Analysis of the Relationship between Land Surface Temperature and Land Cover in Surat through Landsat 8 OLI

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ABSTRACT

Urban Heat Islands (UHIs) are areas of a city where temperatures are considerably higher than that of their rural areas that surround the city. Anthropogenic activities have to be blamed for this. There are two aspects of rise in temperatures in the urban areas. First is the global warming, which is responsible for increase in Earth's temperature as a whole. The second aspect is the local warming. This is caused by the replacement of natural land cover like grass, trees etc. with materials like concrete, bitumen etc. The second aspect favours the first and magnifies its effect. This is due to the property of man-made materials to reduce albedo, heat storage, formation of canyons and restricting wind flow.

To carry out the study Land Surface Temperature of the study area is calculated using GIS software. The relation between Land Surface Temperature and Landuse of a study area is being identified.

KEYWORDS: Urban Heat Island (UHI), Land Surface Temperature (LST), Climate Change, Landsat 8-OLI

Introduction

In 1960, the worldwide urban population was 34% of the total; but, by 2014 the urban population accounted for 54% of the full and continues to grow. By 2050 the proportion living in urban areas is anticipated to succeed in 66% (UNDESA, 2014). Figure shows the modification within the rural and concrete populations of the globe from 1950 through to projected figures up to the year 2050.

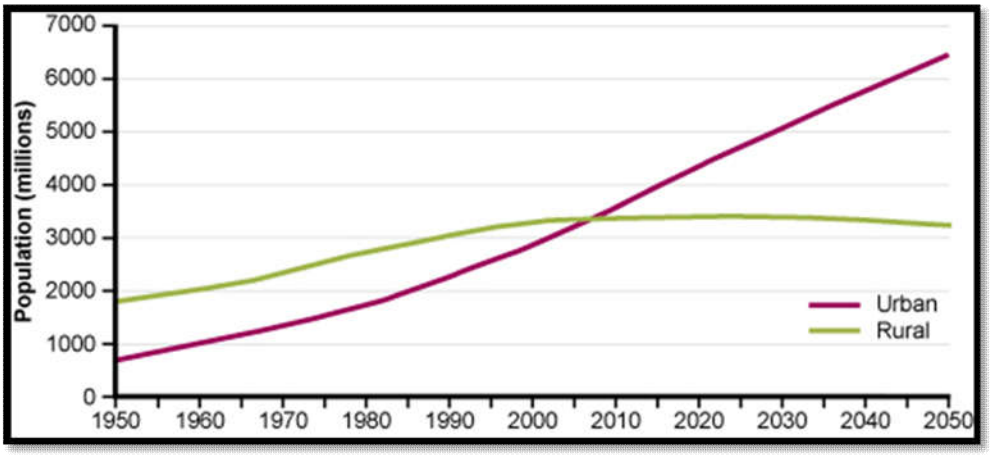

Figure 1 Urban and rural population of the world, 1950–2050

(Source: UNDESA, 2014)

After industrialisation and less amount of profit in agricultural fields more and more people transfers from rural area to urban areas. It increases pressure on urban centers and decreases its efficiency.

Urban Heat Island

An urban heat island (UHI) is an urban area or metropolitan area that is significantly warmer than its surrounding rural areas due to human activities. The temperature difference usually is larger at night than during the day, and is most apparent when winds are weak.

One of the main reasons of increasing urban heat islands is urbanisation. By urbanization, here in this study, it is meant the replacement of natural land covers like water bodies, forest, agro-land etc. into man-made land covers such as concrete buildings, paved surface asphalt pavements etc.

There are mainly two types of heat islands:

- Atmospheric UHI
    - Canopy layer heat island (CLHI)
    - Boundary layer heat island (BLHI)
- Surface heat island (SHI)

The first two refer to a warming of the urban atmosphere; the last refers to the relative warmness of urban surfaces. The urban canopy layer (UCL) is the layer of air closest to the surface in cities, extending upwards to approximately the mean building height. Above the urban canopy layer lies the urban boundary layer, which may be 1 kilometre (km) or more in thickness by day, decrease to hundreds of meters or less at night. It is the BLHI that forms a dome of warmer air that extends downwind of the city.

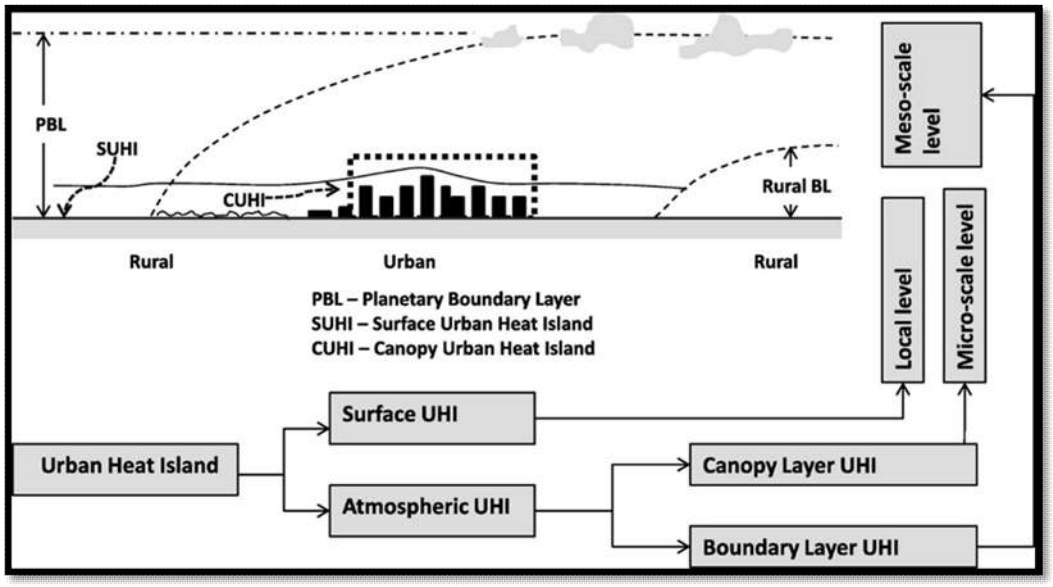

Figure 2 Visualization of UHI in cross section view

(Source: Source: Kotharkar and Surawar (2015))

Land Surface Temperature

The Land Surface Temperature (LST) is the radiative skin temperature of the land surface. Its estimation depends on the albedo, the vegetation covers and the soil moisture. Land Surface Temperature is calculated using thermal bands of satellite imaginary. In this study Landsat 8 and Landsat 7 images are used to derive LST. In Landsat 8 image thermal band 10 was used and in Landsat 7 band 6 was used.

Study Area Profile

Surat is the 8th largest city in India. As per the census 2011, Surat has a population of 4.46 million. Many people migrated to Surat city due to the presence of huge textile and diamond industry.

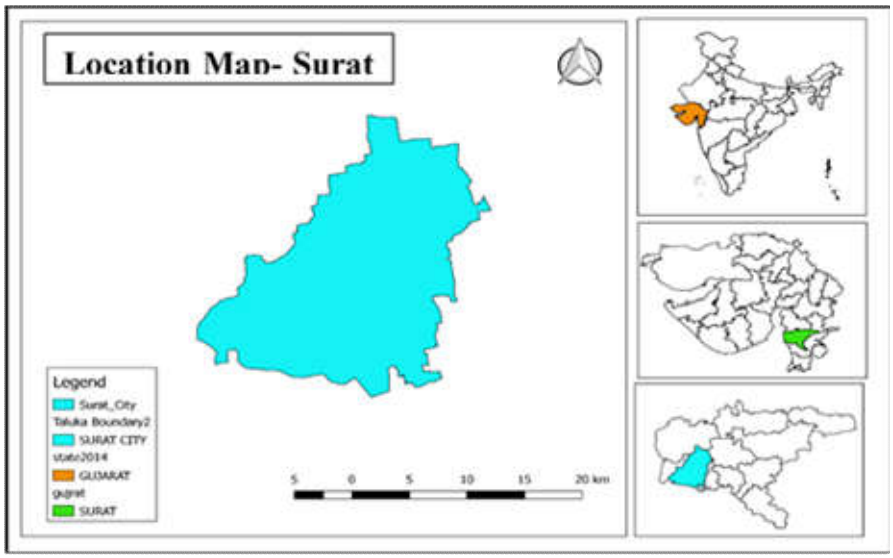

Figure 3 Location Map of Surat City

The city saw an unprecedented growth in the last four decades, recording one of the highest growth rates in the country and a 10-fold population rise over four decades.

Due to industrial development urbanisation took place in Surat city. In the year 1986 the half decadal growth of Surat city is around 54 %. The city area has expanded with time (major expansion being in 2006) and presently covers 326.515 sq.km. The population of Surat is expected to grow from 4.46 million (2011) to 6.4 & 8.5 million by 2021 & 2031.

Table 1 Year wise expansion of Surat City

Year	Area in Sq. Km
1961(Old city)	8.18
1963	21.95
1970	33.8
1975	55.56
1986	111.16
1994	112.28
Feb-06	146.456
Jul-06	326.515

(Source: Surat Municipal Corporation,2018)

Climatological Data

The temperature of Surat is mild to warm with the summer time maximum temperatures averaging to 340C while the winters are relatively cool with the night-time temperatures averaging to around 14 □. In peak summer, the maximum temperature can go up to 44-45 □.

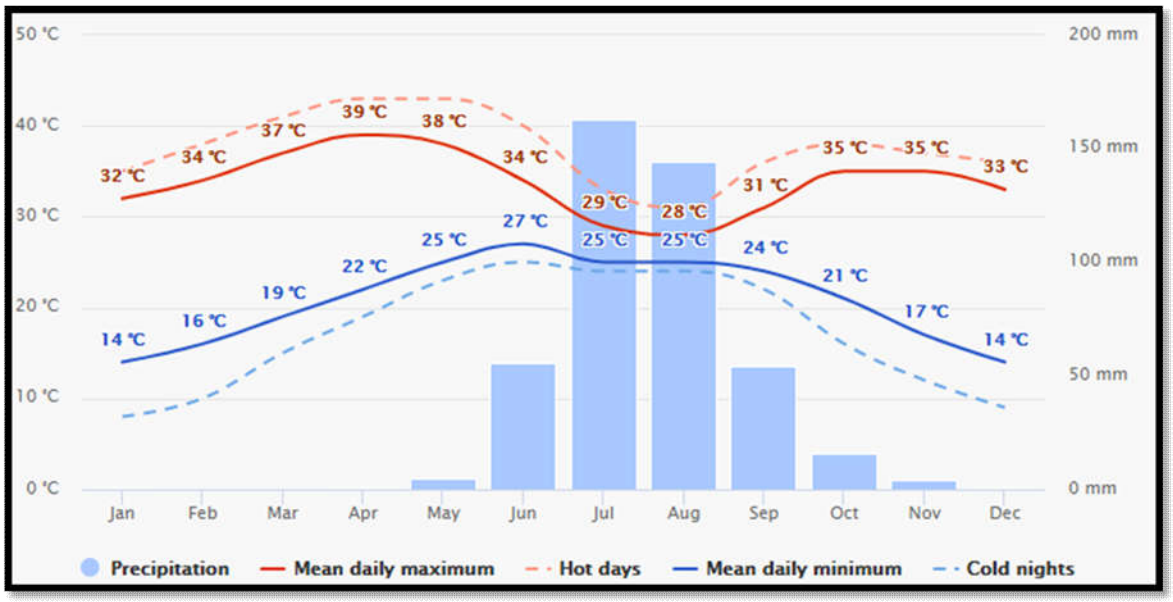

Figure 4 Average Temperatures and Precipitation

(Source: Metablue, 2018)

Image Data

In this study, raw image data of Surat were downloaded from the United States Geological Survey (USGS) website. For calculation of Land Surface temperature, Landsat 8 OLI-TIRS image was downloaded with no cloud cover. The effect of Surface UHI is seen more during the summer time so for the study image of May month is taken.

Table shows the raw image data for Surat. The image is named after it's imaging time by year and day of the year. Image includes the information of its imaging sensor, date, resolution and wave bands. The OLI image consists of visible bands, the near infrared (NIR) band, thermal infrared (TIR) band and short wave infrared (SWIR) band, which are present in TM images, and also the coastal band, panchromatic (Pan) band and cirrus band. TIRS bands are also thermal infrared bands with a higher resolution compared with TIR bands.

In addition, LST retrieval requires radiometric calibration for thermal band. For OLI images, thermal band is band 10 and 11. The specific implementation can be seen in Section.

Table 2 Details of bands in Landsat 8 OLI-TIRS

Sr No.	Bands	Wavelength	Resolution
1	Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
2	Band 2 - Blue	0.452 - 0.512	30
3	Band 3 - Green	0.533 - 0.590	30
4	Band 4 - Red	0.636 - 0.673	30
5	Band 5 - Near Infrared (NIR)	0.851 - 0.879	30
6	Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
7	Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
8	Band 8 - Panchromatic	0.503 - 0.676	30
9	Band 9 - Cirrus	1.363 - 1.384	15
10	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100 * (30)
11	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	101 * (30)

(Source: USGS,2018)

Landsat 8 captures more than 700 scenes a day, an increase from the 250 scenes a day on Landsat 7. The OLI and TIRS sensors will see improved signal to noise radiometric (SNR) performance, enabling 12-bit quantization of data allowing for more bits for better land-cover characterization. Landsat 8 consist of 11 bands in which band 10 & 11 are thermal bands.

Image Pre-Processing

Landsat Images which are downloaded from the USGS Earth Explorer website is in form of raw data. It consists of different bands i.e. Landsat 8 image consist of 11 bands and every band has its own image. To calculate or to extract LST and LULC data from this image the composition of band is necessary.

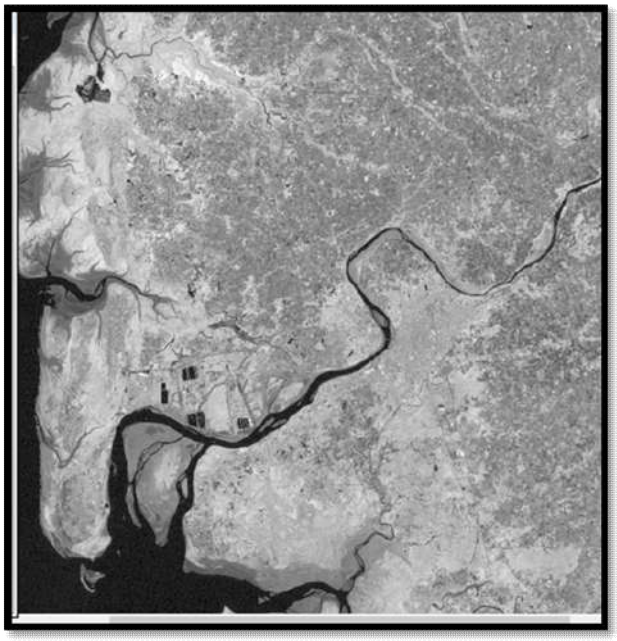


Figure 5 Raw Image of Landsat 8 ImageFigure 6 Composition of Band

(Source: USGS Earth Explorer)

Methodology

To extract Land Surface Temperature from Landsat image certain procedures are to be followed.

Procedure to Calculate LST for Landsat 8 image

1) Calculation of TOA (Top of Atmospheric) spectral radiance

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

Where:

M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_**x**, where x is the band number).
Q_{cal} = corresponds to band 10.

A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_**x**, where x is the band number)

2) TOA to Brightness Temperature Conversion

$$BT = (K_2 / (\ln (K_1 / L) + 1)) - 273.15$$

Where:

K_1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_**x**, where x is the thermal band number).

K_2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_**x**, where x is the thermal band number).

L = TOA

3) Calculate the NDVI

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

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

4) Calculate the proportion of vegetation P_v

P_v = Square (($NDVI - NDVI_{min}$) / ($NDVI_{max} - NDVI_{min}$))

Usually the minimum and maximum values of the NDVI image can be displayed directly in the image (both in ArcGIS, QGIS, ENVI, Erdas Imagine), otherwise you must open the properties of the raster to get those values.

5) Calculate Emissivity ε

$\varepsilon = 0.004 * P_v + 0.986$

Simply apply the formula in the raster calculator, the value of 0.986 corresponds to a correction value of the equation.

6) Calculate the Land Surface Temperature

LST = (BT / (1 + (0.00115 * BT / 1.4388) * Ln(ε)))

This is the final equation of the process of deriving Land Surface Temperature (LST). The final product is shown below un the image.

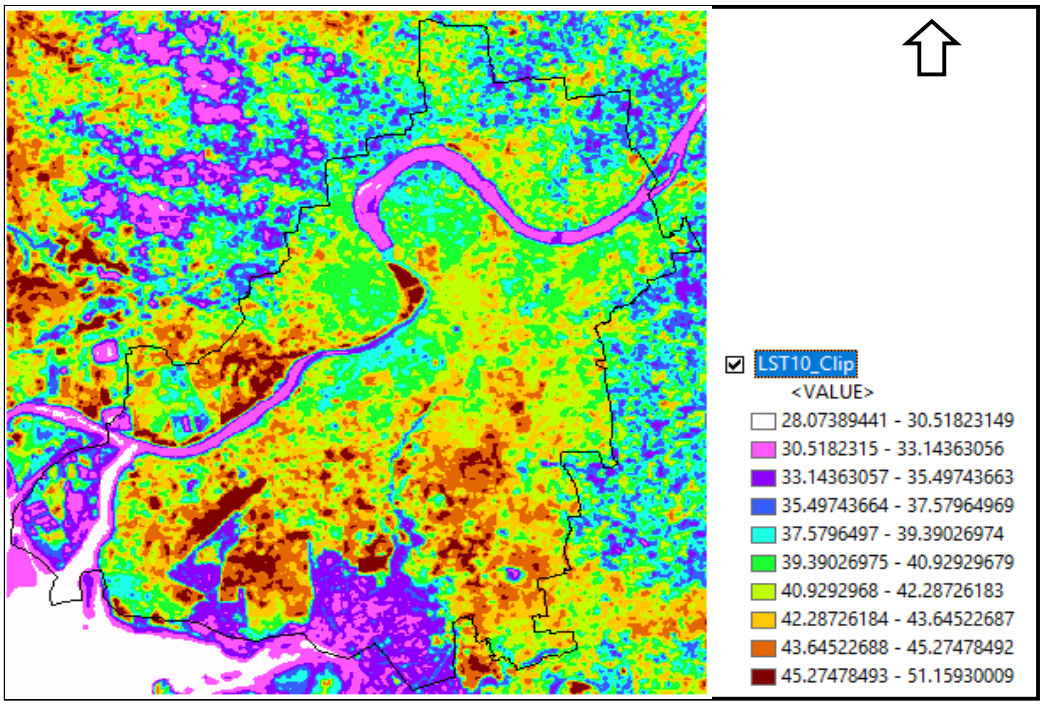

Table 3LST Image of Surat City

Landuse

The landuse of Surat city is prepared using supervised classification tool in ArcMap 10.2.2 software. For landuse preparation Landsat 8 image was used.

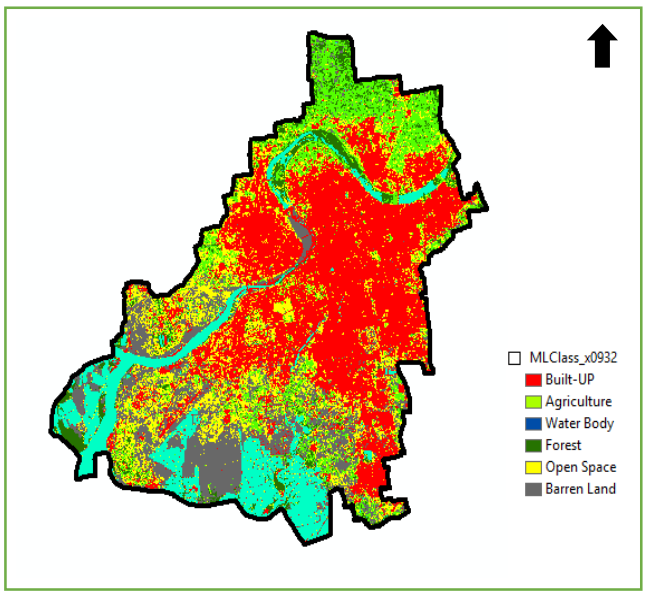

Figure 7Landuse Map Surat City

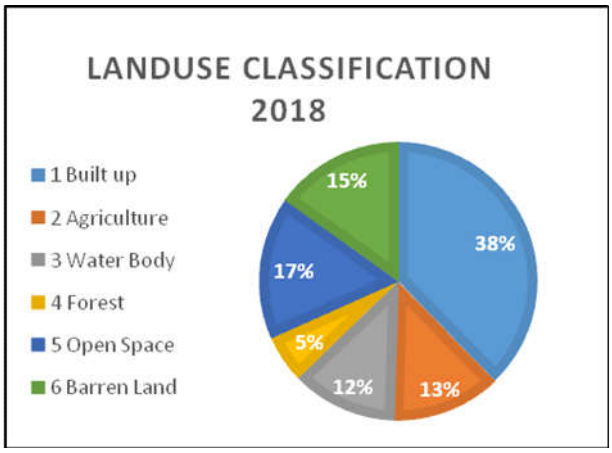

Figure 8Landuse Classification Chart

Result & Discussion

Land surface temperature means temperature of the surface of the earth at the given instance. This mainly depends on the properties of material like heat absorbing capacity, reflectance and albedo of material or surface. Due to these properties temperature of different land use can be observed.

From LST map temperature of 24 points of different landuse of study area is measured and simultaneously graph is prepared for better understanding of the data.

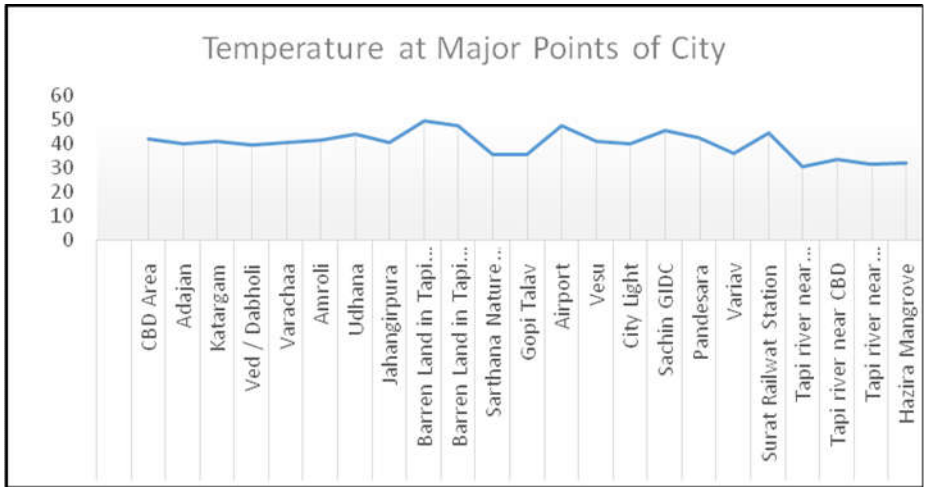

Figure 9Temperature at Major Points of the City

The graph shows the temperature of various points in the study area.

It is clearly shown that temperature of built-up area is higher compare to area which is covered by water body and vegetation. Graph shows temperature of residential and commercial areas like CBD area, Adajan,

Katargam, Amroli are constant between certain limits and then sudden rise of temperature is observed, the rise shows the temperature of barren land. Then again due to green area like sarthana zoo and gopitalav temperature falls tominimum level. Temperature at airport is also higher due to barren land. The minimum temperature is observed is of tapi river near dumas.

From the observation of LST map certain temperature range for different landuse is prepared which is shown in following table.

*Table 4*Temperature Range for Different Landuse Class

Class	Temperature Range (in Celsius)
Built-up	39-43
Water Body	28-35
Barren land	45-49
Green Area	33-38
Industrial Area	42-48

From the table, it shows that temperature range of barren land and industrial area is much higher followed by built up area. Temperature range of green areas and water bodies are low.

Concluding Remarks

- This study has proven that there is an active relationship of Land surface temperature and UHIs with landuse.
- Studies indicate that there is substantial increase in the urban temperatures in the recent past in the city. Increase in population, density, reduction in open spaces and green cover, increase in built up spaces have proved to increase the temperature in Surat. These thermal changes deteriorate the urban environment causing health problems. Therefore, Urban planners, designers, architects need to consider this urban climate while designing and planning cities.

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