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Estimation of Land Surface Temperature using LANDSAT DATA: A case study of Agra city, India

Dr. Vishwa Raj Sharma
vrsharma2002@gmail.com
Shaheed Bhagat Singh College, University of Delhi, New Delhi

Kamal Bisht
kamal_bisht24@hotmail.com
Shaheed Bhagat Singh College, University of Delhi, New Delhi

ABSTRACT

Land Surface Temperature (LST) is an important indicator for the study of climate change, urban environment, heat balance studies, hydrological and agricultural process, and urban land use and land cover as well as user input for climate models. LANDSAT data is utilized for the number of applications such as environment study, digester and resource management. This study has been made to estimate, LST using Arc GIS over Agra, India, using LANDSAT 8 and 5 satellite data. The LST has been estimated with respect to Normalized Difference Vegetation Index (NDVI) values determined from the Red and Near Infrared bands. The Land Surface Emissivity (LSE) is retrieved directly from the Thermal Infrared bands. The present study focuses on ArcGIS Raster functions and Raster calculation using the thermal band 10 and 11 of Landsat 8 satellite and thermal band 6 of Landsat 5 on the month of April. The results are feasible to calculate NDVI, LSE, and LST with appropriate accuracy. In the last drive out the temperature variance in different land use and land cover area of Agra city, India.

Keywords— *Remote sensing, GIS, Land Surface Temperature (LST), Land Surface Emissivity (LSE), Normalized Difference Vegetation Index (NDVI)*

1. INTRODUCTION

LST is the surface temperature of the earth's crust where the Electronic Medical Radiation (EMR) from the sun is absorbed, reflected and refracted. It is usually measured in Kelvin, Ugur Avna and Gordan Jovanovska, 2016. LST changes with a change due to climatic condition and other anthropogenic activates. Worldwide urbanization leads to reshaping the landscape, which results enlarged the greenhouse gases in the atmosphere. Climate deformation reached across all scale due to the change of land cover. Remote Sensing is one of the leading techniques to analyze different phenomena happen on the earth surface. In the last few decades, Remote Sensing is one of the sources to analyze anthropology impact on the earth surface. Development of new technique in remote sensing and GIS lead to awareness among environmental scientist, that remote sensing can play a vital role in understanding the changing man and environment relationship. LAND SURFACE TEMPERATURE (LST) and emissivity for large areas can only be derived from surface-leaving radiation measured by satellite sensors, Prasanjit Dash et al, 2002. LST is a key for calculating the highest and lowest temperature for a particular location. LANDSAT satellite is providing medium spatial resolution data which are suitable for land cover and vegetation mapping for the regional local scale.

Landsat 8 carries to sensors, Operational Land Images (OLI) and Thermal Infrared Sensor (TIRS). O L I collect data at 30 meters. spatial resolution with eight bands collected in the visible and infrared and the shot dead in the polar region of the electromagnetic spectrum and an additional panchromatic than a 15-meter special resolution. TRS radians at the spatial resolution of 100m using two bands located in the atmospheric window between 10 and 12 micrometres. Anandabab, D et al. (2018).

2. STUDY AREA

Agra city is district headquarter of Agra. Agra city is most popular for its heritage monuments. Agra, known for his ironic heritage monuments around the world for its fabulous Mughal-era building such as Taj Mahal and Fatehpur Sikri which define it a great tourist destination in northern India. Every year a large number of domestic as well as international tourists pays a visit to this historical destination. Most of these tourist places are highly significant as they are classified under the UNESCO World Heritage sites. Agra is well connected within the Golden Triangle circuit. It has emerged as the "The Apple of an eye" for our international and domestic tourists. Delhi -Jaipur and the Uttar Pradesh Heritage Arc is a key factor for upgrading the tourism footfall at Uttar Pradesh. The city of Taj Mahal is a perfect example of a mixture of culture and heritage

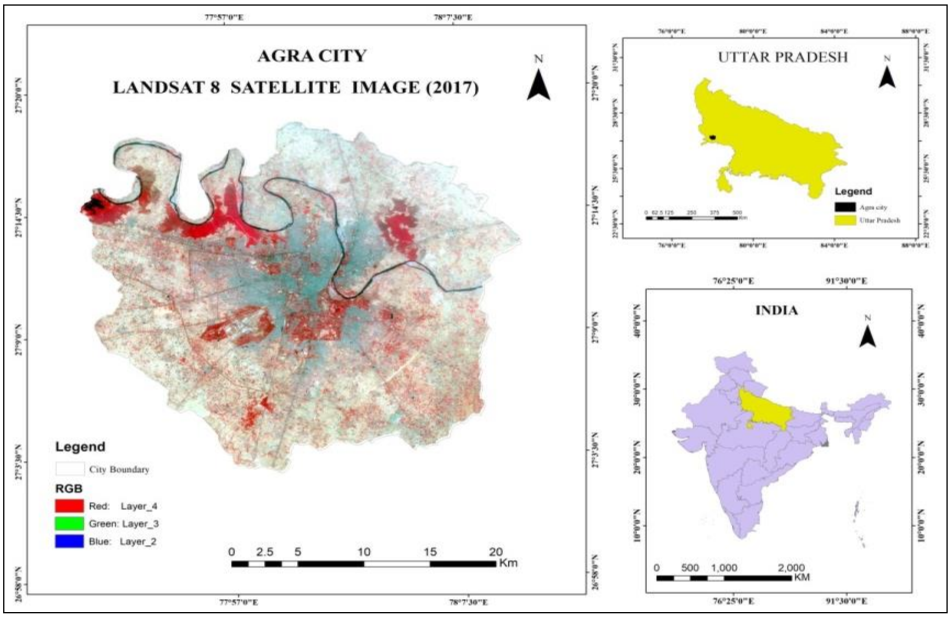

Fig. 1: Study Area, 2017

Source: Compose by Author

3. OBJECTIVES

The aim of this study is to estimate land surface temperature by the following objectives in order to lead the aim is.

- To calculate Normalized Difference Vegetation Index [NDVI]
- To convert TIRS band data to TOA spectral radiance
- To calculate Atmosphere Brightness Temperature
- To estimate Land Surface Temperature [LST]
- To calculate the area for different temperature ranges.

4. MATERIALS AND METHODS

4.1 Data Used

Landsat 8 and 5 is one of the Landsat series of NASA (National Aeronautics and Space Administration). The data of Landsat 8 is available in USGS (United States Geological Survey) Earth Explorer website for research purpose. Landsat 8 and 5 satellite images the entire earth once in 16 days. In the present study, the TIR bands 10 and 11 were used to estimate brightness temperature and bands 4 and 5 were used to generate NDVI of the study area from the Landsat 8 image. The TIR bands 6 were used to estimate brightness temperature and bands 5 and 3 were used to generate NDVI of the study area from the Landsat 5 image. Satellite data over the study region of April of 1999 and 2017 have been used in this study. Landsat 8 and Landsat 5 provides metadata of the bands such as thermal constant, rescaling factor value etc., which can be used for Calculation of LST. Bands, Wavelength and resolution of Landsat 8 and Landsat 5 is given in Table 1and Table 2

Table 1: LANDSAT 8_OLI & TIRS

Bands	Wavelength (micrometres)	Resolution (meters)
Band 1	Ultra Blue (coastal/aerosol) 0.435	30
Band 2	Blue 0.452	30
Band 3	Green 0.533	30
Band 4	Red 0.636	30
Band 5	Near Infrared (NIR) 0.851	30
Band 6	Shortwave Infrared (SWIR) 1 1.566	30
Band 7	Shortwave Infrared (SWIR) 2 2.107	30
Band 8	Panchromatic 0.503	15
Band 9	Cirrus 1.363	30
Band 10	Thermal Infrared (TIRS) 1 10.60	30
Band 11	Thermal Infrared (TIRS) 2 11.50	30

Source: LANDSAT 8 (L8) Data Users Handbook

Following Meta data values are used for calculation

- Radiance Add Band 10 = 0.10000
- Radiance Add Band 11 = 0.10000
- Radiance Mult Band_10 = 0.0003342
- Radiance Mult Band_11 = 0.0003342
- K1 Constant band 10 = 774.8853
- K2 Constant Band 10 = 1321.0789
- K1 Constant Band 11 = 480.8883
- K2 Constant Band 11 = 1201.1442

Table 2: LANDSAT 5_OLI & TIRS

Bands	Wavelength (micrometres)	Resolution (meters)
Band 1	Blue 0.45- 0.52	30
Band 2	Green 0.52- 0.60	30
Band 3	Red 0.63 -0.69	30
Band 4	Near Infrared (NIR) 0.76-0.90	30
Band 5	Mid Infrared 1.55-1.75	30
Band 6	Thermal Infrared 10.40-12.50	30
Band 7	Mid infrared 2.08 -2.35	30

Source: LANDSAT 8 (L5) Data Users Handbook

Following Meta data values are used for calculation

- RADIANCE_MULT_BAND_6 = 5.5375E-02
- RADIANCE_ADD_BAND_6 = 1.18243
- K1_CONSTANT_BAND_6 = 607.76
- K2_CONSTANT_BAND_6 = 1260.56

Softwares used

- Arc GIS Pro 2.0
- ERDAS IMAGINE 2015

4.2 Methodology

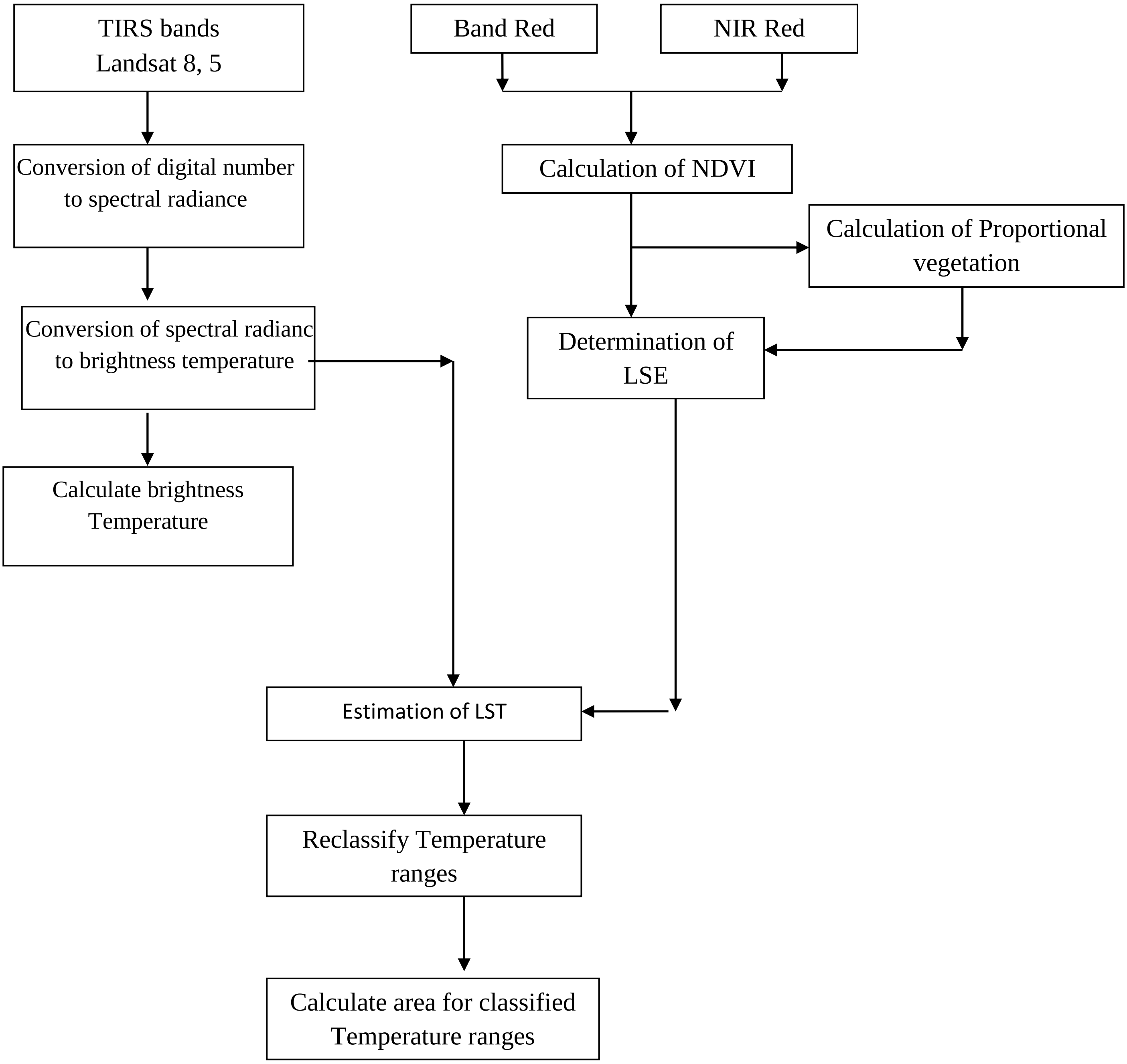

Fig. 2: Methodology *Source: Composed by Author*

4.3 Process

4.3.1 Top of Atmosphere (TOA) Radiance: Using the radiance rescaling factor, Thermal Infra-Red Digital Numbers can be converted to TOA spectral radiance. The following general equation is used to convert a digital number in a Landsat level 1 back to radiance (L).

$$L\lambda = ML * Qcal + AL$$

Where:
$L\lambda$ = TOA spectral radiance (Watts/ (m2 * sr * µm))
ML = Radiance multiplicative Band (No.)
AL = Radiance Add Band (No.)
Qcal = Quantized and calibrated standard product pixel values (DN)

4.3.2 Top of Atmosphere (TOA) Brightness Temperature: Spectral radiance data can be converted to top of atmosphere brightness temperature using the thermal constant Values in Metadata file.

$$BT = K2 / \ln (k1 / L\lambda + 1) - 272.15$$

Where:
BT = Top of atmosphere brightness temperature (°C)
$L\lambda$ = TOA spectral radiance (Watts/(m2 * sr * µm))
K1 = K1 Constant Band (No.)
K2 = K2 Constant Band (No.)

4.3.3 Normalized Differential Vegetation Index (NDVI): The Normalized Differential Vegetation Index (NDVI) is a standardized vegetation index which Calculated using Near Infra-red and Red bands.

$$NDVI = (NIR – RED) / (NIR + RED)$$

Where:
RED= DN values from the RED band
NIR= DN values from Near-Infrared band

4.3.4 Land Surface Emissivity (LSE): Land surface emissivity on an intrinsic property of natural materials is often regarded as an indicator of material compositing especially for the silicate minerals although it varies with viewing angle and surface roughness. Zhoo liang li et al. (2012). Land surface emissivity (LSE) is the average emissivity of an element of the surface of the Earth calculated from NDVI values.

$$PV = [(NDVI – NDVI\ min) / (NDVI\ max + NDVI\ min)]^2$$

Where:
PV = Proportion of Vegitation
NDVI = DN values from NDVI Image
NDVI min = Minimum DN values from NDVI Image
NDVI max = Maximum DN values from NDVI Image

$$E = 0.004 * PV + 0.986$$

Where:
E = Land Surface Emissivity
PV = Proportion of Vegitation

4.3.5 Land Surface Temperature (LST): The Land Surface Temperature (LST) is the radioactive temperature which calculated using Top of atmosphere brightness temperature, Wavelength of emitted radiance, Land Surface Emissivity.

$$LST = (BT / 1) + W * (BT / 14380) * \ln(E)$$

Where:
BT = Top of atmosphere brightness temperature (°C)
W = Wavelength of emitted radiance
E = Land Surface Emissivity

5. RESULT AND DISCUSSIONS

The NDVI map (figure 2) for the month of April 2017 shows that the NDVI value range is 0.332 to 0034. The resulting map shows a high value of NDVI whereas the area under water body has significant low value.

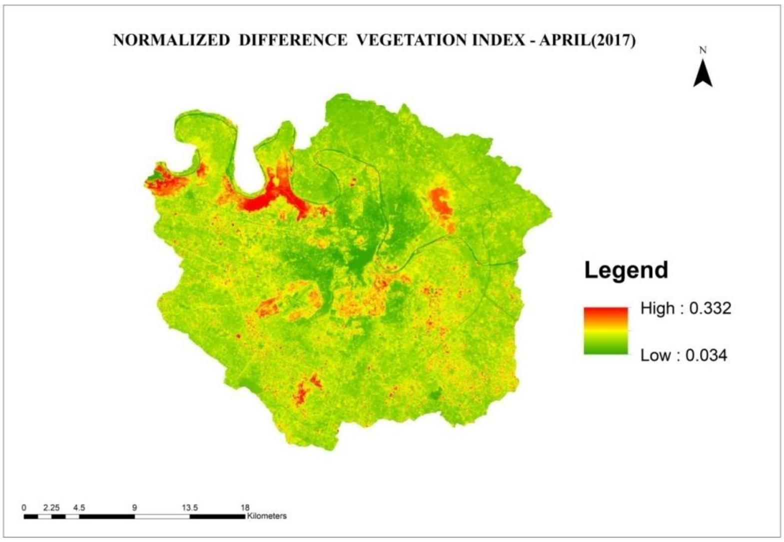

Fig. 2: NDVI April 2017
Source: Compose by Author

The NDVI map for the month of April (1999) shows that the NDVI value ranged between -0.187 to 0.684. The result shows high NDVI values, figure 3.

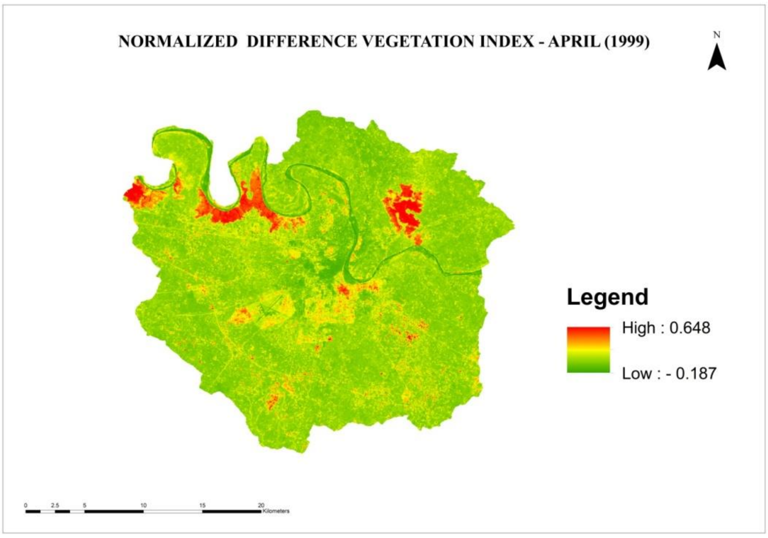

Fig. 3: NDVI April 1999
Source: Compose by Author

Using NDVI values LSE was created for the month of April 2017. The LSE of AOI ranged between 0.986 and 0.988 and LSE was created for the month of April 1999. The LSE of AOI ranged between 0.987 and 0.990. Figure 4 shows the brightness temperature map for the month of April 2017 and the temperature range between 26.717 to 39.155°C

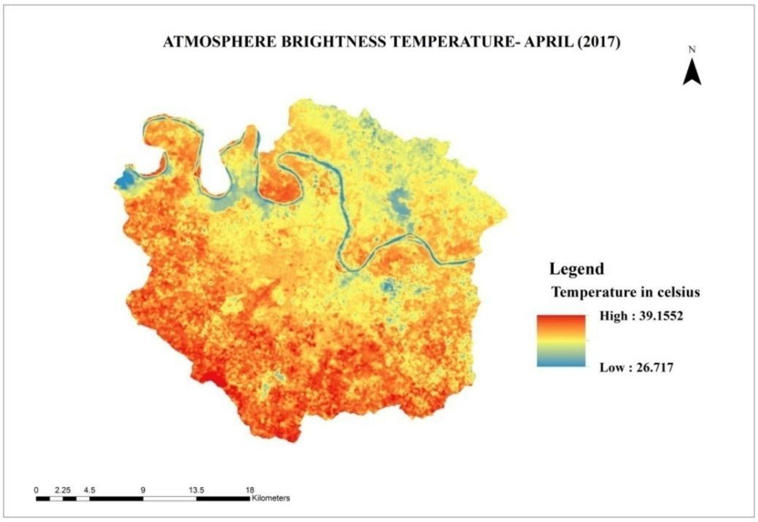

Fig. 4: Atmosphere Brightness Temperature, April 2017
Source: Compose by Author

The Brightness Temperature map for the month of April 1999 shows that the temperature value ranges between 49.84 to 49.84 °C (Figure 5).

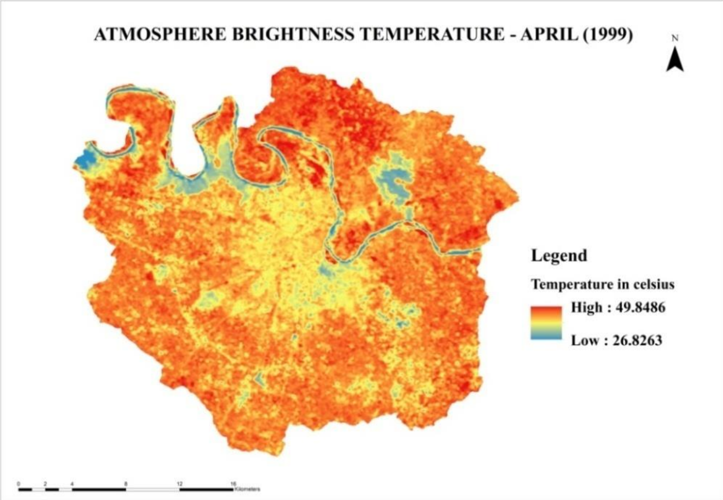

Fig. 5: Atmosphere Brightness Temperature, April 1999
Source: Compose by Author

Land surface temperature map (figure 6) has been derived using brightness temperature and LSE. LST temperature ranges and areas for the month of April 2017 are shown in Table no 3 and graphical representation in figure 7.

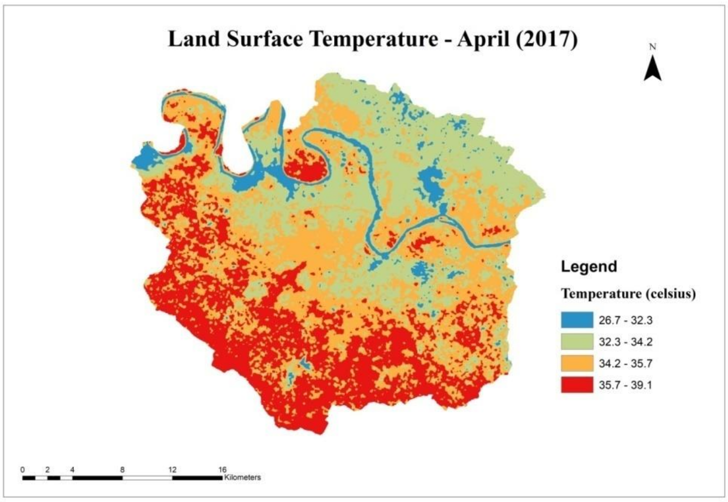

Fig. 6: Land surface Temperature, April 2017
Source: Compose by Author

Table 3: Area under Land surface Temperature, April, 2017

Temperature (°C)	Area (Sq.km)	Percentage (%)
26.7-32.3	38.92929	5.974214
32.3-34.2	237.594	36.46194
34.2-35.7	173.7071	26.65765
35.7-39.1	201.3916	30.9062

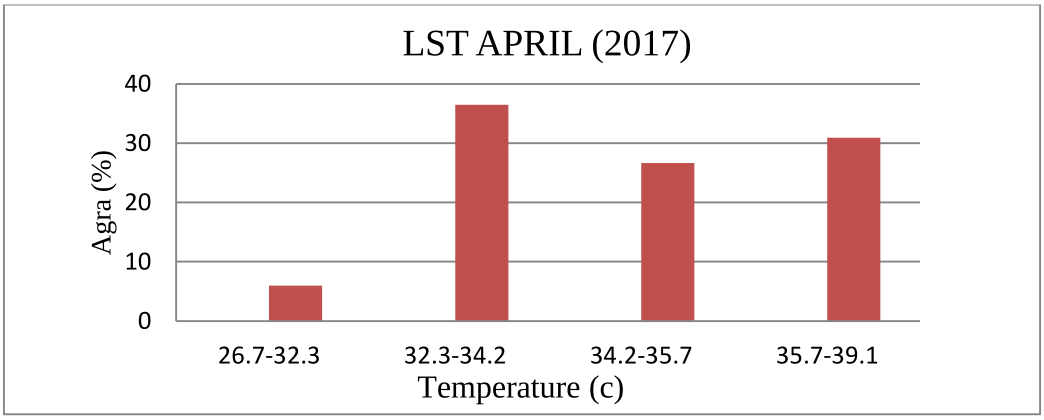

Fig. 7: Area under Land surface Temperature, April, 2017
Source: Compose by Author

Land surface temperature map (figure 8) has been Derived using brightness temperature and LSE. LST temperature ranges and areas for the month of April are shown in table 3 and graphical representation in figure 9.

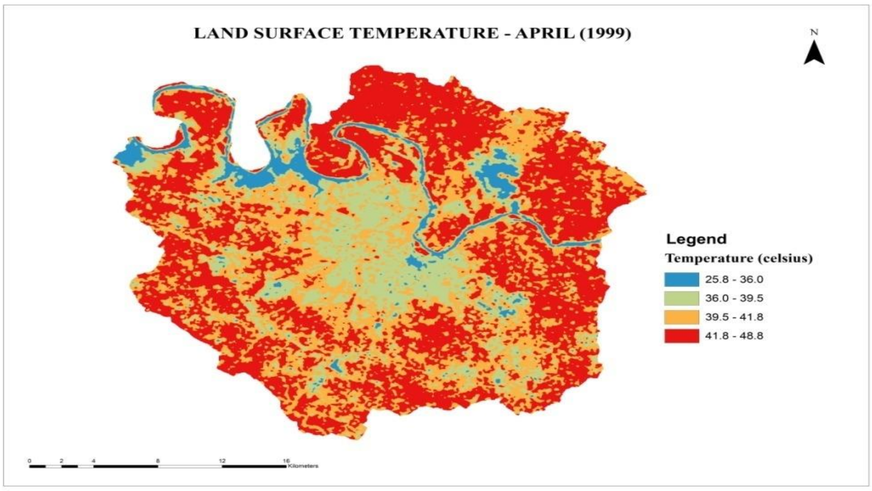

Fig. 8: Land surface Temperature, April 1999
Source: Compose by Author

Table 4: Area under Land surface temperature, April, 1999

Temperature (°C)	Area (Sq.km)	Percentage (%)
25.8 – 36.0	221.0211	33.92005
36.0 -39.5	285.3105	43.78652
39.5- 41.8	114.8123	17.62021
41.8- 48.8	30.45043	4.673219

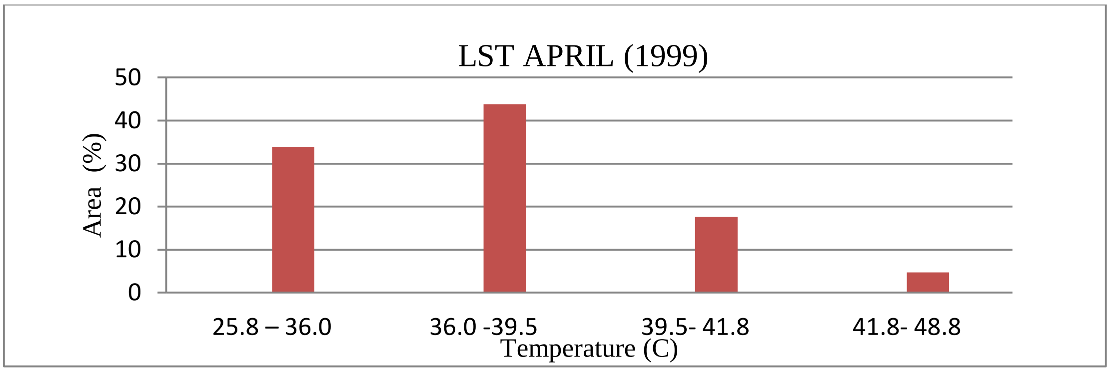

Fig. 9: Area under Land surface temperature, April, 1999
Source: Compose by Author

Land use and land Surface Temperature

A number of work have been worked have been propounded to infer a relationship between urban and land cover and LST change. Significant role of land use and land cover in the variation of the land surface temperature as well as city-specific analysis of annual LST, Stefania Bonafoni and Chaiyapon Keeratikasikorn 2018.

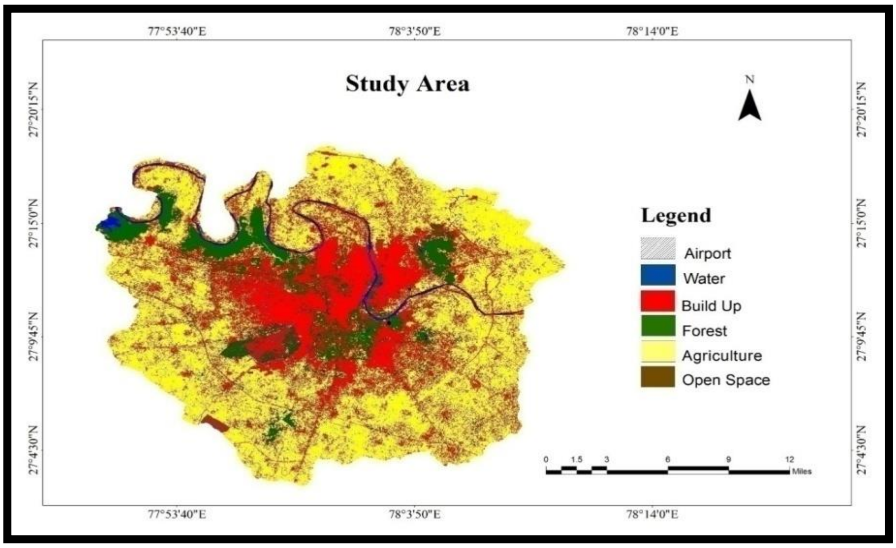

Fig. 10: Land use land cover, 2017
Source: Compose by Author

Table 4: Temperature in Build up area, 1999

	The area in Square Kilometer				
Temperature (°C)	**Water**	**Forest**	**Buildup**	**Agriculture**	**Open Space**
26-32	8.47	17.24	5.17	5.20	2.38
32-34	0.60	1.54	17.99	136.20	14.74
34-35	0.71	15.09	77.61	115.49	26.74
35-39	0.60	1.54	17.99	136.20	14.74

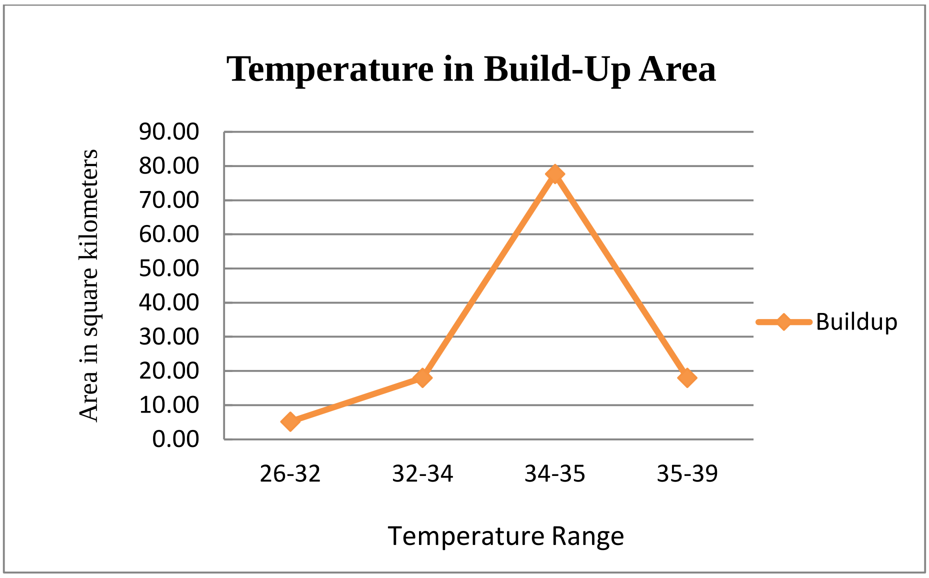

Fig. 11: Temperature in Buildup area, 1999
Source: Compose by Author

6. CONCLUSION

NDVI, brightness temperature, LSE, and LST of an area were determined using Arc GIS. NDVI Maps shows that vegetation is high of the month of April 1999 compared to the month of April 2017. Estimated LST values revel that in the month of April 2017. The temperature lies in the range of 34 -35°C cover 77 % of the Buildup area or human settlement. Thus, LST can be estimated using Landsat 8 and landsat 5 with multiband OLI and TIR images. For upcoming research on LST, David Parastatidis et al, 2017 suggest the Google earth engine for calculating LST and quick visualization.

7. REFERENCES

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