Land Surface Temperature Retrival of Landsat-8 Data Using Split Window Algorithm- A Case Study of Ranchi District

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Abstract - Land surface temperature (LST) is an important factor in global climate change, vegetation growth, and glacier. Its impact will be more in monsoon area because of failure of monsoon and uncertainty and unpredictable in rainfall. In this article we perform Land surface temperature estimation using SPLIT-WINDOW algorithm on Landsat 8 OLI (Operational Land Imager) Sensor and TIRS (Thermal Infrared Sensor) dataset of Ranchi District. TIRS sensor exhibit two thermal Band 10 and 11.SPLIT- WINDOW algorithm require brightness temperature value of both band 10 and 11 as well as land surface emissivity calculated from OLI bands (NIR AND RED) for estimation of land surface temperature.

Keywords **- Land surface temperature, Land surface emissivity, Fractional vegetation cover, Split-window, NDVI.**

I. INTRODUCTION

Land Surface Temperature (LST) means the temperature of the surface which we observe if directly contact or touch it with. It is also refer as skin temperature of the surface. When it rise it causes environmental unbalance situation like melts in glacier, vegetation, climatic condition of monsoon countries leading to unpredictable rainfall. It is measure in kelvin. Thermal infrared remote sensing technology has become one of the important means to study the thermal characteristic of land surface. Many numbers of algorithm are design by many researchers to calculate Land surface temperature like Split-Window algorithm (SW), Dual Angle algorithm (DA), Single-Channel algorithm (SC) etc. In case of Landsat 8 TIRS we have two thermal bands (10 and 11). We prefer Split-Window algorithm to estimate Land surface temperature using moderate resolution Landsat 8 bands (30m). During estimation of LST we required OLI sensor Bands (2-5) for estimation of Land Surface Emissivity (LSE) through Fractional Vegetation Cover (FVC). Split-Window algorithm combined Brightness temperature band 10 and 11 with Land Surface Emissivity (LSE) to estimate LST for each ground pixels vector. In the present study we estimate LST for entire Ranchi district.

Study Area

Ranchi is the capital of Jharkhand state is located at 23.35° N latitude and 85.33° E longitude. Its elevation from sea level is 2140 feet. It is located in southern part of Chotanagpur Pleatu. Hot weather season lasting from March to mid-June, the season of southwest monsoon rains from mid-June to October and cold-weather season from November to February. May is the hottest month.

Data And Software Used

Landsat 8 TIRS (Thermal Infrared Sensor) Band 10 and 11 and OLI (Operational Land Imaginer) sensor Band (1-9) of Ranchi District of date 4th April 2014. Thermal constant K1 and K2 and other image statistic are obtain from metadata of the image file. ERDAS IMAGINE 9.1, ARC MAP 10, ENVI 4.7.

Table-1: Metadata or statistics of Image data

Sensor	No. of Bands	Path/row
OLI	9	140/44
TIRS	2	140/44

Table-2: Thermal constant value

Band	K1	K2
10	774.89	1321.08
11	480.89	1201.14

Table-3: Split-Window coefficients value

Constant	Value
C_0	-0.268
C_1	1.378
C_2	0.183

C_3	54.300
C_4	-2.238
C_5	-129.200
C_6	16.400

[Source: Skokovic et al, 2014; Sobrino et al, 1996; 2003; Shaouhua Zhao et al, 2009]

Table-4: Emissivity values

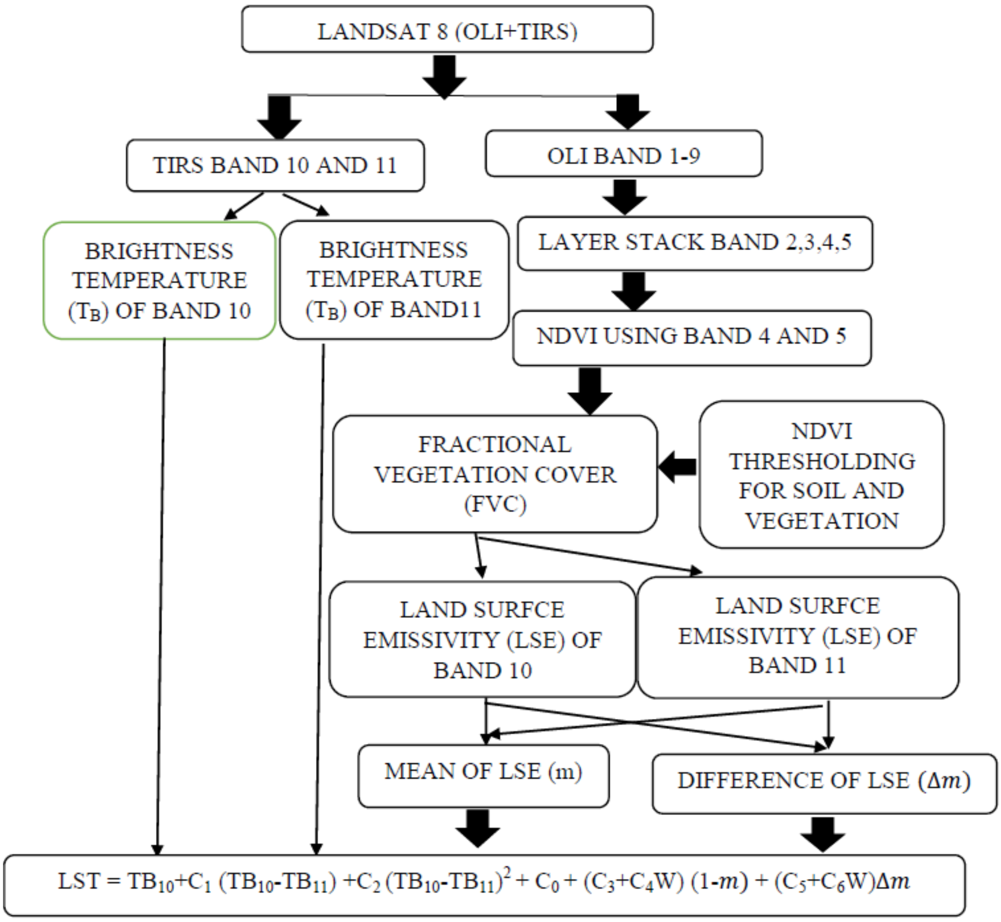
Emissivity	Band 10	Band 11
ϵ_s	0.971	0.977
ϵ_v	0.987	0.989

[Source: Skokovic et al, 2014; Sobrino et al, 1996; 2003; Shaouhua Zhao et al, 2009]

II. METHODOLOGY

Flowchart of the algorithm to be perform during LST estimation using TIRS Band 10 and 11 and OLI sensor Band 2-5 are shown in Fig-1 given as

Fig-1: Flowchart of Algorithm



Following steps are follow to perform operation are given below:

Step1: Estimation of Top of Atmospheric Spectral Radiance of TIRS Band 10 and 11 and OLI sensor of Band 2-5 individually using the algorithm given below. This algorithm transform raw image into spectral radiance image. Using ERDAS IMAGINE 9.1 Modeler we implement algorithm of equation-1 to perform task,

$$L\lambda = \left(\frac{\mathrm{Lmax-Lmin}}{\mathrm{DNmax}}\right)*\mathrm{Band} + L_{min} \quad \textbf{(1)}$$

Where,

$L\lambda$ – Top of Atmospheric Spectral Radiance in watts/ (m^2*srad*μm)

L_{max} – Maximum Spectral Radiance of respective Band

L_{min} – Minimum Spectral Radiance of respective Band

$DN_{max} = Q_{cal\ max} - Q_{cal\ min}$ = Difference of maximum and minimum calibration of sensor

Step2: Estimation of Brightness Temperature (T_B) of Band 10 and 11. Brightness Temperature is the electromagnetic radiation traveling upward from the top of the Earth's atmosphere. Thermal calibration process done by converting thermal DN values of raw thermal bands of TIR sensor into TOA Spectral Radiance and after using Brightness Temperature equation shown in equation-2 we got Brightness Temperature (TB) band as shown in Fig-2. Using ERDAS IMAGINE 9.1 Modeler we implement algorithm of equation-2.

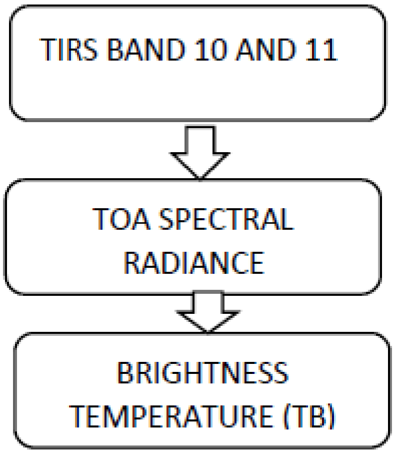


Fig-2: Flowchart of Thermal calibration process

Brightness Temperature = $T_B = \frac{K2}{\log(1+\frac{K1}{L\lambda})} - 273.15$ **(2)**

Where,
K1 and K2 – Thermal constant of Bands from metadata image file
$L\lambda$ – Top of Atmospheric Spectral Radiance layer
Step-3: Estimation of Normalized Difference Vegetation Index (NDVI) using OLI sensor optical Band after layer stacking of Band 2,3,4,5 using algorithm shown in equation-3,

$$\text{NDVI} = \frac{\text{BAND5}-\text{BAND4}}{\text{BAND5}+\text{BAND4}} \quad \textbf{(3)}$$

Range: $-1 < \text{NDVI} < +1$

Step-4: Estimation of Fractional Vegetation Cover (FVC) for an image using NDVI image obtain from Step-3 using the equation-4. Fractional Vegetation cover estimate the fraction of area under vegetation. Fig-3 show the flowchart to perform FVC. Split-Window algorithm utilize FVC to estimate Land Surface Emissivity (LSE). Using ARC MAP 10 we reclassify the NDVI layer into soil and vegetation and calculate NDVI for Soil and Vegetation and using ERDAS IMAGINE 9.1 Modeler we implement the algorithm of FVC of equation-4.

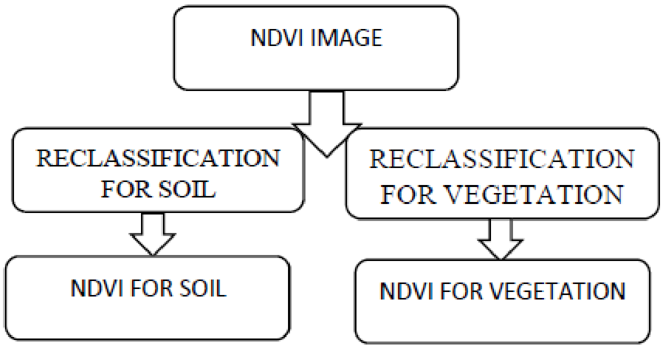


Fig-3: Flowchart for FVC

$$\text{FVC} = \frac{\text{NDVI}-\text{NDVI(SOIL)}}{\text{NDVI(VEGETATION)}-\text{NDVI(SOIL)}} \quad \textbf{(4)}$$

Step-5: Estimation of Land Surface Emissivity (LSE) from FVC layer obtain from step-4 using algorithm in equation-5. Land Surface Emissivity measure the inherent characteristic of earth surface. It measure its ability to convert thermal or heat energy into radiant energy. LSE estimation required emissivity of soil and vegetation of both Band 10 and 11 are given in Table-4. LSE of Band 10 and 11 are individually calculated.

$$\text{LSE} = \epsilon_s*(1-\text{FVC}) + \epsilon_v*\text{FVC} \quad \textbf{(5)}$$

Where,
ϵ_s = Emissivity for soil
ϵ_v = Emissivity for vegetation
FVC = Fractional Vegetation Cover
Step-6: Combination of LSE of Band10 and LSE of Band 11 obtain from step-5 through Mean and Difference in between them as shown in equation-6 & 7

$$\text{Mean of LSE} = m = \frac{LSE10+LSE11}{2} \quad \textbf{(6)}$$
$$\text{Difference of LSE} = \Delta m = LSE_{10} - LSE_{11} \quad \textbf{(7)}$$

Step-7: Estimation of Land Surface Temperature (LST) using the algorithm in equation-8 implemented using ERDAS IMAGINE 9.1 Modeler.

$$LST = TB_{10}+C_1\,(TB_{10}-TB_{11}) + C_2\,(TB_{10}-TB_{11})^2 + C_0 + (C_3+C_4W)\,(1-m) + (C_5+C_6W)\Delta m \quad \textbf{(8)}$$

Where,
TB_{10} and TB_{11} – Brightness Temperature of Band 10 and 11
C_0-C_9 – Split-Window coefficient values
m – Mean LSE
Δm – Difference of LSE
W – Atmospheric water-vapour content = 0.013 [Source: Meteorological Observatory of Dept. of Agricultural Meteorological, Ranchi Agricultural College, Birsa Agricultural University, Ranchi].

III. ANALYSIS AND DISCUSSION

Fig-4 represent NDVI layer of Ranchi district of date 4th April 2014 derived from Band 5(NIR) and Band 4(RED) of OLI sensor using ERDAS IMAGINE 9.1 Modeler .The range of NDVI is varies from 0-0.574185 (zero for negative NDVI values using condition). Increase in NDVI range from 0 to 1 indicate for healthy and green vegetation cover area. From NDVI image we perform reclassification of NDVI layer of Fig-4 for soil and vegetation separately and calculate NDVI for soil and vegetation shown in Table-5. Take the value of NDVI for soil and vegetation form Table-5 we calculate Fractional vegetation cover (FVC) using equation-4 and LSE using equation-5. We implement algorithm in ERDAS IMAGINE 9.1 Modeler as shown in Fig-5 to calculate difference and mean LSE Layer shown in Fig-6 and Fig-7. We take TIRS band 10 and 11 to estimate Brightness Temperature (T_B) in celcius using the algorithm of equation-2 shown in Fig-8 and Fig-10. From Fig-9 and 11 of statistical graph we observe that class 4 exhibit 55.78% of the total area at a temperature in between 35-40℃ from T_B of Band10 and class 3 of T_B of Band 11 exhibit maximum of 62.80% of the total area at a temperature in between 30-35.Fig-12 represent the Algorithm which we implement to estimate LST using Modeler. Fig-13 represent the final LST layer of Ranchi district on 4th April 2014. Area statistics graph of LST layer in Fig-14 proof that, it divide the whole area into two major surface temperature class of 4 and 5with statistics of 51.5 % of area under an average surface temperature of 37.5℃ in class 4 and 41.048 % of an area under an average surface temperature of 42.5℃. Remain 5.41% of an area by class 3 exhibit an average of 32.5℃. Water bodies area exhibit an average of 27.5℃. Healthy vegetation land cover area exhibit an LST in between 30-35℃.

Table-5: NDVI for Soil and Vegetation

NDVI for Soil	0.2
NDVI for Vegetation	0.574185

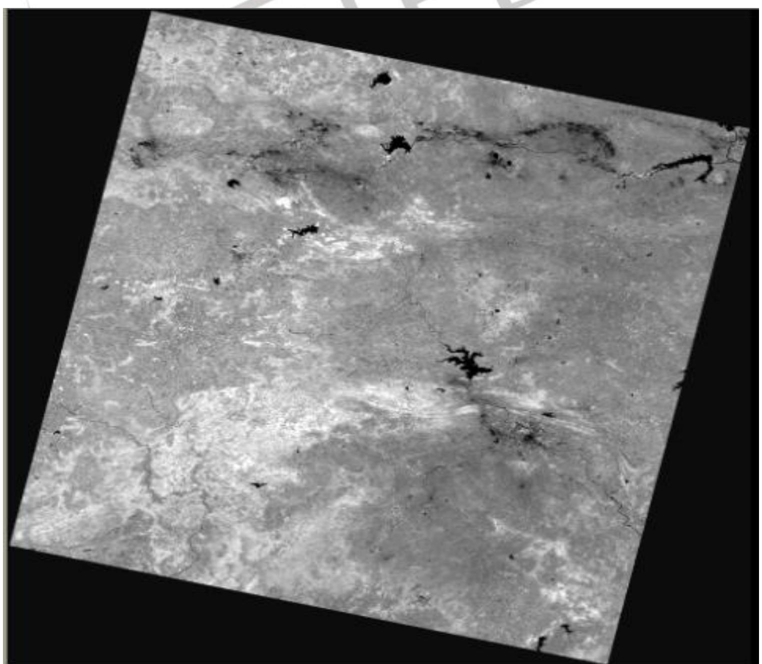


Fig-4: NDVI Layer of Ranchi district on 4th April 2014

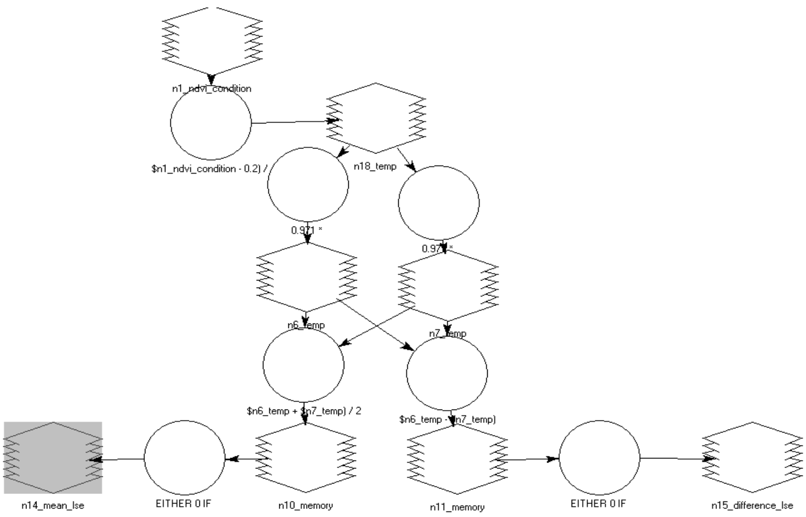


Fig-5: Algorithm for Mean and Difference LSE in Modeler

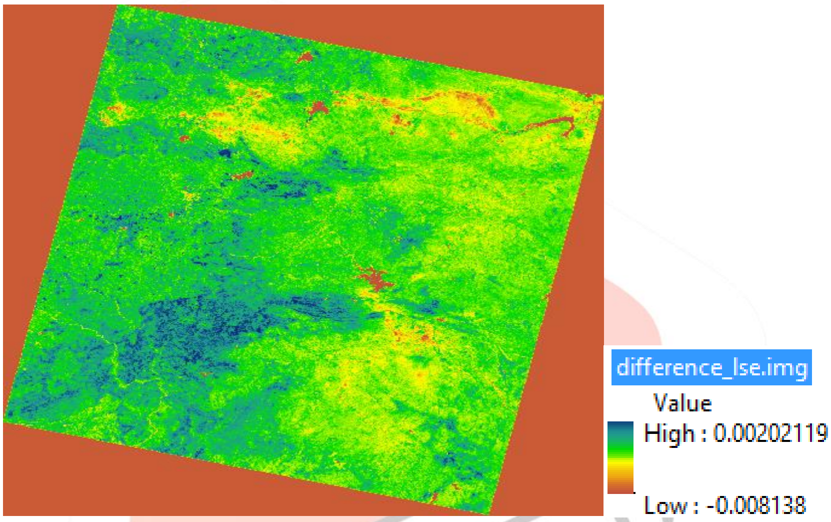


Fig-6: Difference LSE layer between Band 10 and 11

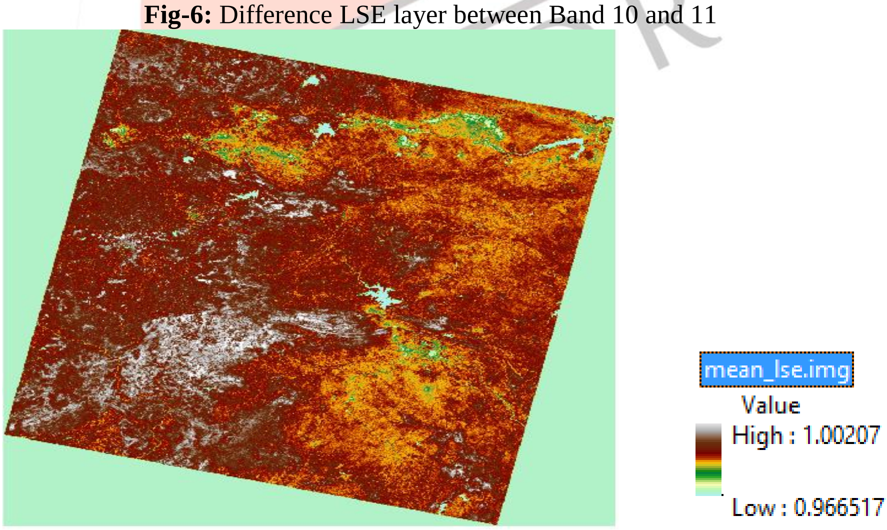


Fig-7: Mean of LSE layer between band 10 and 11

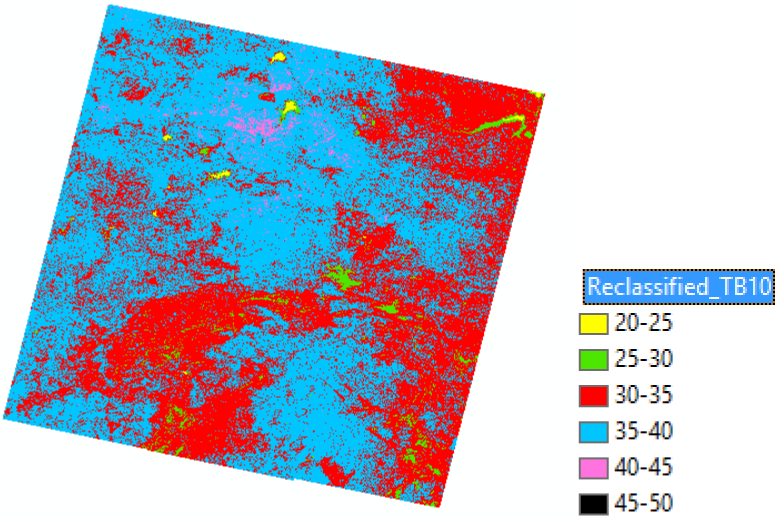


Fig-8: T_B of Band 10 with label of Temperature intervals

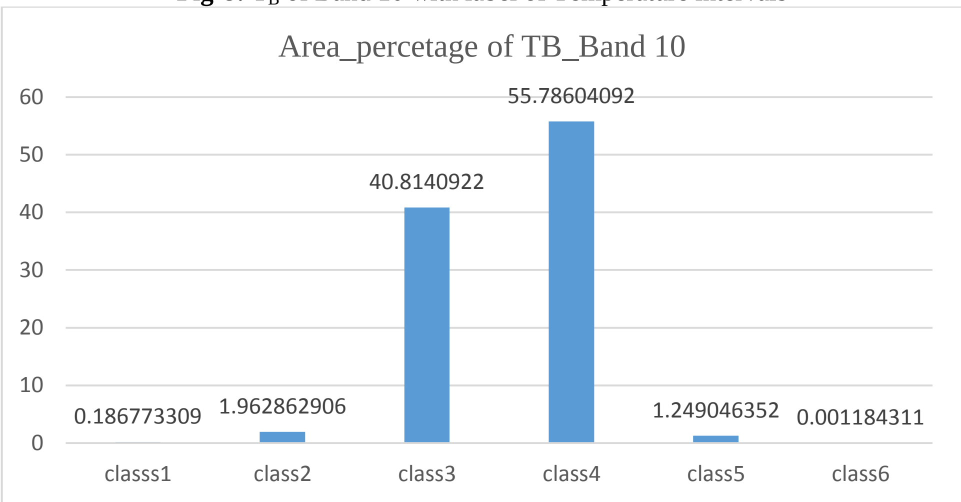


Fig-9: Area statistics of classified TB layer of Band10

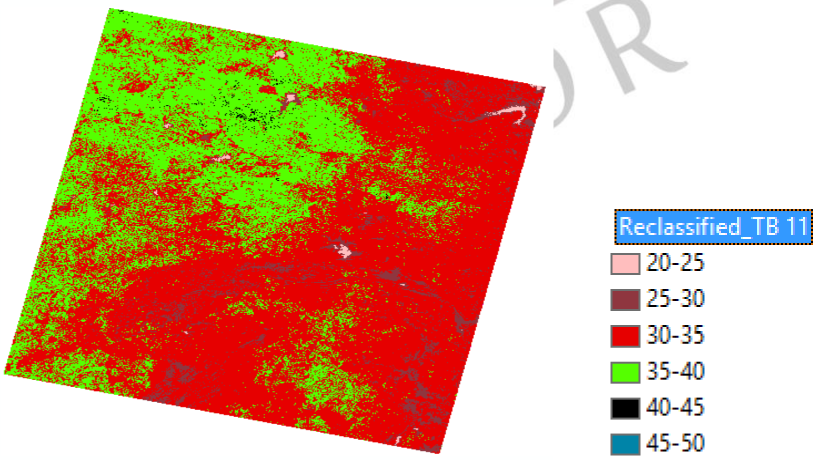


Fig-10: T_B of Band 11 with label of Temperature intervals

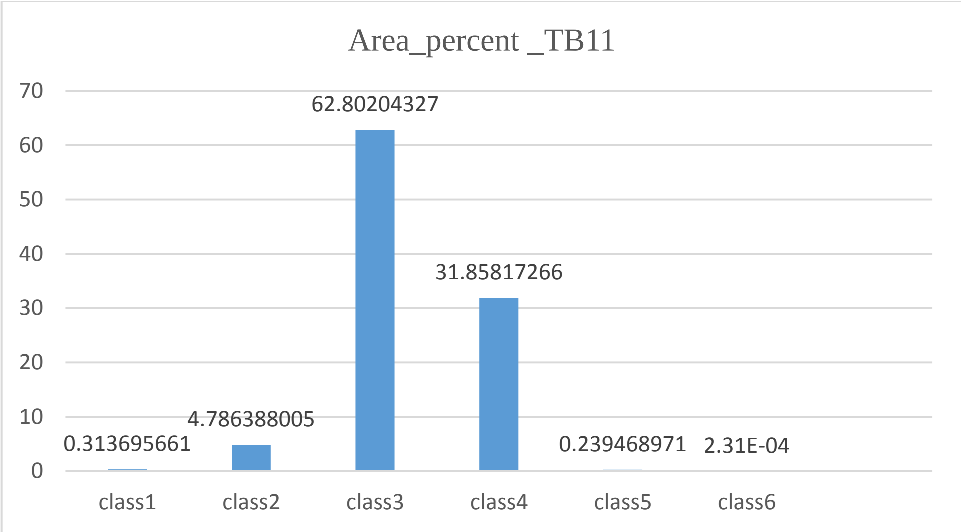


Fig-11: Area statistics of classified TB layer of Band11

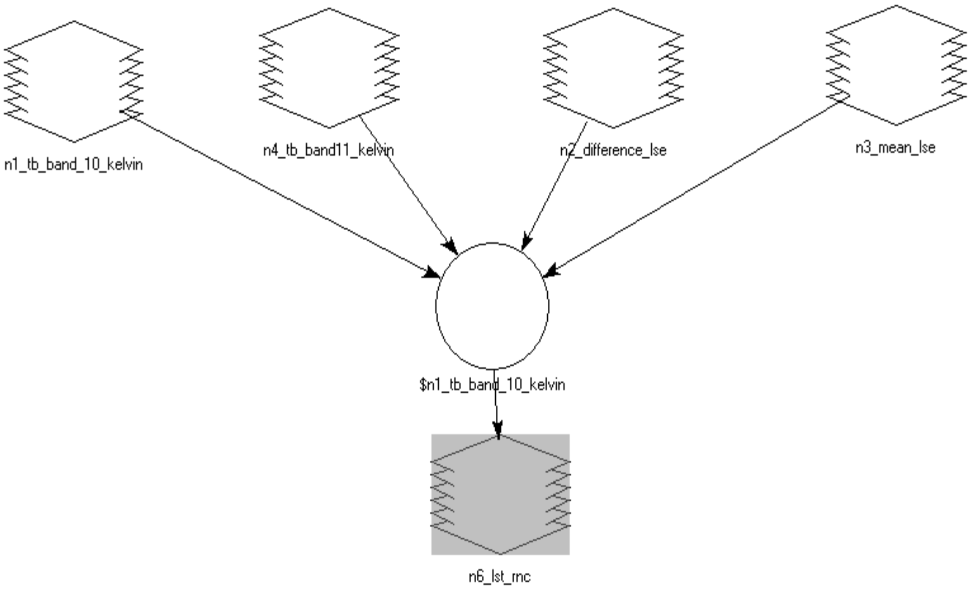


Fig-12: Algorithm of Land Surface Temperature using Modeler

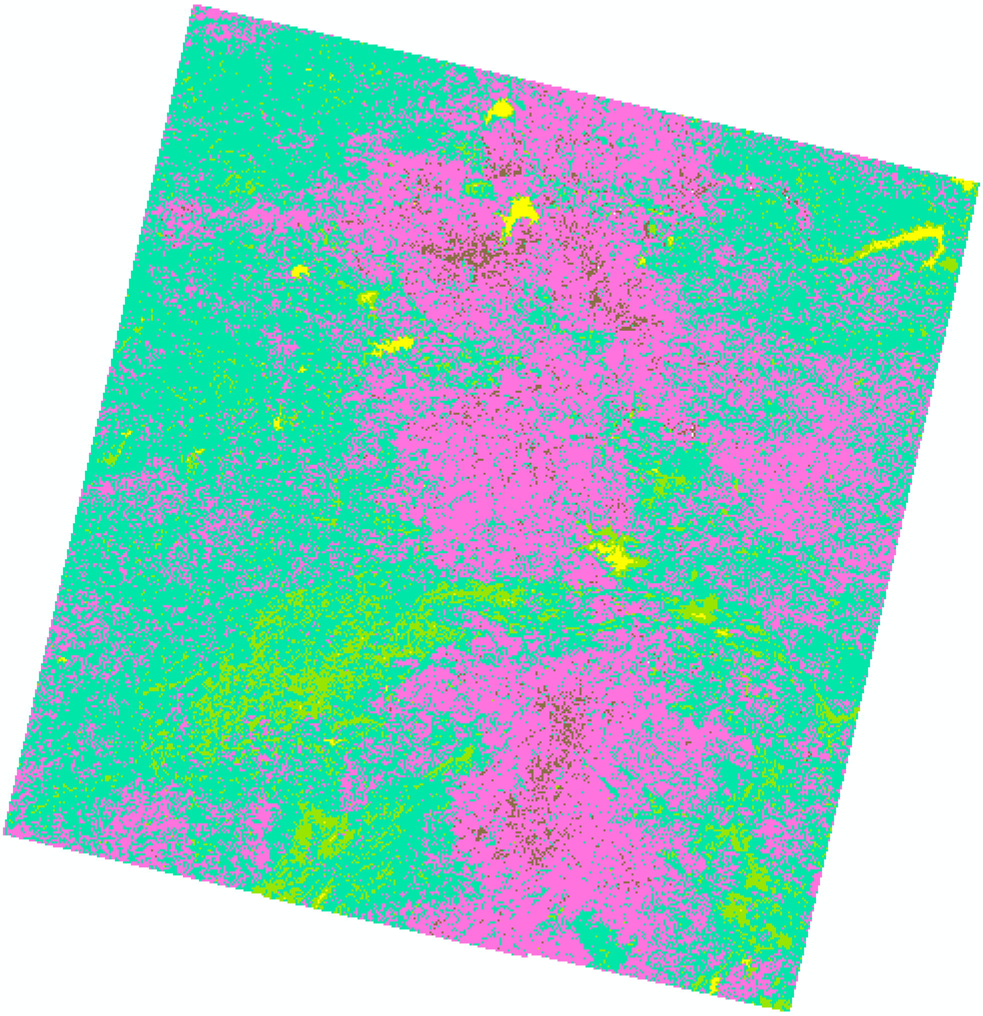


Fig-13: Land Surface Temperature Layer of Ranchi District on 4th April 2014

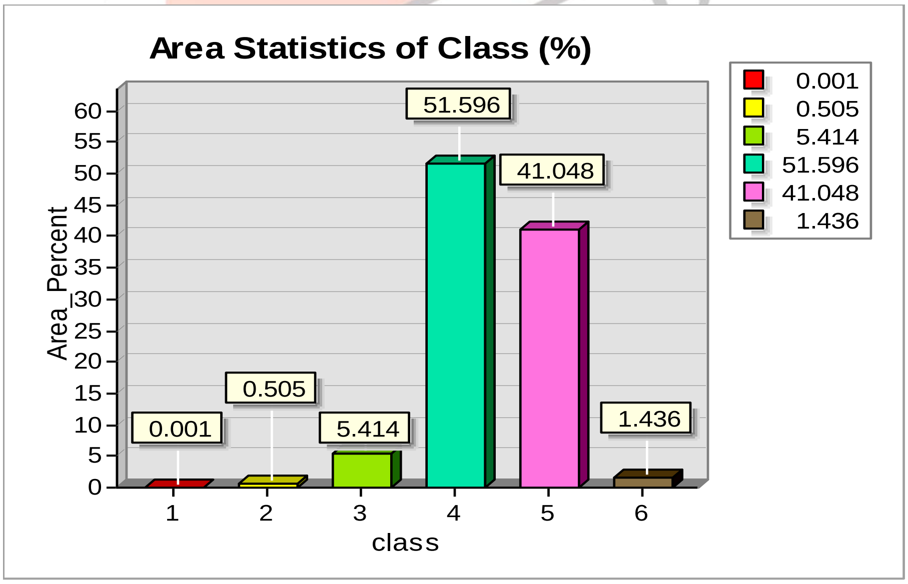


Fig-14: Graph of Area occupied (%)

Table-6: Statistics of LST layer of Fig-13

TEMPERATURE_CLASS	TEMPERATURE_INTERVAL	AVERAGE_TEMPERATURE	AREA (%)
1	20-25	22.5	0.001
2	25-30	27.5	0.505
3	30-35	32.5	5.414
4	35-40	37.5	51.596
5	40-45	42.5	41.048

6	45-50	47.5	1.436

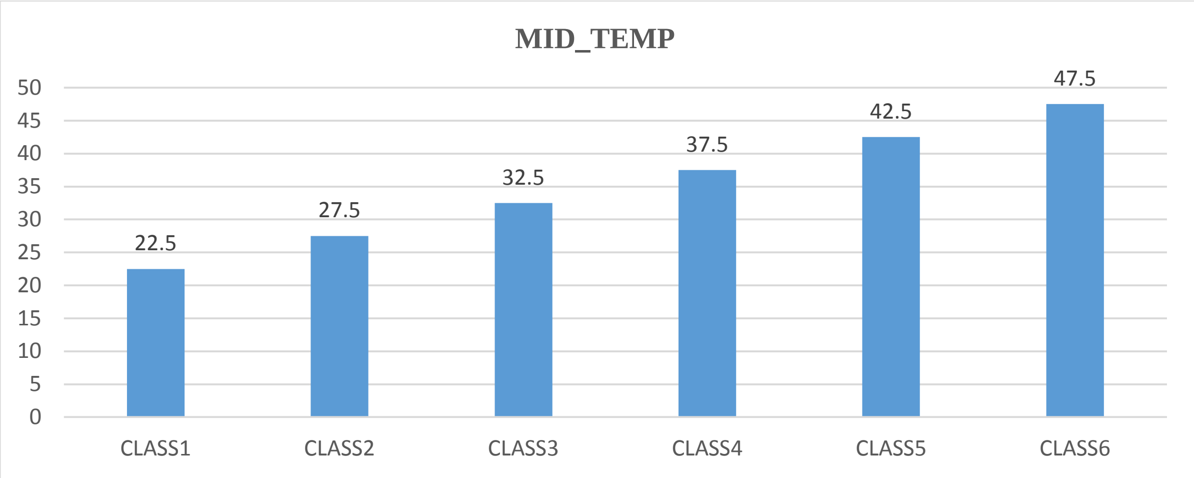


Fig-15: Graph of Mid value LST

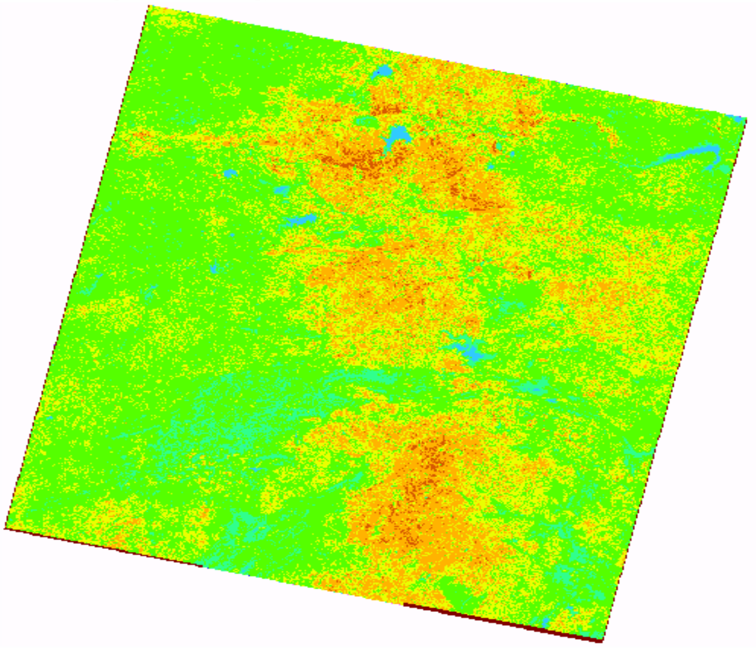


Fig-16: ¼ Standard Deviation class of LST Layer

IV. CONCLUSIONS

Split-window algorithm a dynamic mathematical tool provide the Land surface temperature (LST) information using brightness temperature of thermal bands of TIRS sensor and Land surface emissivity (LSE) factor derived from Fractional vegetation cover (FVC) of optical bands of OLI sensor. 51.596% of the total area are under temperature of 35-40℃ and other 41.048% of the total area are under temperature of 40-45℃. Overall we say around 92.644% of the total area exhibit a surface temperature of 40℃ in 4th April 2014. From Fig-15 we observe that average LST is 35℃. Thus, LST can be calculated using SW algorithm on Landsat 8 with multiband OLI and TIR images.

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