A Review and Examination of Urban Heat Island UHI in Urban Cities DELHI, AHMEDABAD, BANGALORE in INDIA Utilizing LANDSAT 8 and MODIS

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Abstract— The growth of urban areas and similar landscape transformation has been a major driver of local, regional and global environmental change. The turning of urban greenery to impervious landscapes has been identified as a key factor influencing the distinctive urban heat and related consequences. Due to the high demand for space in urban areas, creation and preservation of urban greenery as heat sinks is commonly perceived as unrequired space. Consequently, there is an expanding requirement for creation and preservation of such spaces, because of these physical changes, i.e. decrease in green cover and increase in built-up area in cities, the land surface temperature LST is bound to increase. Urban heat islands can cause deterioration of living environment, increase in energy consumption, elevation in ground level ozone, and even an increase in mortality rates. To determine the contribution of urban greenery as possible remedy to Urban Heat Island UHI we have to analyse the association between built-up, green cover NDVI and land surface temperature for which we are studying the 3 major cities of India i.e. Delhi, Ahmedabad and Bangalore. This study sought to quantify multi-seasonal heat contribution of major Land Use Land-Cover LULC within these cities using the recently launched Landsat 8 and MODIS Land Surface and Temperature LST data sets. , this study demonstrates the value of remotely sensed data sets in understanding the implication of LULC types on the urban micro climate. The study is particularly valuable for designing sustainable urban socio-economic and environmental strategies at local, regional and global climate change.

Keywords—LST; NDVI; LULC; UHI; MODIS; LANDSAT 8

1. INTRODUCTION

Urban Heat Island (UHI) is the situation with elevated air or surface temperatures in urban areas in contrast to their non-urban rural vicinities.Urban centers have their typical morphology, materials and geometry that bring about changes in the surface and atmospheric properties. These changes include alterations in the reflective and thermal properties of the surface as a result the new materials (e.g. asphalt, concrete etc.) abundant in urban setup have higher heat capacity or lower albedo for instance. Urban areas tend to reflect less and store more heat for longer periods, which cause further inadvertent alterations in the energy budget. The phenomenon is present all over the world in all big and small cities with varying intensities. Along with modifications in surface properties, the atmospheric changes, such as higher emission of GHG (that store heat), accumulation of air pollutants (again very heat loving particles), and other factors including urban geometry (due to buildings, skyscrapers, etc.) and increased anthropogenic heat generation due to concentrated human population, greatly contribute to accumulation of large amounts heat in the urban centers.The focus is on Ahmedabad , Bangalore and Delhi as theses cities have gone through rapid urbanization in the last few decades. These are classified as one of the most populous cities of India. Rapid urbanization has seen many negative environmental impacts on the city,which include, diminishing lakes, traffic congestion along with high air pollution levels, urban flooding during heavy rains and increase in summer temperatures. All the above environmental impacts are related to Urban Heat Island effect, which is mostly related to the manner urban development takes place. If the current scenario continues,These cities could lose its charm of enjoying the weather conditions.

A. Need of study on UHI

It is estimated that for every 0.6°C rise in temperature, there is an increase in electricity consumption of about 2%. [1]. Increase in thermal discomfort has led to increase in use of air conditioning appliances, resulting in increased emission of harmful greenhouse gasses which has led to global climate change. Harmful gasses released from power plants cause further increase the air pollution, and in due course, intensify the UHI. The undesirable effects of urban heat islands can be summarized as Increased heat transfer indoor leading to increased electricity consumption for cooling in tropical countries.Thermal discomfort (both indoor and outdoor) leading to health hazards.Increased rainfall intensities over urban areas.Increased emission of greenhouse gasses leading to global climate change .Risk of fire breakouts

Thus, in the developing countries having tropical climate, the issue of urban heat island has become critical, and is predicted to increase significantly in the near future. With increasing severity of the problem, vast research is being dedicated to this subject and sufficient literature is available.

B. Studies on Urban Heat Islands in major cities

Mina Babazadeh Parvendra Kumar(2015)[2]: The statistical analyses for the city of Delhi revealed that under the same weather pattern, the concentrations of many air pollutants increased with the UHI intensity (decrease air quality. The convergence phenomenon usually generated in the nocturnal period due to the UHI causes the accumulation of air quality (increase amount of pollutants), as well as other air pollutants, thereby affecting the air quality during the subsequent daytime period.

Ajanta Goswami ,Pir mohamed, Ashim Sattar(2016)[3]: Quantitative estimation of the UHI in the city of Ahmedabad is estimated over a span of 12 years. The UHI signature is profoundly seen using night LST. This is evident of the thermal radiation by materials during the night. A seasonal variance can also marked in the study, as UHI is more profound during winter (Jan-Feb) than in summer (May-June). The UHI of Ahmedabad city has an accurate correlation with the LULC of the city, as maximum UHI is evident in the built up area at the centre of the city.

T.V Ramachandra and Uttam Kumar (2010)[4]: In a study conducted by them, it was revealed that in Bangalore, there has been 525% growth in built-up area in the last 40 years, which corresponds to a 78% decline in vegetation and 79% decline in water bodies.It was concluded that increased urbanization has resulted higher population densities in certain wards, which incidentally have higher LST due to high level of anthropogenic activities. Also, in a transect survey carried out in various directions of Bangalore, water bodies and vegetation patches were found to be helping in lowering temperatures of their surrounding areas.

George Thomas,Sherin A.P, ShareekulAnsar, E.J. Zachariah(2013)[5]: The Urban heat Island intensity and spatial temperature distribution during summer and winter season observed in Kochi, a coastal city in South West India shows a good correlation with the Local Climate Zone Classification. Maximum intensity was seen in Compact Midrise zones which cover the central part of the city. Most intense cooling was observed in openset and sparsely built regions in all seasons.

Aakriti Grover and Ram Babu Singh(2015)[6]: Delhi and Mumbai contrast each other with respect to location, climatic conditions and the nature of urban growth. The two largest cities of the country have undergone a differential sort of urbanization process. In Mumbai, the daily movement of people from nearby districts is much more prominent than Delhi. Mumbai also has a larger number of high rises than Delhi.The regression analysis between LST and NDVI proves that Delhi has a larger area under green cover, and hence, the UHI effect is diminished. In Mumbai, the absence of tree cover along with other factors has led to increased LST. In this scenario, it becomes imperative to focus on a stricter implementation of urban planning norms and to stress increasing green cover in the cities.

Neha Yadava,Chhemendra Sharma(2018)[7]: The study reveals that intracity UHI has tempora variation with high values observed during the late evening period compared to forenoon period. UHI values generated in spatial maps for Delhi are in good agreement with the UHI value obtained from measured values at five fixed sites located in various areas of Delhi. The areas showing high UHI in both July and November are Rajour Garden and Raja Garden in West Delhi and low UHI areas are Hauz Khas and Saket in South Delhi and Delhi Cantonment in South West Delhi.

Shrinidhi Ambinakudige(2011)[8]: In this study the effects of UHI in Bangalore have been analysed with respect to the relationship betweeen vegetation cover and temperature in context of Bangalore. Results of this study showed that the city core temperatures varied by 1 ºC to 7 ºC within different land cover classes. However, the city cores were observed to have significantly lower mean temperatures than the city's outgrowth zones. This was because of the presence of water bodies and vegetation in the core city. This can be observed in Figure 2.18. It was concluded that the continued expansion of urban infrastructure and new residential neighborhoods that lack vegetation were the cause of the substantially higher temperatures in the outgrowth zones

2. AREA OF FOCUS

Ahmedabad lies at 23.03°N 72.58°E in western India at 53 metres above sea level on the banks of the Sabarmati river, in north-central Gujarat.It covers an area of 464 km2 .Ahmedabad has a hot, semi-arid climate.The weather is hot from March to June; the average summer maximum is 43 °C,and the average minimum is 24 °C.From November to February.At the 2011 Census of India Ahmedabad had a population of 5,633,927, making it the fifth most populous city in India.The urban agglomeration centred upon Ahmedabad, then having a population of 6,357,693, now estimated at 7,650,000, is the seventh most populous urban agglomeration in India.

Bangalore lies in the southeast of the South Indian state of Karnataka. It is in the heart of the Mysore Plateau (a region of the larger Precambrian Deccan Plateau) at an average elevation of 900 m.It is located at 12.97°N 77.56°E and covers an area of 741 km2.Due to its high elevation, Bangalore usually enjoys a more moderate climate throughout the year, although occasional heat waves can make summer somewhat uncomfortable. The coolest month is January with an average low temperature of 15.1 °C and the hottest month is April with an average high temperature of 35 °C.It has become the third most populous city in India and the 18th most populous in the world. It has experienced a growth rate of 38% between 1991 and 2001.Bangalore's 2020 population is now estimated to be 12,326,532.

Delhi is located in Northern India, at 28.61°N 77.23°E. The city is bordered on its northern, western, and southern sides by the state of Haryana and to the east by that of Uttar Pradesh (UP).The warm season lasts from 21 March to 15 June with an average daily high temperature above 39 °C.The cold season lasts from 26 November to 9 February with an average daily high temperature below 20 °C. the population of Delhi , as of 1st March, 2011, was 16.78 million as against 13.85 million on 1st March, 2001. about 97.50 per cent of the population of Delhi lives in urban areas and the remaining 2.5 percent in rural areas.

3. METHODOLOGY AND CALCULATIONS

C. Selection and collection of data for the study area.

1) We will select our study area based on the geography and and the trend of urban agglomeration in the past few decades.

The collection of data for this project will be done using the satellite images provided by the U.S. Geological Survey (USGS) and Environmental Systems Research Institute (Measurements and Analysis

1) Using the data downloaded from the servers we will use software called Arcgis which is a geographic information system for working with maps and geographic information maintained by Esri.
2) The analysis will be done on these images using two major factors:Land Surface Temperature(LST) and the Normalized Differential Vegetation Index(NDVI).The analysis of images for past two decades will be done and the values of highest temperature,lowest temperature and mean temperature will be calculated.And also the NDVI values(highest,lowest and mean) for the same years will be calculated to study the vegetational variations in the study area.

D. Observations and inference.

Summary of the observed trends of Urban Heat pockets for each study area were summarize together to determine a relation between the urban planning characteristics and the variations in each area.

About the satellites and the data products used:

We use landsat 8 and MODIS (Moderate Resolution Imaging Spectroradiometer) images.the products used in this paper were Landsat 8 OLI/TIRS collection 1 Level 1(2014-2019) and MOD11A2 v006 with MOD13A2 v006(2001,2005,2010-2019).Image taken for Ahmedabad for the months of february and may.Image taken for Bangalore for the months of January and April.Images taken for Delhi for the months of January and May.Landsat8 images have 11 various bands to capture details and modis products used by us gives collective data for multiple days image composites.

Calculation of Land Surface Temperature from landsat 8 images:

The process is synthesized in six steps as shown below.

1.- Calculation of **TOA** (Top of Atmospheric) spectral radiance.

$$\mathbf{TOA\ (L) = ML * Qcal + AL} \quad (1)$$

where:

ML = Band-specific multiplicative rescaling factor from the metadata (radiance_mult_band_x, where x is the band number).Qcal = corresponds to band 10.AL = Band-specific additive rescaling factor from the metadata (radiance_add_band_x, where x is the band number).

TOA = 0.0003342 * "Band 10" + 0.1

2.- **TOA** to **Brightness Temperature** conversion.

$$\mathbf{BT = (K2 / (\ln (K1 / L) + 1)) - 273.15} \quad (2)$$

where:

K1 = Band-specific thermal conversion constant from the metadata(k1_constant_band_x, where x is the thermal band number).K2 = Band-specific thermal conversion constant from the metadata(k2_constant_band_x, where x is the thermal band number).

L = TOA

Therefore, to obtain the results in Celsius, the radiant temperature is adjusted by adding the absolute zero (approx. -273.15°C).

3.- Calculate the **NDVI.**

$$\mathbf{NDVI = (Band\ 5 - Band\ 4) / (Band\ 5 + Band\ 4)} \quad (3)$$

Note that the calculation of the NDVI is important because, subsequently, the proportion of vegetation (Pv), which is highly related to the NDVI, and emissivity (ε), which is related to the Pv, must be calculated.

NDVI = Float(Band 5 – Band 4) / Float(Band 5 + Band 4)

4.- Calculate the **Proportion of vegetation (Pv)**

$$\mathbf{Pv = ((NDVI - NDVImin) / (NDVImax - NDVImin))^2} \quad (4)$$

Usually the minimum and maximum values of the NDVI image can be displayed directly in the image.

5.- Calculate **Emissivity (ε)**

$$\mathbf{\varepsilon = 0.004 * Pv + 0.986} \quad (5)$$

6.- Calculate the **Land Surface Temperature.**

$$\mathbf{LST = (BT / (1 + (0.00115 * BT / 1.4388) * Ln(\varepsilon)))} \quad (6)$$

Calculation of Normalized Differential Vegetation Index from Landsat 8 images:

NDVI is used to quantify vegetation greenness and is useful in understanding vegetation density and assessing changes in plant health. NDVI is calculated as a ratio between the red (R) and near infrared (NIR) values in traditional fashion: (NIR - R) / (NIR + R)

In Landsat 8,

$$\mathbf{NDVI = (Band\ 5 - Band\ 4) / (Band\ 5 + Band\ 4)} \quad (3)$$

NDVI is delivered a single band product.The value of NDVI is always in the range of -1 to +1.With positive values signifying greenery.

Calculation of Land Surface Temperature from MODIS:

Using the downloaded image in hdf file format on ArcMap, open the day time LST layer and create attribute table.In the attribute table multiply the values of pixels by a scale factor of 0.02 and subtract 273.15 to get the answer in Degree Celsius.Scale factor is derived from the meta data file.

Calculation of Normalized Differential Vegetation Index from MODIS:

Using the downloaded image in hdf file format on ArcMap, open the day time LST layer and create attribute table.In the attribute table multiply the values of pixels by a scale factor of 0.0001 .The scale factor is derived from meta data file.The value of NDVI is always in the range of -1 to +1.With positive values signifying greenery.

RESULTS

Results from Ahmedabad city:

After analysing the images for the city of ahmedabad.following images were obtained as results.

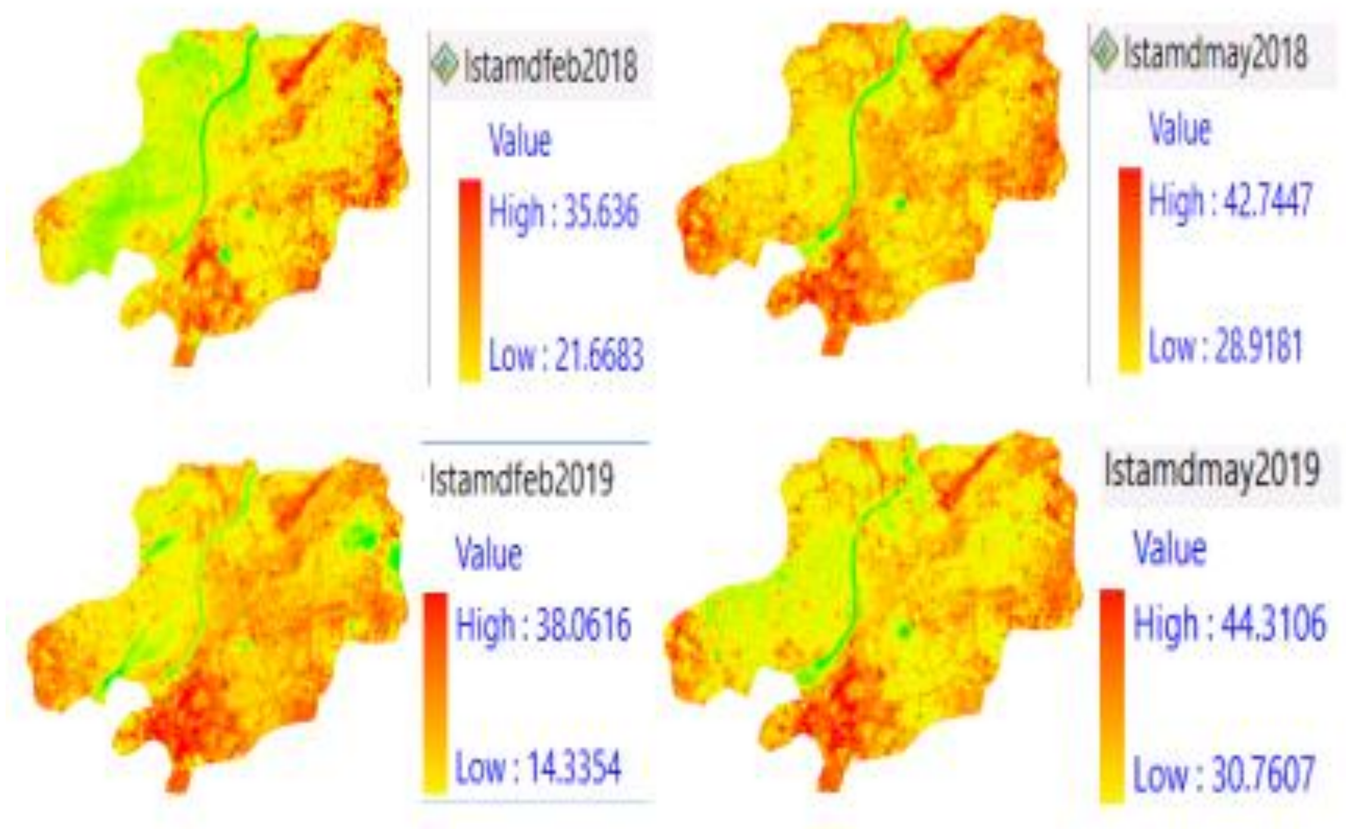


Fig.1. lst Ahmedabad february and lst Ahmedabad may (2014-2019)

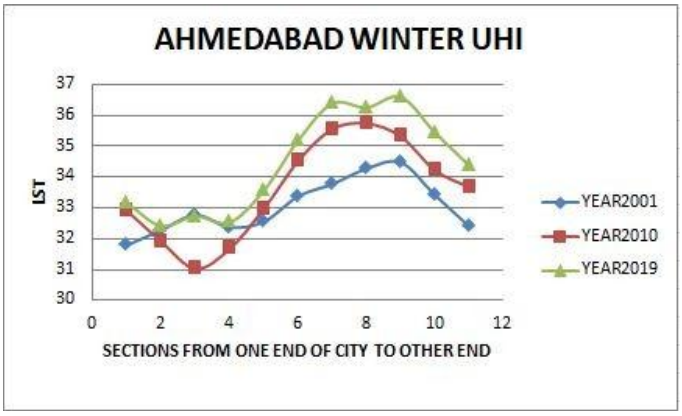


Fig.2.Ahmedabad winter UHI

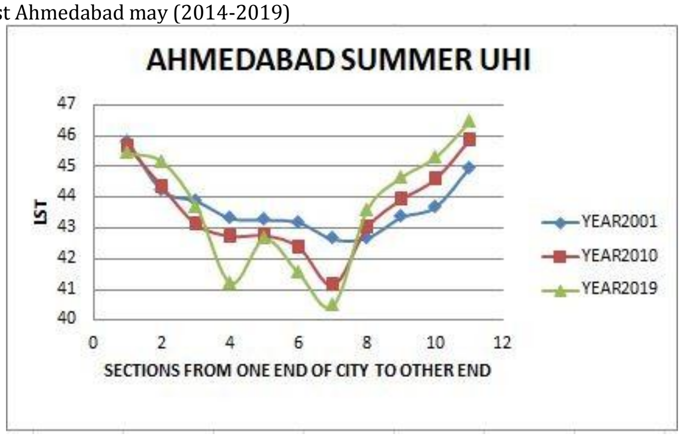
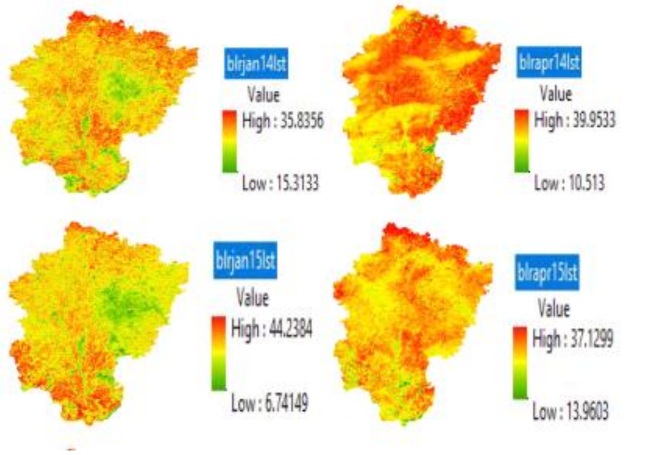


Fig.3.Ahmedabad summer UHI

As it is clearly visible in Fig.1 the data represented is provided color gradation from low to high as green to red.The river sabarmati is clearly visible in green as the temperatures on the surface are very low for a river.To understand how the UHI affects the city we took values of temperatures in a single line

Results from Bangalore city:

After analysing the images for the city of Bangalore. following images were obtained as results.



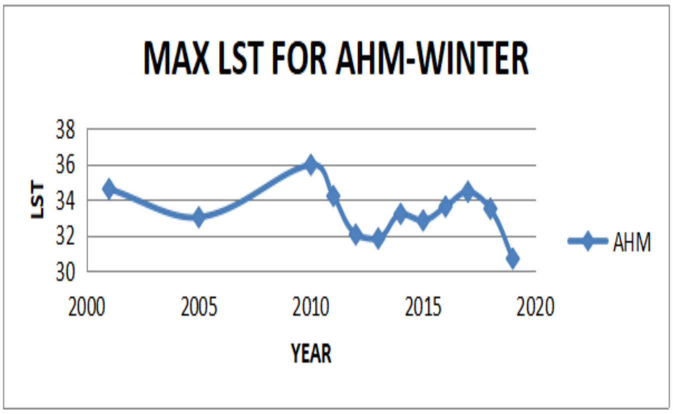


Fig.4.Ahmedabad winter max lst.

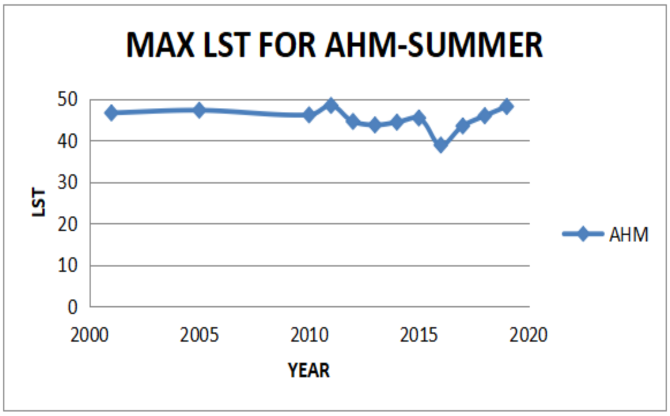


Fig.5 Ahmedabad summer max lst

from north-east to south west of the city.And the results are represented in fig.2 and fig.3.It can be noticed that the temperatures in the summer are very high in the north east and north west region.We can also see the temperatures in winter are higher in the central region of the city.

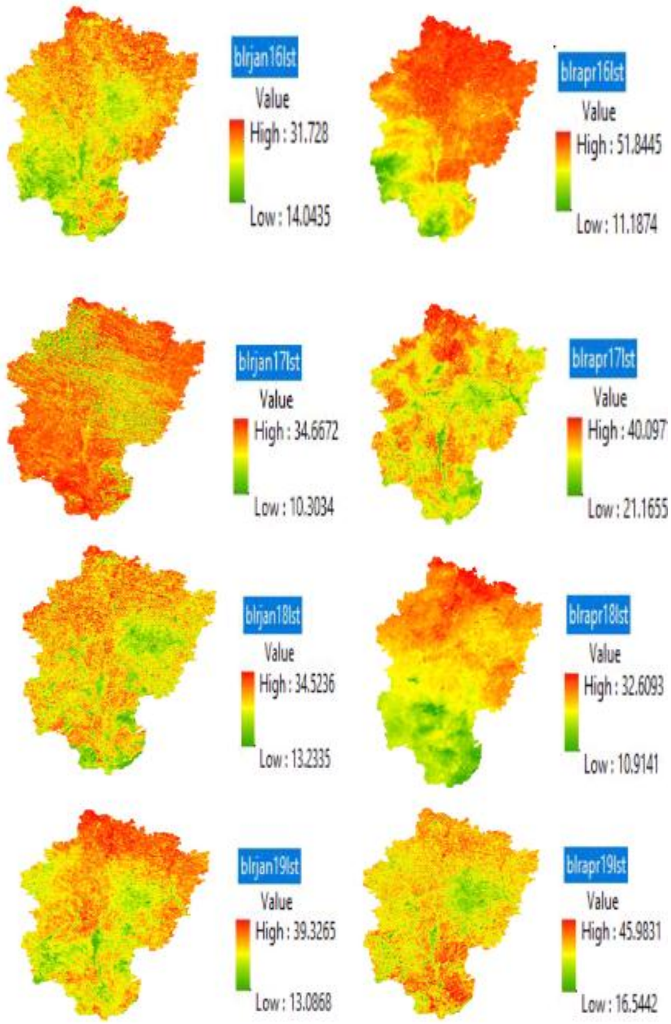


Fig.6.lst Bangalore january and lst Bangalore april (2014-2019)

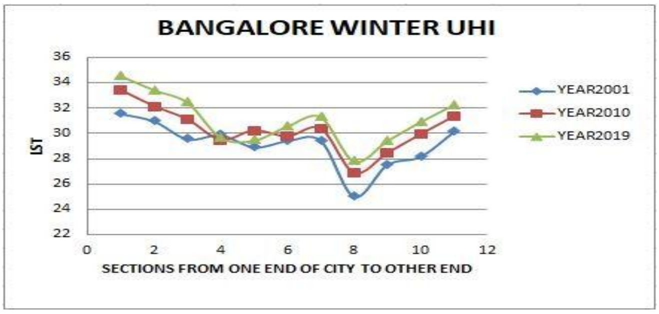


Fig.7 Bangalore winter uhi

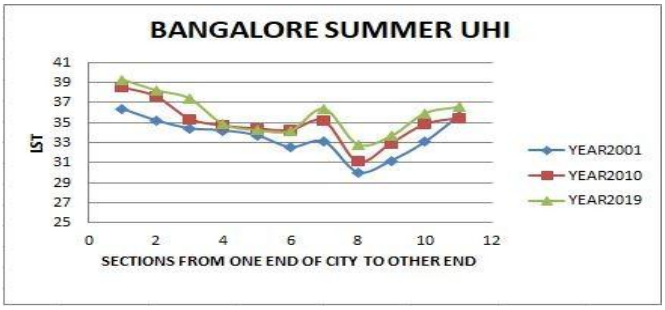


Fig.8. Bangalore summer uhi

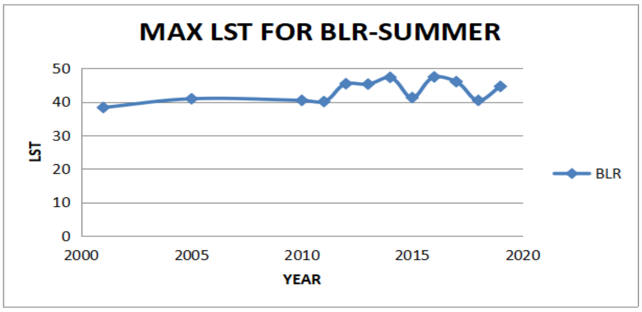


Fig.9. Bangalore summer max lst

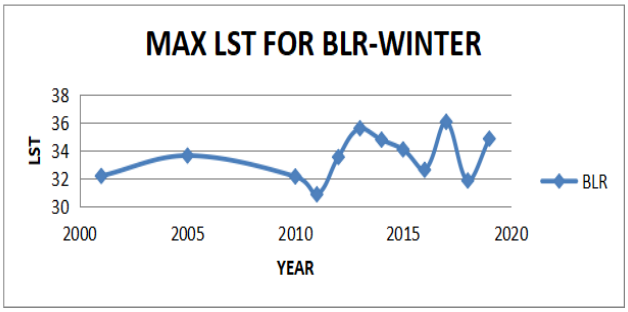


Fig.10 Bangalore winter max lst

As it is clearly visible in Fig.6 the data represented is provided color gradation from low to high as green to red.In case of city of Bangalore it has been noted that there is an inverse case of UHI.or it can also be called an urban cool island(UCI).from the image it is clearly visible that the temperatures in the centre of the city is much lower than the suburban expanse all around it.It can be noticed that Bangalore has a central region

Results from Delhi city:

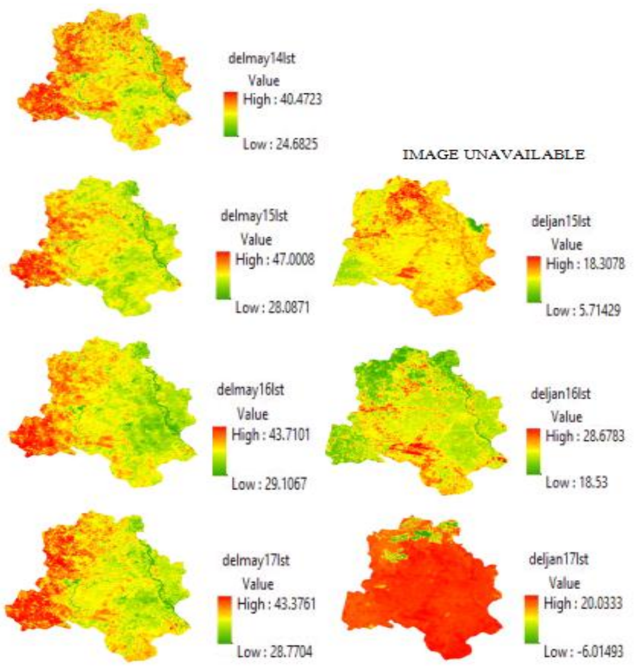


Fig.11 lst Delhi may and lst Delhi january(2014-2019)

That's cooler than its surrounding suburban areas.in winter the To understand how the UHI affects the city we took values of temperatures in a single line from west to east of the city.And the Fig.7 and Fig.8 show UHI effect.temperature in the centre is very low compared to the surrounding.In summer the temperature of the central region also increases.

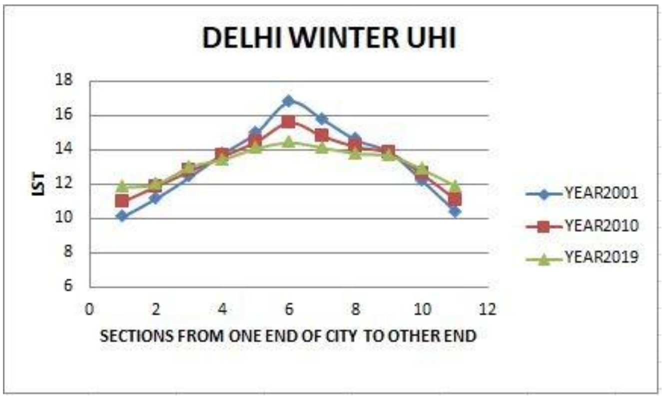


Fig.12.Delhi winter uhi

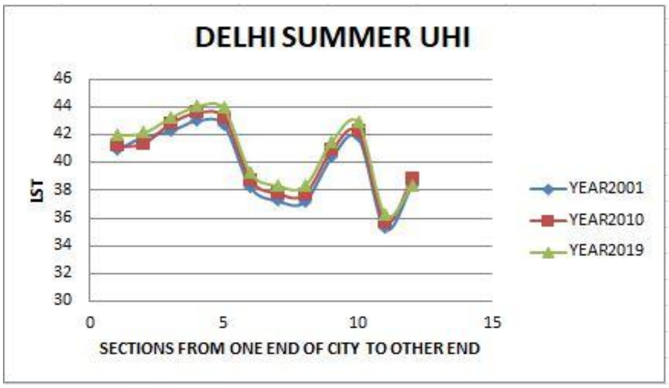


Fig.13.Delhi summer uhi

As it is clearly visible the data represented in the fig.11 is provided color gradation from low to high as green to red.In case of Delhi the images show that due to rapid expansion of built up portion in the north west region the temperatures are very high as compared to the other sections of the city.Delhi has a moderate amount of green cover but the population density and pollution levels are very high.To understand how the UHI affects the city we took values of temperatures in a single line from north west to south east of the city.In winters the central region displays increased temperatures.in summers the north west and some hotspots show high temperatures.

INFERENCE/OBSERVATION

I. Ahmedabad:

It can be noticed that the temperatures in the summer are very high in the north east and north west region. We can also see the temperatures in winter are higher in the central region of the city Also it can be noticed that the max LST for summer has been rising for the past 5 years at a rapid rate. In the northwest region, the temperature saw an increase of 1.5° C in the summer LST of a selected place over the course of two decades and of 1.98° C in the winter LST of the same. While the central regions have reported decreasing values of LST in the summer, due to the rising vegetation, the winter LST shows increase. This justifies the study done by Ajanta Goswami, Pir Mohammad, Ashim Sattar in which the results clearly confirm the boosting of UHI magnitude.Many more papers can be referred to understand the effect of this phenomena.

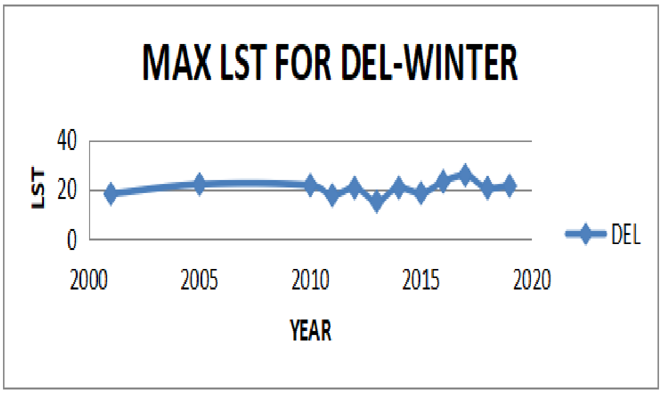


Fig.14.max lst for Delhi winter

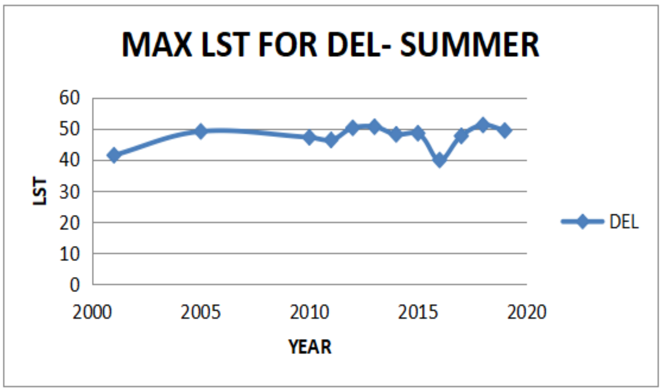


Fig.15 max lst for Delhi summer

II. Bangalore:

In case of city of Bangalore it has been noted that there is an inverse case of UHI or it can also be called an urban cool island(UCI).from the image it is clearly visible that the temperatures in the centre of the city is much lower than the suburban expanse all around it.Also, it can be noticed that the max temperatures for summer and winter months has been on a rise for the past 5 years at a rapid rate. Furthermore, on an overall basis the whole city has witnessed an increase of about 2° C to 3° C in the LST values in the last two decades which can be attributed to the continued expansion but the fact that the city is an urban cool island remains unchanged. This also draws parallels from the study carried out by Shrinidhi Ambinakudige and the results are identical.

III. Delhi:

A high variability exists in the LST values across the city which makes it tough to classify it as an optimum example of UHI. What can be said though about the city is that higher temperatures exist in the north west to south west regions and the southern regions while the central and the eastern regions have lower temperatures, in the summer. In fact, in most of the images from the various years, the region between the north west and south west has been hotter while the zone in between these regions has been relatively cooler, in the summer seasons.The same regions were found to be cooler and the zone in between the said two regions was relatively warmer, in the winter season. Over the last two decades, the winter season has seen an increase in the daytime minimum temperatures and a decrease in the daytime maximum temperatures, which has sort of flattened the winter UHI curve.The results were focused on these aforementioned regions. Although the study done by Neha Yadava and Chhemendra Sharma, in its results, also shows intra-variability, it uses night time data to find the variations which is in contrast with the day time data, used in our study, and hence the results are varying too.

CONCLUSION

Remotely sensed dataset have emerged as valuable dataset in analysis of landscape.Using the data on multi-seasonal MODIS LST and the recently launched Landsat 8 dataset, this study has depicts the value of remotely sensed data in understanding the influence of urban LULC types on LST. The qualitative and quantitative evidence from remotely sensed data can be valuable is designing current and future sustainable urban socio-economic and environmental plans. The consistently low NDVI in areas of built-up is a clear indication of the value of the less urban green landscape in increasing UHI. Furthermore, this study shows that an integration of built-up and urban greenery is a valuable measure in mitigating urban heat. Consequently, initiatives like greening of suburbs and industrial zones are valuable measures in mitigating urban heat. This study concludes that the creation and maintenance of urban greens is a critical measure in sustainable urban planning. Such measures are therefore critical in mitigating global warming and climate change and associated implications.

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