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Estimation of the Relationship between Urban Vegetation and Land Surface Temperature of Calicut City and Suburbs, Kerala, India using GIS and Remote Sensing data

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Abstract Land surface temperature was the most important determining factor for the analysis of urban heat island. The Vegetation content in urban areas has a great influence on the temperature variation of those areas. Satellite remote sensing is very much helpful in the analysis of urban heat islands by using Land Surface Temperature. By analyzing the Landuse, Temperature and NDVI from satellite images the temperature and the variations was studied. Landsat 7 images are used in the calculation of Temperature, NDVI and Landuse. Land surface temperature of Calicut Corporation was estimated by using Mono Window Algorithm from land sat 7 ETM images. Landsat images for the years 2003, 2008 and 2015 were down loaded from the USGS earth explorer web site. Temperature band or band 6 was used for the land surface temperature estimation. NDVI was derived from the band 3 and band 4 using the ERDAS imagine for the year 2003, 2008 and 2015. Supervised classification was done to classify the images in different land use categories like vegetation, built up and water bodies. From the temperature map a gradual increase in land surface temperature was noticed from 2003 to 2015. This is due to the decrease in urban vegetation as observed in the landuse. A negative correlation was obtained by correlating the NDVI with the temperature. The landuse changes between these three years are analyzed. The vegetated area was reduced in the year 2015 because of increasing the built up areas.
Keywords *NDVI; LST; LULC; Brightness Temperature; Thermal Band*

1. Introduction

Population growth, widespread industrialization and migration of rural population to urban areas lead to urban population growth, and expanding the urban sprawls. Urban growth and sprawl is a global phenomenon and have significant influence on the biophysical environment leading to severe ecological and environmental problems. Rapid and unplanned urbanization will change the land use/ land cover (LULC) of the area, especially reduction in vegetation cover which in turn increased the built-up areas. A major implication of urbanization is increase of land surface temperature (LST), mainly by heat discharge due to increased energy consumption, increased built-up surfaces having high heat capacities and conductivities, and decrease in vegetation cover. Vegetation cover usually provide shade which helps lower surface temperature and also reduces air temperature through the process of evapotranspiration, in which plants release water to the surrounding air, dissipating ambient heat. The relationship between LST and urban vegetation cover has been extensively documented.

In the past, there were many studies focusing on the relationship between urban vegetation and LST (Weng et al., 2004). The advent of Geographical Information System (GIS) and satellite remote sensing technology has made it possible to study LST and urban vegetation remotely as well as in any scale from local to global. Satellite remote sensing provides an excellent cost-effective and time-saving methodology to analyze spatially and temporally distributed LST, since the coverage of satellite imagery extends over a large area (Senanayake et al., 2013). Several studies used the Landsat ETM+ imagery to develop LULC maps as well as for deriving the surface temperature. Numerous studies had been made to examine the effect of the vegetation on the LST, which showed that there was negative correlation between LST and urban vegetation abundance measured by Normal Difference Vegetation Index (NDVI) and the percent cover of urban vegetation (Weng et al., 2004; Chen et al., 2006; Mallik et al., 2008; Sundara Kumar et al., 2012).

However, in India studies focusing on the relationship between urban vegetation and LST using Landsat ETM+ imagery is rather limited. Hence through this study we examined the relationship between urban vegetation and LST of Calicut city, Kerala, India using Landsat ETM+ imagery. Specific objectives of this study were: i) to derive LST and to analyze their spatial variations using Landsat ETM+ thermal measurements; ii) to estimate urban vegetation abundance, Normalized Difference Vegetation Index (NDVI); and iii) to investigate the relationship between LST and NDVI.

2. Methodology

2.1. Study Area

The study was carried out in the Calicut city and suburbs (75°44'30"- 75°52'30" E, 11°12'- 11°19' N), which is an important social-economic centre of Malabar region of Kerala, located in the coast of Southwest India. The climate of the city is humid tropical along with abundant rainfall, both from the south-west monsoon and north-east monsoon. Temperatures tend to remain constant with maximum values of between 30°C and 36°C, while the minimum between 22°C and 23°C. The average total annual rainfall was 3130 mm and the Relative humidity is around 79.3%. The extent of the study area is 207 km^2 (Figure 1) with a population of 4,32,097 people (Census, 2011) and the city is selected due to rapid urban development activities over the last two decades and heterogeneous LULC.

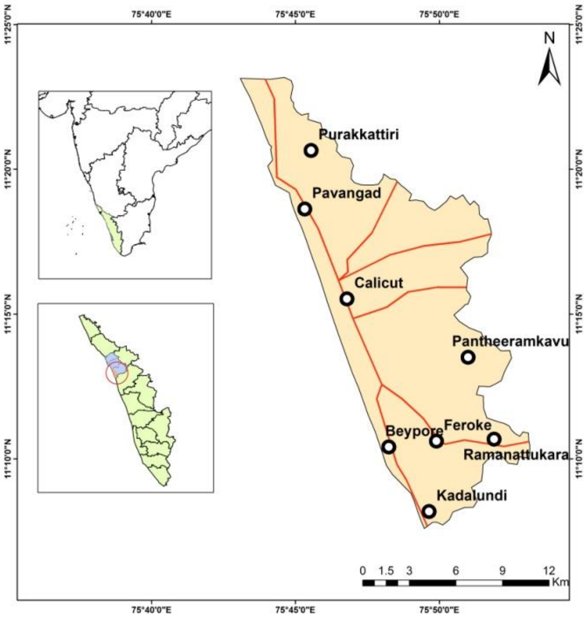


Figure 1: *A map of the study area*

2.2. Methods

Various stages involved in this study were i) satellite image acquisition and processing; ii) generation of land use/ land cover (LULC) map; iii) land surface temperature (LST) retrieval; iv) normalized difference vegetation index (NDVI) assessment; and vi) determination of the relationship between NDVI and LST. The conceptual flow of the applied methodology of this study is shown in Figure 2.

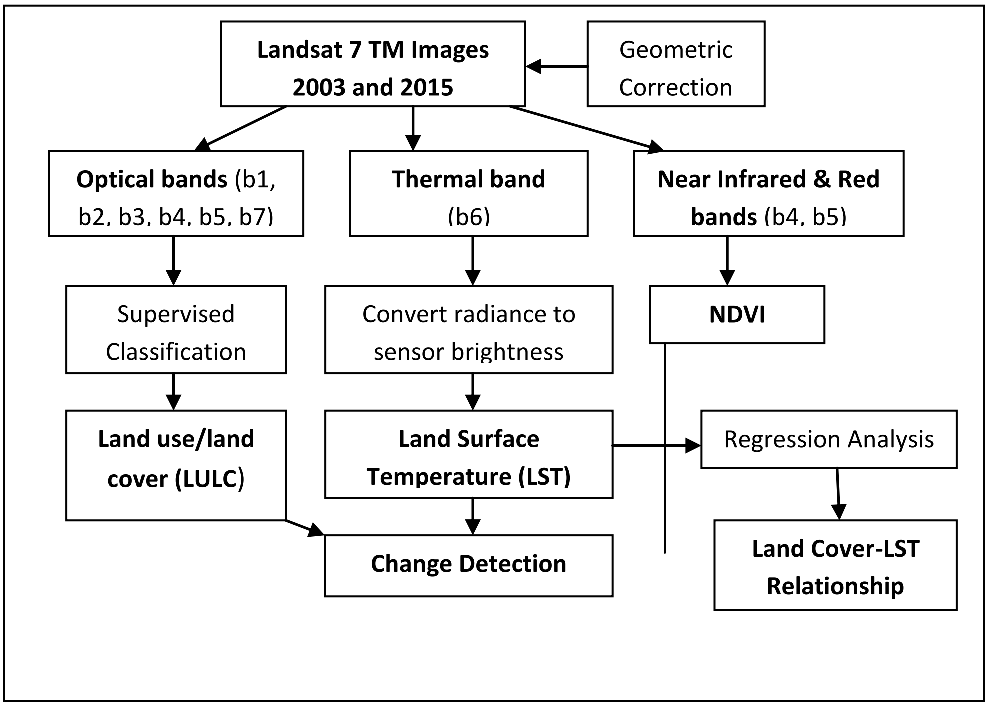


Figure 2: *Conceptual flow chart of the applied methodology*

2.2.1. *Satellite image acquisition and pre-processing*

Landsat 7 Enhanced Thematic Mapper Plus (ETM+) image (Row/Path: 145/52) of January 2003 and 2015 were used in this study (Table 1). These imageries were downloaded from USGS website. Using the ERDAS imagine digital image processing software, the multi-temporal images were co-registered to Universal Transverse Mercator Coordinate System (UTM 43 N / WGS84). Landsat 7 TM, ETM images bands 1-5 and 7 have a spatial resolution of 30 m, and the thermal infrared band (band 6) has a spatial resolution of 60 m. The images were further resampled using the nearest neighbor algorithm with a pixel size of 30 by 30 m for all bands including the thermal band. The resultant root mean square error (RMSE) was found to be less than 0.5 pixels. A subset function was used to limit the scene to the study area.

Table 1: *Details of Landsat data collected*

Date of image	Satellite/sensor	Reference system/ Path/ Row
11/01/2003	Landsat-7/ ETM+	WRS-II/145/52
15/01/2015	Landsat-7/ ETM+	WRS-II/145/52

2.2.2. *Generation of land use/land cover maps*

A supervised classification was carried out in ERDAS imagine 2013 using the maximum likelihood method; three land cover classes were identified including vegetation, water bodies and built up areas. The classified images were converted to shape files and imported to ESRI ArcGIS 10.2 feature class in a geographic database. The areas of the urban class were calculated from each feature class.

2.2.3. *Land surface temperature (LST) retrieval*

Land surface temperatures (LST) were derived from geometrically corrected Landsat ETM+ thermal infrared (TIR) band (band 6) images. The raw digital numbers (DNs) were converted to spectral radiances (L_λ) by using the following equation;

$$L_\lambda = L_{min} + (L_{max} - L_{min}) * DN/255$$

where, L_λ = Spectral radiance; $L_{min} = 3.200$ (spectral radiance of DN value 1); $L_{max} = 12.650$ (Spectral radiance of DN value 255); DN = Digital Number

The next step is to convert the spectral radiance to satellite brightness temperature (i.e., blackbody temperature, TB) under the assumption of uniform emissivity (Landsat Project Science Office, 2002). The conversion formula is;

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda} + 1\right)}$$

where T_B is effective at-satellite temperature in K, L_λ is spectral radiance in W/m^2 ster μm; and K_2 and K_1 are pre-launch calibration constants ($K_2 = 1282.71$ K, and $K_1 = 666.09$ mW cm^{-2}sr^{-1}μm^{-11}). The temperature is then converted from Kelvin to Celsius.

2.2.4. *Normalized difference vegetation index (NDVI) assessment*

Differentiation between vegetated and non-vegetated areas was made according to the normalized difference vegetation index (NDVI) values, which were computed from visible $(0.63-0.69)^{\mu m}$ and near-infrared $(0.76-0.90)^{\mu m}$ bands of the ETM+ images based on the following equation;

$$NDVI = \frac{R_{NIR} - R_{red}}{R_{NIR} + R_{red}}$$

where, R_{NIR} and R_{red} are the spectral reflectance in the TM and ETM+ red and near-infrared bands. The NDVI algorithm subtracts the red reflectance values from the near-infrared and divides it by the sum of near-infrared and red bands.

2.2.5. *Relationship between LST and NDVI*

To obtain the relationship between LST and NDVI, 49 sample points were measured within the study area. Regression analysis was carried out to determine the correlation between these two parameters. The regression equation models are retrieved by fitting the trend line using Microsoft Excel.

3. Results and Discussion

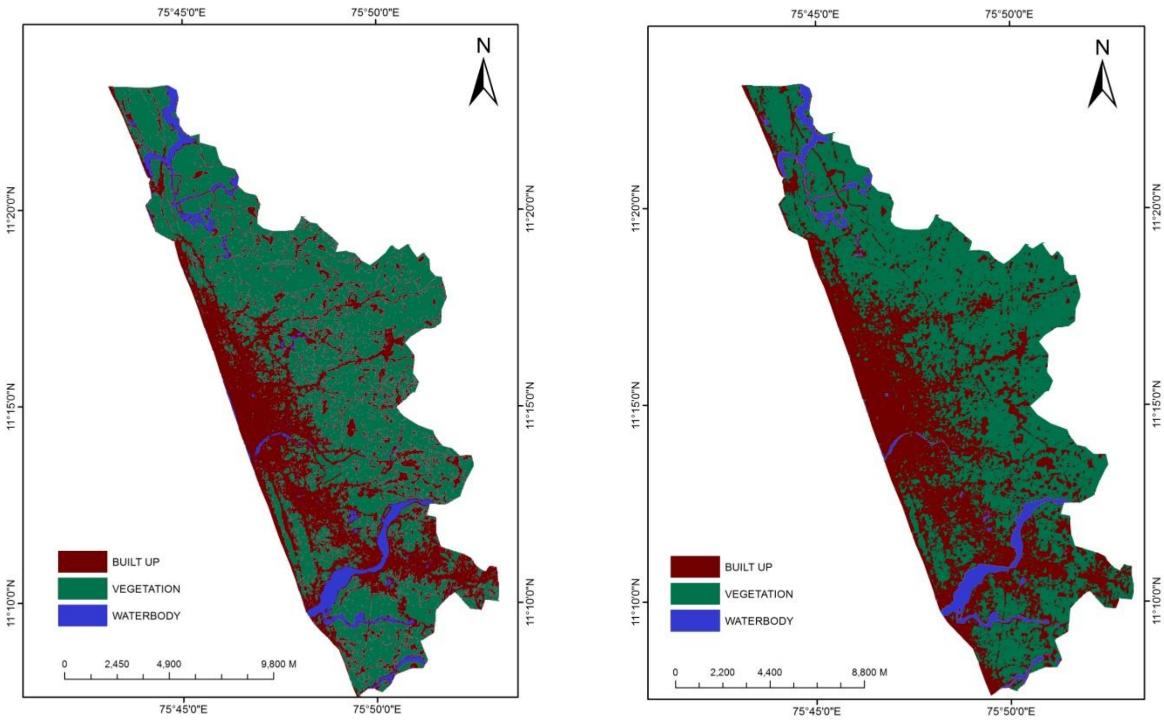
Results and analysis of this study is divided into four phases of outputs. The first output is the land use/land cover change for the year 2003 and 2015. The second output is a LST map of study area in 2003 and 2015. The third output is NDVI assessment for the year 2003 and 2015. The fourth output is correlation plotted onto vegetation indices with respect to LST.

3.1. Land use/ land cover changes

The Landsat TM image was classified into three classes using supervised classification in ERDAS Imagine 2013. As the aim of this study is to correlate the temperature distribution and vegetation cover, only three classes were derived: built-up areas, vegetation and water bodies. The land use/ land cover changes for the year 2003 and 2015 of the Calicut City and suburbs are significantly detected and presented in Figure 3a & b. The total acreage of the study area is 207 km^2. The detail acreage of the individual land cover of the study area is listed in Table 2. Over the period of 12 years, the total area for the vegetation category and water bodies decreased by 3.95% and 0.29% respectively and the built-up areas have expanded dramatically by 4.25%.

Table 2: *Land use / land cover changes as detected from LANDSAT multi-temporal images*

Land Use/ Land Cover Class	Area in km^2				
	2003	Percentage	2015	Percentage	Changes (%)
Vegetation	125.82	60.80	117.64	56.85	-3.95
Water body	10.31	4.98	9.70	4.69	-0.29
Built-up	70.82	34.22	79.61	38.47	+4.25
Total	206.95	100.00	206.95	100.00	

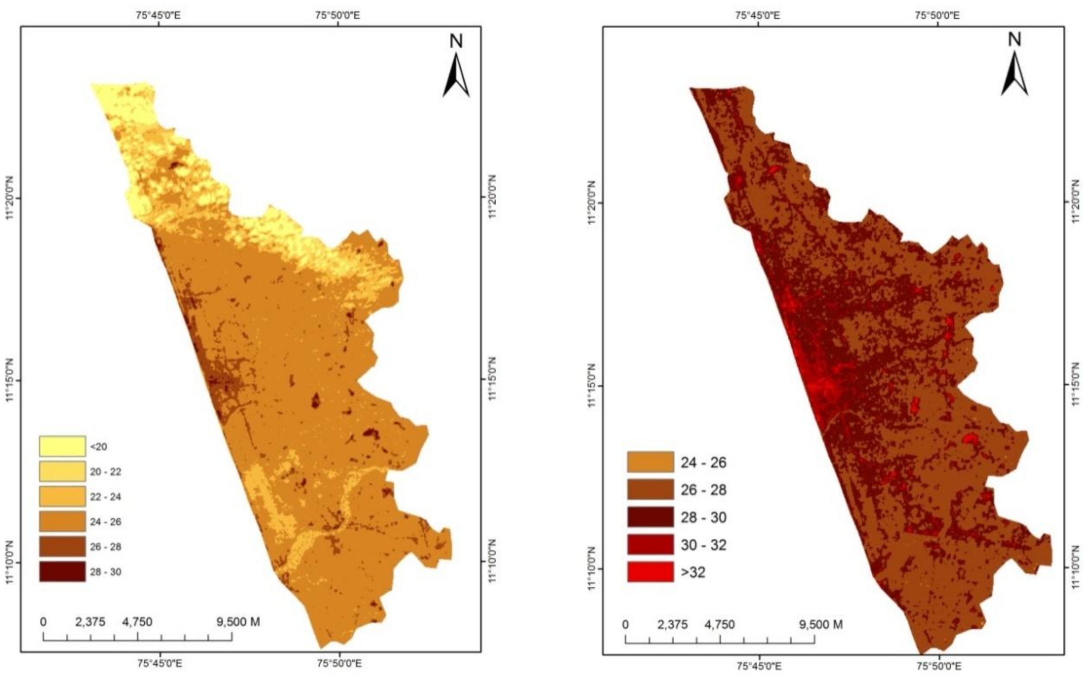


(a) (b)

Figure 3: *(a) Land use/ land cover map of 2003; (b) Land use/ land cover map of 2015*

3.2. Land surface temperature (LST)

From brightness temperature (TB) and Emissivity images the final Land Surface Temperature image was obtained by developing a temperature model in ArcGIS 10.2. The LST distributions of 2003 and 2015 are shown in the Figure 4a & b. The lowest and highest radiant temperature for 2003 were 18.2°C (in the high density vegetative area) and 30.7°C (in the built-up area) respectively. Meanwhile, for 2015 the radiant temperatures range between 24.9°C and 36.5°C. The highest temperatures were recorded within the built-up areas while the lowest was within vegetative areas. The implication of urban development especially in the coastal areas if Calicut city by replacing vegetative areas to built-up surfaces such as concrete, stone, metal and asphalt clearly increased the surface radiant temperature.

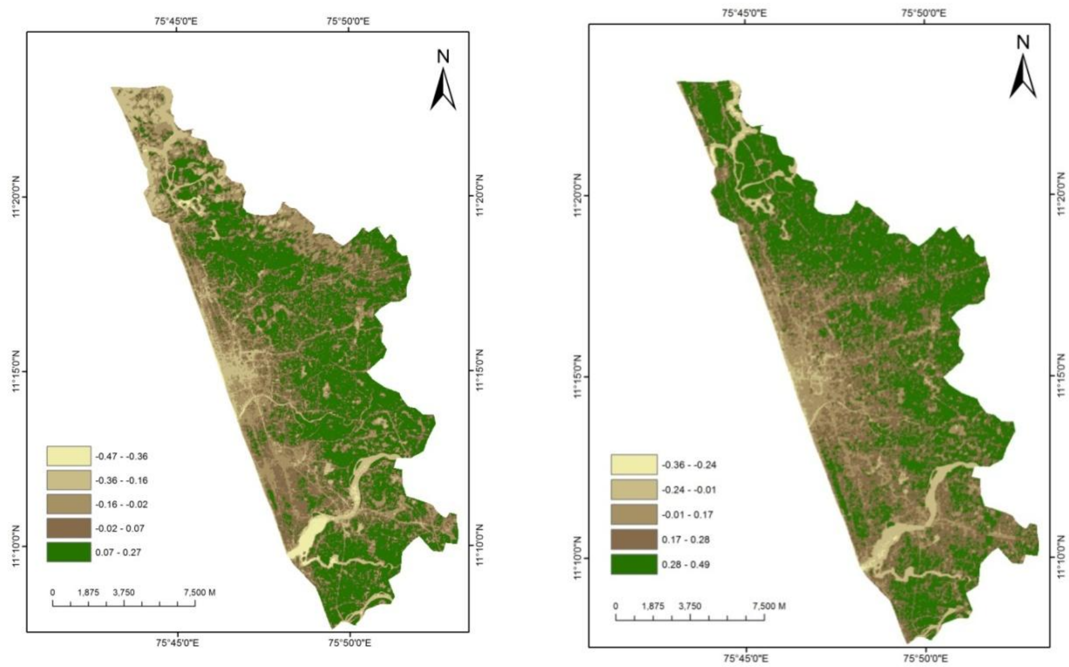


(a) (b)

Figure 4: *(a) LST (oC) for 2003; (b) LST (oC) for 2015*

3.3. Normalized difference vegetation index (NDVI)

Figure 5(a) & (b) show the NDVI maps generated from the Landsat 7 TM imagery for the year 2003 and 2015. The decrease in the vegetation growth coverage within the study area can clearly be seen. Lower NDVI values are clearly evident water bodies and built-up areas.

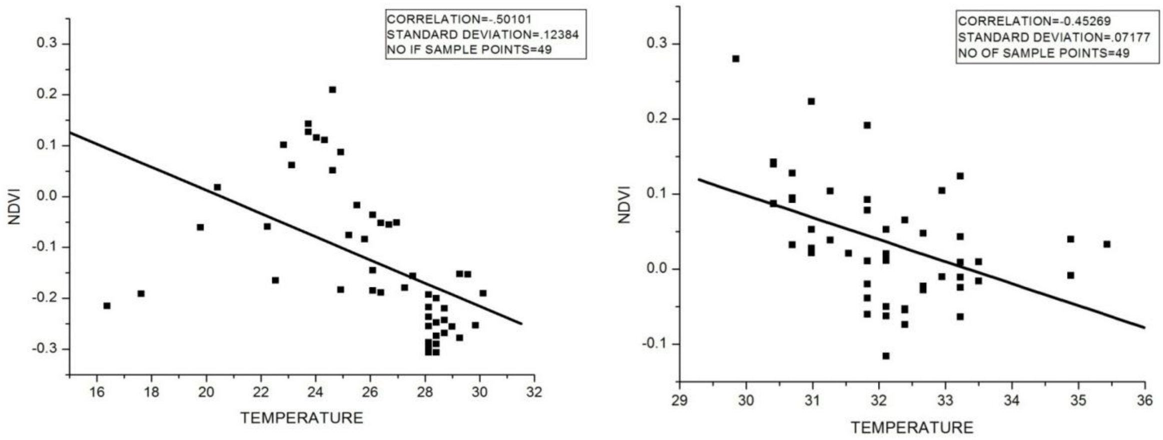


(a) (b)

Figure 5: *(a) NDVI image for 2003; (b) NDVI image for 2015*

3.4. Correlation between LST and NDVI

Land surface temperature (LST) is sensitive to vegetation cover. Figure 6(a) & (b) shows the correlation of LST and NDVI in the study area for the year 2003 and 2015 respectively. There is strong negative correlation between LST and NDVI values in Calicut city area. Thus, by greening landscaping in the urban area can help to reduce the radiant temperature of the built-up area. This study proves the positive impact of vegetation in built-up areas especially in urban centers and significantly important to help mitigate the phenomena of Urban heat island.



(a) (b)

Figure 6: *(a) Relationship of LST and NDVI in 2003; (b) Relationship of LST and NDVI in 2015*

4. Conclusion

Use of satellite remote sensing coupled with GIS provided a time and cost effective methodology for this analysis. Landsat 7 TM, ETM images were widely used to monitor the land cover changes and to analyse the spatial distribution of land surface temperature. The study is also based on the image analysis of Landsat 7 TM, ETM images to study the relationship between land surface temperature and the vegetation cover in Calicut city and suburbs, Kerala, India. The results revealed that the built-up areas in Calicut city and suburbs have expanded significantly on the expense of the vegetative areas. The total area captured in the image is equivalent to 207 km^2. In 2003, the built-up areas were 70.82 km^2 equivalents to 34.22 % of the total area and in 2015 reached an area of 79.61 km^2 equivalent to 34.47 % of the study area. Analysis the land surface temperature revealed slightly fluctuating values; the results show that LST and thermal signal of built-up and cleared land have distributed to rise average radiant temperature while vegetative areas and water bodies experiencing lower temperature.

Although this study is not conclusive, initial findings have shown that there are significant increases in the built-up areas in the Calicut city and suburbs over a period of 12 years which resulted in higher LST in built-up areas as compared to the vegetated areas. There is strong negative correlation between LST and NDVI, which indicates vegetation helps to reduce the LST of an area. Vegetation plays vital roles to alleviate the heat island effect by means of transpiration, shading and heat absorption to reduce the emissivity of the hard surface reflectivity by covering the built-up area by its shadow.

References

Chen, X.L., Zhao, H.M., Li, P.X., & Yin, Z.Y. (2006). Remote sensing image-based analysis of the relationship between urban heat island and land use/cover changes. *Remote Sensing of Environment, 104*(2), 133-146.

Mallik, J., Yogesh Kant, & Bharath, B.D. (2008). Estimation of land surface temperature over Delhi using landsat-7 ETM+. *J. Ind. Geophysics Union, 12*(3), 131-140.

Senanayake, I., Welivitiya, W., & Nadeeka, P. (2013). Remote sensing based analysis of urban heat islands with vegetation cover in Colombo city, Sri Lanka using Landsat-7 ETM+ data. *Urban Climate, 5*, 19-35.

Sundara Kumar, K., Udaya Bhaskar, P., & Padmakumari, K. (2012). Estimation of Land Surface Temperature to study Urban Heat Island effect using Landsat ETM+ Image. *International Journal of Engineering Science and Technology, 4*(2), 771-778.

Weng, Q., Lu, D., & Schubring, J. (2004). Estimation of land surface temperature-vegetation abundance relationship for urban heat island studies. *Remote Sensing of Environment, 89*, 467-483.