GEO-EYE

RESEARCH ARTICLE

Thermal Insights: Unraveling Land Surface Temperature Dynamics in Dakshina Kannada District, Karnataka

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OPEN ACCESS

Received: 27.02.2024
Accepted: 27.02.2024
Published: 18.03.2024

Citation: Sasi M, Anil SS. (2024). Thermal Insights: Unraveling Land Surface Temperature Dynamics in Dakshina Kannada District, Karnataka. Geo-Eye. 13(1): 9-14. https://doi.org/10.53989/bu.ge.v13i1.8

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Funding: None

Competing Interests: None

Published By Bangalore University, Bengaluru, Karnataka

ISSN
Print: 2347-4246
Electronic: XXXX-XXXX

Abstract

The sustainability of natural resources and biological processes are greatly influenced by landscape dynamics. Planning and responsible resource management are made easier with an understanding of terrain dynamics(1) . Intense urbanization in Indian cities has resulted in extraordinary changes to the country's land use patterns, which have drastically altered the city's thermal characteristics due to rising surface temperatures, the presence or absence of greenery, and water bodies(2) . Land surface temperature (LST) is a critical input for climate models and is studied in many domains, such as urban land use and cover, geophysical and biophysical research, and studies of global climate change. LST is a critical input for climate models and is studied in many domains, such as urban land use and cover, geophysical and biophysical research, and studies of global climate change(3) . The variability of retrieved land surface temperatures (LSTs) with respect to Normalized Difference Vegetation Index (NDVI) values for different land use/land cover (LU/LC) types determined from the Landsat 8 visible and NIR channels has been investigated using the LANDSAT 8 - Operational Line Imager & Thermal Infrared Sensor (OLI & TIRS) satellite data(3) . Bantval, Baltangvadi, Puttur, and Sulya in the Dakshina Kannada district have been considered for LST assessment in the current study taluk. According to estimates, the lowest LST is 53.70C and the maximum is 78.670C.

Keywords: Land Surface Temperature (LST); LULC; NDVI; Landsat 8 (OLI & TIRS)

1 Introduction

Expanding urban areas exert a considerable anthropogenic strain on the natural environment, imposing a substantial burden on essential resources like space, water, and air quality. The climatic conditions in metropolitan regions diverge significantly from their rural counterparts, with alterations in radiation balance, moisture content, and thermal stability occurring as urbanization advances(2). Uncontrolled construction and economic activities contribute to rapid urban sprawl and land surface expansion, potentially escalating environmental crises(4). An indispensable variable for scrutinizing surface energy budgets, land surface processes, urban heat islands, and retrieving atmospheric variables is the LST, also referred to as land skin temperature(4).

LST plays a crucial role in assimilating data into land surface models. Influenced by surface air temperature and various surface and subsurface factors such as soil moisture, texture, vegetation type, elevation, and radiations, LST reflects the complex interplay of these elements [4]. Despite the local connection between surface air temperature and LST, notable disparities exist in the magnitudes of their diurnal oscillations [2].

Remote sensing, exemplified by the utilization of the NDVI, stands as a pivotal tool for monitoring plant growth and assessing regional-scale plant health and drought conditions [5]. In tandem with NDVI, LST serves as a crucial parameter for understanding surface energy distribution. Challenges, however, arise from the delayed response of NDVI and LST to rainfall events. LULC changes, captured by satellites like Landsat, Terra, and Aqua, prove indispensable for managing disasters such as landslides, urban flooding, and the repercussions of climate change on a regional scale [6]. These changes in land use and cover, driven by factors like population growth, urbanization, agricultural practices, and land use policies, transform landscapes into diverse mosaics with multifaceted implications for nutrient cycling, bio-geochemical cycles, hydrologic processes, and carbon sequestration [1,7,8].

In a specific case study focusing on the taluks of Bantval, Baltangvadi, Puttur, and Sulya in the Dakshina Kannada district, Karnataka, the analysis of LST using data from the LANDSAT 8 satellite provides valuable insights into landscape dynamics [1]. The sensitivity of LST to various factors, including vegetation, the canopy layer, and soil moisture, makes it a potent tool for detecting and understanding LULC changes and their linkages to climatic variations [9,10]. This understanding not only aids in disaster management but also informs sustainable planning and management of natural resources at a temporal scale, showcasing the intricate interplay between LST variations and landscape dynamics [1].

1.1 Study Area

Situated between 12°27' and 13°01' N and 74°04' and 75°41' E, Dakshina Kannada, the southernmost coastal district of Karnataka State, encompasses an area of 4866 square kilometers and is marked by distinct geographical features. Bounded by the sea to the west, the Eastern Ghats, Udupi District, and Kerala State demarcate its eastern, northern, and southern borders, respectively. The district, with its administrative hub in Mangaluru, comprises major taluks such as Bantwal, Belthangady, Puttur, and Sullia. Boasting a climate akin to other West Coast districts in India, Dakshina Kannada experiences high humidity levels (78 percent) throughout the majority of the year, with temperature variations ranging from 9.70°C to 35.40°C. Annual rainfall averages 3912 mm in the region, influencing the diverse landscape that transitions from flat terrain inland to rugged mountainous expanses in the Western Ghats to the east, adorned with teak, bamboo, and rosewood trees on steep slopes. The district is crisscrossed by three primary rivers, namely Netravati, Swarna, and Gurupur, all flowing westward and emptying into the Arabian Sea. Featuring lateritic sandy soil and coastal alluvium in the coastal region (Mangalore Taluk), the district predominantly consists of gravelly red soil, placing it within the coastal zone as per the classification of agro-climatic zones [11,12].

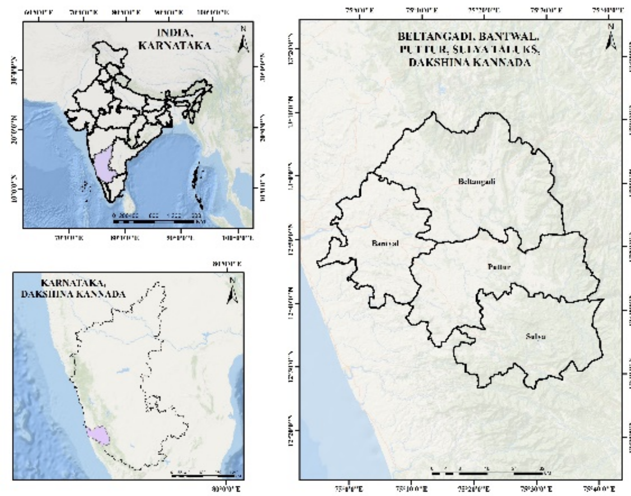

Fig. 1. Location map of the taluks of Dakshina Kannada

2 Methodology

In the present investigation, the analysis of LST in the taluks of Bantval, Baltangvadi, Puttur, and Sulya within the Dakshina Kannada district of Karnataka was conducted utilizing data acquired from the LANDSAT 8- OLI & TRS satellite. To gauge LST across the major taluks in the district, a comparative study involving the examination of NDVI data from the US Geological Survey (USGS) and LULC information from Environmental Systems Research Institute (ESRI) was carried out. Table 1 furnishes details about the source of the data and its spatial resolution, providing essential insights into the methodology employed for the study.

Table 1. Data, source, and spatial resolution wereused for the study

Data	Source	Spatial Resolution
Landsat 8 (OLI & TIRS	USGS Earth Explorer	30 m
LULC	ESRI	10m

Figure 2 depicts the methodology for the proposed effort to estimate LST. Data from LANDSAT 8 can only be processed using this method. Band 10 is used in this study to determine NDVI while bands 4 and 5 are used to evaluate brightness temperature Figure 3 .

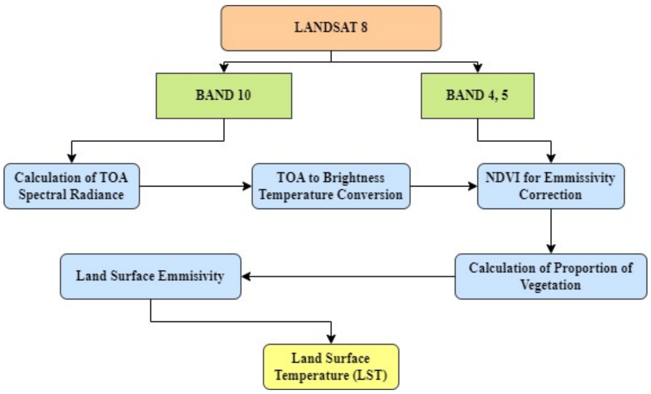

Fig. 2. Methodology flow chart to estimate the LST

The following literature provides a full breakdown of the stages required for the planned work.

Step1: Geometrically corrected data were produced from the satellite data [2] .

Using the following equation, the DN (Digital Number) values of band 10 are first converted to at-sensor spectral radiance in the proposed study (1) [3] :

$$\mathrm{TOA}\,(\mathrm{L}_{\kappa}) = \mathrm{M_L} * \mathrm{Q_{cal}} + \mathrm{A_1} - \mathrm{Q_i} \tag{1}$$

where,

TOA (L_λ) = TOA spectral radiance (watts/m^2*srad*μm))

M_L = Band-specific multiplicative rescaling factor

Q_{cal} = Quantized and calibrated standard product pixel values (DN)

A_l = Band-specific additive rescaling factor

Q_i = is the correction value for Band 10 of Landsat 8

Step2: After converting DN values to at-sensor spectral radiance, the TIRS band data should be converted to brightness temperature (BT) using the thermal constants given in the metadata file and the following equation(2) [3] :

$$\mathrm{BT} = \mathrm{K2/Ln(K1/TOA)+1)) - 273.15} \tag{2}$$

where,

BT = Top of atmosphere brightness temperature

Ln = Total spectral Radiance

K1 = COSNTANT_BAND 10

K2 = CONSTANT_BAND 10

Step 3: To identify the various land cover types in the study area, the NDVI (2) is crucial. The NDVI has a range of -1.0 to +1.0. The normalised difference between the near-infrared band (0.85-0.88□m) and the red band (0.64 - 0.67 m) of the pictures is used to determine the NDVI on a per-pixel basis (3)using the equation (3).

$$\mathrm{NDVI} = \mathrm{NIR(\ Band\ 5)} - \mathrm{Red(\ Band\ 4)/NIR(Band\ 5)+Red\ (Band\ 4)} \tag{3}$$

Where NIR(2) is the near-infrared band value of a pixel and RED is the red band value of the same pixel. Calculation of NDVI is necessary to further calculate proportional vegetation (Pv) and emissivity (ε) [3] .

Step 4: The next step (equation 4) is to calculate proportional vegetation (Pv)(2) from NDVI values obtained in step 3. This proportional vegetation gives the estimation of the area under each land cover type. The vegetation and bare soil proportions are acquired from the NDVI of pure pixels(3).

$$\mathrm{Pv} = (\mathrm{NDVI} - \mathrm{NDVI_{min}}/\mathrm{NDVI_{max}} - \mathrm{NDVI_{min}})^2 \tag{4}$$

where,

Pv = Proportion of Vegetation

NDVI = Normalised Difference Vegetation Index

NDVImin = refers to the previous result of NDVI minimum value

NDVImax = refers to the previous result of NDVI maximum value.

Step 5: Calculation of land surface emissivity (LSE)(2) is required to estimate LST since LSE (equation 5) is a proportionality factor that scales the black body radiance (Plank's law) to measure emitted radiance and it is the ability to transmit thermal energy across the surface into the atmosphere. At the pixel scale, natural surfaces are heterogeneous in terms of variation in LSE. In addition, the LSE is largely dependent on the surface roughness, nature of vegetation cover,etc [3] .

$$\epsilon = 0.004 * \mathrm{Pv} + 0.986 \tag{5}$$

where,

ϵ= Land surface emissivity

Pv = Proportion of Vegetation

0.986 = correction value for the equation.

Step 6: Using the brightness temperature (BT) [2] of band 10 and the LSE obtained from Pv and NDVI, the last step is to compute LST. LST is retrievable [3] using the equation 6.

$$\mathrm{Ts} = \mathrm{BT}/((1+(K*\mathrm{BT/p})*\mathrm{Ln}(\sigma))) \tag{6}$$

where ρ is (h xc/σ) which is equal to 1.438 x 10-2 mK in which σ is the Boltzmann constant (1.38 x 10-23 J/K), h is Plank's constant (6.626 x 10-34), and c is the light velocity (3 x 108 m/s). Ts is the LST in Celsius (o C), BT is at-sensor BT (o C), and λ is the average wavelength of band 10 [3].

The LULC obtained from ESRI has been masked with the study for a comparative study for analyzing the LST.

3 Results and Discussion

3.1 Comparing LULC with LST

In the designated study area, LULC has been systematically classified into distinct categories encompassing water bodies, vegetation cover, built-up areas, barren terrain, and agricultural land, with the latest LULC classification dating from

2021. The prevalence of vegetation in Figure 3 is visibly apparent and deduced from the NDVI. The positive correlation between NDVI and LULC implies that areas with higher vegetation cover exhibit lower land temperatures owing to increased moisture levels within the vegetation [13]. Notably, approximately 91 percent of the region is characterized by vegetation cover, underscoring the predominance of greenery in the study area. Current statistics reveal that a mere 4% of the land has undergone development, of which only 0.2 percent is allocated for agricultural purposes, while 0.7 percent is occupied by water bodies (Table 2). This highlights the extensive vegetation cover within the research region [14].

Upon comparing LULC with LST (Figure 3), it becomes evident that elevated LST values are concentrated in built-up and barren terrains, registering an average temperature of approximately 78.67°C. In contrast, areas exhibiting good vegetation cover display lower to moderate LST, with an average temperature of around 53.70°C. This juxtaposition suggests a subtle alteration in land surface temperature within the research area, emphasizing the influence of land cover on temperature dynamics.

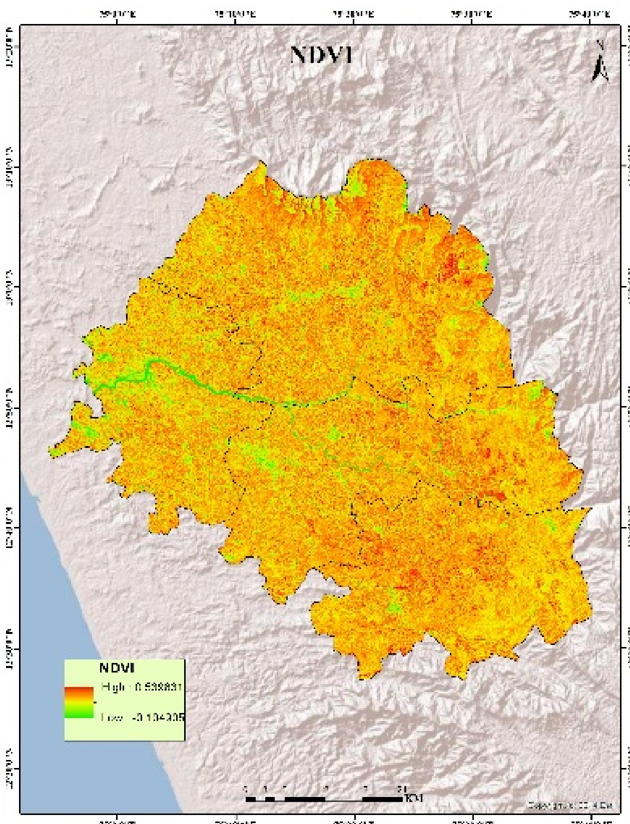

Fig. 3. LULC of the 4 taluks of Dakshina Kannada

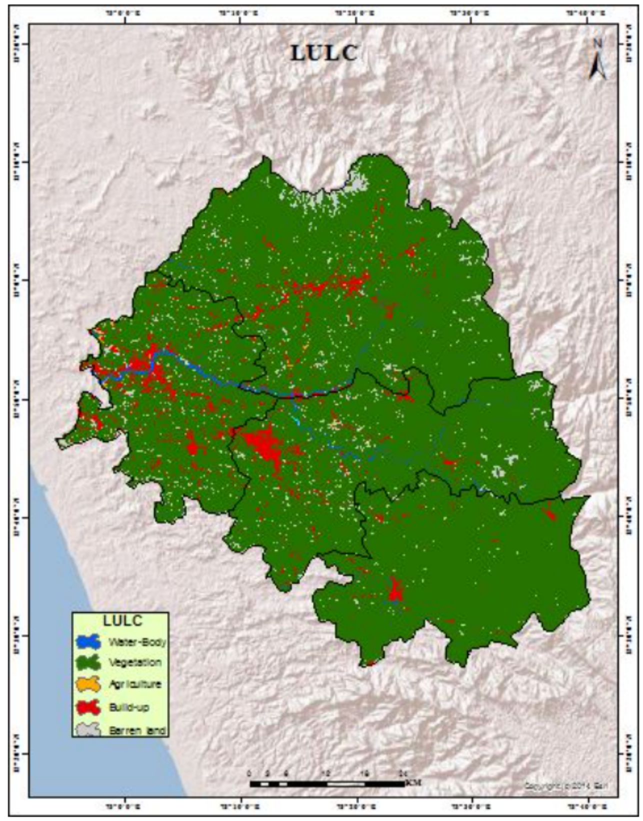

Fig. 4. NDVI of the 4 taluks of Dakshina Kannada

3.2 Comparison of NDVI and LST

NDVI calculations in this study utilize Landsat 8 Bands 4 and 5 (Red and NIR), yielding an expected range of NDVI values from -0.10 to 0.53 (Figure 4). The observed NDVI range suggests a moderate to high vegetation cover in the research region, with the maximum value nearing 0.53. Upon comparing NDVI values with LST, an inverse relationship is evident. Areas with low vegetation cover exhibit high LST, while regions with abundant vegetation display notably lower LST values. The disproportionately high NDVI cover in the study area contributes to the discovery of a minimum LST of 53°C (Figure 4). The research area, characterized by a subtropical moist broadleaf forest ecoregion in the western ghats, features primary forest types with high emissivity, effectively absorbing radiation. Land Surface Emissivity (LSE) assessment further supports this, with values ranging from 0.986 to 0.988, indicating that LSE retrieves LST due to dense vegetation [3].

Distinct patterns emerge for water bodies, as evidenced by the lowest NDVI and surface radiation temperature values. The explanation points to the primary contribution of vegetation in regulating surface radiation temperature through structural changes in the underlying surface that

Table 2. Land Use and Land Cover are its percentage in the taluks of Bantwal, Belthangady, Puttur, and Sullia, Dakshina Kannada district

Classes	**Area (km^2)**	**%**
Waterbody	29	0.73
Vegetation cover	3644	91.35
Agriculture	8	0.20
Build-up	170	4.26
Barren Land	138	3.46
Total	3989	100

store heat and innovative energy evapotranspiration processes[5]. Urban surfaces, lacking flora and characterized by high heat conductivity, exhibit a non-evapotranspiration dry nature, resulting in elevated heat retention[15]. Section plane analysis extends to the spatial distribution of NDVI and surface radiation, revealing intricate relationships between NDVI and LST responses (Figure 6)([13]).

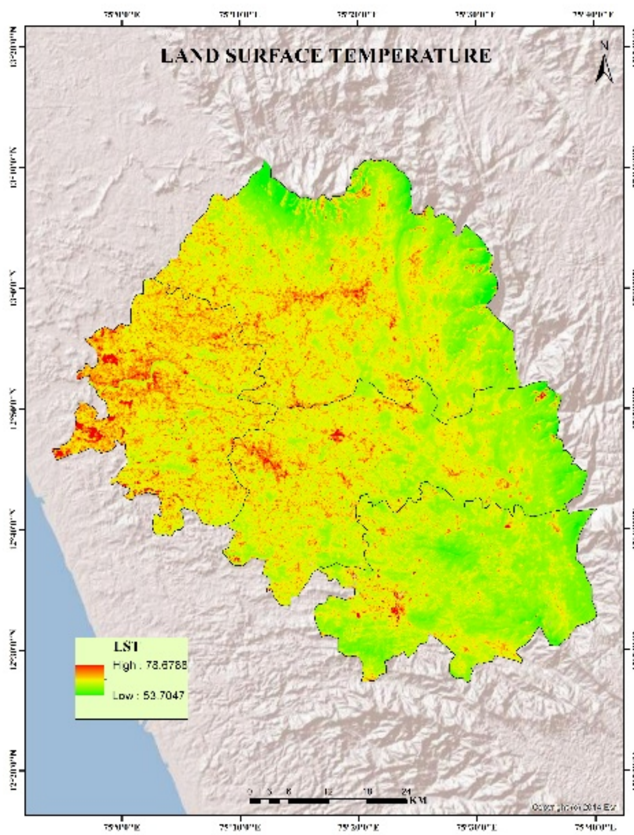

Fig. 5. LSE of the 4 taluks of Dakhsina Kannada

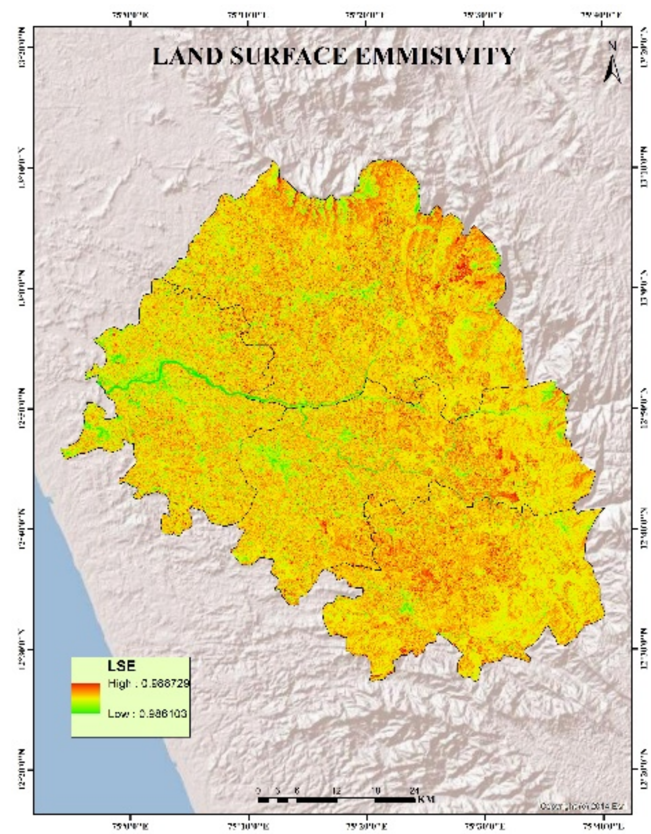

Fig. 6. NDVI of the 4 taluks of Dakshina Kannada

4 Conclusion

The study reveals intricate interactions between land cover change and basin-scale hydrology, radiation, heat fluxes, and surface temperature, highlighting their importance in calculating LST and understanding the environmental impacts of urban expansion[16]. The research showcases its dynamic ability to estimate LST by utilizing brightness temperature data from a TIR sensor and LSE derived from proportional vegetation cover observed in optical bands from a LANDSAT 8 sensor[3]. Within the study area, a moderate LST range of 53.7 to 78.67 has been identified. To decipher the reasons behind this moderate LST, a comprehensive comparison involving NDVI, LULC, and LST has been conducted, focusing on the significant taluks of Bantwal, Belthangady, Puttur, and Sullia, in addition to the district capital Mangalore. These taluks are emerging as important tourism destinations, warranting detailed analysis. The study suggests potential extensions, such as considering the entire district, exploring surface air temperature for a comprehensive examination, and delving deeper into the specifics of the research region[3].

References

1) Ramachandra TV, Setturu B, Dey M. Land surface temperature responses to land use dynamics across the agro-climatic zones of Karnataka. . Available from: https://doi.org/10.37285/bsp.ic2uhi.38.
2) Das DN, Chakraborti S, Saha G, Banerjee A, Singh D. Analysing the dynamic relationship of land surface temperature and landuse pattern: A city level analysis of two climatic regions in India. *City and Environment Interactions*. 2020;8:100046–100046. Available from: https://dx.doi.org/10.1016/j.cacint.2020.100046.
3) Reddy SN, Manikiam B. Land Surface Temperature Retrieval from LANDSAT data using Emissivity Estimation. *International Journal of Applied Engineering Research*. 2017;12. Available from: http://www.ripublication.com.
4) Khandelwal S, Goyal R, Kaul N, Mathew A. Assessment of land surface temperature variation due to change in elevation of area surrounding Jaipur, India. *The Egyptian Journal of Remote Sensing and Space Science*. 2018;21(1):87–94. Available from: https://dx.doi.org/10.1016/j.ejrs.2017.01.005.
5) Mishra GC, University KN, Sanskriti. Innovative energy technology systems and environmental concerns : a sustainable approach. .
6) John J, Bindu G, Srimuruganandam B, Wadhwa A, Rajan P. Land use/land cover and land surface temperature analysis in Wayanad district, India, using satellite imagery. *Annals of GIS*. 2020;26(4):343–360. Available from: https://dx.doi.org/10.1080/19475683.2020.1733662.
7) Ganasri BP, Dwarakish GS. Study of Land use/land Cover Dynamics through Classification Algorithms for Harangi Catchment Area, Karnataka State, INDIA. *Aquatic Procedia*. 2015;4:1413–1420.
8) Eswar R, Sekhar M, Bhattacharya BK. A simple model for spatial disaggregation of evaporative fraction: Comparative study with thermal sharpened land surface temperature data over India. *Journal of Geophysical Research: Atmospheres*. 2013;118(21):44–44. Available from: https://dx.doi.org/10.1002/2013jd020813.
9) Shwetha HR, Kumar DN. Prediction of high spatio-temporal resolution land surface temperature under cloudy conditions using microwave vegetation index and ANN. *ISPRS Journal of Photogrammetry and Remote Sensing*. 2016;117:40–55.
10) Das M, Das A. Assessing the relationship between local climatic zones (LCZs) and land surface temperature (LST) – A case study of Sriniketan-Santiniketan Planning Area (SSPA), West Bengal, India. *Urban Climate*. 2020;32:100591–100591. Available from: https://dx.doi.org/10.1016/j.uclim.2020.100591.
11) Naik D, Mustak MS. A checklist of butterflies of Dakshina Kannada District, Karnataka, India. *Journal of Threatened Taxa*. 2016;8(12):9491–9491. Available from: https://dx.doi.org/10.11609/jott.3066.8.12.9491-9504.
12) Kasabi GS, Murhekar MV, Yadav PD, Raghunandan R, Kiran SK, Sandhya VK. Kyasanur Forest disease. *Emerg Infect Dis*. 2011;19(2):278–81.
13) Kumar D, Shekhar S. Statistical analysis of land surface temperature–vegetation indexes relationship through thermal remote sensing. *Ecotoxicology and Environmental Safety*. 2015;121:39–44. Available from: https://dx.doi.org/10.1016/j.ecoenv.2015.07.004.
14) Naim MNH, Kafy AA. Assessment of urban thermal field variance index and defining the relationship between land cover and surface temperature in Chattogram city: A remote sensing and statistical approach. *Environmental Challenges*. 2021;4:100107–100107. Available from: https://dx.doi.org/10.1016/j.envc.2021.100107.
15) . .
16) Biggs TW, Scott CA, Gaur A, Venot JP, Chase T, Lee E. Impacts of irrigation and anthropogenic aerosols on the water balance, heat fluxes, and surface temperature in a river basin. *Water Resources Research*. 2008;44(12). Available from: https://dx.doi.org/10.1029/2008wr006847.