Assessment of Land Surface Temperature Variation in Anaiyur Catchment Using Remote Sensing Algorithm

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Authors’ contributions

This work was carried out in collaboration among all authors. Author KB designed the study, performed the analysis and wrote the first draft of the manuscript. Authors MB, MA and RA managed the analyses of the study. Author JR guided throughout the analysis and drafted the final format of manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JGEESI/2020/v24i830246
Editor(s):
(1) Prof. Anthony R. Lupo, University of Missouri, USA.
Reviewers:
(1) Xiangjun Tang, China Academy of Space Technology, China.
(2) Selami Selvi, Balıkesir University, Turkey.
Complete Peer review History: http://www.sdiarticle4.com/review-history/62567

Received 06 September 2020
Accepted 12 November 2020
Published 07 December 2020

Original Research Article

ABSTRACT

Land Surface Temperature (LST) is one of the important indicators to understand the spatial changes and surface processes on the earth surface that leads to actual assessment of environmental quality from local to global scales. In this paper, the thermal infrared bands of the Landsat 8 data were used to retrieve Land Surface Temperature for Anaiyur catchment located at Ramanathapuram district. Two images of April 05, 2017 and August 22, 2019 were used in this study to assess the land surface temperature. The results showed that LST from April, 2017 has higher temperature than August, 2019 because of the different season. The period of images taken were based on two different seasons. Overall, Remote sensing algorithms were effective for monitoring and analysing spatially and temporal variation of Land Surface Temperature.

Keywords: Land surface temperature; landsat 8 image; remote sensing.

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1. INTRODUCTION

Land Surface Temperature (LST) is an important parameter in understanding the exchange of energy between the earth surface and the environment. LST rise by various anthropogenic activities like increased land surface coverage by artificial materials and energy consumption [1]. It is also associated with the decreases in vegetation and water surfaces, which are the major factors that reduce surface temperature through evapo-transpiration. LST depends on land use activities and land cover. LST and emissivity for large areas can be derived from surface-leaving radiation measured by satellite sensors.

Currently, there are many satellites with varying spatial and spectral resolutions captured images that can be used for mapping and monitoring land surface temperature. Landsat 8 is the most recently launched satellite of the Landsat series. Landsat 8 satellite images have two different sets of images that are from Operational Land Imager (OLI) Sensor with nine bands (band 1 to 9) and Thermal Infrared Sensor (TIRS) with two bands (band 10 and 11) [2].

Prasanjit Dash et al., [3] described the land surface temperature and emissivity estimation from passive sensor data and their practices and current trends. Voogt and Oke [4] used spatio-temporal data to develop models of land surface atmosphere exchange, and to analyze the relationship between temperature and land use and land cover (LULC) in urban areas. Latif [5] performed land surface temperature estimation using split-window algorithm on Landsat 8 for the dataset of Ranchi District. Ramachandran et al., [6] derived the Land Surface Temperature from thermal bands of the Landsat 8 Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) by using split window algorithm in Diverse Environment of Lalgudi Block, Trichy District in Tamil Nadu.

LST is useful to witness the changes and activities in land use/cover located in the arid and semi-arid areas [7]. On the other hand, high temperature in these arid and semi-arid regions evaporates water, decreases probability of vegetation growing and increases soil erosion activity.

This study aims at using freely available Landsat 8 Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) spectral remote sensing data to estimate land surface temperature in relation to Land use types in Anaiyur catchment located at Ramanathapuram district.

2. MATERIALS AND METHODS

2.1 Study Area

Anaiyur catchment, Kamuthy block, located at Ramanathapuram District, Tamil Nadu, India was selected for this study. The geographical location of Anaiyur Catchment is shown in the Fig. 1. The northern part of Anaiyur has cropped areas, barren lands and water bodies. The southern part is bounded by cropped area, barren lands and urban settlements.

2.2 Image Selection

Landsat 8 is the most recently launched satellite of the Landsat series. The Landsat 8 satellite images are downloaded from the USGS Earth Explorer website. Two images of April 05, 2017 and August 22, 2019 were used in this study to assess the land surface temperature. The period of images taken were based on two different seasons. The images were selected such that there is no or minimum cloud cover in order to avoid error. LST was calculated from the thermal band (band 10) radiance values of Landsat 8 image.

2.3 Estimation of Surface Temperature

Land Surface temperature (Ts) deals with energy exchange between the earth surface and the environment. It was calculated from the thermal band (band 10 or 11) radiance values of the Landsat 8 image. The overall procedure for estimation of surface temperature is shown in Fig. 2.

The equation for estimation of surface temperature is as follow as:

\[ T_s = \frac{K_2}{\ln\left(\frac{\varepsilon_s * K_1}{\rho_b}\right)} \] (1)

The radiance pb of the thermal band (band 10) is calculated from Equation 2. The constants K1 and K2 for band 10 are 774.8853 and 1321.0789
which is taken from the metadata file. The surface emissivity ($\varepsilon_s$) is calculated from equation 3. The radiance ($\rho_b$) is calculated from the pixel values of different bands ($D_N b$) using the following equation:

$$\rho_b = Add_{rad,b} + (Mult_{rad,b} \times D_N b)$$  \hspace{1cm} (2)$$

where $Add_{rad,b}$ is additive and $Mult_{rad,b}$ is multiplicative terms related to different band radiance. The values of $Add_{rad}$ and $Mult_{rad}$ terms of band 10 are 0.10000 and 3.3420E-04. Surface emissivity ($\varepsilon_s$) is the ratio of the thermal energy radiated by the surface to the thermal energy radiated by a blackbody at the same temperature.

**Fig. 1.** Study area-Anaiyur catchment

**Fig. 2.** Overall procedure for estimation of land surface temperature
Thus the surface emissivity is empirically derived from NDVI. NDVI is the ratio of difference in reflectivity of near-infrared (NIR) band and red band to their sum. The expression for estimation of NDVI is given by

$$\varepsilon_s = \begin{cases} 1.009 + 0.047(\ln(NDVI)) & (NDVI > 0) \\ 1 & (NDVI < 0) \end{cases}$$  \quad (3)$$

In Landsat 8 image, the near infrared is band 5 and the red is band 4. Using Raster Calculator tool in ArcGIS, the above calculation was done to estimate the land surface temperature raster.

3. RESULTS AND DISCUSSION

In the present study, land surface temperature was estimated by the single-channel from TIRS (Thermal Infrared Sensor) data of the Landsat 8 images. The radiance values of Anaiyur Catchment of April, 2017 ranges from 7.27 to 9.92 (Fig. 3) and for August, 2019 ranges from 6.82 to 10.5 (Fig. 4). The Surface Emissivity of Anaiyur Catchment for April, 2017 varies between 0.70 and 0.96 (Fig. 5) and for August, 2019 varies between 0.86 and 0.97 (Fig. 6). The predicted value of LST in Anaiyur Catchment for April, 2017 ranges (Fig. 7) from 14.90 and 50.91 degree Celsius and of August, 2019 ranges between 10.39 and 41.56 degree Celsius (Fig. 8). Ibrahim and Abu-Mallouh (2018) also reported that the spatial distribution of estimated LST ranged from 24°C to 51°C (mean = 38°C).

In April 2017, the maximum value of LST ranging from 35 to 49°C was recorded in barren land. Subsequently, semi-urban settlements in the western and southern part exhibited higher temperature ranging from 30-40°C. The LST of cropped areas was in the range of 23 to 25°C. The water bodies exhibited LST around 14 – 20°C. Ramachandran et al. [6] also reported an LST value for a lake located was around 20°C.

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$$\text{NDVI} = \frac{\text{NIR} - \text{RED}}{\text{NIR} + \text{RED}}$$  \quad (4)$$

**Fig. 3. Radiance of Anaiyur catchment - April, 2017**
In August, 2019 the maximum value of LST ranging from 30-40°C was recorded in barren land. Subsequently, semi-urban settlements in the western and southern part exhibited higher temperature ranging from 28-35°C (August, 2019). The LST of cropped areas was in the range of 25 to 30°C. The water bodies exhibited LST around 14-20°C (August, 2019). The
plantations, forest area and Prosopis juliflora showed LST value ranging from 22 – 25°C. The results show April, 2017 has higher temperature than August, 2019 because of the different season. The semi urban settlements and barren lands exhibit higher temperature than cropped areas and water bodies. The other research studies [8,6] shows that results obtained which were similar to them indicating water bodies and cropped areas having lower temperature compared to barren land and urban settlements.

Fig. 6. Surface emissivity of Anaiyur catchment - August, 2019

Fig. 7. Surface temperature of Anaiyur catchment - April, 2017
4. CONCLUSION

Land Surface Temperature (LST) is one of the important indicators to understand the spatial changes and surface processes on the earth surface that leads to actual assessment of environmental quality from local to global scales. The LST monitoring in arid and semi-arid regions is necessary to make an appropriate decision about Land surface temperature and environmental status. The split-window algorithm was used to estimate LST from thermal bands of the Landsat 8 Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). The results showed that April, 2017 has higher temperature than August, 2019 because of the different season. This kind of monitoring studies helps in adopting suitable policies to overcome or minimize the problems triggered by increase in land surface temperature.

ACKNOWLEDGEMENTS

The authors acknowledge the Chairman and the Principal of Nammazhvar College of Agriculture and Technology, Peraiyur, Kamuthy, Ramanathapuram – 623708 for their guidance and support.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/62567