance of TOA; θ_{SE} = Local sun elevation angle and θ_{SZ} = Local solar zenith angle; where $\theta_{SZ} = 90^{\circ} - \theta_{SE}$

Top of Atmosphere (TOA) Brightness

Temperature: Spectral radiance data converted to top of atmosphere brightness temperature using the thermal constant Values in Meta data file.

$$BT = \frac{K_2}{\left(\ln \frac{K_1}{L_{\lambda}} + 1\right)^{-273.15}} \quad \text{Eq -7}$$

Where: BT = Top of atmosphere brightness temperature ($^{\circ}C$); L_{λ} = TOA spectral radiance in Watts/ ($m^2 * sr * \mu m$); K_1 = K1 Constant Band (No.); K_2 = K2 Constant Band (No.)

LST Calculation: The land surface temperature (LST) given by:

$$LST = \frac{BT}{(1+W * BT/C_2)^{1/\ln(E)}} \quad \text{Eq -8}$$

Where: BT = Top of atmosphere brightness temperature ($^{\circ}C$); W = Wavelength of emitted radiance (For band 10 -10.8 μm and Band 11- 12 μm); $C_2 = h \cdot c/s = 1.38 * 10^{-23} mK = 14388 \mu m$; s = Boltzmann Constant = 1.3806488 x 10⁻²³ Joules per degree Kelvin (J/K); c = Velocity of light = 3.0 x 10⁸ m/s; E = Land Surface Emissivity (Fig. 7).

4. DISCUSSION

Present study has indicated that satellite data can record frequent changes in land use pattern of the coastal areas. Still micro level changes in erosion and accretion rate left and recorded due to coarse resolution of satellite data. Nevertheless, this button neck can be possible to avoid by taking fine resolution LISS IV satellite data. Based on the present study, that accurate forest cover, and change detection in tropical hilly environment is effective in using high-resolution satellite data or microwave data. This paper focuses on improvements to the LU / LC and LST in urban areas in tropical India, using

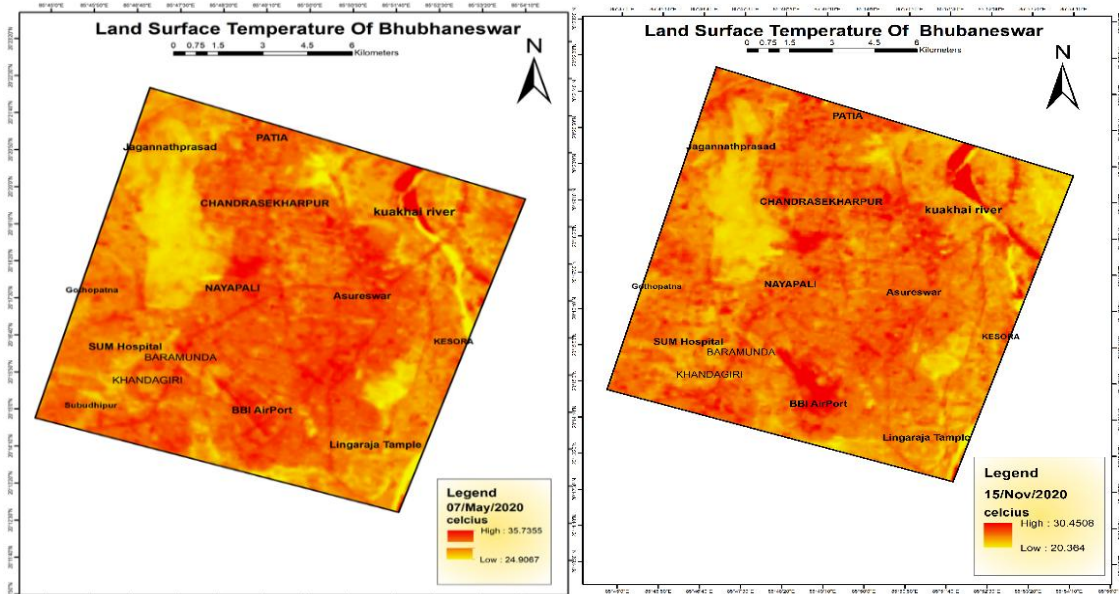


Fig. 7. The LST difference between summer and winter (On 7 May and 15 Nov of 2021)

remote sensing data and GIS technology in Bhubaneswar, India. The results clearly show that LU / LC changes during the period 1990 to 2000 and 2000 to 2020 were substantial [34,35].

From 1999 onwards Super cyclone, many a cyclonic storms above severe cyclonic storm (SCS) that hit south Odisha coast devastated the vegetation and forests of Bhubaneswar. The major cyclones are Phailin (2013), Hudhud (2014), Fani (2019), and Amphan (2020), Mishra et al. [36]. The disastrous effect of whirlwind and rainfall have devastated the forests and afforestation's in the urban area. The bald terrain has raised the LST due to rise in solar radiation. The anthropogenic stresses made due to surge in concrete areas along with effects of cyclones, rise in solar insulation, population have made the panoramic, cool and tranquil area a crowdie and urban heat island, Bide [37], Dash et al., [38].

There is visible considerable expansion of built-up area. On the other hand, agricultural area is decreasing; water spread area, and forest areas. This study clearly shows the impact of population and their developmental activities on changes in LU / LC. This study proves how effective tool for urban planning and management is integration of GIS and remote sensing technologies. Quantifying LU / LC changes in the BBSR region is useful for environmental monitoring, policy-making and for the public benefits [37-39].

In this NDVI calculation, the area of Bhubaneswar city for vegetation is gradually

increase high indices vegetation from 2000 to 2020. LST of an area was determined using Arc GIS. Estimated LST values revel that in the month of May 35.7^oc, and in the month November, LST was 30.4^oc. Thus, LST can be estimated using Landsat 8 with multiband OLI and TIR images [36,40,41].

Within the hills, meadows, rivers, drainage network and swamps of the BMC need efforts to restore green cover by limiting resilience, and resistance to sustain diversity, as in pre-Anthropocene to save the natures deterioration. The future necessity for the sustainability of green and smart Bhubaneswar are:

- i. Planting more fruit bearing plants, restoration of water bodies to enhance food security and maintaining the cityscape in addition to smart city planning.
- ii. It is pertinent that the city need a map in 1:1000 or 1:2000 (Large scaled map) for microscale planning both by BMC with other line departments by using modern surveying technologies like use of UAV, drones, GNSS etc.
- iii. The green building concept for energy optimization through rainwater harvesting shall be of primal option.
- iv. The save the city from future water demand, it is necessary to restore waterbodies, recharging ground water table and develop new water supply schemes as sources the Kuakhai, and Daya as source.

- v. To encourage water harvesting structures in outskirts Chandaka area for the necessities flora and fauna particularly elephants of Chandaka forest to avoid the human animal conflict occurring as on date
- vi. The slum rehabilitation shall be on priority to make the smart city panoramic, green and healthy.
- vii. Development of satellite towns in outskirts along with landscaping shall accommodate more of its stakeholders.
- viii. Finally like other modern cities like New York, Shanghai and Mumbai etc. Bhubaneswar city should change its housing plan from horizontal extension to vertical expansion to accommodate its growth demographic and economic.
- ix. The city need use of the space available below the surface as underground metro rails, tunnels and bypasses.
- x. Periodical gathering and analysis of LU/LC, soil, water, climatic, urban, meteorological data of temporal and spatial to be stored as big data in cloud platform for later use in planning, modelling and management.

5. CONCLUSION

RS data with GIS and ERDAS software used to construct knowledge, the LU/LC, NDVI and LST of the tentative Bhubaneswar Municipal Corporation. Since inception from 1950, demographic escalation and infrastructural expansion, indicate that the LU/LC variations become significant from 1980 onwards. Significant growth of built-up area detected at the cost of scrub areas, water bodies, swamps, forests and agricultural land around Lingaraj temple. Present investigation indicates that the substantial influence of population and their development accomplishments on LU/LC change. There is increase in built up areas (31.23%) and plantations (20.83%) sacrificing the bare land (50.46%) and water bodies 1.6%. The built up areas have increased the land surface temperature and the plantations have partly balanced it. Overall, the study infers that integration of RS/GIS technologies is active tool for urban planning and management.

The future scope of present research is to monitor the LULC changes periodically, to accesses the impact of built-up area and urban expansion of Bhubaneswar. The area shall exacerbate warming along with tough *kal-baishki* during summer. Surge in RCC structures shall

invite critical heat island effect both temporally or spatially to the present ideal smart city.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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