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SEASONAL DISTRIBUTION OF URBAN HEAT USING LANDSAT-8 MULTISPECTRAL DATA: A CASE STUDY IN BHUBANESHWAR, ODISHA, INDIA.

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Abstract: Urban heat islands (UHIs) are increasing in urban centers of developing and underdeveloped countries. Its rapid growth is attributed to a fast-growing population, as well as unplanned settlements. In this study, we use multispectral satellite images over the summer and winter from 2014 to 2021 as a case study for understanding the UHI in Bhubaneshwar city. With the help of thermal remote sensing technique and multispectral thermal imagery, the Land Surface Temperature (LST), Urban Heat Island (UHI), Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-up Index (NDBI) have been determined. As compared to 2014, UHI values of Bhubaneshwar are significantly higher in 2021. Therefore, the issues must be concerned with decision-makers as well as communities regarding its effects and future planning.

Keywords: Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), Normalized Difference Build-up Index (NDBI), Urban Heat Island.

Introduction:

Deforestation, increasing built up, and pollution are major concerns of urban development. Landuse and land cover changes by human intervention alters natural landscape. Odisha is of no exception of this globalized urbanization paradigm. A few significant cities are becoming challenging for town planners and policy makers to incorporate knowledge about climatic conditions within urban spaces and manage towards minimal impacts on human health (Baker, 2012; Corburn, 2009; Rapoport, 2016). In such cases, it would be even more difficult for underdeveloped countries where these urban spaces invaded by unplanned settlements, characterized with heavy material such as concrete to construct residential units and have no home-garden areas (Ngie, 2020; Trainer & Trainer, 1995). For this reason, studies should be conducted for the spatial-temporal estimation of the urban heat island. There is lack of

vegetation and impervious paved surfaces that characterize urban environment. As a result of the larger volume of asphalt, brick, concrete, and other urban surfaces, they provide greater thermal storage capacity. The urban canopy also stores large amounts of energy during the day, which it radiates back at night (Goward, 1981; Sarrat et al., 2006). In addition, heat generated by automobiles, air conditioners, and other machinery, urban areas experience relatively higher temperatures than their surrounding environment. This has been described as one of the primary challenges to sustainable livelihoods in urban areas. The excess temperature near the ground of the central urban locations is higher than those of nearby or surrounding areas (Oke et al., 2017; Voogt & Oke, 2003). This phenomenon has previously been taken as the difference between urban and rural areas. Still, with recent developments in cities, there is no distinct borderline between 'urban' and 'rural' fields due to urban growth (Alcoforado & Andrade, 2008; Rotach et al., 2005; Yow, 2007). Rapid urbanization is an ongoing dynamic process and is the most dominant phenomenon in all developing countries (R. B. Thapa & Murayama, 2008). Being the capital city of Odisha, Bhubaneshwar is in rapidly urbanizing phase in core as well as shadow zones and becoming increasingly challenging to the urban planners. This study enquires continuous urbanization in metropolitan as well as peripheral zones of Bhubaneshwar city.

Objective:

The main objective of this study is to investigate various causes of increasing pattern of Urban Heat Islands by using the multispectral satellite images from the year 2014 to 2021 and provide some measures to monitor the unplanned urbanization process of the study area.

Materials and Methods:

About the Study Area:

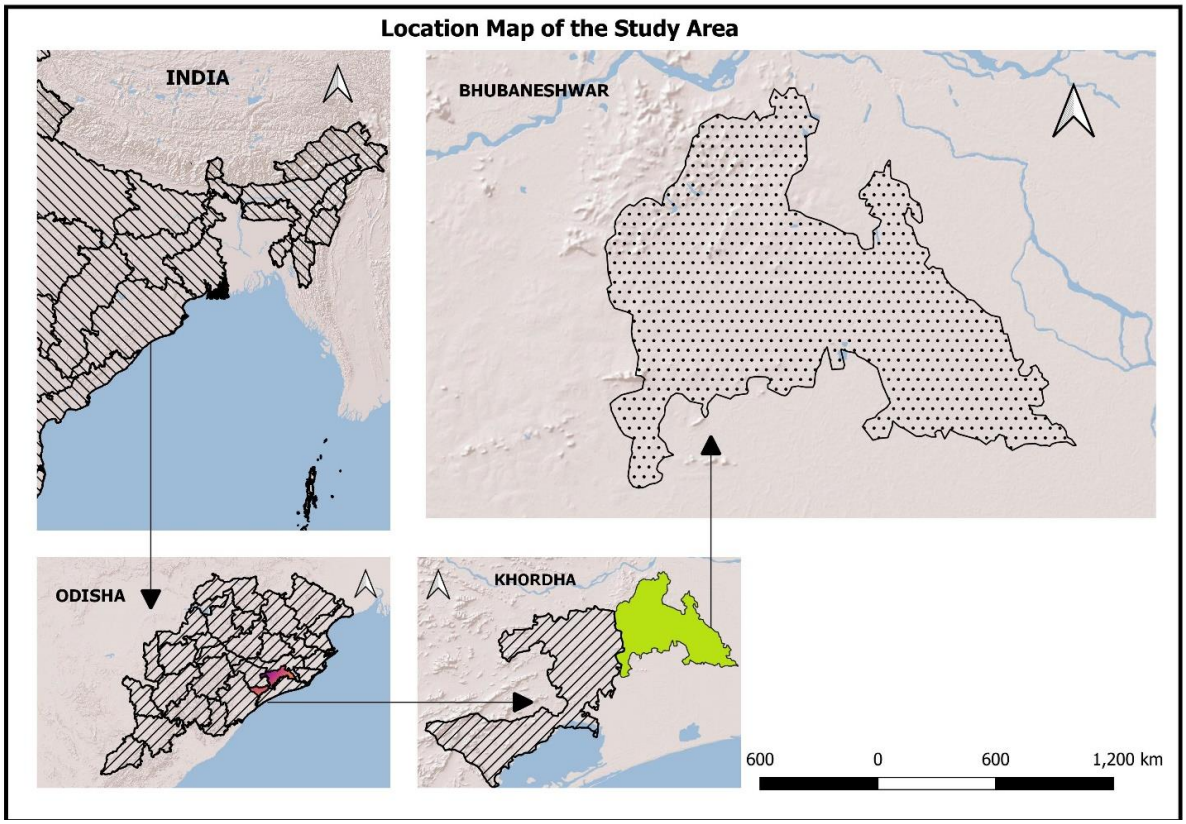

Figure 1: Study area Map

Odisha is considered to be India's state with the fastest rate of urbanization. In 2011 census, the proportion of people living in urban areas of the state is 16.68%. Odisha, however, had a population density of 269 persons per square km in 2011. Bhubaneswar is located in the Khurda District of Odisha. Odisha's capital is also known as the temple city because of its numerous temples. The study area covers an area of 270 square kilometers. The urban center lies on the Howrah - Chennai main line of the South Eastern Railway, 435 km from Howrah and 1215 km from Chennai. The NH-5 that links Chennai and Kolkata runs through the town as well. The city is on the west bank of the river Kuakhaiis southwest of Cuttack, in the Mahanadi Delta. The river Daya which has cut off from Kuakhai moves along the southeastern part of the city. After the independence, the Bhubaneswar region has gone through a lot of expansion and growth. Administrative and institutional activities have contributed to the increase in the volume of trade and commercial activity. The city lies in between 21°15' north latitude 85° 15' longitudes. Bhubaneswar has a good climate with the average temperature in winter is 12 degree Celsius and the maximum temperature is 43 degree Celsius. The megacity has three different seasons. These are summer (from March to June), Monsoon (July to October), and winter (From November to February). According to the Koppen bracket, the megacity comes under Champaign (ISDR Report, 2002). The average periodic downfall of the megacity is 1498 mm (Bhubaneswar main report). The mean periodic temperature of Bhubaneswar lies between 27 °C to 41°C. The climate remains sticky for the month of June to October). A proper look at its demographic and socio-cultural conditioning reveals that this state is one of the least urbanized among the major states of India (13.5% of the state population resides in civic areas). 69 percent of the state population is involved in agribusiness. Nonetheless, the state has the third-smallest population growth rate in the country. The knowledge rate is hardly lower than the public mark. Ultramodern Bhubaneswar is a well-planned megacity with wide roads and numerous premises and auditoriums. The frame was made by Otto H. Koenigsberger. Though part of the megacity has remained as planned, it has developed hastily over the decades and has made the planning process clumsy.

Data Used and Methods:

Landsat eight satellite data downloaded from the United States Geological Survey (USGS) website over two different seasons downtime (November-December) and summer (May-June) for two different times were 2014 and 2021 of Bhubaneshwar city have been incorporated in this study. Satellite images of two seasons downloaded from earth discoverer with lower than 5 percent cloud cover.

The Urban Heat Island (UHI), Land surface temperature (LST), Normalized Vegetation Index (NDVI), and Normalized Difference Built-up Index (NDBI) are extracted from Landsat eight images using ArcGIS 10.5 and QGIS 3.22. Top of Atmosphere (ToA) of the particular images have also been calculated using the following equations:

Top-of-atmosphere reflectance (or TOA reflectance) is the reflectance measured by a space-based sensor flying higher than the earth's atmosphere. These reflectance values will include contributions from clouds and atmospheric aerosols and gases.

- **TOA (Top of the Atmospheric Correction)** has been calculated as below equation: (0.0003342* "Band10" +0.1) Band 10 is the thermal band of Landsat 8.

Brightness temperature (also referred to as TB) is a measure of the radiance of microwave radiation traveling upward from the top of Earth's atmosphere. The conversion from radiometer counts to top-of-the-atmosphere TB is called the calibration process.

- **Brightness Temperature (BT)** calculated: (K2 /ln (K1 / "TOA") +1) - 273.15K2 is Landsat 8 constant 1321.0789, K1 constant 774.8853.

NDVI and NDBI are calculated using the following equations:

- **NDVI**= Float (Band 5-Band4)/Float (Band5+Band4),
- **NBDI**= Float (Band 6- Band 5)/ Float (Band 6+Band 5).

The normalized difference vegetation index (NDVI) is a simple graphical indicator that can be used to analyse remote sensing measurements, often from a space platform, assessing whether or not the target being observed contains live green vegetation and the Normalized Difference Built-up Index (NDBI) uses the NIR and SWIR bands to emphasize manufactured built-up areas. It is ratio based to mitigate the effects of terrain illumination differences as well as atmospheric effects.

For the computation of Land surface temperature (LST) firstly calculate the proportion of vegetation index (PVI) and emissivity, and finally, the **Land Surface Temperature (LST)** derived from the following:

- **PV**= Square (NDVI- NDVI $_{min}$)/(NDVI $_{max}$- NDVI $_{min}$)
- ε = 0.004* "PV" +0.986 (**ε** = Emissivity)
- **LST**= ("BT" / (1+ (0.00115* "BT" /1.4388) *ln ("ε")))

An urban heat island(UHI) occurs when a city experiences much warmer temperatures than nearby rural areas. The difference in temperature between urban and less-developed rural areas has to do with how well the surfaces in each environment absorb and hold heat. The **UHI** has been extracted using the following method:

- $UHI = \mu + \sigma/2$

In which μ is the mean LST value of the study area, and σ is the standard deviation of the LST.

Result and Discussion:

The

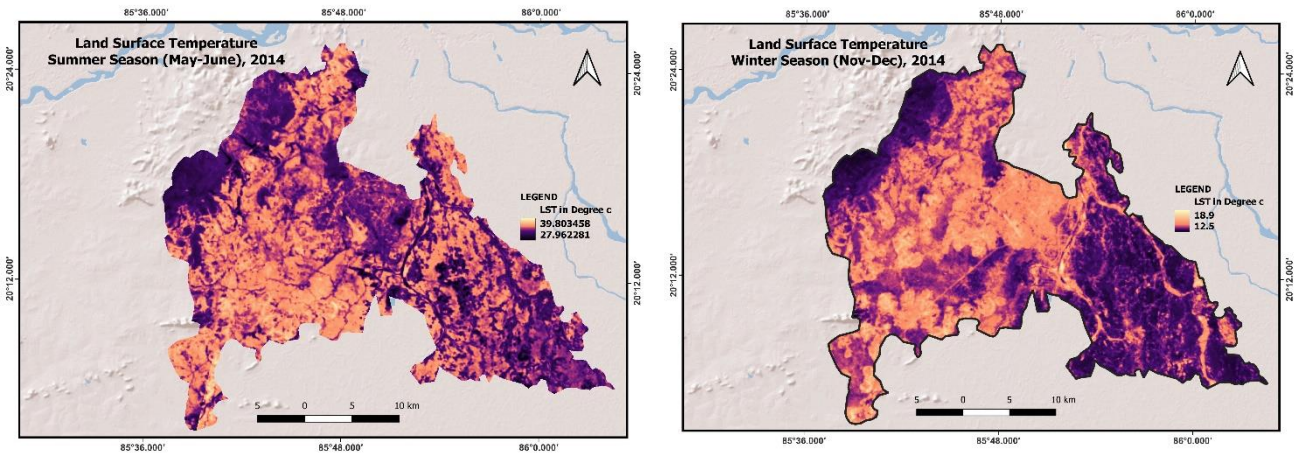

Figure 2: LST map of winter and summer season of the year 2014

above maps (figure 2) show the Land surface temperature of Bhubaneshwar in 2014 for two seasons: winter and

summer. Both seasons depicts higher surface temperature between 29 and 39 degrees in the two cases in urban sprawl zones. In Bhubaneshwar, middle-upper part is the main city area and the city area is more heated compared to the outer part. In the summer season, barren lands are more heated compared to the city area because of the open soil absorb more radiation compare to the city area, whereas in the winter season the map represents that the city area is more heated compared to the barren area and LST range varies between 12.5℃ to 18℃.

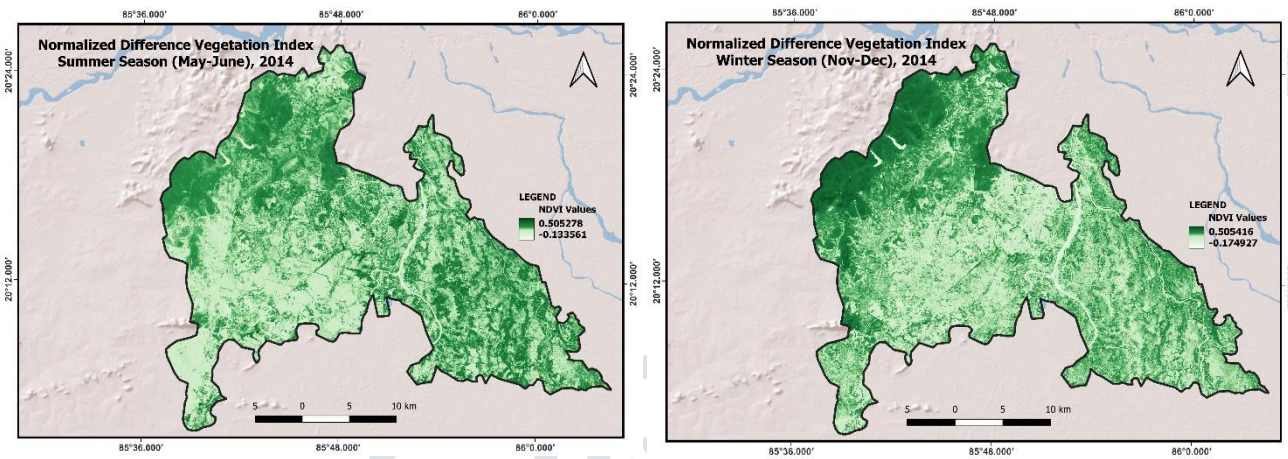

Figure 3: Normalized Difference Vegetation Index map of winter and summer season of the year 2014

The map illustrates the normalized difference vegetation index of summer and winter for Bhubaneshwar (Figure 3). The Normalized Difference Vegetation Index (NDVI) applies to understanding the vegetation pattern. Here, NDVI is higher where there are low built-up area and higher landuse pattern for agricultural areas. For both seasons, the entire city has significantly lower NDVI in most parts, as shown on the map. Only the western part of the region belongs to high NDVI values compare to the eastern part of the study region. On the contrary in summer season, the NDVI range varies from -0.1 to 0.5 and the winter range is -0.17 to 0.5.

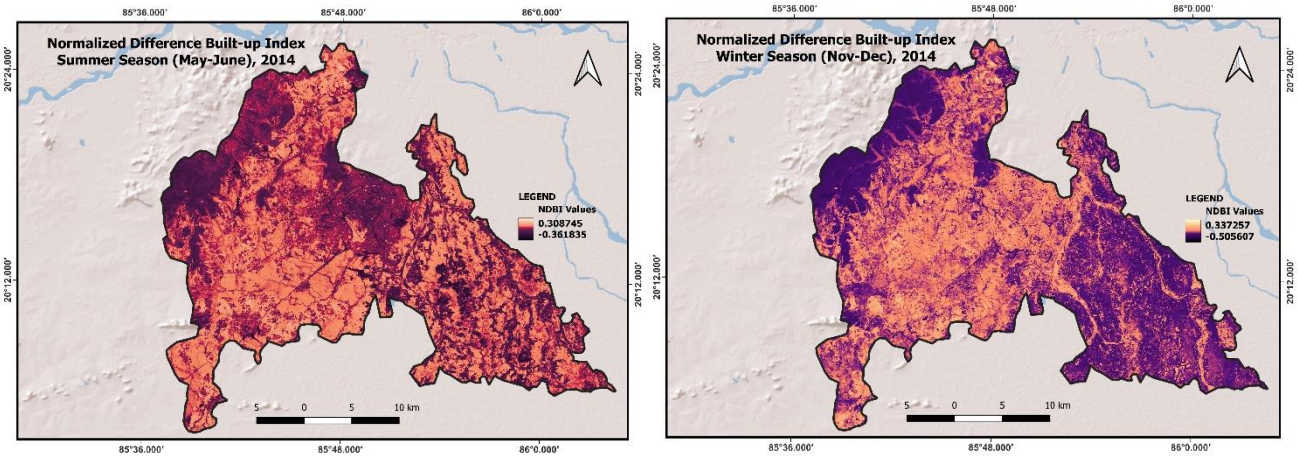

Figure 4: Normalized Difference Built-up Index of winter and summer season of the year 2014

For extraction of urban areas, the Normalized Difference Built-up Index demarcated in the study area. The results showed that in both the seasons in two images have higher NDBI with only a few areas of lower NDBI. It signifies the built-up area is more significant than other areas.

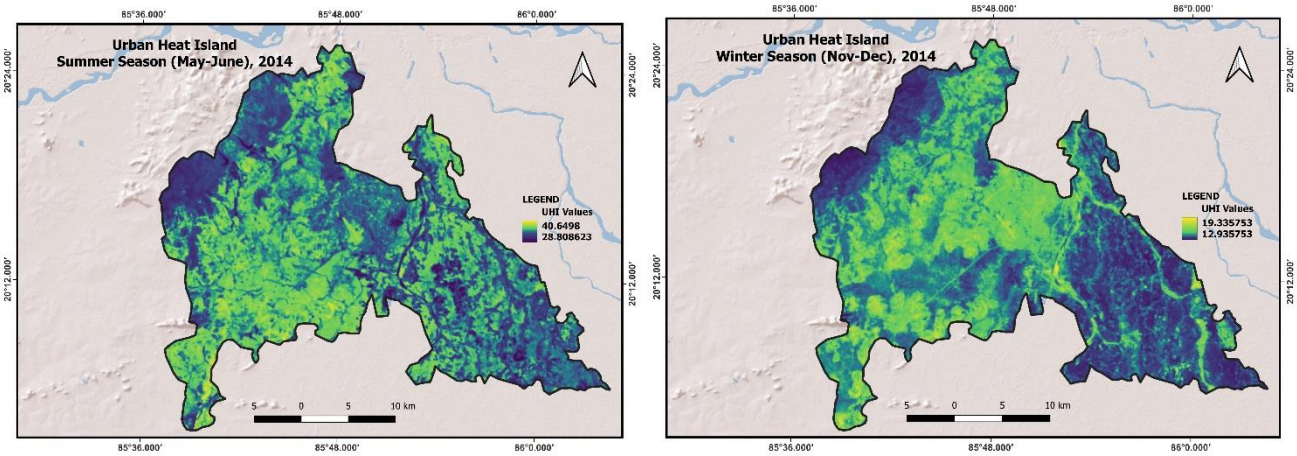

Figure 5: Urban Heat Island map of winter and summer season of the year 2014

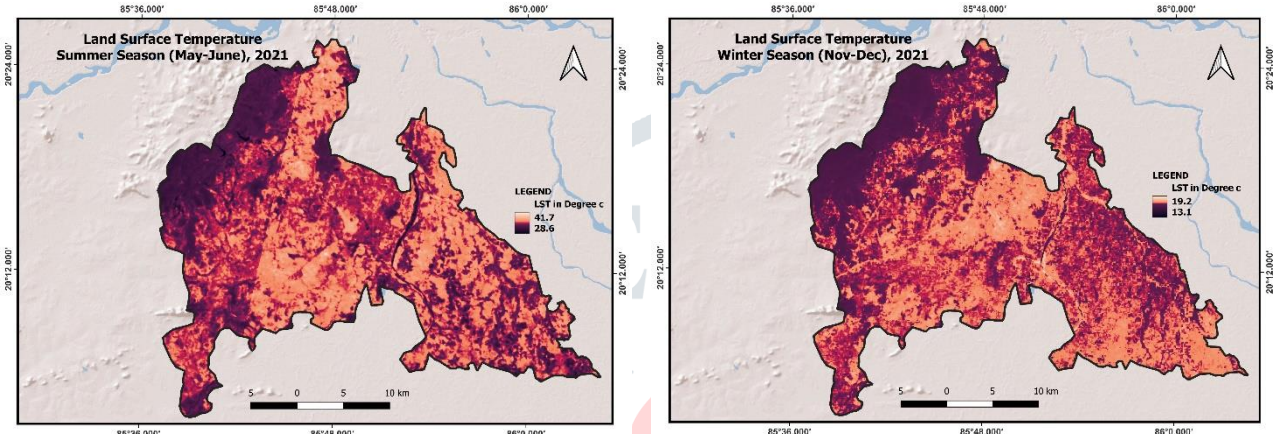

Figure 6: Land Surface Temperature map of winter and summer season of the year 2021

The results showed that the Urban Heat Island (UHI) values of Bhubaneshwar ranges in winter between 12.94 and 19.34 (Figure 5 right side); whereas from 28.81 to 40.65 in summer (Figure 3, May-June'2014).

The results showed that the Land Surface Temperature (LST) value of Bhubaneshwar in winter range between 13.1 and 19.2 (Figure 6 right side); where summer have lower and higher value from 28.6 to 41.7 (Figure 3, May-June'2014). From the above maps, it's clear to us that heat increased from 2014 data. The output is a result of Green House gases and the global warming effect.

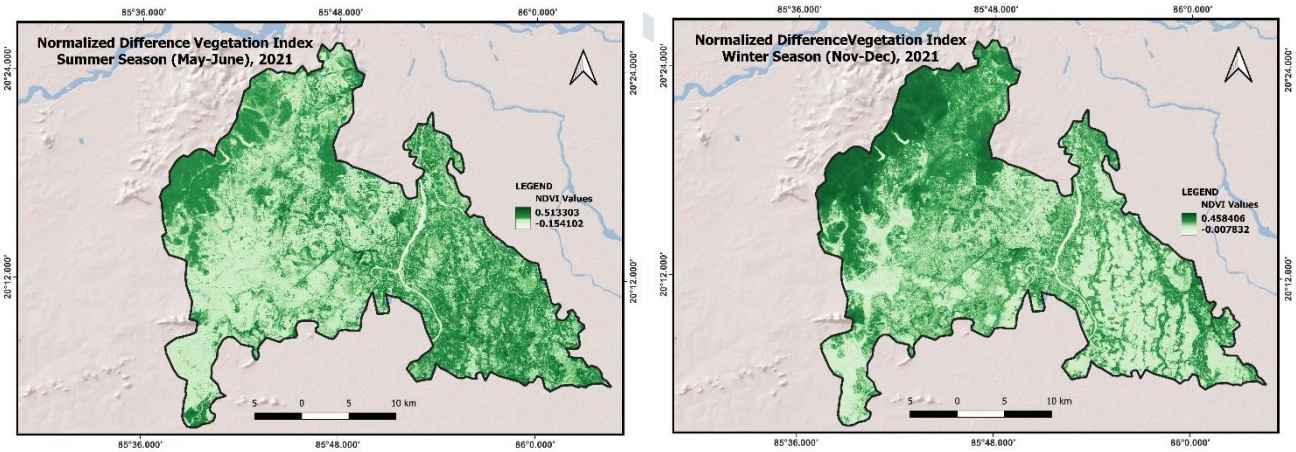

Figure 7: Normalized Difference Vegetation Index map of winter and summer season of the year 2021

The map showed that the Normalized Vegetation Index (NDVI) of Bhubaneshwar in winter and summer range low and medium to significantly a more considerable extent. Also, higher is intensity for two seasons. NDVI values also changed significantly in the central core and outlying areas of Bhubaneshwar. The magnitude of change was high in

the surrounding areas compared to the city. It suggests that vegetation decreased significantly over the past five years and increased urban area with the removal of vegetation in both places.

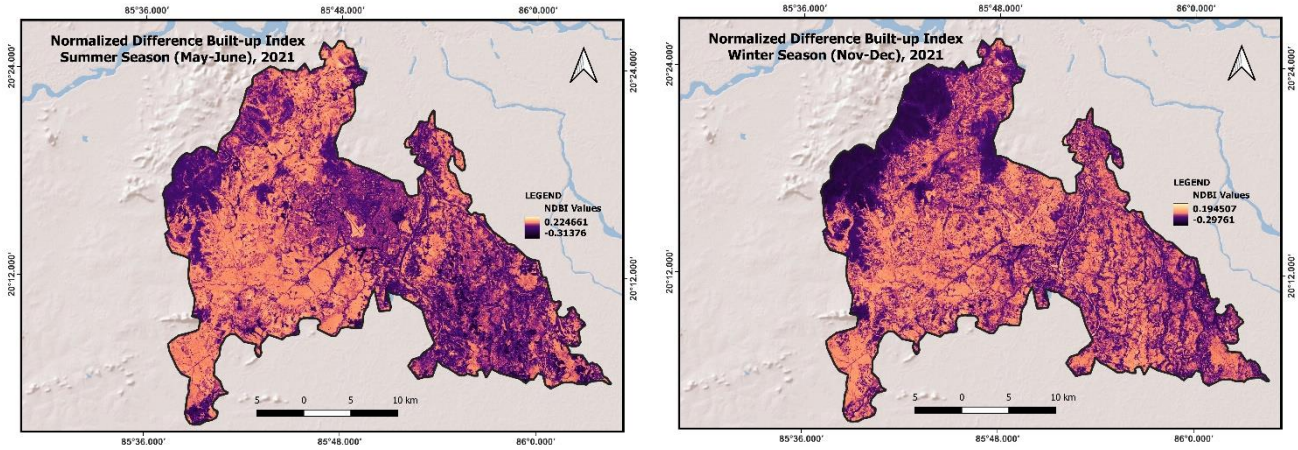

Figure 8: Normalized Difference Built-up Index map of winter and summer season of the year 2021

The results showed that the Normalized Difference Built-up Index (NDBI) value of Bhubaneshwar in winter and summer has higher that contains a greater extent of the city improvisation commonly both remarkably spreading over expeditiously. In the summer season the data ranges between -0.3 to 0.2, whereas, in the winter season the data

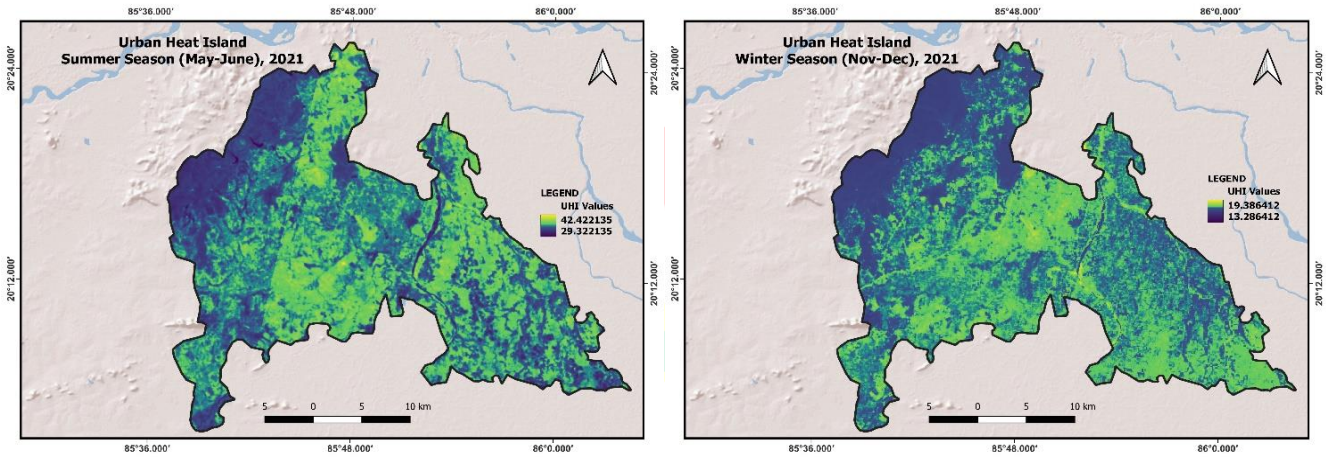

Figure 9: Urban Heat Island map of winter and summer season of the year 2021

range between -0.2 to 0.19.

The map showed that the Urban Heat Island (UHI) value of Bhubaneshwar in winter and summer ranges between higher and medium that is significantly higher due to the rapid increase of urban area. These results manifest a notable rise in LST, NDVI, NDBI, and UHI in 2021 than in 2014.

Discussion:

To comprehend an urban heat island (UHI) using Landsat eight is one of the analysis technique for understanding the temperature, vegetation, and built-up areas of Bhubaneshwar city. It detects the change of temperature, vegetation, and built-up areas between 2014 and 2021 in two seasons namely summer and winter. UHI is prominently observed from images during summer and winter (Chidi et al., 2021). This study enquires an urban heat island, Bhubaneshwar city through Landsat eight satellite images using Arc GIS and QGIS software. As a whole, such an approach to analyzing UHI, NDVI, NDBI, and LST of the city environment with this methodology still has certain limitations. However, it identifies a significant increase in urban heat islands. Few similar research studies are using the same

method and parameters to assess the UHI (Guha et al., 2018; Guo et al., 2015; Peng et al., 2018; Sarrat et al., 2006). According to the many research outcomes, Bhubaneshwar is vulnerable to urban heat islands due to substantial land surface modifications (S. Thapa, 2017). Highlands on the western side of the area affect pollution and built-up area. It contributes to higher day time temperature and air pollution, which increases the risk of human health and high demand for energy supplies (Jacobson, 2009). Therefore, the UHI phenomenon is essential to study because it affects many aspects of life, such as infrastructure, health, energy consumption, environmental stress, and discomfort, and leads to additional costs in building infrastructure (Azevedo et al., 2016). Depending on the nature and developmental phase, UHI can have detrimental socio-economic effects (Liang et al., 2020).

UHI effect has multiple implications for the living condition of human life. In Bhubaneshwar, UHI condition worsens; the increasing trend shows that it will increase further in near future. Increasing UHI can have adverse health effects by significantly increasing air temperatures above average values, impeding the body's ability to adapt and stay cool (Aleksandrowicz et al., 2017; De Carolis, 2012). Thus, regular monitoring of land surface temperature, normalized vegetation index, normalized built-up area index, and urban heat index requires monitoring in the urban area. It can analyze and monitor via satellite image that provides synoptic views of large areas at a given time. The process of data acquisition and analysis through GIS is quicker and cheaper as compared to conventional methods. Recent advances in remote sensing technologies and satellite data provide great potential for spatial analysis to identify and monitor urban heat islands at desirable spatiotemporal scales (Miller & Small, 2003).

Conclusion:

The UHI analysis provides the current situation of heat islands for Bhubaneshwar in 2021 and 2014. It reduces by increasing Vegetation, water bodies, less heavy material surface, bringing clean energy in cities, and roofing with gardens. Using these steps will minimize the impact of the heat island. Other factors contributing to the heat islands are the significant decrease of green space and the rapid increase of buildings and roads. The study reflects higher values of LST and lower values of NDVI in Bhubaneshwar city for two seasons, winter and summer. Besides, a significant rise of NDBI verifies the rise of urban areas in the study area. It decreases by proper planning of urban places with compulsory gardening in the middle and both sides of roads, rooftop etc.

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