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Estimating land surface temperature in ArcGIS using Landsat-8, Hoshangabad district, (Madhya Pradesh)

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Abstract
Landsat surface temperature (LST) can be applied for finding Global Warming, vegetation suitability, glacier, urban heat temperature monitoring and many more. Landsat 8 with a payload of new instrument called the Thermal Infrared Sensors (TIRS).This devices captures the Earth's surface radiation through two bands, band 10 and band 11.
The main purpose of this paper is to automate the surface temperature mapping through various ArcGIS geoprocessing tools in this paper we perform Land surface temperature estimation using SPLIT-WINDOW algorithm on Landsat 8 TIRS (Thermal Infrared Sensor) and OLI (Operational Land Imager) Sensor dataset of Hoshangabad District. Thermal Infrared Remote Sensor exhibit two thermal Bands 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. The study also showed that there is a difference between the temperature values that has calculated from band 10 and band 11. From the resulted maps, the temperature of the North-Western side of the study area have the highest temperature values.

Keywords: Surface temperature mapping, thermal infrared remote sensors, landsat 8 data, ArcGIS, split window

1. Introduction
Surface Temperature mapping is one of the main components in Remote Sensing areas. These data have a vast usages in environmental and ecological studies as well as for spatial decision making in GIS. LST is an important factor in many areas of studies, such as global climate change, hydrological and agricultural processes, and urban land use/land cover. Calculating LST from remote sensed images is needed since it is an important factor controlling most physical, chemical, and biological processes of the Earth (Becker *et al*., 1990) [2]. This study presents an algorithm for the automatic mapping of land surface temperature from LANDSAT 8 data. Many researchers had estimated LST using satellite image (A. Rajeshwari and N. Mani, 2014; Barsi *et al*., 2014; Becker *et al*., 1990; Latif, 2014, Barsi *et al*., 2014, Sameen *et al*., 2014; Ugur *et al*., 2016; Shrivastava *et al*., 2009; Liu *et al*., 2012; Jamneez *et al*., 2014; USGS 2013) [6, 2, 1, 4, 7, 5, 11].
In the present study LST was estimated for the Hoshangabad district using two TIR bands and four OLI bands. The major objectives of the study are to find the brightness temperature using band 10 and band 11 of TIR, calculate the LSE using PV and NDVI threshold technique and estimate the LST of Hoshangabad district using Split-Window (SW) algorithm. Split-window algorithm a dynamic mathematical tool provide the Land surface temperature (LST) information using brightness temperature of thermal bands of TIRS sensor.

2. Study Area
The present work is carried out of Hoshangabad District. Hoshangabad district lies between latitudes 22º15'to 23º00' N and longitudes 77º15' to78º42' E in part of Survey of India toposheet Nos. 55F & 55J.The district has an covered total area about 5408.23 km²(fig 1.) Physiographically, the district consist of Satpura range in the south, alluvial plain in the middle. Geologically, the district are consist of upper Vindhyan group, lower Gondwana group, alluvium and Deccan Traps etc.

The entire district is drained by Narmada River and its tributaries. The climate of Hoshangabad district is characterized by a hot summer and general dryness except during the south west monsoon season.

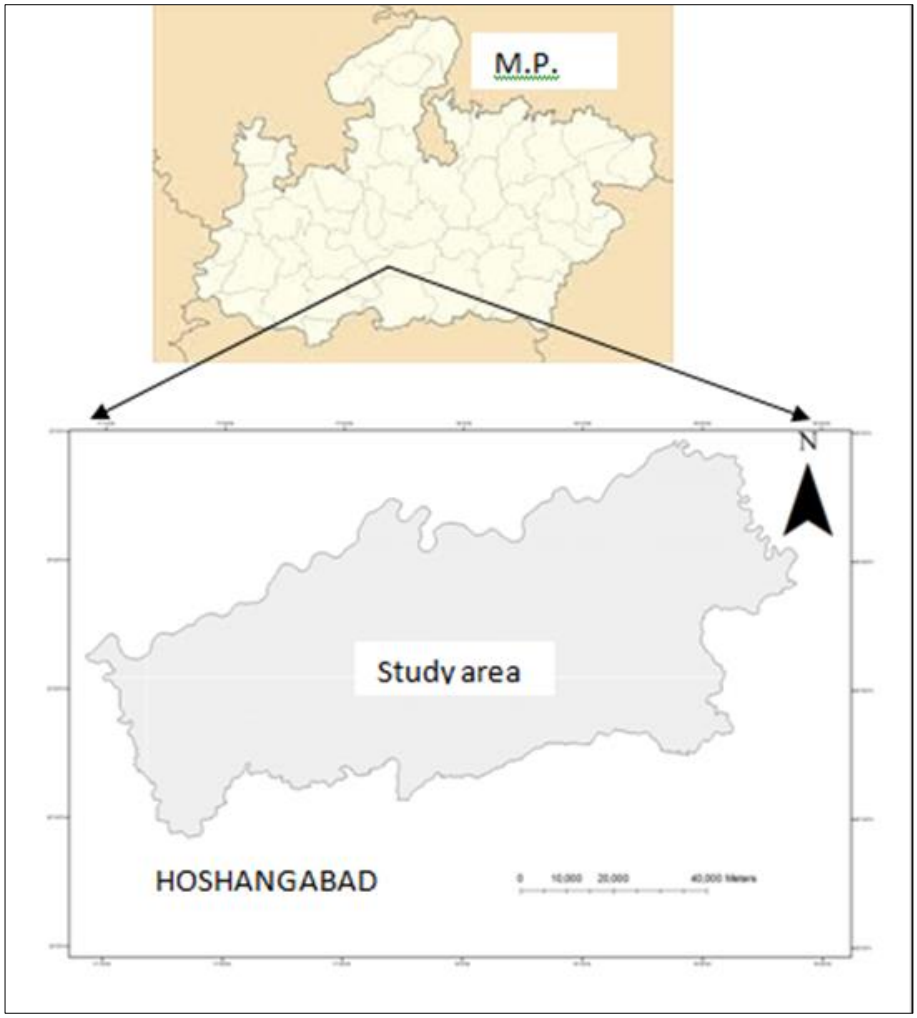

Fig 1: Location map of the study area

3. Data and Software used

Landsat 8 data were downloaded using the USGS website. The process is done by using ARC GIS Tools raster calculator. In the present study, the TIR bands 10 and 11 were used to estimate brightness temperature of the Hoshangabad district of 19th of October 2015(fig.2). Landsat 8 provides metadata of the bands such as thermal constant, which can be used for calculating various algorithms like LST. Thermal constant K1 and K2 and other image statistic are obtain from metadata of the image file.

The details of the Landsat satellite images for the present study are given in the table 1 and table 2 below.

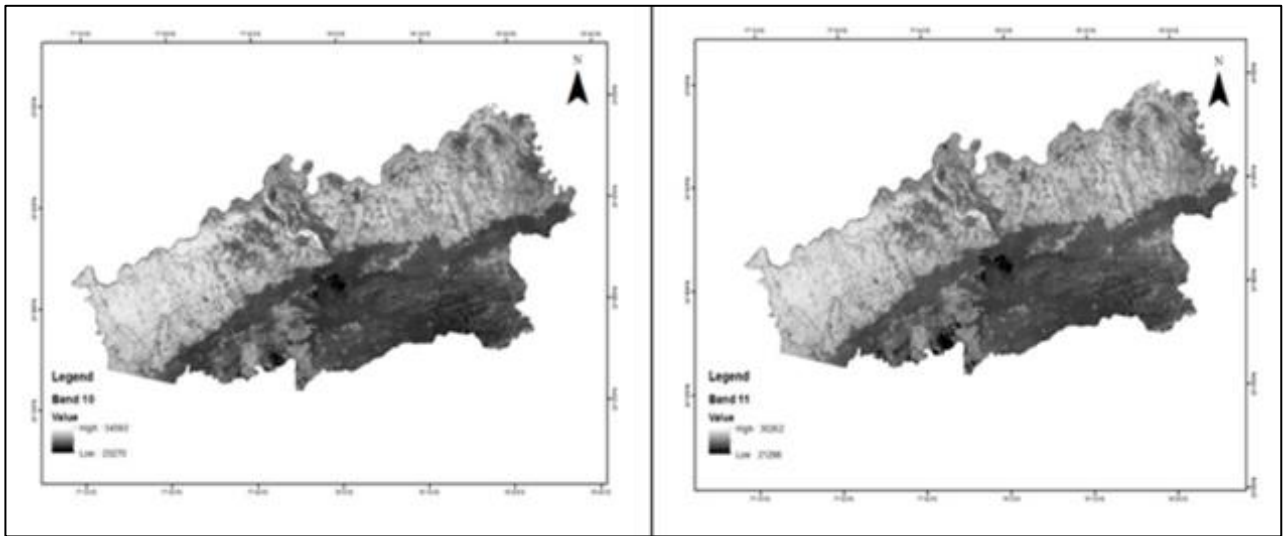

Fig 2: Landsat 8 image of band 10 and 11 of the study area.

Table 1: Landsat 8 TIRS (Thermal Infrared Sensor) image

Satellite Data	Date acquired	Sensor	Bands	WRS_ PATH/ WRS_ROW	Resolution (m.)
Landsat 8	19-10-2015	TIR	10 and 11	145/044	100
		OLI	2,3,4,5	145/044	30
Scene Centre Time	"05:14:18.1513487Z"				

Table 2: Statistics of Landsat Image data

	BAND 10	BAND 11
Radiance Multiplier(ML)	0.0003342	0.0003342
Radiance Add(AL)	0.1	0.1
K1(Thermal Constant)	774.89	480.89
K2 (Thermal Constant)	1324.08	1201.14

4. Methodology: The Methodology flowchart of the algorithm to be perform during LST estimation using TIRS Band 10 and 11 and OLI sensor Band 4-5 are shown in Fig-3 and fig.4 given as:

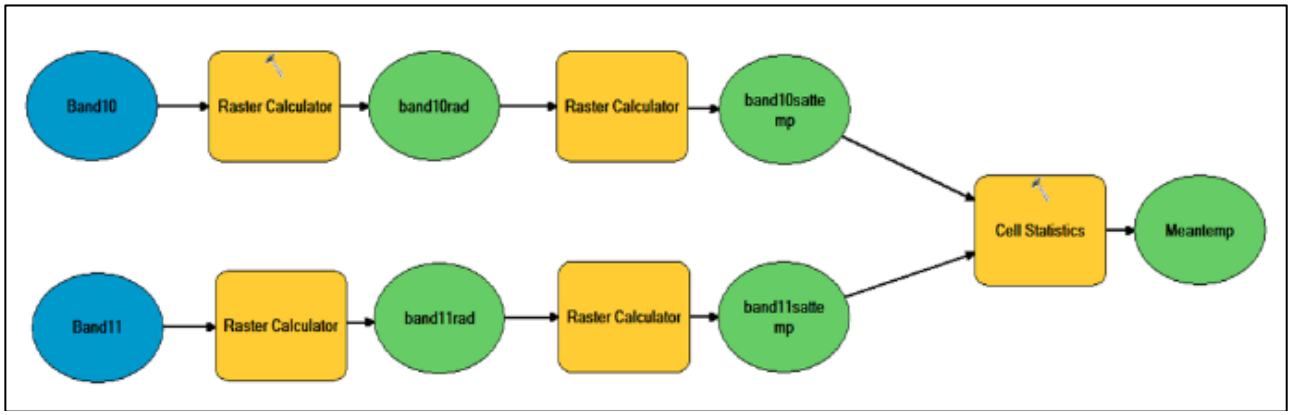

Fig 3: The Model of mean Temperature Calculator in ArcGIS

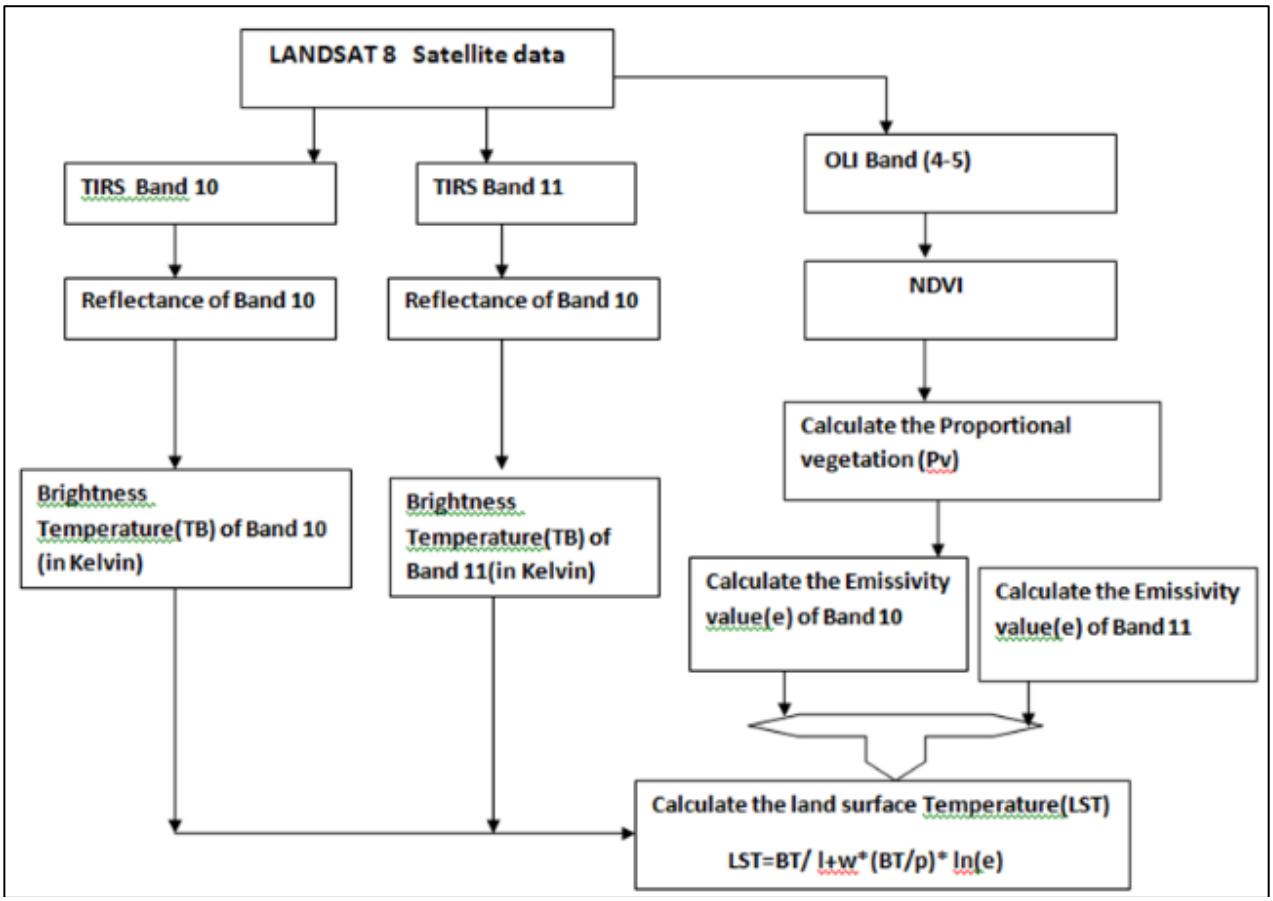

Fig 4: Methodology used for Calculation of land surface temperature in the present study

The process is done by using ARC GIS Tools. All these steps are done by raster calculator tools (Table 6). The integration of ArcGIS software makes this task quite easy because of the effective spatial analyst of these software.

Table 6: Process of estimating land surface temperature following six steps in ArcGIS

First step : Conversion to TOA Radiance:	Thermal infrared remote sensor(TIRS) data converted to spectral radiance(L_λ) using the radiance rescaling factors provided in the metadata file by using the given formula below: $L_\lambda = M_L Q_{cal} + A_L$ (1) where: L_λ = TOA spectral radiance (Watts/(m2 * srad * μm)) M_L = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number) A_L = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number) Q_{cal} = Quantized and calibrated standard product pixel values (DN)
SECOND STEP: Conversion to At-Satellite Brightness Temperature	Top of Atmospheric Spectral radiance(L_λ) data converted to brightness temperature (T_B)using the thermal constants(K1 AND K2) provided in the metadata file: $T_B = \frac{K_2}{ln(\frac{K_1}{L_\lambda}+1)}$ (2) where: T_B = At-satellite brightness temperature (K) L_λ = Top of Atmospheric (TOA) spectral radiance (Watts/(m2 * srad * μm)) 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)
THIRD STEP: Calculation of NDVI value	Estimation of Normalized Difference Vegetation Index (NDVI) using OLI sensor optical Band after layer stacking of Band 4,5 using algorithm shown in equation-3 NDVI= BANDS 5-BAND 4/BANDS 5+BANDS 4 (3) Range: -1 < NDVI < + 1
/FOURTH STEP: Calculation of Pv	Proportion Vegetation: Pv was estimated using NDVI Threshold method. Pv= (NDVI -NDVI min /NDVI max- NDVI min)^2 (4)
FIFTH STEP: Calculation of Emissivity value	Deriving Land surface emissivity: e=0.04+Pv+0.996 (5)
SIXTH STEP: Estimation of LST	Land surface temperature (LST): To find LST it is necessary to calculate the LSE of the area. LST=BT/ 1+w*(BT/p)* ln(e) (6) Where, BT= At -satellite brightness temperature w= wavelength of emitted radiance(11.5um) p= h*c/s(1.438*10^-2mk) h= Planks Constant(6.626*10^ 34 Js) s= Boltzmann Constant(1.38*10^ 23 J/k) c= Velocity of light(2.998*10^ 8 m/s p= 14380

5. Result and Discussions

LST can be calculated using SW algorithm on Landsat 8 with multiband OLI and TIR images. We take Landsat- 8 TIRS band 10 and 11 to estimate Brightness Temperature (TB) in Celsius using the algorithm of equation 2. Split-window algorithm a dynamic mathematical tool provide the Land surface temperature (LST) information using equations 1 to 6 brightness temperature of thermal bands of TIRS sensor and Land surface emissivity (LSE) factor derived from proportional vegetation cover (Pv) of optical bands of OLI sensor. Fig-5 represent the final Land Surface Temperature (LST) map of Hoshangabad district on 19 october 2015. Figure 6 water bodies land cover area exhibit an LST in between 27.5 degree Celsius to 38.4 Celsius.

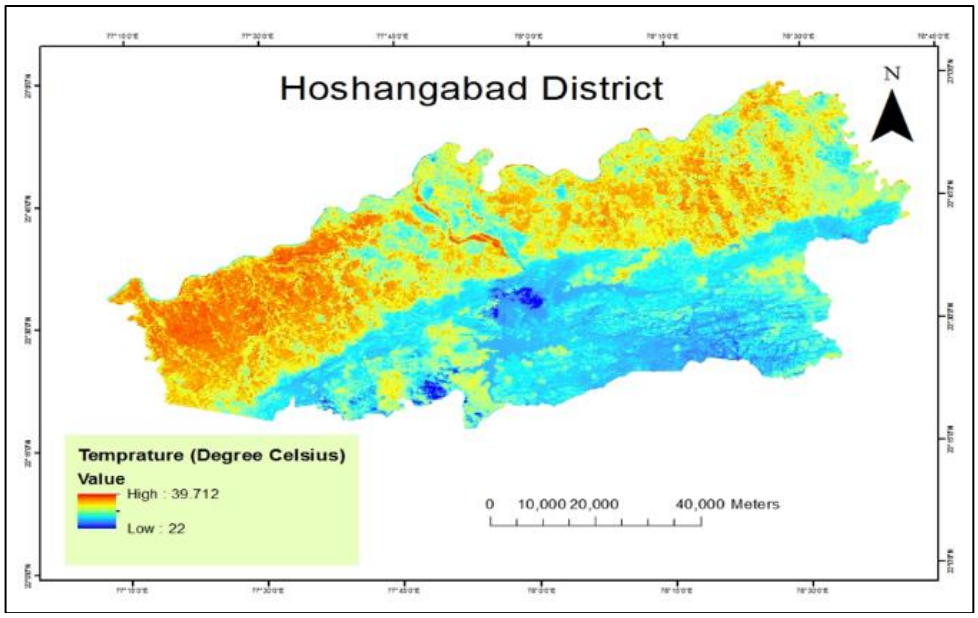

Fig 5: Spatial distribution of land surface temperature over the study area using Landsat-8TIRS.

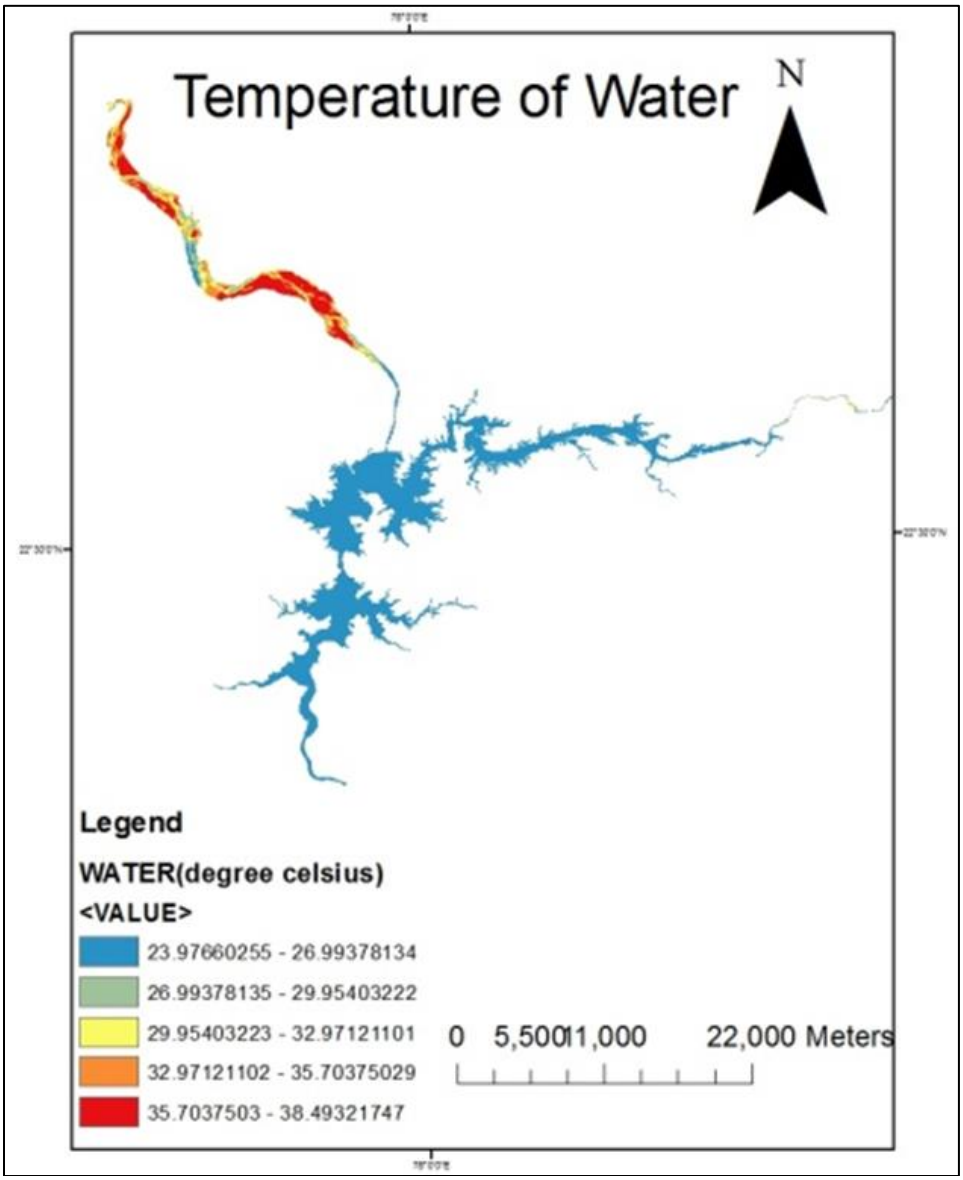

Fig 6: Water bodies land surface temperature map

6. Conclusion

Split-window algorithm a dynamic mathematical tool provide the Land surface temperature (LST) information .LST can be calculated using SW algorithm on Landsat 8 with multiband OLI and TIR images. Landsat surface temperature (LST) can be find out for vegetation, water bodies, urban heat areas and many more. The study clearly revealed that as the district had more vegetative cover in hilly regions the LST in southern part was low and the northern plains with barren lands, uncultivable land and urban areas experienced high LST.

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