ESTIMATION OF LAND SURFACE TEMPERATURE OF DINDIGUL DISTRICT USING LANDSAT 8 DATA

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Abstract

Land Surface Temperature (LST) is an important phenomenon in global climate change. As the green house gases in the atmosphere increases, the LST will also increase. This will result in melting of glaciers and ice sheets and affects the vegetation of that area. Its impact will be more in the monsoon areas, because the rainfall is unpredictable, failure of monsoon and there will be heavy down pour of rainfall. LST can be estimated through many algorithms viz., Split-Window (SW), Dual-Angle (DA), Single-Channel (SC), Sobrino and Mao. With the advent of satellite images and digital image processing software, now it is possible to calculate LST. In this study, LST for Dindigul District, Tamil Nadu, India, was derived using SW algorithm with the use of Landsat 8 Optical Land Imager (OLI) of 30 m resolution and Thermal Infrared Sensor (TIR) data of 100 m resolution. SW algorithm needs spectral radiance and emissivity of two TIR bands as input for deriving LST. The spectral radiance was estimated using TIR bands 10 and 11. Emissivity was derived with the help of NDVI threshold technique for which OLI bands 2, 3, 4 and 5 were used. The output revealed that LST was high in the barren regions whereas it was low in the hilly regions because of vegetative cover. As the SW algorithm uses both the TIR bands (10 and 11) and OLI bands 2, 3, 4 and 5, the LST generated using them were more reliable and accurate.

Keywords: *Land surface temperature, Split-window algorithm, OLI, TIR, NDVI.*

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1. INTRODUCTION

Land Surface Temperature (LST) can be defined as the temperature felt when the land surface is touched with the hands or it is the skin temperature of the ground [1, 2, 3]. LST is the temperature emitted by the surface and measured in kelvin. It was greatly affected by the increasing green house gases in the atmosphere. As it rises, it melts the glaciers and ices sheets in the polar region. Thus it leads to flood and sea level rise. Increase in LST also affects the climatic condition of the monsoon countries leading to unpredictable rainfall. The vegetation in the entire Earth surface will be affected by this. Land use/ Land cover (LU/LC) of an area can be used for estimating the amount of LST. The natural and anthropogenic activities change the LU/LC of an area. This also influences LST of that area. As its value changes the local climate of the area also changes. It is an important phenomenon to be investigated. Hence, many researchers had calculated LST using various algorithms and techniques.

Before the invention of Earth Observation Satellites (EOS), it was hard to estimate the LST of an area. Generally, it was calculated for a particular set of sample points and interpolated into isotherms to generalize the point data into area data. Now with the advent of satellites and high resolution sensors it is possible to estimate LST spatially. It can be calculated for a region at a stretch with the use of thermal infrared bands supplied by satellites. Landsat 8 comes with two different sets of images from Operation Land Imager (OLI) sensor with nine bands (band 1 to 9) and Thermal Infrared sensor (TIR) with two bands (band 10 and 11).

1.1 Literature Reviewed

LST was generated using MODIS (31 and 32 bands) and ASTER data of same date and time for one of the semi-arid region in Iran. LST output of MODIS exactly matches with the ASTER output [4]. Mono-window and single channel algorithm were used to estimate LST for Alashtar city, Iran. Emissivity was calculated using NDVI and supervised classification method of LU/LC. LST was compared with in situ and the result showed a positive correlation with NDVI and LU/LC method [5]. NDVI was found for four different years in Kunsan city Chollabuk_do, Korea. Using NDVI threshold technique LST was derived. The output of LST was compared with the NDVI output and a positive correlation was found in between them. Changes over period was also assessed and found that LST was increasing [6]. LST and NDVI were estimated using Landsat 7 image. The Fractional Vegetation Cover (FVC) for each pixel was calculated and it was used in LST analysis. A correlation study was conducted between LST and NDVI data. The output revealed that there was a strong positive correlation between them and the methodology is more feasible to estimate NDVI and surface emissivity [7].

Single –Window algorithm for estimating LST was adjusted for Landsat 8 data for better accuracy. The basic inputs for SW algorithm were brightness temperature and Land Surface Emissivity (LSE). The adjusted SW algorithm's accuracy was estimated using MODTRAN 4.0 software. The study was conducted in the northern Negev Desert, Israel [8]. Sobrino and Mao methods were used individually for retrieving LST with MODIS data in Hebei and Shanxi, North China Plain. The maximum, minimum and mean of Sobrino and Mao LST methods were cross checked with the standard LST values and found that Sobrino output range greater while Mao method had less value than standard LST. Hence, a combined method of Sobrino and Mao was evolved as Sobmao method. It is as accurate as Sobrino and simple to use [9]. Along-Track Scanning Radiometer-2 (ATSR-2) data was processed in MODTRAN 3.5 simulations. Split-Window, dual-angle and mixed structures algorithms were used to generate LST and Sea Surface Temperature (SST) in a part of New South Wales. The dual-angle algorithm has low sensitive to aerosol effects [10].

Thus many researchers had estimated LST using satellite image. A number of algorithms were developed and adopted by them to estimate LST. Some of the frequently used algorithms are Split-Window (SW), Sobrino, Mao, Dual-Angle, and Sobmao. Most of the studies were done for urban areas and arid and semi-arid regions and in many of the studies, single thermal band was used. In the present study LST was estimated for the entire 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 NDVI threshold technique and estimate the LST of Dindigul district using Split-Window (SW) algorithm.

1.2 Study Area

Dindigul district is one of the drought prone districts in Tamil Nadu State, India. The district lies between 10°0' 50" N to 10°50'35" N latitude and 77°15'53"E to 78°21'2"E longitude. The district consists of Palani and Kodaikanal hills in the south west, a few small hills viz., Sirumalai and Karanthmalai in the south east. Northern part of the district is undulating plain and majority of the area was under rainfed cultivation. Due to frequent failure of monsoon, the district faces severe drought since 2012. Hence, this district has been selected purposively for the present study.

1.3 Data and its Source

Landsat 8 is one of the Landsat series of NASA. The data of Landsat 8 is available in Earth Explorer website at free of cost. In the present study, the TIR bands 10 and 11 were used to estimate brightness temperature and OLI spectral bands 2, 3, 4 and 5 were used to generate NDVI of the study area. The district was covered in four tiles. Landsat 8 provides metadata of the bands such as thermal constant, rescaling factor value etc., which can be used for calculating various algorithms like LST.

Table – 1: Metadata of Satellite Images

Sensor	No. of Bands	Resolution (m)	Path/ Row	Date of Acquisition
OLI	9	30	143/053 &143/052	24th March 2014
TIR	2	100		

Table – 2: K1 and K2 Values

Thermal Constant	Band 10	Band11
K1	1321.08	1201.14
K2	777.89	480.89

Table - 3: Rescaling Factor

Rescaling Factor	Band 10	Band 11
M_L	0.000342	0.000342
A_L	0.1	0.1

2. METHODOLOGY

2.1 Flowchart

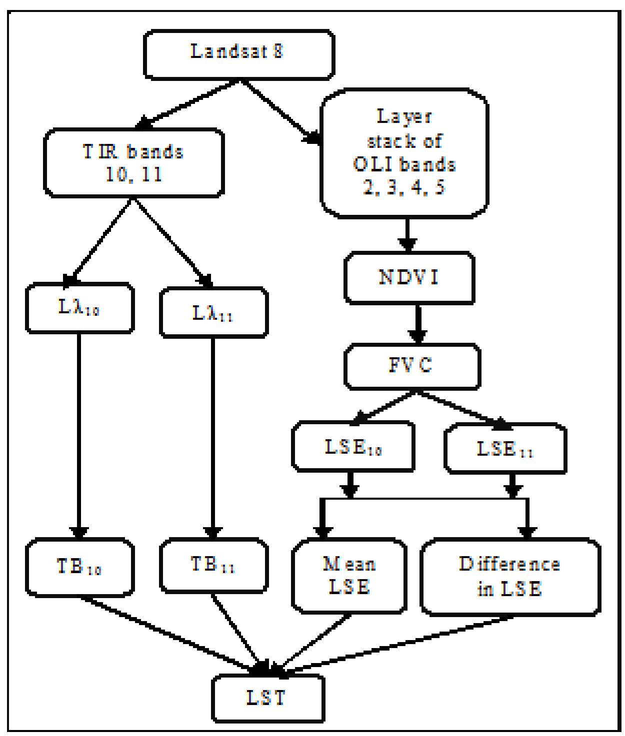


Fig - 1: Flow Chart

2.2 Process

LST was calculated by applying a structured mathematical algorithm viz., Split-Window (SW) algorithm. It uses brightness temperature of two bands of TIR, mean and difference in land surface emissivity for estimating LST of an area. The algorithm is

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

Where,
LST - Land Surface Temperature (K)
C_0 to C_6 - Split-Window Coefficient values (table – 4) (Skokovic et al, 2014; Sobrino et al, 1996; 2003; Shaouhua Zhao et al, 2009)
TB_{10} and TB_{11} – brightness temperature of band 10 and band 11 (K)
ε – mean LSE of TIR bands
W – Atmospheric water vapour content
Δ ε – Difference in LSE

Table – 4: SW Coefficient Values [11]

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

2.2.1 Brightness Temperature

Brightness temperature (TB) is the microwave radiation radiance traveling upward from the top of Earth's atmosphere. The calibration process has been done for converting thermal DN values of thermal bands of TIR to TB. For finding TB of an area the Top of Atmospheric (TOA) spectral radiance of (Lλ) was needed. TB for both the TIRs bands was calculated by adopting the following formula,

$$TB = \frac{K2}{Ln\left(\left(\frac{K1}{L\lambda}\right) + 1\right)} \quad (2)$$

Where,
K1 and K2- thermal conversion constant and it varies for both TIR bands (table 2)
Lλ – Top of Atmospheric spectral radiance.

2.2.2 Top of Atmospheric Spectral Radiance

The value of Top of Atmospheric (TOA) spectral radiance (Lλ) was determined by multiplying multiplicative rescaling factor (0.000342) of TIR bands with its corresponding TIR band and adding additive rescaling factor (0.1) with it.

$$L\lambda = M_L * Q_{cal} + A_L \quad (3)$$

Where,
Lλ - Top of Atmospheric Radiance in watts/ (m^2*srad*μm)
M_L - Band specific multiplicative rescaling factor (radiance_mult_band_10/11)
Q_{cal} - band 10/ 11 image.
A_L - Band specific additive rescaling factor (radiance_add_band_10/11)

2.2.3 Land Surface Emissivity

To find LST it is necessary to calculate the LSE of the region. LSE was estimated using NDVI threshold method.

$$LSE = \varepsilon_s (1-FVC) + \varepsilon_v * FVC \quad (4)$$

Where,
ε_s and ε_v - soil and vegetative emissivity values of the corresponding bands.

Table – 5: Emissivity Values [11]

Emissivity	Band 10	Band 11
ε_s	0.971	0.977
ε_v	0.987	0.989

FVC - Fractional Vegetation Cover was estimated for a pixel. FVC for an image was calculated by

$$FVC = \frac{NDVI - NDVIs}{NDVIv - NDVIs} \quad (5)$$

Where,
NDVIs – NDVI reclassified for soil
NDVIv – NDVI reclassified for vegetation

2.2.4 NDVI Threshold

OLI bands 2, 3, 4 and 5 were layer stacked and NDVI was calculated using ERDAS Imagine software. The output value of NDVI ranged between -1 and 0.59. To get NDVIs and NDVIv, the NDVI image was reclassified into soil and vegetation; the classified data were used to find out FVC. After generating LSE for both the bands of TIR, the mean and difference LSE was found as,

$$\varepsilon = (\varepsilon_{10}- \varepsilon_{11)/2} \quad (6)$$

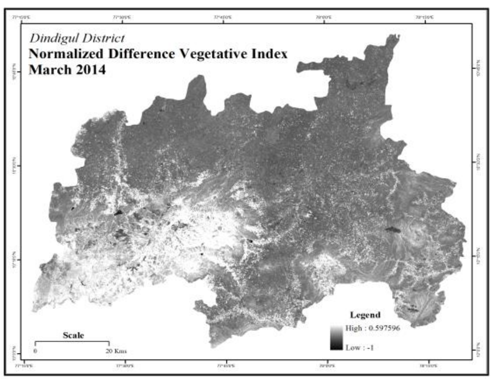
$$\Delta\varepsilon = \varepsilon_{10} - \varepsilon_{11} \quad (7)$$

Where
ε – Mean LSE
$\Delta\varepsilon$ – LSE difference
ε_{10} and ε_{11} - LSE of band 10 and 11.

Finally, the LST in kelvin was determined using SW algorithm.

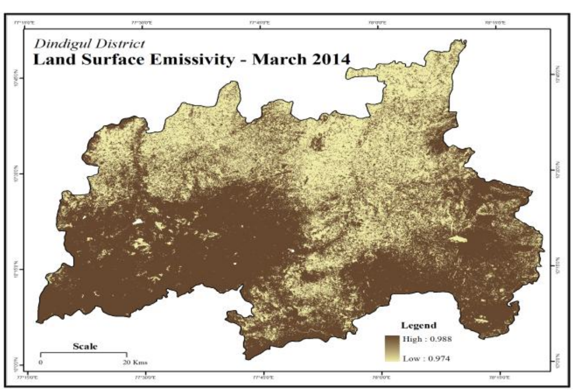
3. ANALYSIS AND DISCUSSION

NDVI map revealed that the NDVI value ranged between -1 to 0.59. South western part of Dindigul district had highest NDVI value whereas area under water body had negative value (Map - 1). The NDVI value of area under vegetation was more than 0.17 and for built-up and barren land it was 0 to 0.17.



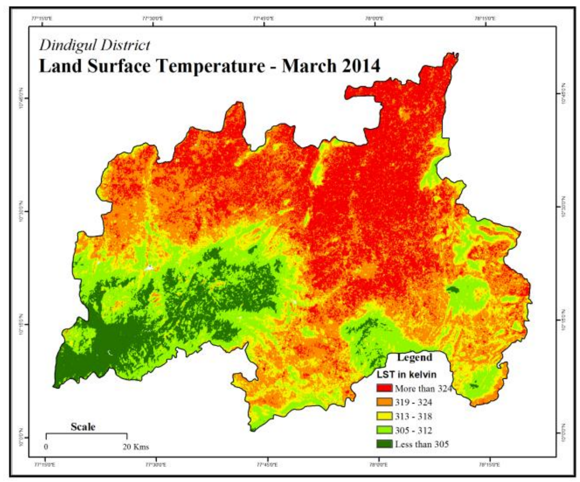
Map - 1

LSE was created using NDVI threshold technique (Map - 2). The LSE of Dindigul district ranged between 0.97 and 0.988. Highly elevated regions in the district had more vegetative cover, hence LSE was high in these regions. High LSE was found in southern, south eastern and south western parts of the district, whereas low LSE was noticed in northern and central parts of the study area.



Map - 2

Map - 3 has been derived using LSE, brightness temperature and emissivity difference between LSE of band 10 and 11 of TIR. LST output portrayed that it varied from less than 305 kelvin to more than 324 kelvin. The highest LST of more than 324 kelvin was traced in the northern plains of the study area, where barren lands and wastelands were mostly found. The 313 to 318 kelvin LST was traced in the foothill regions and area under cultivable land in the plains. The lowest category of less than 305 kelvin was seen in the highly elevated regions with dense vegetation. Similarly the regions of moderate vegetation had 305 to 312 kelvin.



Map – 3

4. CONCLUSIONS

LST of an area was determined based on its brightness temperature and LSE using SW algorithm. In this study, OLI and TIR bands of Landsat 8 had been used. 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. Dindigul district being a drought prone district the area under vegetation was less and it is restricted to hilly areas in the south western and south eastern parts. Thus, LST can be calculated using SW algorithm on Landsat 8 with multiband OLI and TIR images.

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BIOGRAPHIES

Rajeshwari.A obtained M.Sc degree in Geoinformatics in 2006 and Ph.D in GIS and Satellite Imageries Aided Impact Assessment of Watershed Development Projects in Dindigul District in 2010. She is currently working as Assistant Professor, since 2010, in Geoinformatics, in the Department of Rural Development, the Gandhigram Rural Institute (Deemed University). Her area of specialisation are watershed, application of Geographical Information System and Remote Sensing.

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