International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 10 Issue 10 ǁ October 2022 ǁ PP. 364-372

Analysis of Correlation between Built up scenario and urban heatisland effect of Bangalore urban area of Karnataka

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Abstract:
Urbanization is considered to be a precursor of development. The world is currently in the grip of rapid urbanization and the developing countries are not an exception in this context. Since the last decade, the developing nations of the world has exhibited large scale urban development. Bangalore urban district of Karnataka is one such rapidly developing urban set up. However, rapid urbanization has also triggered the urban heat island phenomena as a result of which the city centre is experiencing a higher temperature than its rural counterparts and is turning out to be a source of discomfort for the urban dwellers. This in turn has triggered the use of different cooling instruments such as refrigerators and air conditioners which are considered to be the major source emission of ozone depleting substances. The present research work makes an attempt to portray the correlation between built up scenario and urban heat island effect of Bangalore urban area of Karnataka using geospatial techniques for the years 2015 and 2021. The study revealed that the study area has experienced a significant rise in built up area from 2015 to 2021. The temperature range has slightly dropped from 24.2°C in 2015 to 24.1°C in 2021 owing to the lockdown imposed due to outbreak of the COVID-19 pandemic. However, both the years exhibited a positive correlation between built up and urban heat island effect with R^2 value of 0.2487 in 2015 and 0.3319 in 2021. The study suggests adoption of sustainable urbanization strategies to minimize the urban heat island effect on one hand and carry out urban development on the other.

Keywords: *Urbanization, Urban Heat Island, Geospatial technique, Positive Correlation, Sustainable Urbanization.*

Date of Submission: 02-10-2022 Date of acceptance: 15-10-2022

I. INTRODUCTION

Urbanization is referred to a situation when there is large scale shifting of population from the rural areas to the urban areas. It is considered to be a transition of a rural society to an urbanized and modernized social system. Urbanization is exhibited in each and every part of the world specially in the developing nations of the world popularly known as the 'Third World'. Urbanization is considered to be a precursor of development (Roy, 2020). The rural areas of third world nations do not have enough employment opportunities, good medical facilities and scopes for higher education. In order to avail all these facilities, people from rural areas migrate to the nearby town and city where all these facilities are available. This phenomenon is known as 'Rural urban migration' and is considered as one of the most important triggering factor of urbanization of the third world nations. India does not possess exception in this regard. The largest democracy of the world has been witnessing urban development since time immemorial (Khullar, 2014). Urbanization of India has a long history of development. The story of urban development of India started with the evolution of Indus Valley Civilization dating back to 2350 B.C when Harappa and Mohenjodaro were the two most popular urban settlements (Sidhhartha & Mukherjee, 2019). Rapid growth of towns and cities continued during the Aryan civilization in North India and Dravidian civilization in South India. The country also experienced significant urban developments during the Gupta period, the Sultanate rule and the Mughal reign. The urbanization pattern of India underwent a significant change during the British rule. The most important urban development that occurred during this period was the creation of the three metropolitan port cities namely Delhi, Calcutta (Kolkata) and Madras (Chennai). The Government of India took strenuous effort to keep the pace of urban development after India became free from the bondage of the British rule. Chandigarh, Bhubaneshwar, Gandhinagar, Itanagar and Dispur are some of the manifestations of urban development during post-independence period. As the pace of urbanization started to gather momentum, proportion of population

residing in urban areas also started to rise. In 1901, the proportion of population residing in urban areas was 10.84% which became 31.16% in 2011 (Khullar, 2014). The number of urban agglomerations in 1901 were 1915 which increased to 7935 in 2011 i.e. it has exceeded four times the number present in 1901. Concentration of opportunities and amenities in urban areas is attracting large population which in turn is making the cities congested. Construction of skyscrapers are taking place at a rapid rate with the objective of providing shelter to maximum population within limited space (Goswami et al., 2022). At present times, tasks of urban development are taking place in a very unplanned way. Vegetation is destroyed and waterbodies are filled up for the purpose of construction of apartments, flats and multi-storied buildings. If viewed from a general outlook, it can be stated that urbanization is taking place. However, if we look deep insight, it is seen that urban development is occurring at the expense of city's ecology. Destruction of vegetation, filling up of wetlands and waterbodies and unplanned concretization are bringing about a degradation in city's environment and is imparting a negative impact on the physical and mental health of the city dwellers (Mukhopadhyay & Banik, 2020). Unplanned urbanization is taking place so rapidly that it is making the urban development a monotonous event as stated by Constantinos Apostolou Doxiadis (Mukhopadhyay & Banik, 2020: Goswami et al., 2022). Unscientific and unplanned urbanisation has also triggered the problem of urban heat island. Concretization of earth surface and masonry structure traps a large part of the solar radiation which in turn raises the temperature of the city than the rural counterparts and this is known as 'Urban Heat Island' or UHI. This UHI creates discomfort among city residents and stimulates them to use more ozone depleting substance emission devices like refrigerators and air conditioners. This indicates a change in human behaviour and attitude owing environmental changes which in most cases stimulated by man himself.

Initially, it was very difficult to monitor the changes that has been taking place owing to urbanization. Rapid advancement of geospatial technology has become an indispensable tool in the hand of the present day researchers for continuous identification and monitoring of the changes (Roy & Sen, 2021). Using remote sensing, land surface temperature of a study area can be identified from thermal band of satellite images. Besides, landuse and land cover change data generated of landuse maps prepared using GIS also help in identification and analysis of change in built up cover of the area of interest. Besides, band indices like Normalized Difference Built up Index or NDBI also help in determining the change in built up cover of a study area. Since satellite image of the same area is available for different years, it has become possible for continuous monitoring of the change in urban development and urban heat island scenario of the area of interest.

The present research work makes an attempt to identify and analyse the correlation between urbanisation and urban heat island scenario of Bangalore urban district in the state of Karnataka. At present, Bangalore is considered to be 'Silicon Valley of India' owing to large scale concentration of IT industry and is thus one of the most rapidly advancing urban systems.Urban development of Bangalore Urban is unique as vegetation and aerosols influence the magnitude and intensity of the UHI effect (Sussman et al., 2019).

II.OBJECTIVES AND METHODOLOGY

The main objectives of the present study are:

- To identify the change in land use and land cover scenario of the district between the years 2015 and 2021.
- To determine the change in NDBI values between the year 2015 and 2021.
- To have an insight about the change in Land Surface Temperature scenario of the district between 2015 and 2021.
- Finally, to determine the correlation between built up coverage and land surface temperature scenario of the study area for the two years taken for study.

The researchers have applied geospatial technique for accomplishing the present task. Landsat 8 OLI satellite images of the study area for the years 2015 and 2021 were downloaded from USGS Earth Explorer. Land use and land cover maps of the study area were prepared using supervised technique and ERDAS Imagine 2014 software was used. NDBI maps were prepared using shortwave infrared band and near-infrared band. Band 10 or thermal band was used to prepare Land Surface Temperature (LST) maps. The details of satellite image used for the purpose are given in Table 1:

Table 1: Details of Satellite image used

Date of Acquisition	Satellite and Sensor	Path/Row/Reference System
19/04/2015	Landsat 8 OLI	144/51/UTM-43 N.
19/04/2021	Landsat 8 OLI	144/51/UTM-43 N.

Calculation of Normalized Difference Built up Index (NDBI):

Emphasis on built up scenario is exhibited using Normalized Difference Built up Index or NDBI. It uses shortwave infrared band (SWIR) and near-infrared band (NIR). The highest value of NDBI is +1 while the

lowest value is -1 (Bhatta, 2011). Higher the value of NDBI, greater is the concentration of built up (Roy & Sen, 2021; Goswami et al., 2022). The formula for computation of NDBI is shown in equation 1:

$$NDBI = \frac{SWIR-NIR}{SWIR+NIR} \textit{(Equation 1)}$$

In Landsat 8 OLI satellite, band 6 is the shortwave infrared while band 5 is the near infrared band. Substituting the band numbers in equation 1, formula for calculating NDBI is in Landsat 8 OLI is as followed:

$$NDBI = \frac{Band\ 6-Band\ 5}{Band\ 6+Band\ 5} \textit{(Equation 2)}$$

Calculation of Land Surface Temperature:

Estimation of land surface temperature is performed using thermal band. It involves a set of steps which are followed and it is discussed below. In Landsat 8 OLI, band 10 is the thermal band

The first step is to calculation of Top of Atomospheric (TOA) spectral reflectance and is done using equation 3:

$$TOA\ (L) = M_L * Q_{cal} + A_L \textit{(Equation 3)}$$

Here: M_L is band-specific multiplicative rescaling factor and its value is 0.0003342. Q_{cal} stands for the thermal band (band 10) and A_L is band-specific additive rescaling factor and its value is 0.1.

The second step is the computation of brightness temperature in Degree centigrade and is done using equation 4:

$$BT = (K_2 / (\ln (K_1 / L) + 1)) - 273.15 \textit{.(Equation 4)}$$

Here, K_1 and K_2 are band-specific thermal conversion constant. In Landsat 8 OLI, value of K_1 is 774.8853 while value of K_2 is 1321.0789 and is applicable for band 10 only.

In the third step, NDVI or Normalized Difference Vegetation Index is calculated. It uses near infrared band (band 5 for Landsat 8) and visible red (band 4 for Landsat 8). Formula for calculating NDVI is shown in Equation 5.

$$NDVI = \frac{Band\ 5-Band\ 4}{Band\ 5+Band\ 4} \textit{(Equation 5)}$$

The fourth step involves the calculation of proportion of vegetation (Pv) and it is done using the formula mentioned in equation 6.

$$P_v = Square\ ((NDVI - NDVI_{min}) / (NDVI_{max} - NDVI_{min})) \text{ (Equation 6)}$$

In the fifth step, emissivity (ε) is calculated using the equation number 7.

$$\varepsilon = 0.004 * P_v + 0.986 \textit{(Equation 7)}$$

In the last step, land surface temperature or LST is computed using the formula mentioned in equation 8.

$$LST = (BT / (1 + (0.00115 * BT / 1.4388) * Ln(\varepsilon))) \textit{ (Equation 8)}$$

All these calculations were performed using ArcGIS 10.8 software. Maps and graphs prepared were finally analysed and interpreted to arrive at the necessary results (Sen & Chakraborty, 2021).

III.RESULTS AND DISCUSSIONS

A brief idea about the Study area:

Bangalore urban is considered to be the most densely populated district of the state of Karnataka and it came into existence in 1986 when Bangalore district was partitioned to form Bangalore rural and Bangalore urban.Bangalore is one of the fastest-growing metropolitan cities in India, other than Delhi, Mumbai, Chennai, etc., due to the rapid increase in the Information Technology Industries has, in turn, made the city more urbanized. The district has five taluks. It has latitudinal extension from 12.662° N to 13.234°N and its longitudinal extension is from 77.327°E to 77.834°E. The district has a total area of about 2198 square kilometres. The district is bounded by Bangalore rural in the north and east, Ramnagara district in the west and Krishnagiri district of Tamil Nadu in the south. Bangalore city is the district headquarter. According to census 2011, the total population of the district is 9621551 with population density of 4378 persons per square kilometres. Population growth rate for the decade 2001-2011 was 46.68%. Bangalore has been experiencing unprecedented urbanization and sprawl in recent years owing to concentrated developmental activities with an impetus for economic development. (Ramachandran & Kumar, 2010)

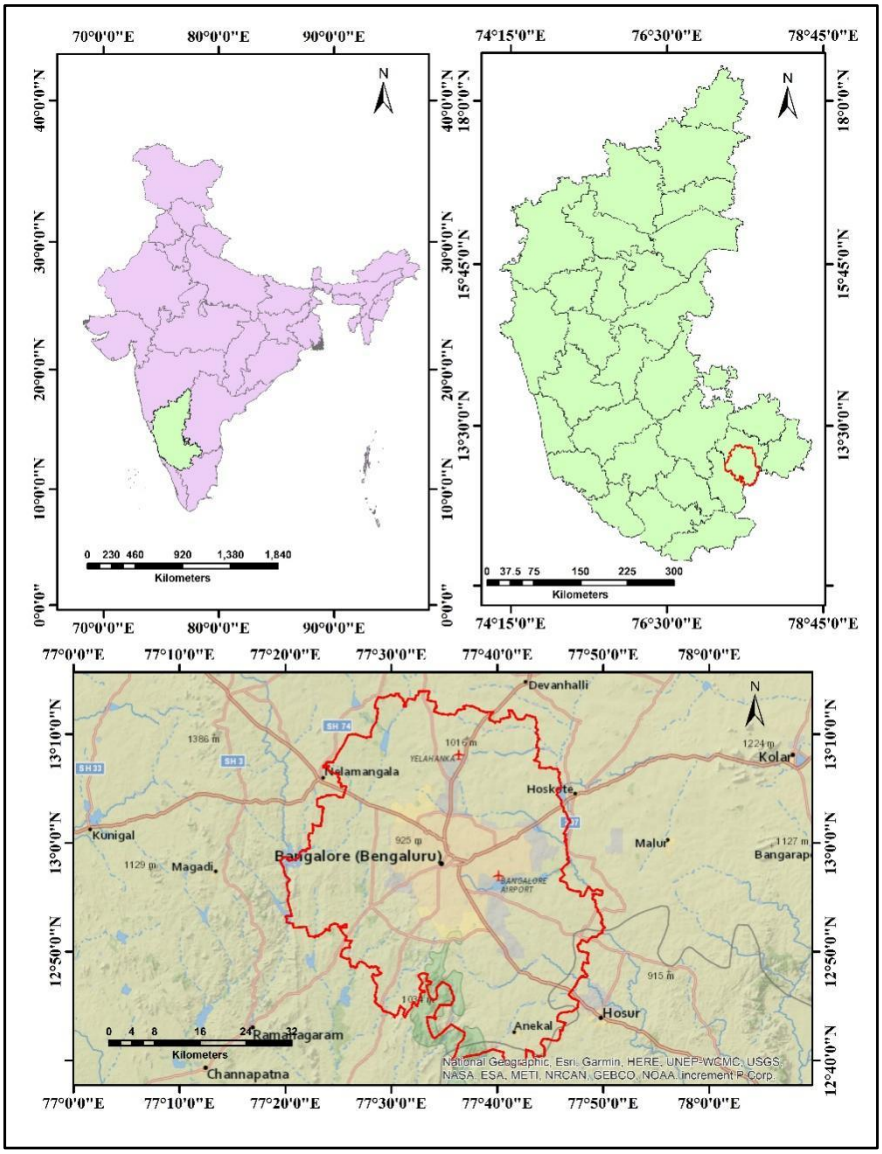

Figure 1: Location Map of the Study area

Change in land-use pattern of the study area between 2015 and 2021:

Change detection of built up of an area can be analysed through the comparison of land use and land cover map of the study area for the years taken for study. The present research work had prepared land use maps for the years 2015 and 2021 for having a detailed knowledge about the change in built up scenario of the study area. Supervised classification was done with accuracy of 85.71% for the landuse map of the year 2015 and 83.34% for the land use map of the year 2021. Six classes of land use and land cover were generated and their areas were calculated in hectares. In the year 2015, about 17098.1 hectares of land were covered with waterbodies which accounted for about 7.8% of the total study area. However, in 2021, the areal coverage under waterbodies declined to 5272.38 hectares accounting for about 2.4% of the total area. The main reason of this decline was large scale filling up of waterbodies for construction activities. But a considerable portion of waterbodies also dried and were converted into marshy lands. Marshy lands covered about 24419.1 hectares accounting for about 11.1% of the total area and it increased to become 34800.3 hectares accounting for about 15.8% of the study area in 2021. The reason responsible for the significant rise in areal coverage of marshy lands is drying up of waterbodies of the study area partially by man for building purposes. Vegetation coverage exhibited a paradoxical situation and showed a rise between in the years 2015 and 2021. In 2015, about 76049.6 hectares was under vegetation cover and it accounted for about 34.6% of the study area. In 2021, it marked a significant rise and became 94831.23 hectares accounting for about 43.1% of the study area. Plantation activities and afforestation programmes undertaken by the Government are responsible for this. Parks and gardens of the city of Bangalore are properly maintained. Trees are planted on either side of the roads to ensure proper maintenance of urban vegetation of the city and for this reason Bangalore is also known as 'Garden City'

of India. Besides, celebration of 'Neralu Tree Festival' since 2017 is also considered to be responsible for increase in vegetation coverage of the study area. Built up area also exhibited a meteoric rise from 23042.9 hectares (10.5% of the study area) in 2015 to 43123.4 hectares (19.6% of study area) in 2021. Area under cultivable lands declined from 63072.4 hectares (28.7% of the study area) in 2015 to 36400.7 hectares (16.6% of the study area) in 2021. This decline is owing to large scale conversion of cultivable lands into urban areas for accelerating the pace of urban development. Similarly, area under barren lands declined from 16190.1 hectares (7.4% of the study area) in 2015 to 5444.19 hectares (2.5% of the study area) in 2021. This decline is owing to large scale conversion of barren lands into urban areas for accelerating the pace of urbanization. Land use map of the years 2015 and 2021 are shown in figure 2A and 2B respectively.

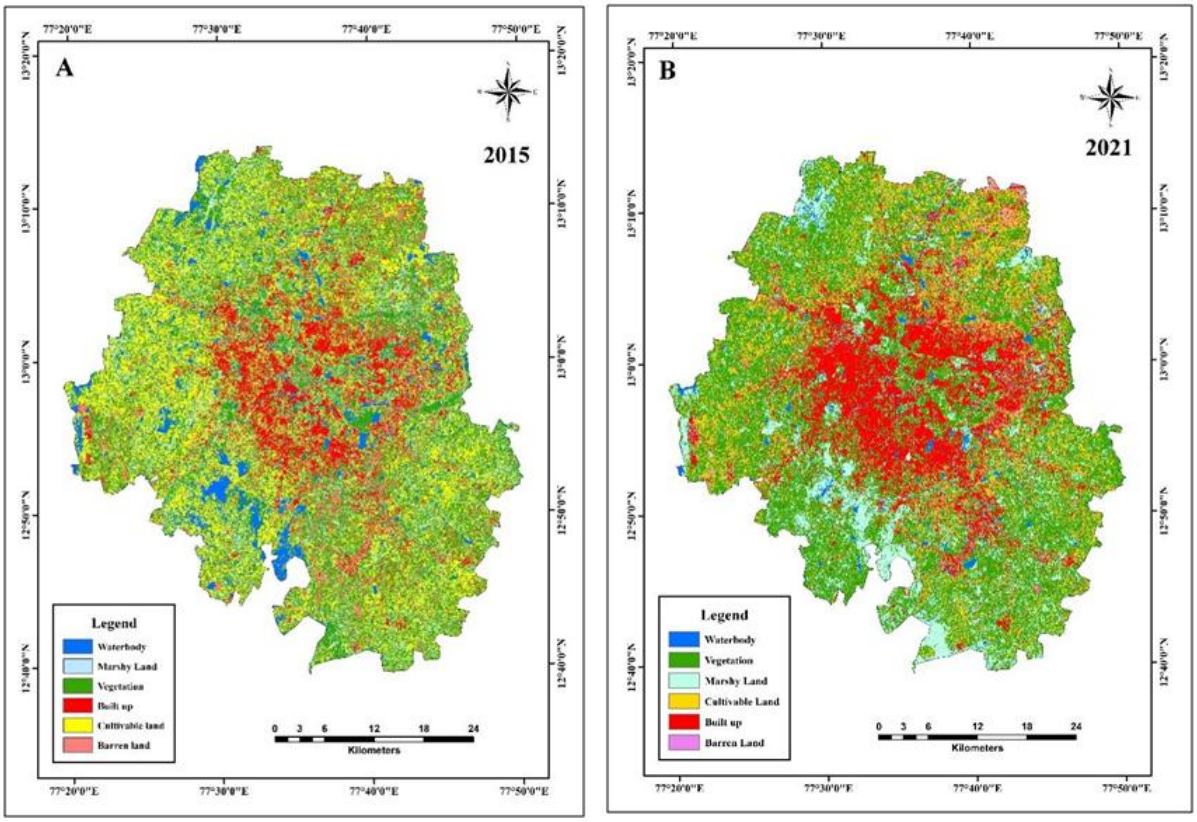

Figure 2: Landuse of Bangalore Urban in 2015 (A) and 2021 (B)

Comparison between NDBI scenario of Bangalore urban between 2015 and 2021:

It has been already stated that Bangalore urban district experienced rapid urbanization. It is already seen in the rise in built up scenario of the study area. Since NDBI is an important band ratio index used for determining the scenario of built up coverage, NDBI maps of the study area have been prepared for the years 2015 and 2021. It is seen from the maps that the highest value of NDBI in the year 2015 was about 0.51 (Figure 3A) which increased to become 0.61 in 2021 (Figure 3B). This rise in NDBI value is a manifestation of urban development of the study area.

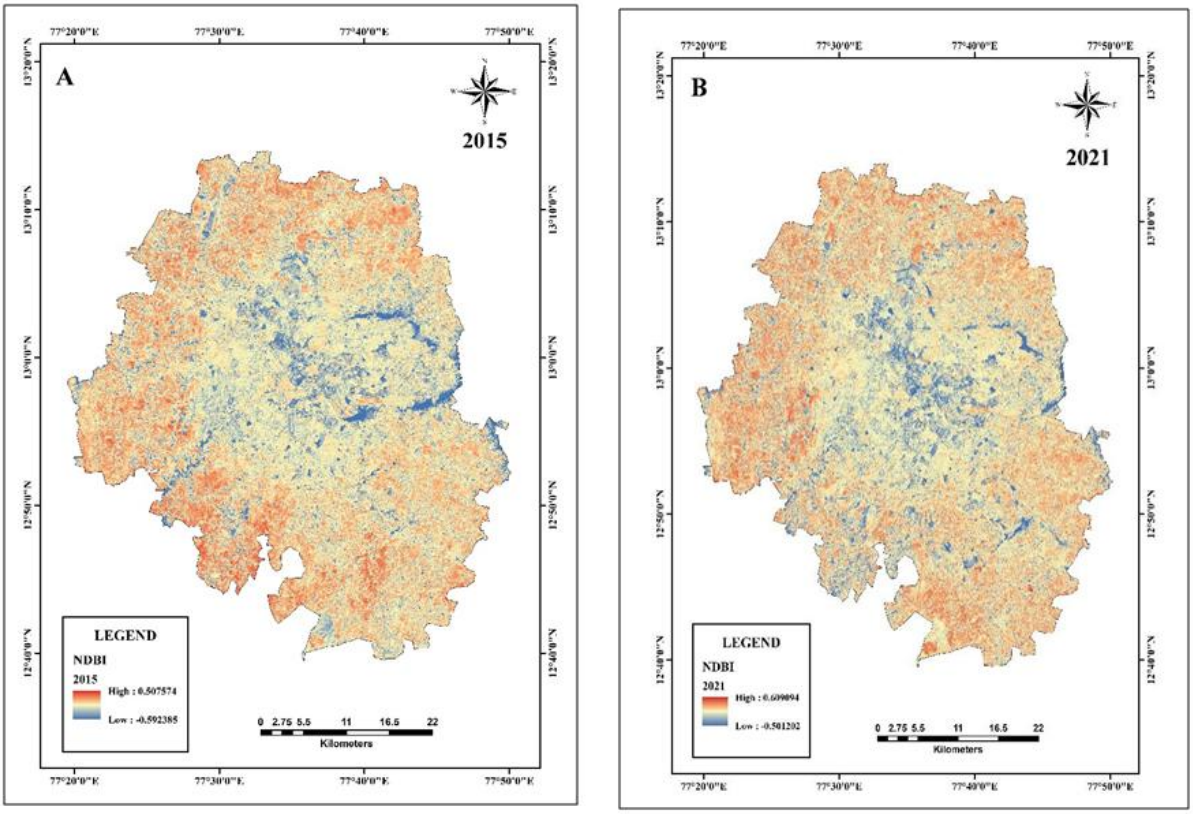

Figure 3: NDBI scenario of Bangalore Urban in 2015 (A) in 2021 (B)

Land Surface Temperature of Bangalore Urban in 2015 and 2021:

Land Surface Temperature maps of the study area have been prepared using thermal band to have an idea about the temperature scenario of the study area. Analysis of 40 years of temperature data for the study area from 1981 to 2021 reveal that the normal maximum temperature of the study area for the month of March should have been 37.7°C. However, in 2015 the maximum temperature turned out to be 41.3°C (Figure 4A) which is 3.6°C above normal while in 2021, it was 39.3°C which is 1.6°C above normal (Figure 4B). Similarly, it is also seen that the normal minimum temperature of the study area for the month of March should have been 14.6°C. However, in 2015 the minimum temperature turned out to be 17.1°C (Figure 4A) which is 2.5°C above normal while in 2021, it was 15.2°C which is 0.6°C above normal (Figure 4B). Hence, it is seen that in both the years, maximum and minimum temperatures exhibited a tendency to remain above the normal and this tendency is owing to the prevalence of Urban Heat Island effect within the study area. But it is seen that both maximum and minimum temperatures declined from 2015 and 2021. Such decline was owing to the suspension of urban developmental activities due to nation wise lockdown imposed in 2020 owing to the outbreak of COVID-19 pandemic. Industrial sector and transport sector had to stop their services during lockdown for which the level of pollution was much lower. Besides, urban developmental activities also suffered a setback due to lockdown and thus the triggering effect of urban heat island was absent for a considerable time and environment was regaining its normalcy.

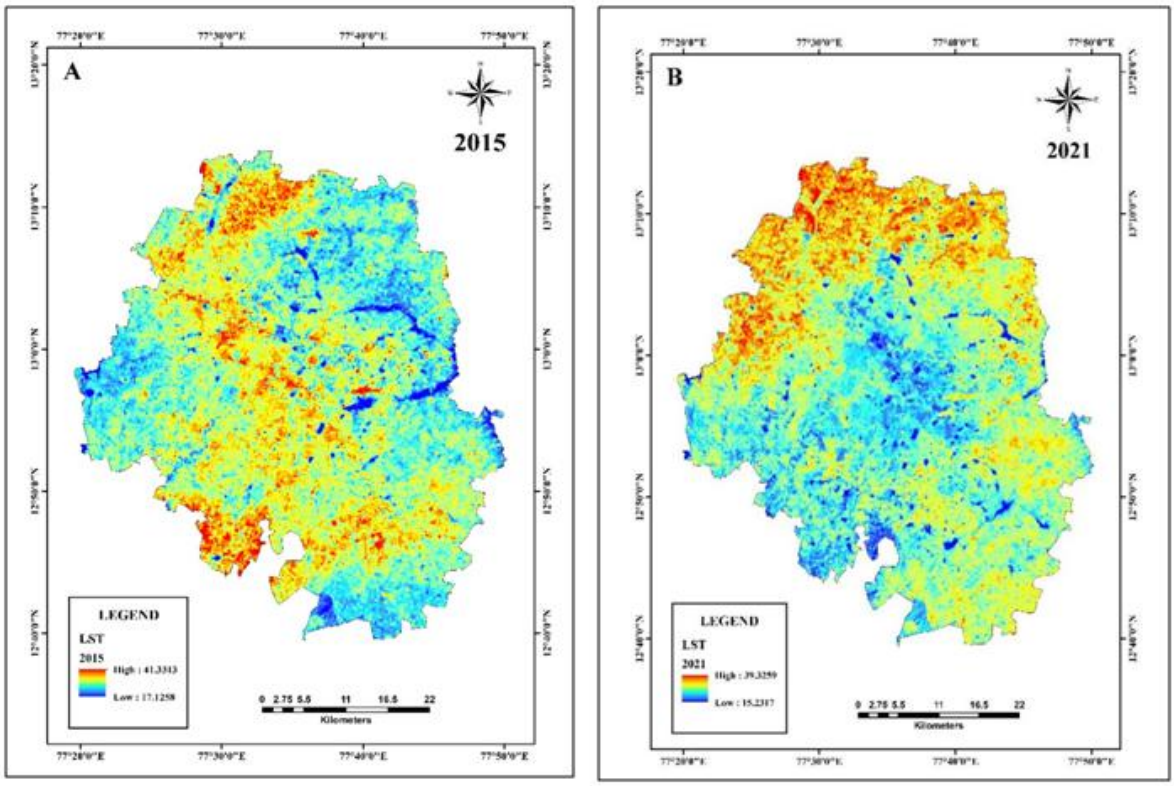

Figure 4: Land Surface Temperature scenario in 2015 (A) and 2021 (B)

Study of correlation between Built up cover and Land Surface Temperature:

There exists a close relationship between built up scenario and land surface temperature. Concretized surface traps a large portion of solar radiation. Besides, masonry structure and vertical walls of skyscrapers also traps a considerable portion of the solar radiation. This trapped heat raises the temperature within the city and creates the urban heat island effect. Hence, it can be stated that as the amount of built up increases, more and more heat will be trapped and this will trigger the urban heat island effect. Thus, it can be stated that land surface temperature and built up will have positive correlation. In the present study, NDBI and land surface temperature data has been collected from 247 locations of the study area and a positive relationship between NDBI and land surface temperature was found with R^2 values of 0.2487 in 2015 (Figure 5) and 0.3319 in 2021 (Figure 2021). Vegetation cover has decreased, which might be one of the reasons for UHI (Urban Heat Island), as there exists a direct relationship between the vegetation cover and aerosol condition.

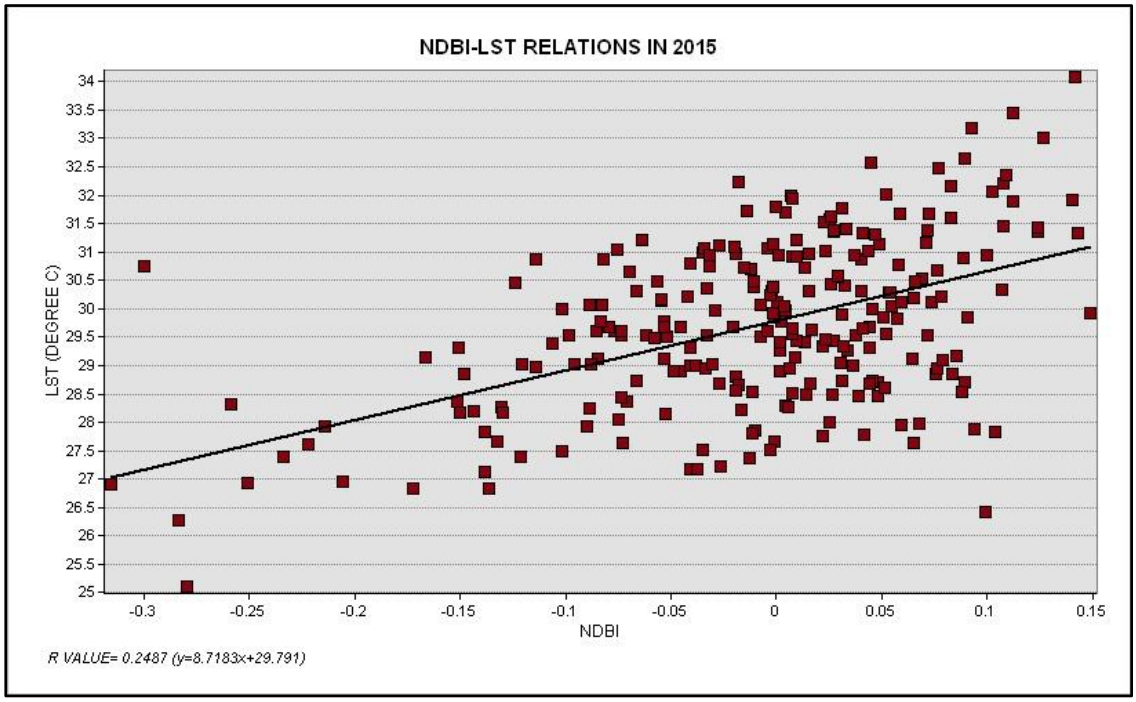

Figure 5: NDBI and LST correlation in 2015.

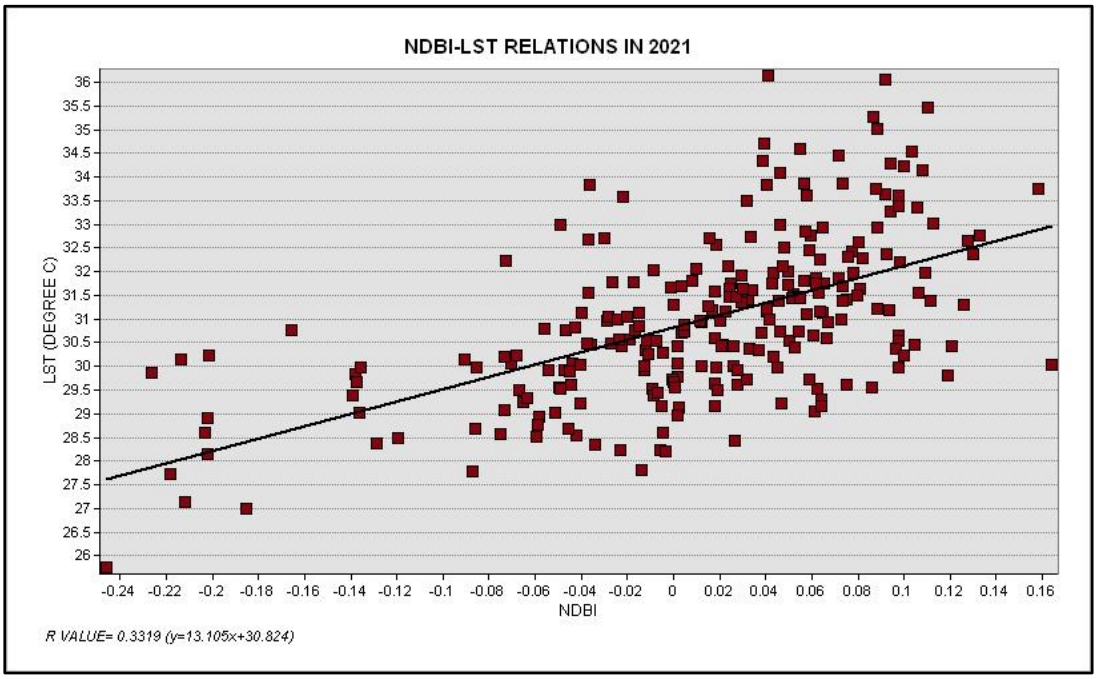

Figure 6: NDBI and LST correlation in 2021.

IV. CONCLUSION

Urbanisation has become a part and parcel of our daily life. Without urban development, the degree of progress of a country will slow down and it is very much true for a developing nation like India. Urban development creates numerous opportunities in the field of job creation, medical facilities and scope for higher education.Bangalore Urban has seen a tremendous change since the inception of the IT industry. With the increasing population, the built-up area has expanded to accommodate the people, which has changed the city landscape. Unplanned and unscientific urbanisation has to be avoided and issue of environmental and ecological status should be kept in mind. There is no doubt of the fact that administrative authorities and local people of the city of Bangalore have kept a vigilant watch in maintaining the ecological condition of the city through afforestation programmes. This awareness has to be spread among all the local people of the entire study area and local NGO and clubs must come forward in this regard. Awareness about ecological scenario has to be

spread at the grass root level and issues of unscientific urban development should be nipped at the bud.The city is trying to retain the greenery area by conserving the water bodies and growing trees in the urban areas. Today, a city needs to develop in this globalized world to cope with the present scenario so that it does not leave behind itself in the race for development. Proper planning and strategies for urban development has to be undertaken both by the state and the central Government. If all these steps are undertaken properly, then only planned and scientific urban development along with good environment and ecological condition will be maintained.

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