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Estimation of Land Surface Temperature using LANDSAT 8 Data

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ABSTRACT

Land surface temperature (LST) is an important factor in many areas like climate change, urban land use/land cover, heat balance studies and also a key input for climate models. LANDSAT Data has given a lot of possibilities to study the land processes using remote sensing. This study has been made to estimate LST using Arc GIS over Hosur, Krishnagiri district, Tamil Nadu, India, using LANDSAT 8 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 LANDSAT 8 April and November, thermal Bands (10 & 11). The results are feasible to Calculate NDVI, LSE, and LST with appropriate accuracy.

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

1. INTRODUCTION

LST (Land Surface Temperature) is the earth surface temperature which is directly in contact with the measuring instrument (usually measured in Kelvin). LST is the surface temperature of the earth's crust where the heat and radiation from the sun are absorbed, reflected and refracted. LST changes with a change in climatic condition and other human activities where the exact prediction becomes challenging. Worldwide urbanization has significantly increased in greenhouse gases and reshaped the landscape, which has important climatic implications across all scales due to the simultaneous transformation of natural land cover and introduction of urban materials i.e. anthropogenic surfaces. Ground surveys would permit a highly accurate Land Use Land Cover (LULC) classification, but they are time-consuming, burdensome and expensive, which highlights remote sensing an evident and preferred alternative. Identification and characterization of Urban Heat Island (UHI) is typically based on LST that varies spatially, due to the non-homogeneity of land surface cover and other atmospheric factors. LST is the key factor for calculating highest and lowest temperature of a particular location. Medium spatial resolution data, such as that from the LANDSAT and SPOT are suitable for land cover or vegetation mapping at regional local scale. LANDSAT 8 carries two sensors, i.e., the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). OLI collects data at a 30m spatial resolution with eight bands located in the visible and near-infrared and the shortwave infrared regions of the electromagnetic spectrum, and an additional panchromatic band of 15m spatial resolution. TIRS senses the TIR radiance at a spatial resolution of 100m using two bands located in the atmospheric window between 10 and 12 μm.

2. STUDY AREA

Hosur is an Industrial City of Tamil Nadu where Hosur is considered as a gateway of Karnataka and has become a satellite town of Bangalore. Hosur block is geographically located in the Northern part of Tamil Nadu State. It is located about 40 kms South-East of Bangalore. It lies between 12.7409°N latitude and 77.8253° E longitude and it forms a part of the Survey of India (SOI) topographic sheets on 1:50000 scale. The study area covers a total area of about 956.98 sq kms including Sulagiri region and is situated at an altitude of 950 m above mean sea level (MSL). According to 2011 census, Hosur had a population of 116,821 as per 2011 census with a female population of 968 and male population of 1,000. The study area accommodates 30 panchayats and 89 villages. A small city located right near the border between the states of Tamil Nadu and Karnataka, Hosur, is an industrial community, with about 110,000 of residents.

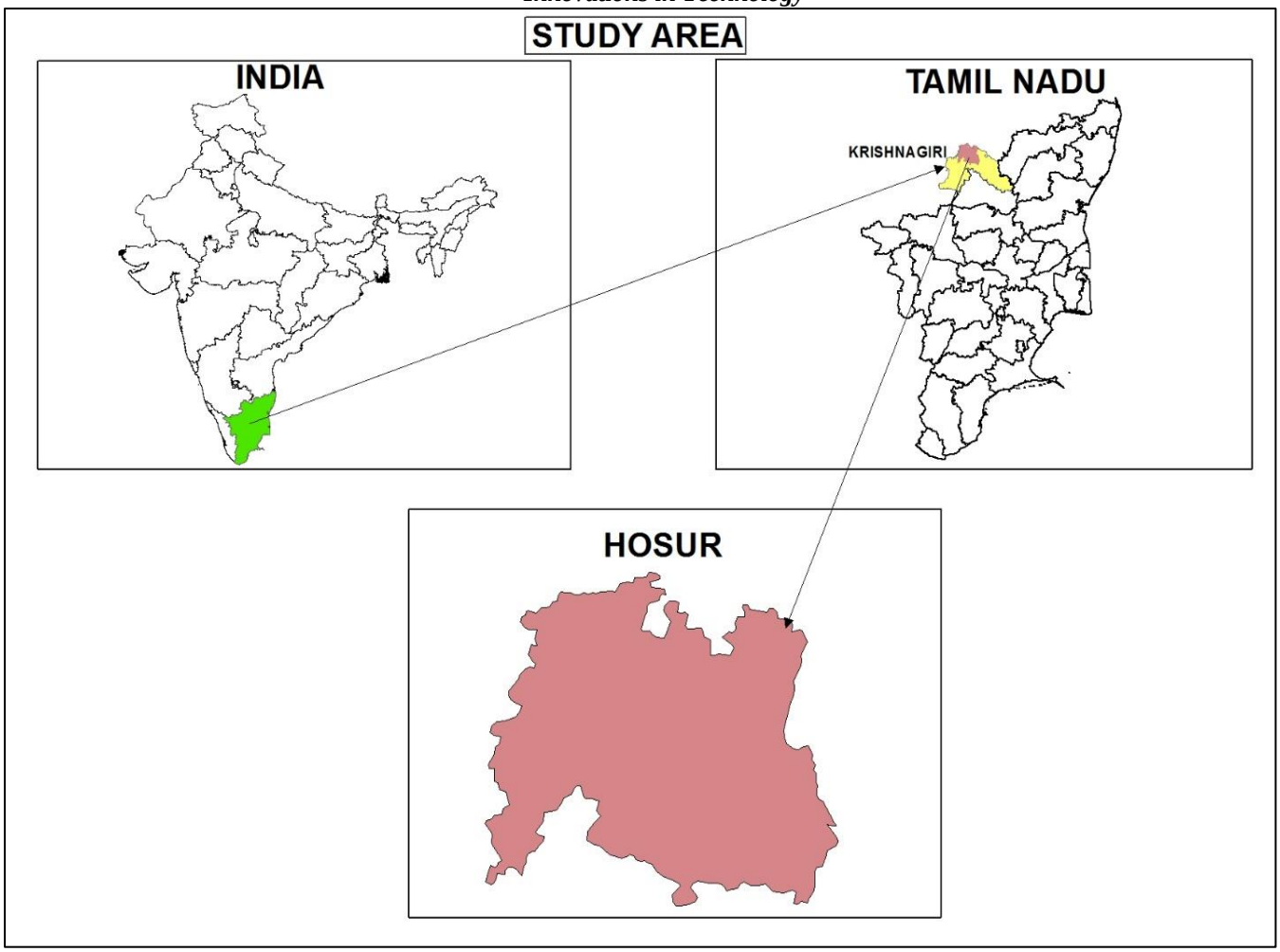

Fig-1: Location Map

3. OBJECTIVES

The aim of this study is to estimate land surface temperature by the following objectives in order to persuade the aim are,

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

4. MATERIALS AND METHODS

4.1 Data Used

Landsat 8 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 at free of cost. Landsat 8 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. Satellite data over Hosur region of April and November of 2017 have been used in this study. Landsat 8 provides metadata of the bands such as thermal constant, rescaling factor value etc., which can be used for Calculation like LST. Bands, Wavelength and Resolution of Landsat8 are as given in Table – 1.

Table–1: LANDSAT8_OLI & TIRS

Bands	Wavelength (micrometers)	Resolution (meters)
Band 1 - Ultra Blue (coastal/aerosol)	0.435 - 0.451	30
Band 2 - Blue	0.452 - 0.512	30
Band 3 - Green	0.533 - 0.590	30
Band 4 - Red	0.636 - 0.673	30

Band 5 - Near Infrared (NIR)	0.851 - 0.879	30
Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30
Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
Band 8 - Panchromatic	0.503 - 0.676	15
Band 9 - Cirrus	1.363 - 1.384	30
Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	30
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	30

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

4.2 Software's Used

- Arc GIS Pro 2.0
- ERDAS IMAGINE 2015

4.3 Methodology

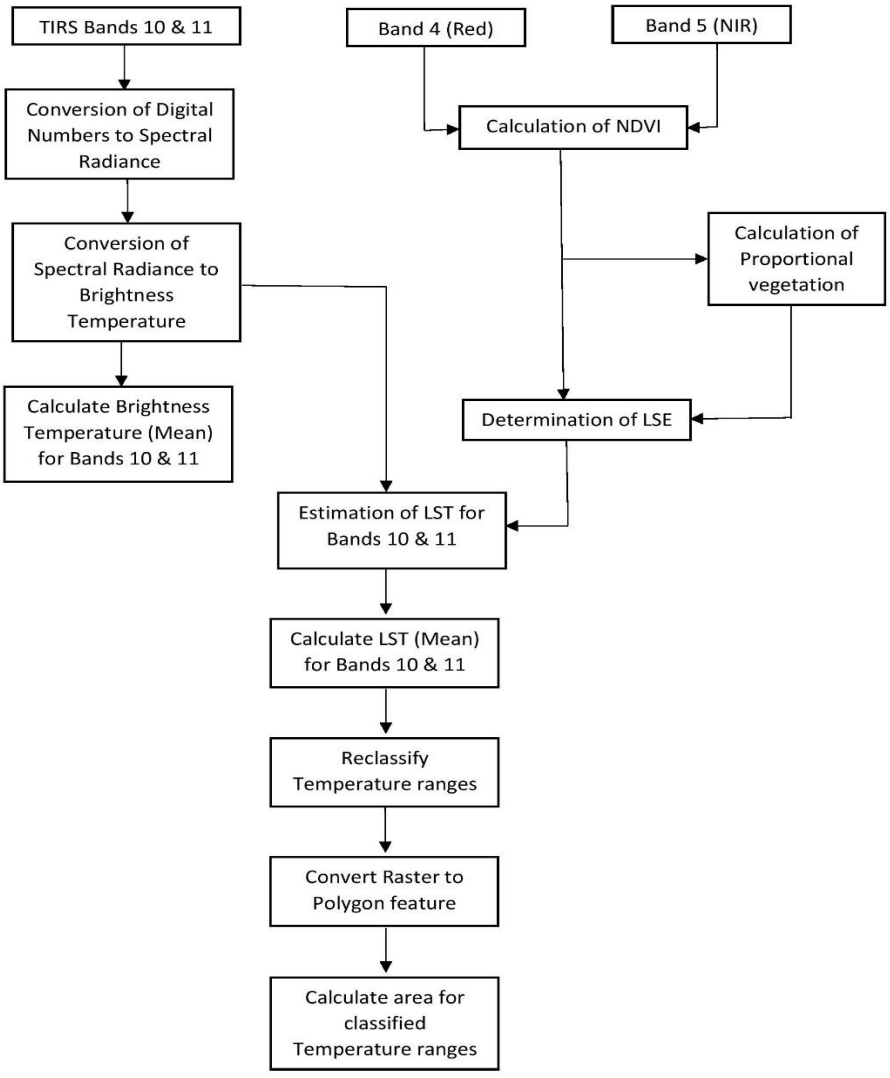

Fig – 2: Flowchart

4.3.1 Process

i. Top of Atmosphere (TOA) Radiance:

Using the radiance rescaling factor, Thermal Infra-Red Digital Numbers can be converted to TOA spectral radiance.

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

Where:
Lλ = 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)

ii. Top of Atmosphere (TOA) Brightness Temperature:

Spectral radiance data can be converted to top of atmosphere brightness temperature using the thermal constant Values in Meta data file.

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

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

iii. Normalized Differential Vegetation Index (NDVI):

The Normalized Differential Vegetation Index (NDVI) is a standardized vegetation index which Calculated using Near Infra-red (Bnad 5) and Red (Band 4) bands.

$$NDVI = (NIR – RED) / (NIR + RED)$$

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

iv: Land Surface Emissivity (LSE):

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

v: Land Surface Temperature (LST):

The Land Surface Temperature (LST) is the radiative 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 for the month of April shows that the NDVI value ranged between -0.255 to 0.539. The resulting map shows moderate NDVI whereas area under water body has significant low value (Fig-3).

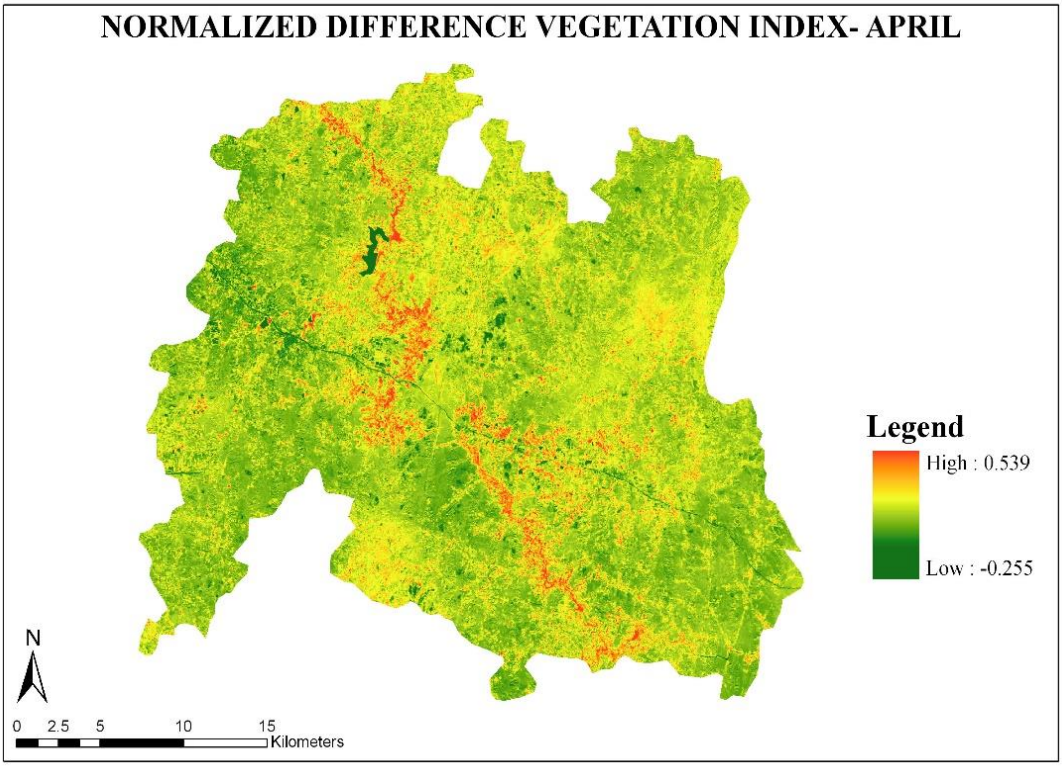

Fig - 3

The NDVI map for the month of November shows that the NDVI value ranged between -0.268 to 0.592. The resulting map shows high NDVI (Fig-4).

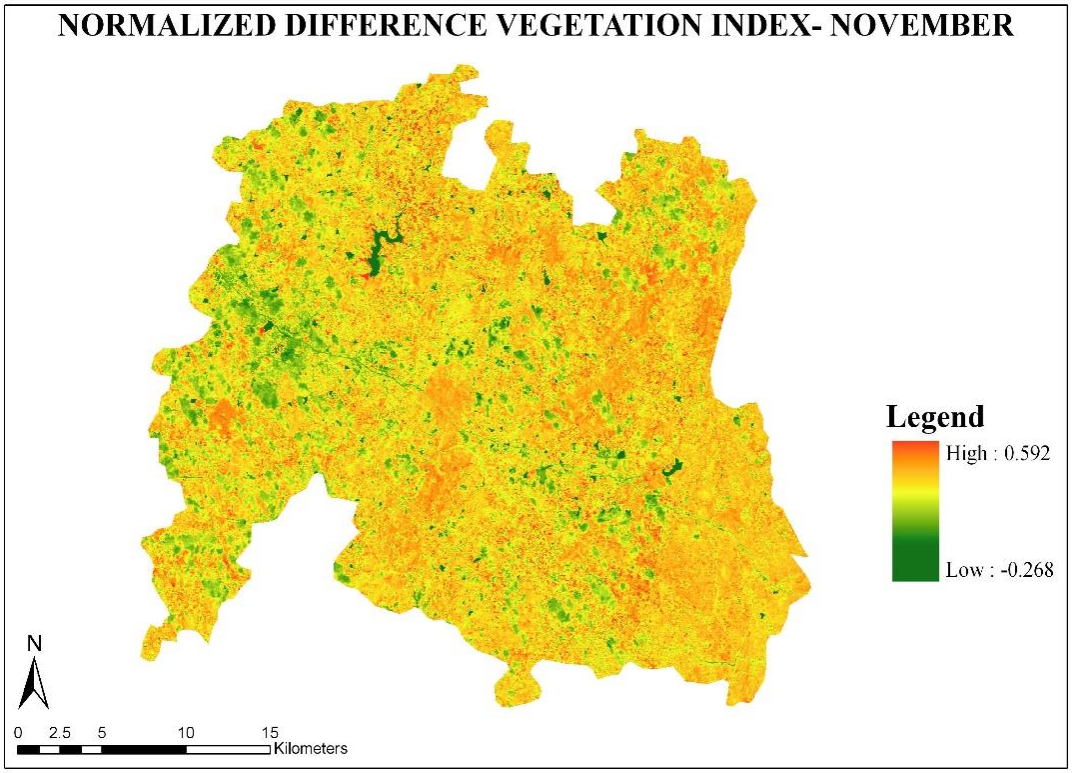

Fig - 4

Using NDVI values LSE was created for the month of April (Fig-5). The LSE of AOI ranged between 0.987 and 0.992. Highly elevated regions in the district had a more vegetative cover, hence LSE was moderate in these regions.

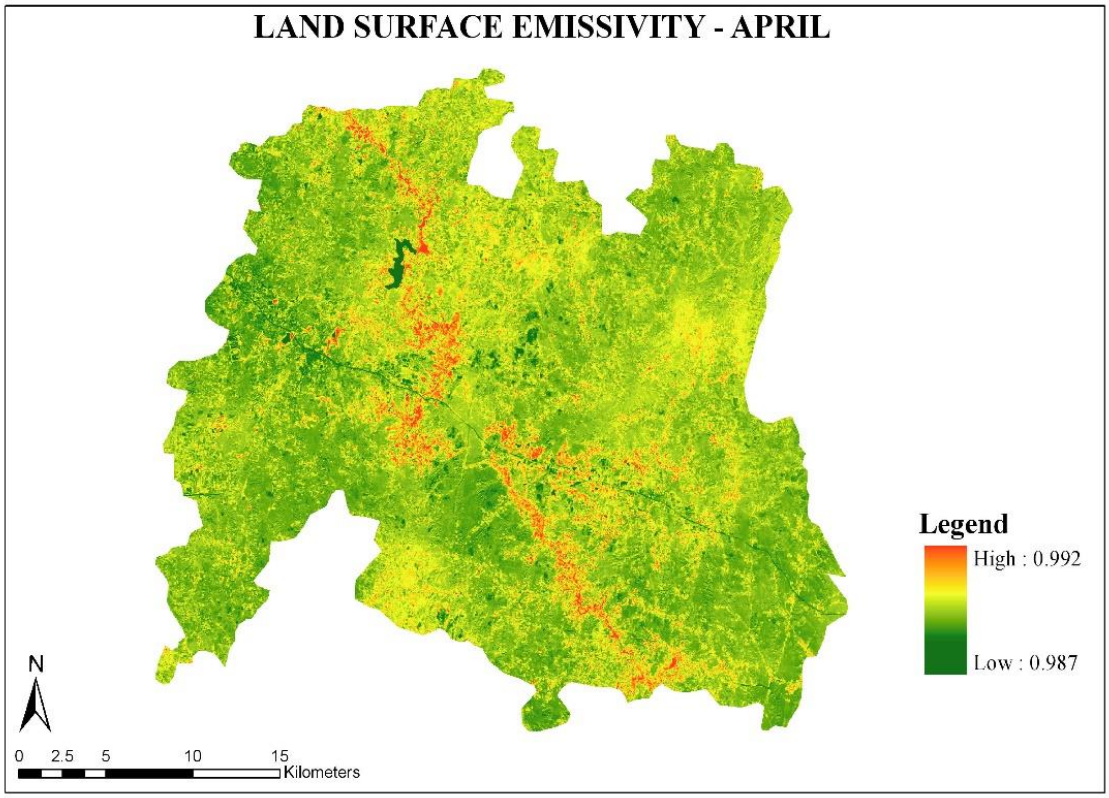

Fig – 5

Using NDVI threshold technique LSE was created for the month of November (Fig-6). The LSE of AOI ranged between 0.987 and 0.993. LSE was high in these regions.

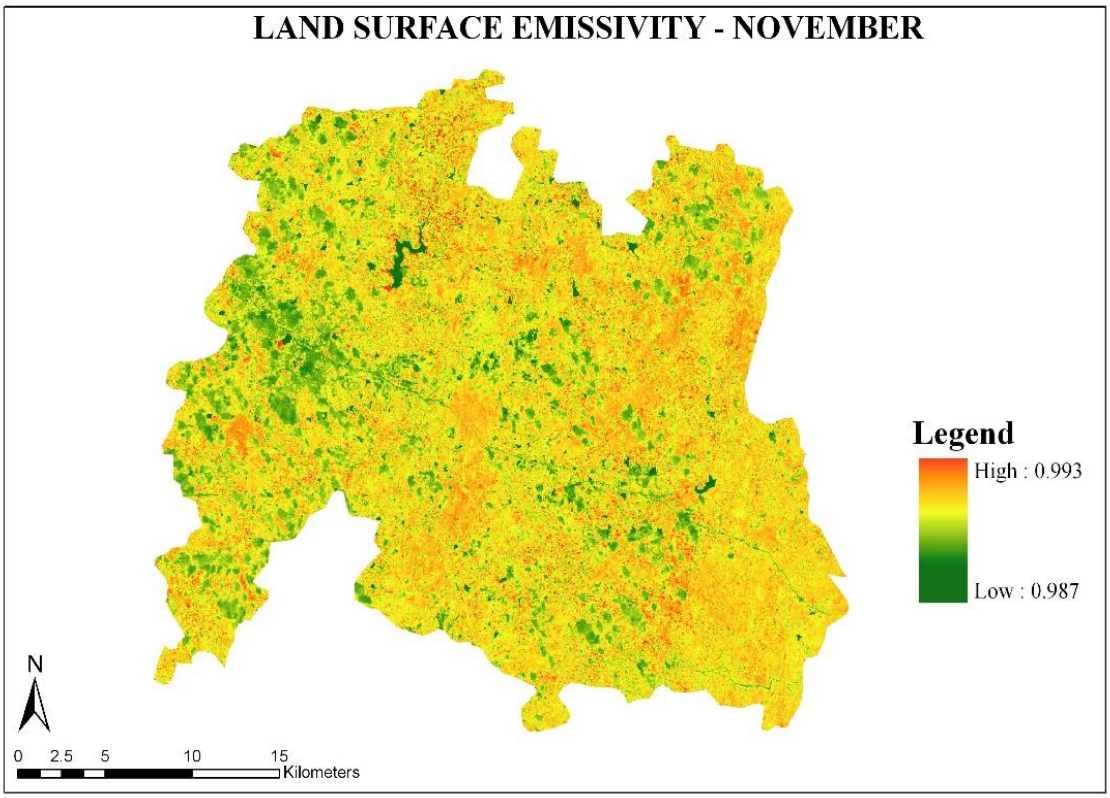

Fig - 6

The Brightness Temperature map for the month of April shows that the temperature value ranges between 24.639 to 38.208**°C** (Fig-7).

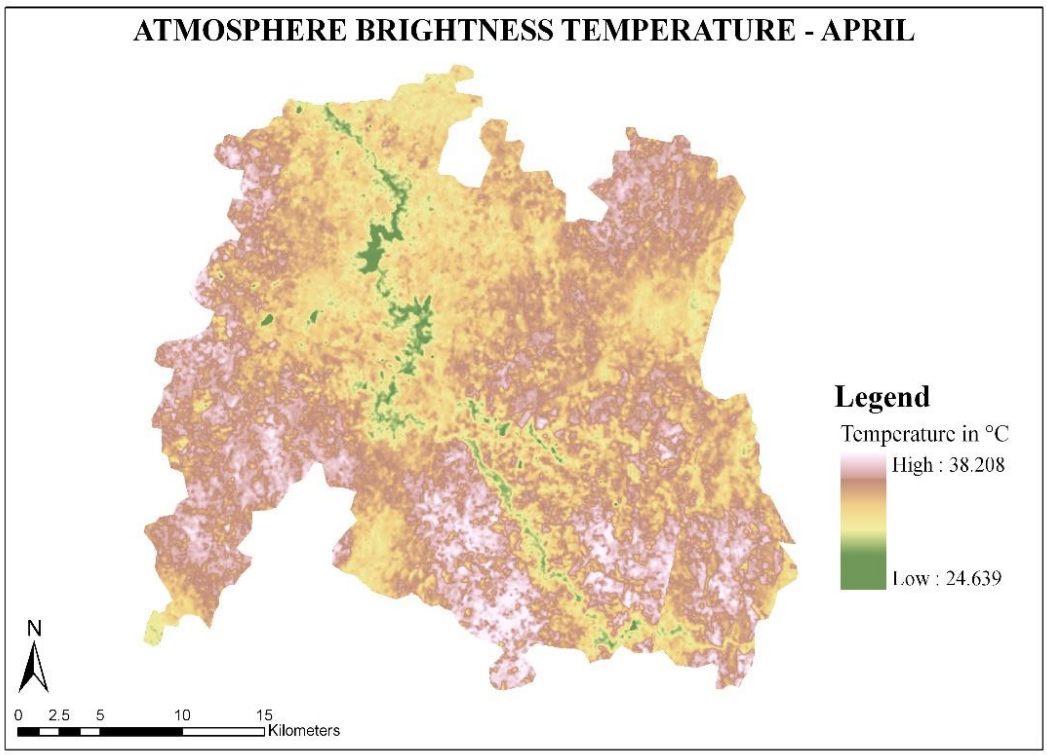

Fig - 7

The Brightness Temperature map for the month of November shows that the temperature value ranges between 15.325 to 32.125°**C** (Fig-8).

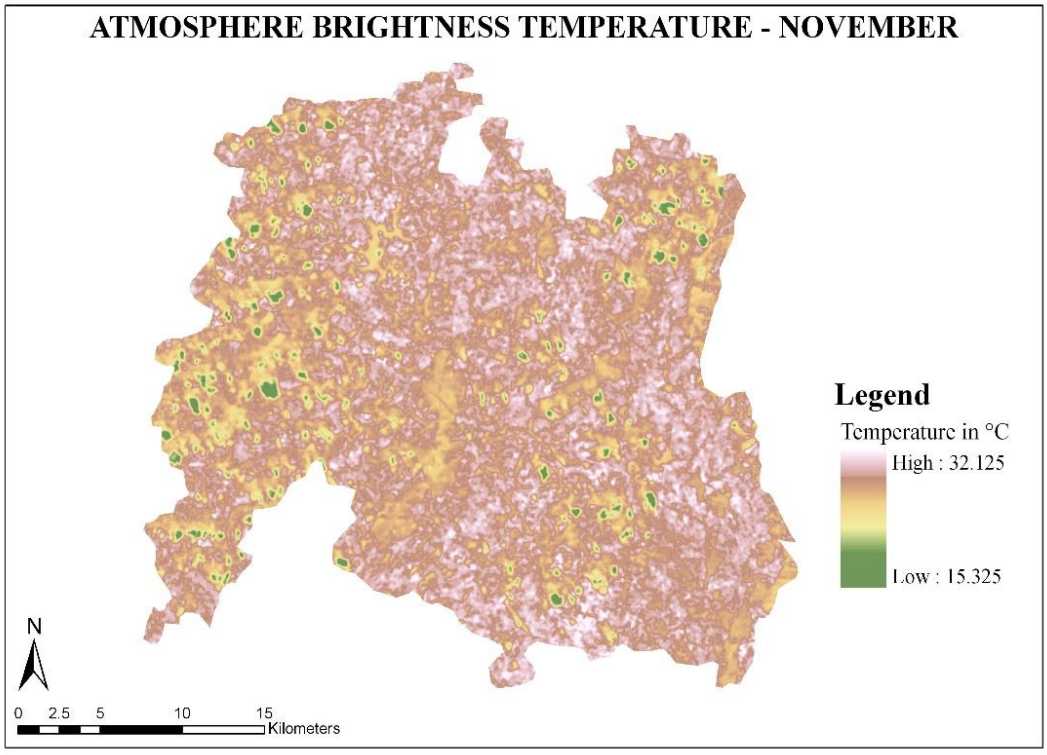

Fig - 8

Land surface map (Fig-9) has been derived using brightness temperature and LSE. LST temperature ranges and areas for the month of April are shown in table-2.

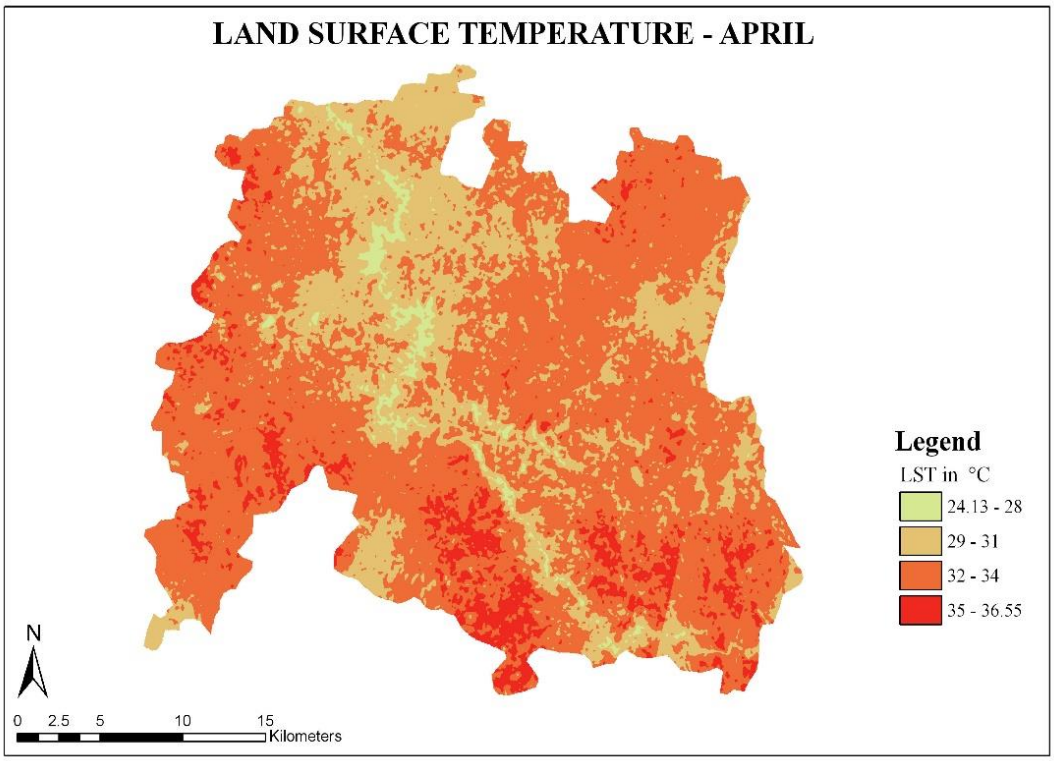

Fig - 9

Table-2

S.No	Temperature (°C)	Area (Sq.km)	Percentage (%)
1	24.13 - 28	18.94	1.98
2	29 - 31	265.67	27.76
3	32 - 34	601.21	62.82
4	35 - 36.55	71.16	7.44

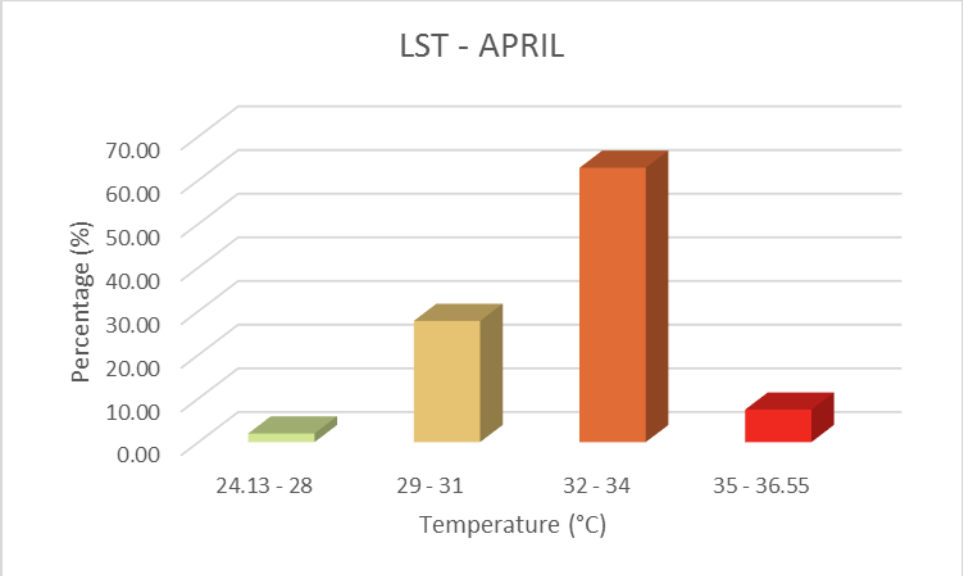

Fig - 10

Land surface map (Fig-11) has been DERIVED using brightness temperature and LSE. LST temperature ranges and areas for the month of November are shown in table-3.

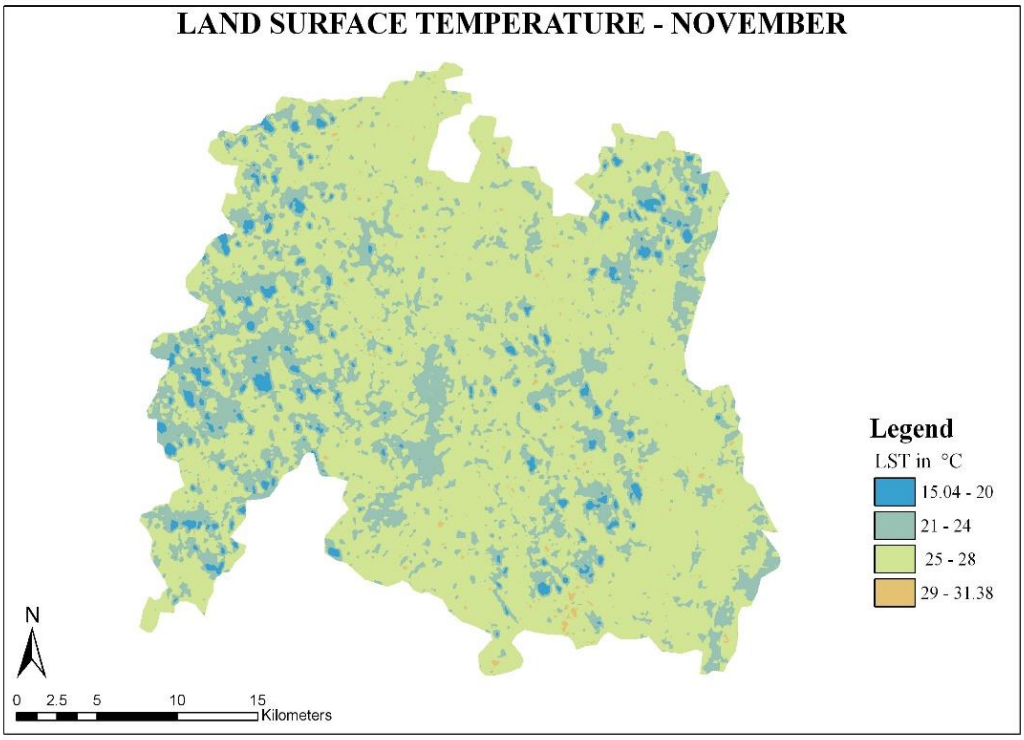

Fig – 11

Table-3

S. No	Temperature (°C)	Area (Sq.km)	Percentage (%)
1	15.04 - 20	22.48	2.35
2	21 - 24	217.72	22.75
3	25 - 28	713.12	74.52
4	29 - 31.38	3.66	0.38

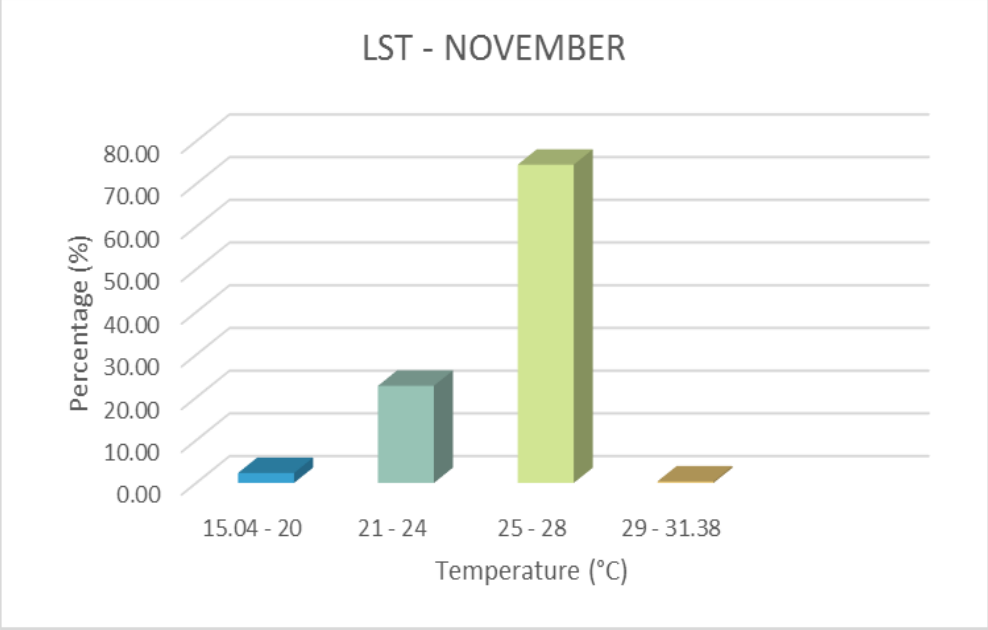

Fig-12

6. CONCLUSION

NDVI, brightness temperature, LSE, and LST of an area was determined using Arc GIS. NDVI Maps shows that vegetation is high in the month of November when compared with the month of April. Estimated LST values revel that in the month of April 62.82% of the total area, surface temperature lies in the range of 32 -34°C and in the month of November 74.52% of the total area, surface temperature lies in the range 25 – 28°C. Thus, LST can be estimated using Landsat 8 with multiband OLI and TIR images.

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