Science and Technology Publishing (SCI & TECH)
ISSN: 2632-1017
Vol. 5 Issue 10, October - 2021

Correlation Analysis of Vegetation and Land Surface Temperature in Uyo, Nigeria Using Satellite Remote Sensing and Python-Based Geographic Information System

Oloyede, Adamson O.[1]
Department of Electrical/Electronic and Computer Engineering, University of Uyo, Akwa Ibom State, Nigeria
adamskrd@gmail.com

Olatunbosun, Emmanuel Dapo[1]
Special Duties Department, Advanced Space Technology Applications Laboratory Uyo, Akwa Ibom State, Nigeria
dolatunbosun@astaluyo.gov.ng

Asuquo, Philip M.[2]
Department of Electrical/Electronic and Computer Engineering, University of Uyo, Akwa Ibom State, Nigeria
philipasuquo@uniuyo.edu.ng

Udo, Uwem E.[3]
ASTAL Geodigital Consultancy Services, Advanced Space Technology Applications Laboratory Uyo, Akwa Ibom State, Nigeria
uudoh@astaluyo.gov.ng

Essien, Imoh Okon[4]
ASTAL Geodigital Consultancy Services, Advanced Space Technology Applications Laboratory Uyo, Akwa Ibom State, Nigeria
iessien@astaluyo.gov.ng

***Abstract*— In this paper, Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Landsat 8 satellite remotely sensed data is acquired to analyze the correlation between vegetation and land surface temperature, in Uyo local government Area of Akwa Ibom State, Nigeria. The study area lies between latitude 5°5’2.288”N and 4°52’32.477”N and longitude 7°47’25.785”E and 8°0’54.393”E. Python scripted ArcGIS program was used to carryout image preprocessing on the Landsat 8 satellite data. In addition, Python scripted ArcGIS program was also used to extract a subset of the multispectral band and thermal infrared band out of eleven bands contained in the acquired satellite image data. The OLI band 4 (Red) and band 5 (Near-Infrared) are used in the Normalized Difference Vegetation Index (NDVI) computation, while TIRS band 10 (TIRS1) is employed for estimation of the brightness temperature. The NDVI value is ranged between -1 (low) and 1 (high). The results show that at a point when NDVI is 0.7, surface temperature is 21°C, also when NDVI is -0.1, surface temperature is 25.3°C. There is a clear indication of a negative correlation between vegetation and land surface temperature, with value of -0.623 at p<0.001 level of significance. This implies that as the vegetation cover of the land surface increases, the land surface temperature decreases.**

Keywords— Data Analysis, Satellite Remote Sensing, Geographic Information System, Normalized Difference Vegetation Index (NDVI), Land Surface Temperature (LST)

1. Background

Urban heat islands (UHI) are the new normal trends experience in metropolitan areas across the world. UHI arise when surface temperature and air are hotter, compared to their rural surroundings [1]. Anthropogenic activities of man such as urbanization leads to decrease of vegetated surfaces and comparative increase of built-up surface area. Built-up surfaces confine solar radiation by day and consequently emit it by night [2]. Several studies carried out to investigate the impact of UHI [3]; [4] [5]; [6] shows that the worrying phenomena of UHI cannot be denied. Thus, actions should be taken to mitigate and combat UHI effects at every level of the society.

Technology has advanced to a point that information about the Earth surface, and surroundings can be acquired without any physical contact. This science is termed Remote Sensing. Remotely sensed data are then subjected to analysis, using a variety of computer programs, referred to as Geographic Information System software. Satellite remotely sensed Landsat imagery has widely been used to monitor changes in land use and as well derive land surface temperature of an area. Examples on the use of this satellite imagery in UHI studies can be found in [4] and [7]; [8] reported that vegetated lands play vital rolls in keeping temperature of its surroundings lower than non-vegetated areas. This study aims to investigate the association between land use changes and the surface temperature of Uyo local government area of Akwa Ibom State, Nigeria.

2 Study Area

The study area includes the area within the boundary of Uyo. It is in the tropical rainforest belt of Nigeria, between latitude 5°5’2.288”N and 4°52’32.477”N and longitude 7°47’25.785”E and 8°0’54.393”E. Uyo is the most developed local government area of Akwa Ibom state, Nigeria. It has a total land area of 187.473756 Sq. Km. The climate of Uyo is generally humid because of its proximity to the sea. Based on its geographical location, the climate of Akwa Ibom State can be described as a tropical rainy type, which experiences abundant rainfall with very high temperature. Annual mean temperature in Uyo ranges from 26°C to 29°C, while the mean sunshine accrue to about 1,450 hours per annum. The annual mean rainfall ranges between 2.000mm and 3.000mm, depending on the area. The month of January holds record for the minimum relative humidity, and July holds record of maximum humidity. Thick cumulonimbus type of cloud is experienced between the months March and November. High annual evaporation values that ranges between 1500 mm and 1800 mm are recorded in Uyo. Selected features for analysis, in the study area includes bare land area, built-up area, vegetation covered area and water bodies. All the data are re-projected to a Universal Transverse Mercator (UTM) coordinate system, datum WGS84, zone 32N. The following is a map of the study area, Uyo LGA, showing Akwa Ibom State and Nigeria at large.

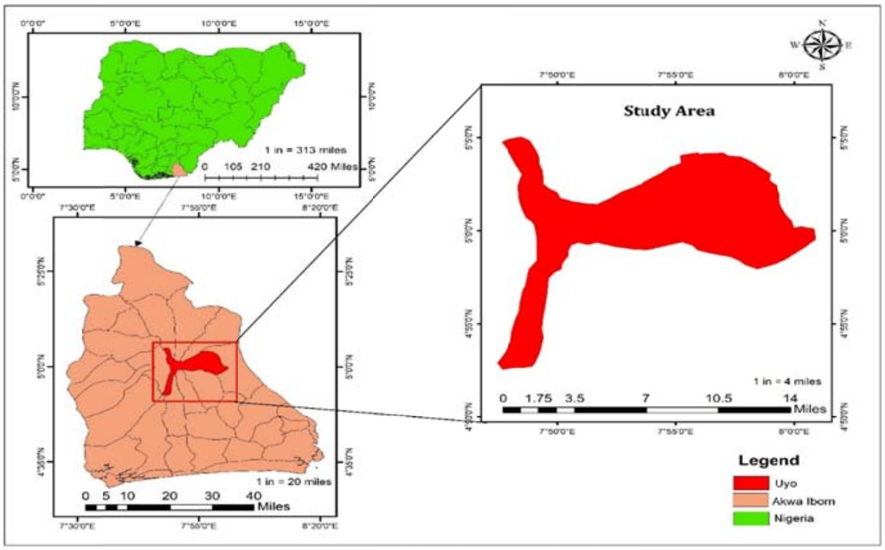

Figure 1: Location of the Study Area

3 Methodology

There are four stages in the method utilized for this analysis. The following is a highlight of the stages.

i. Acquisition of data.
ii. Data processing: This includes image preprocessing, subset of multispectral and thermal infrared bands.
iii. LST and NDVI retrieval.
iv. Data analysis.

Landsat 8 – Operational Land Imager & Thermal Infrared Sensor (OLI & TIRS) satellite data was used for this study to generate Normalized Difference Vegetation Index (NDVI) and the land surface temperature maps. Landsat 8 satellite is in the near polar orbit, revolving planet Earth in a sun-synchronous or heliosynchronous path. The following table gives details of the Landsat 8 satellite.

Table 1: Metadata of the Landsat 8 Satellite

Satellite Name	Description	Bands
Landsat 8 (Landsat Data Continuity Mission, LDCM)	Launched February 11, 2013	Band 1: Visible, 30m
	Sun-synchronous, near polar orbit.	Band 2: Visible, 30m
	Altitude of 705km.	Band 3: Visible, 30m
	Inclination angle of 98.2°.	Band 4: Red, 30m
	Cycle of 16 days.	Band 5: Near-Infrared, 30m
	740 scenes per day, on worldwide reference system-2 path/row system.	Band 6: SWIR 1, 30m
	Scene size of 185km x 180km.	Band 7. SWIR 2, 30m
		Band 8: Panchromatic, 15m
		Band 9: Cirrus, 30m
		Band 10: TIRS 1, 100m
		Band 11: TIRS 2, 100m

In this research analysis, thermal infrared sensor band 10 TIRS1 is employed for estimation of the brightness temperature, while operational land imager band 4 (Red) and band 5 (Near-Infrared) are used in the computation of NDVI.

3.1 Data Acquisition and Data Processing

Landsat 8 satellite image of 2021 is downloaded from USGS Earth Explorer website. The land use/land cover (LULC) was generated from this imagery using ArcGIS 10.5 software, which is scripted with python programming language. The satellite data product was an already geometrically corrected data set. The four land use/land cover features identified from this Landsat image are;

i. Built-up area,
ii. Water bodies,
iii. Vegetated areas and
iv. Bare land

The land use/land cover of the study area is classified according to the four features highlighted above, composed and presented in figure 2.

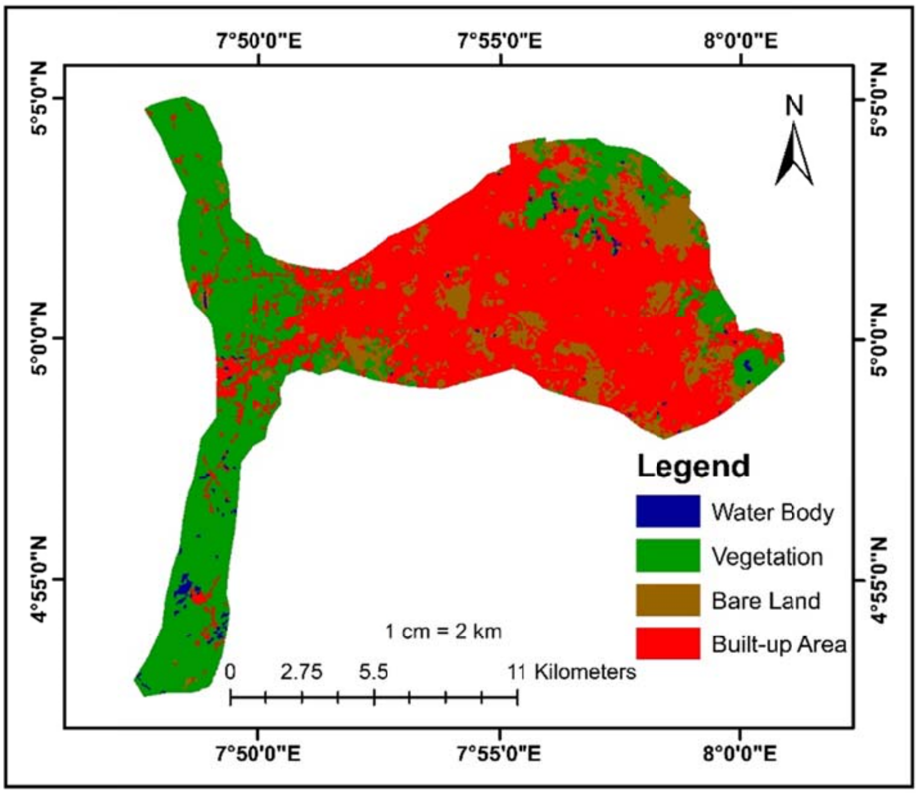

Figure 2: LULC of Uyo

3.2 Retrieval of Land Surface Temperature

The thermal infrared band (Band 10) records the radiation with spectral range between 10.6 - 11.19μm with 100m resolution from the earth surface [9]. The metadata of the satellite image is presented in Table 2.

3.2.1 The first step of LST retrieval is to convert the DN (Digital Number) values of band10 to at-sensor thermal radiance using the following equation [10].

$$L\lambda = ML * \text{Qcal} + \text{AL} \quad (1)$$

Where:

Lλ is the spectral radiance ($Wm^{-2}sr^{-1}\mu m^{-1}$)

ML = Radiance multiplicative Band (No.)

AL = Radiance Add Band (No.)

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

Table 2: Metadata of the satellite image

Variable	Description	Value
K_1 K_2	Thermal constants, Band 10	774.8853 1321.0789
Q_{calmax} Q_{calmin}	Maximum and Minimum values of Quantize Calibration, Band 10	65535 1
ML	Radiance multiplicative Band 10	3.3420E-04
AL	Radiance Add, Band 10	0.10000

3.2.2 The second step is converting the TIRS band data to brightness temperature (BT) using the thermal constants given in metadata file (Table 2) using the following equation:

$$BT = K2/ln(k1/ L\lambda + 1) - 273.15 \quad (2)$$

Where:

BT = brightness temperature (°C)

3.2.3 The third step is to calculate the Normalized Difference Vegetation Index (NDVI), which is essential to identify different land cover types of the study area using Band 5 and Band 4. NDVI ranges between -1.0 to +1.0. NDVI computation per pixel is achieved using equation 3, where the normalized difference between the red band 4 of the image ranging between 0.64 - 0.67µm and near infrared band 5 is in the range of 0.85-0.88µm [11].

$$NDVI = Float(NIR - RED)/Float(NIR + RED) \quad (3)$$

Where:

NIR = the value of the pixel near infrared band

RED = the value of the pixel red band

$$NDVI = Float(Band\ 5 - Band\ 4)/Float(Band\ 5 + Band\ 4) \quad (4)$$

The computed value of NDVI is required for the computation of proportional vegetation (P_v) and emissivity (ε).

3.2.4 Next step is to calculate proportional vegetation (P_v) from NDVI values. The P_v value is used to ascertain the area under each of the land cover type. While the value for vegetated surfaces ($NDVI_{min}$ = 0.5) may be too low in some cases, for higher resolution data over agricultural sites, $NDVI_{mIn}$ can reach 0.8 or 0.9 [10]. P_v will be calculated using equation 5 [12].

$$P_v = (NDVI - NDVI_{min}/NDVI_{max} - NDVI_{min})^2 \quad (5)$$

3.2.5 Calculating emissivity (ε): Land surface emissivity (LSE) is the average emissivity of an element of the surface of the Earth [13] calculated from NDVI. LSE is largely dependent on the surface roughness, nature of vegetation cover [14]. Computation of the value of land surface emissivity is required for the estimation of LST.

$$\varepsilon = 0.004 \times P_v + 0.986 \quad (6)$$

Where:

ε = Land surface Emissivity (LSE)
P_V = Proportion of Vegetation
0.986 correspond to a correction value of the equation

3.2.6 Land Surface Temperature (LST) Calculation

Land Surface Temperature, denoted as LST, is the radiative skin temperature of the land surface, which is computed from the three parameters. These parameters are:

1. Land Surface Emissivity,
2. Top of Atmosphere brightness temperature,
3. Wavelength of emitted radiance.

Land surface temperature was calculated using equation 7 [15]:

$$LST = BT \,/\, (1 + \left(\lambda \times \frac{BT}{c2}\right) \times \ln(E) \quad (7)$$

Where:

BT = Top of atmosphere brightness temperature (°C)
λ = Wavelength of emitted radiance. The value of λ for Landsat 8: for B10 is 10.8
E = Land surface Emissivity
c2= h*c/s=1.4388*10^{-2} mK = 14388 µm K
h = Planck's Constance = 1.38*10^{-34} Js
s = Boltzmann constant = 1.38*10^{-23} JK
c = velocity of light = 3*10^8 m/s
The following is a flowchart describing the methodology adopted for LST retrieval.

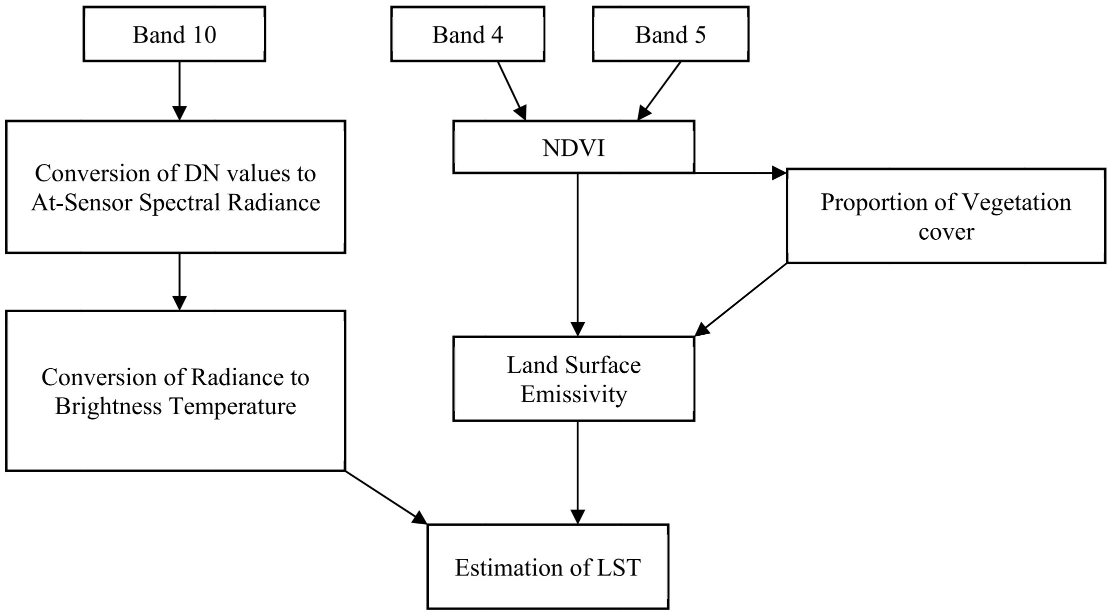

Figure 3: Flow chart for LST retrieval

4 RESULTS

The study area, which is Uyo LGA, Nigeria, is shown in Figure 1. Satellite imagery (Land Sat 8 data of 2021-02-18; Path/Row: 188/56) was downloaded from USGS website and used for this study. The features of the study area chosen includes water body, bare land, vegetation cover and built-up area, and it is shown in Figure 2.

After conversion of DN values to spectral radiances and dark object subtraction using the band minimum, NDVI and LST of the dataset is calculated. The NDVI and LST images are composed and presented in Figure 4 and 5 respectively. The NDVI values range between -1.0 to +1.0. LST was estimated and the image is shown in Figure 5 with a minimum temperature of 19.37°C and maximum temperature of 27.88°C.

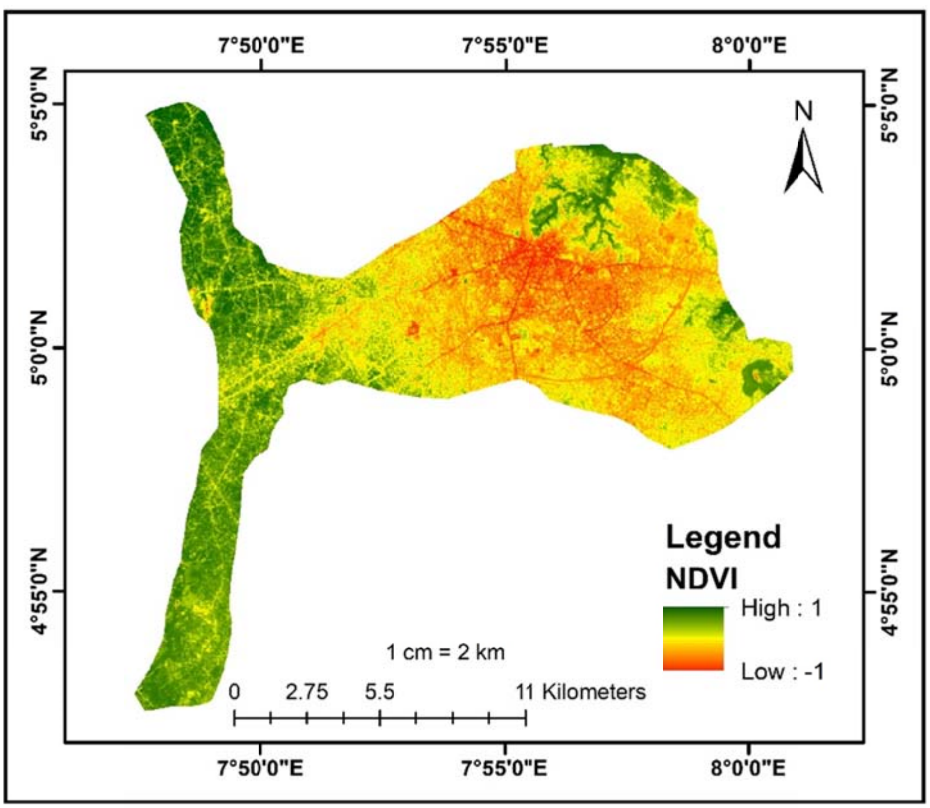

Figure 4: NDVI

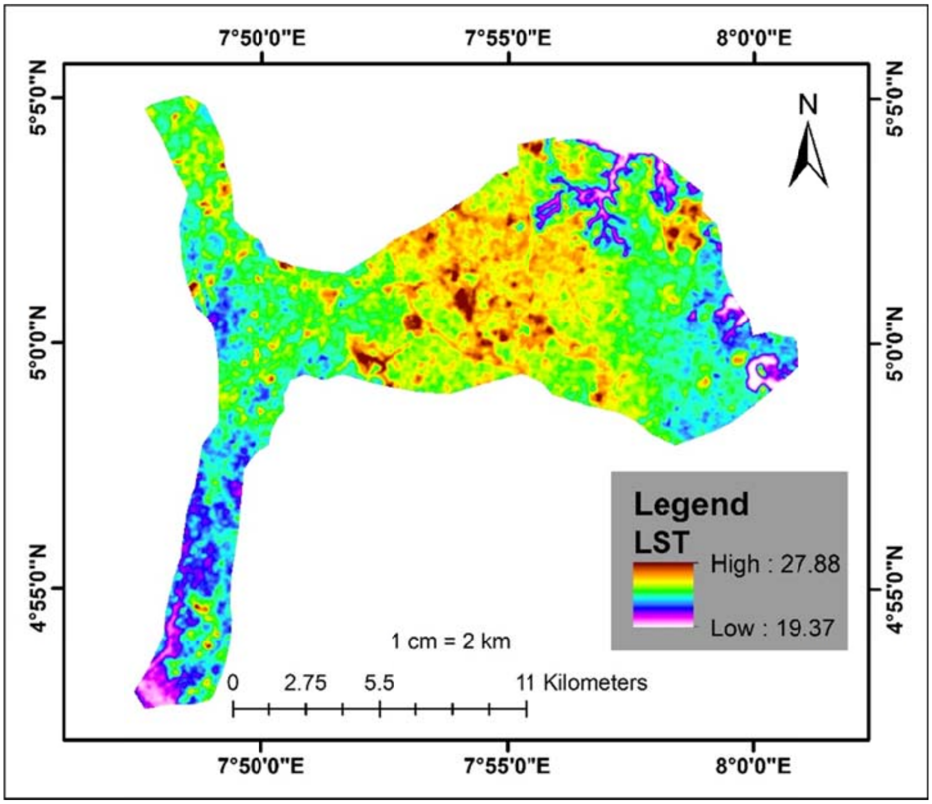

Figure 5: LST

4.1 Retrieval of LST and NDVI Values

The LST and NDVI values were retrieved using the Fishnet tool of python scripted ArcGIS 10.5. For the selected study area, 815 points were randomly generated to retrieve both LST and NDVI of same point. A scattered plot and correlation coefficient of the retrieved data using SPSS 20, a statistical tool, is shown in Figures 6 and 7.

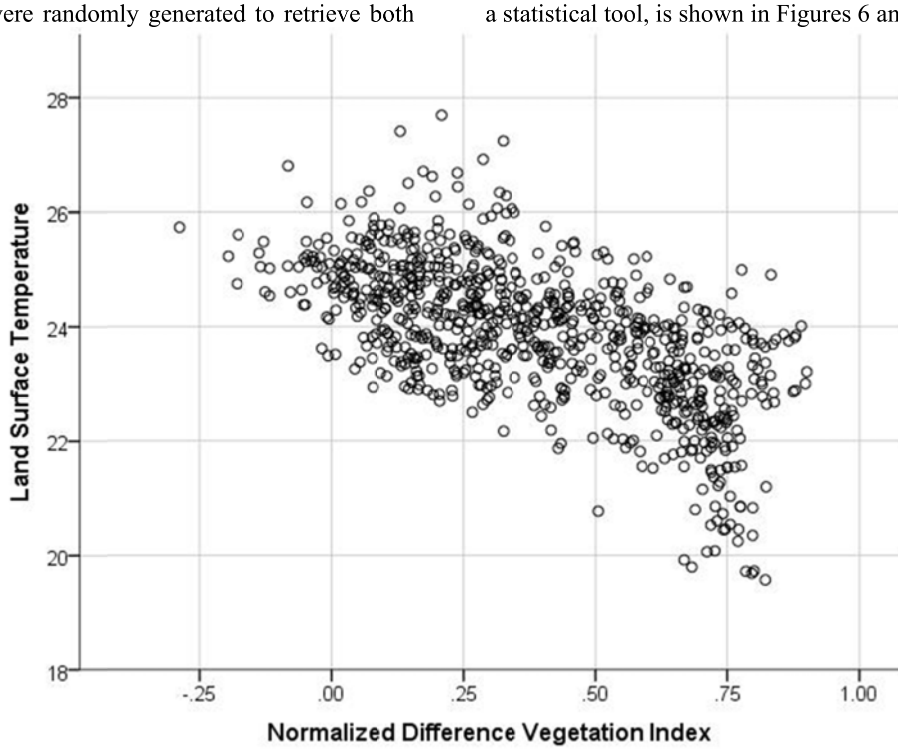

Figure 6: LST vs NDVI

		Land Surface Temperature	Normalized Difference Vegetation Index
Land Surface Temperature	Pearson	1	-.623**
	Sig. (2-tailed)		.000
	N	815	815
Normalized Difference Vegetation Index	Pearson	-.623**	1
	Sig. (2-tailed)	.000	
	N	815	815

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 7: Screenshot of Correlation between LST and NDVI

4.2 Transect Profile between NDVI and Land Surface Temperature

As shown in Figure 10, the cross-section profiles pass through different types of land use/land cover (Residential, Vegetation, Barred Land, and Water body). Figure 8 shows the NDVI value rage from -1 to 1 and Figure 9 shows the surface temperature range from 19.37°C to 27.88°C. Areas with high vegetation index have low surface temperature concurrently (refer to Figures 8 and 9). The value of NDVI at 3,000m on X-axis is approximately above 0.7 which is a high value that indicate healthy vegetation, similarly, the surface temperature of the same location is approximately 21°C. Also, the NDVI value at approximately 100m is -0.1 which indicates no vegetation present and the surface temperature is approximately 25.3°C. These figures show a clear relationship between vegetation and surface temperature. However, this relationship is a negative one as shown in figure 7 with a correlation value of -0.623 at < 0.1 Significance.

Figure 8: NDVI Cross Sectional Profile

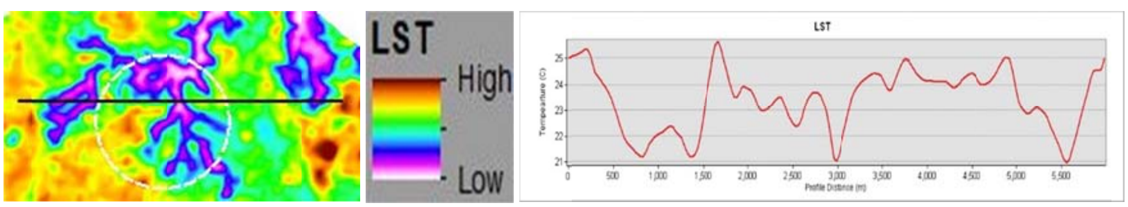

Figure 9: LST Cross Sectional Profile

Figure 10: Google Earth Image 2021

5 CONCLUSION AND RECOMMENDATION

This study has shown that land use land cover has impact on the surface temperature of the environment, especially built-up areas with little or no vegetation cover have higher temperatures compare with areas with vegetation cover and water bodies. This indicate that vegetation and water bodies have significant influence on the surrounding surface temperature. Although anthropogenic activities of man such as deforestation and urbanizations lead to increase in LST, urban green roof, tree planting should be considered as measures to mitigate the imbalance caused by the activities of man. Comprehensive ground truth work is needed to further validate the results acquired from satellite imagery.

REFERENCES

[1] L. M. Gartland, "Heat Islands: Understanding and Mitigating Heat in Urban Areas," *Routledge,* p. 208, 2008.

[2] W. D. Solecki, C. Rosenzweig, G. Pope, M. Chopping, R. Goldberg and A. Polissar, "Urban Heat Island and Climate Change: An Assessment of Interacting and Possible Adaptations in the Camden, New Jersey Region," *Environmental Assessment and Risk Analysis Element,* 2004.

[3] M. Javed and R. Atiqur, "Impact of population density on the surface temperature and micro-climate of Delhi," *CURRENT SCIENCE,* 2012.

[4] H.-A. Choi, W.-K. Lee and W.-H. Byun, "Determining the Effect of Green Spaces on Urban Heat Distribution Using Satellite Imagery," *Asian Journal of Atmospheric Environment,* pp. 127-135, 2012.

[5] Y. Hai, W. Xue, H. Peiyao and D. Li, "Study on the microclimatic characteristics and human comfort," *Procedis Environmental Sciences,* pp. 755-765, 2012.

[6] P. Shahmohamadi, A. I. Che-Ani, A. Sairi, M. Mohd-Nor and M. Surat, "Mitigating the Urban Heat Island Effect: Some Points," *European Journal of Scientific Research,* pp. 204-216, 2009.

[7] A. Buyadi, W. Mohd and A. Misni, "Impact of vegetation growth on urban surface temperature distribution," *Earth and Environmental Science,* 2014.

[8] S. N. A. Buyadi, W. M. N. W. Mohd and A. Misni, "Impact of Land Use Changes on the Surface Temperature Distribution," *Procedia - Social and Behavioral Sciences,* pp. 516 - 525, 2013.

[9] D. Jeevalakshmi, S. N. Reddy and B. Manikiam, "Land Surface Temperature Retrieval from LANDSAT data using Emissivity Estimation," *International Journal of Applied Engineering Research,* pp. 9679-9687, 2017.

[10] W. Fei, Q. Zhihao, S. Caiying, T. Lili, K. Arnon and Z. Shuhe, "An Improved Mono-Window Algorithm for Land Surface Temperature Retrieval from Landsat 8 Thermal Infrared Sensor Data," *remote sensing,* pp. 4268-4289, 2015.

[11] T. J. Charlie, C. Lee, T. E. John and B. Christopher, "Remote sensing land surface temperature for meteorology and climatology: a review," *METEOROLOGICAL APPLICATIONS,* vol. 18, pp. 296-306, 2011.

[12] S. Qinqin, T. Jianjun and X. Yonghang, "An ERDAS image processing method for retrieving LST and describing urban heat evolution: a case study in the Pearl River Delta Region in South China," *Environ Earth Sci,* vol. 59, pp. 1047 - 1055, 2014.

[13] A. Ugur and J. Gordana, "Algorithm for Automated Mapping of Land Surface Temperature Using LANDSAT 8 Satellite Data," *Journal of Sensors,* 2016.

[14] M. Javed, K. Yogesh and B. Bharath, "Estimation of land surface temperature over Delhi using Landsat-7 ETM+," *J. Ind. Geophys. Union,* vol. 12, pp. 131 -140, 2008.

[15] Y. Xiaolei, G. Xulin and W. Zhaocong, "Land Surface Temperature Retrieval from Landsat 8 TIRS—Comparison between Radiative Transfer Equation-Based Method, Split Window Algorithm and Single Channel Method," *remote sensing,* vol. 6, pp. 9829-9852, 2014.