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The Impact of Land Use and Land Cover Change on Land Surface Temperature Using Geospatial Techniques in Sokoto North Local Government Area of Sokoto State, Nigeria

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Abstract: Remote sensing and GIS play an important role in monitoring the land use and land cover changes. In recent years, researchers have conducted many researches on the impact of land use and land cover on land surface temperature (LST). In this study, the impact of land use and land cover on LST in Sokoto North was analyzed using geospatial techniques. Landsat8 image of 2013 and 2018 was downloaded due to the unavailability of land use/land cover map of the study area for supervised classification using maximum likelihood in ArcGIS 10.5. Four classes were selected, namely; vegetation, water body, built up area and bare land. In the computation of LST thermal bands 10 and 11 were used in the study, NDVI and land surface emissivity (LSE) were used as an input in estimating LST. Relationship between LULC and LST was realized and the finding from the research revealed that bare land and built up area exhibited more surface temperature than water body and vegetation in 2013 and 2018 year. In 2013 it shows that bare land exhibited value that range from 37°C to 41°C, built up area with the value from 35°C to 37°C, vegetation and water body revealed low surface temperature with the value from 30°C to 35°C while in 2018 bare land and built up area exhibited more surface temperature with values from 38°C to 43°C and 35°C to 38°C. Vegetation and water body revealed low surface temperature with a value range between 29°C to 35°C. Based on the correlation analysis conducted the R square value obtained was 0.9893 in 2013 and 0.9845 in 2018,therefore the result indicated that there is a positive correlation between NDVI and LST in the study area.
Keywords: LST, NDVI, LULC, LSE, Remote Sensing, GIS.

I. INTRODUCTION

Land surface temperature (LST) is related to surface energy and water balance, at local through global scales, with principal significance for a wide variety of applications, such as climate change, urban climate, the hydrological cycle, and vegetation monitoring [9]. LST variations in space and time, measured by satellite remote sensing, are used for the estimation of a multitude of geophysical variables, such as evapotranspiration, vegetation water stress, soil moisture, and thermal inertia [9],[13]. Land Surface Temperature (LST) is the temperature of the surface which can be measured when the land surface is in direct contact to the measuring instrument [5],[11]. LST is nothing but the skin temperature of the land surface [6]. Worldwide urbanization has significantly reshaped the landscape, which has important climatic implications across all scales due to the simultaneous transformation of natural land cover and introduction of urban materials i.e. anthropogenic surfaces [6],[2]. Urbanization transforms the natural land surfaces to modern land use and land cover such as buildings, roads and other impervious surfaces, making urban landscapes fragmented and complex and affecting the inhabitability of cities [7],[3]. One of the major issues of climate change in urban areas is the increase in surface temperature. For example, IPCC (2014) predicted an increase of the global surface temperature over the 21st century, the effects of this phenomenon could lead to periods of heat wave which will impact in particular urban population around the world [10].

The degree of land surface temperature (LST) is affected by the surface attributes, which are significantly influenced by the elevation, slope and aspect. However, topography is one of the factors that control the soil moisture distribution and exerting an

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additional influence on the land surface temperature [12]. In recent years, researchershave conducted many researches on the impact of land cover on land surface temperature. GISand remote sensing play an important role in monitoring the land use and land cover changes, Recent significant advances in the data and technological integration between remote sensing and GIS suggest that the integration is a powerful and effective tool in urban studies[1]. The integration of remote sensing and GIS was found to be effective in monitoring and analyzing urban growth patterns and in evaluating urbanization impact on surface temperature [4].It has become imperative to detect LULC changes accurately at appropriate scales, and in a timely manner so as to better understand their impacts on climate and provide improved understanding on other environmental implications [8].

II. STUDY AREA

Sokoto North is a local government area in Sokoto State, Nigeria. Its headquarters are in the state capital of sokoto state. It has an area of 51km^2 and a population of 232,846 at the 2006 census. Sokoto State is a city located in the extreme northwest of Nigeria, near the confluence of the Sokoto Rima River. Sokoto North local government is located between latitude **13^0 03’ 00’’ to 13^0 08’ 00’’** and longitude **05^0 11’ 00’’ to 05^0 18’ 00’’**, it share boundary with Sokoto South LG, Kware LG and Wamakko LG.

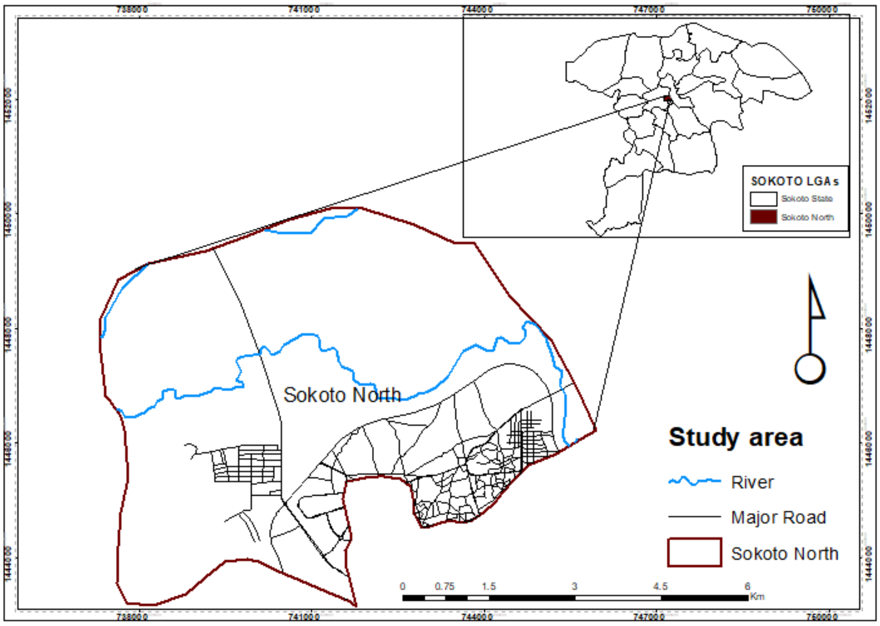

Figure1: Map of the Study area.

III. MATERIALS AND METHODS

A. Data Used

The data used in this research were landsat8 image of 2018 and the administrative map of the study area. Landsat8 was downloaded from www.usgs earth explorer; the satellite image was acquired on April 4, 2018. The landsat8 image consists of 11 bands with 30m resolution except band 8 (panchromatic) which has 15m resolution.

B. Data Processing

The data downloaded were pre-processed before the analysis was carried out. Image pre- processing which comprises layer stacking, image enhancement, band combination and false color combination were applied to the images. Pan-sharpening was done in order to improve the quality of the image. The image was projected to WGS-1984-UTMZone 32N. Supervised classification was carried out in this research and four classes were selected, namely; vegetation, water body, built up area and bare land. In addition, land surface temperature (LST), land surface emissivity (LSE) and Normalized Difference Vegetation Index (NDVI) were computed to observe the effects of land cover on LST. The land surface temperature was computed using thermal (band10) of landsat8 image.

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C. Data Analysis

Land cover map of the study area was produced in ArcGIS 10.4 software. The data was imported into the software environment, training sample manager was used to create the classes and the maximum likelihood techniques was used for the classification. The land surface temperature was computed in raster calculator under the spatial analyst tool in ArcGIS 10.4 software through the steps the following steps:

D. Steps in Computing Land Surface Temperature

1) *Step1:* Conversion of digital number to radiance. ML and AL parameters were given from the Meta data while Qcal is the actual band (band 10 and band 11).

Lλ = ML × Qcal + AL **(1)**

ML - multiplicative band
Qcal – actual digital number
AL – additive band
Lλ – spectral radiance

2) *Step2:* Conversion to At satellite brightness temperature, given the equation below the satellite temperature (T) was calculated; k_1, k_2 are thermal constant for (band 10 and band 11)given from the meta data file and Lλ was computed from equation (1). The temperature value was converted to degree Celsius (°C=T-273.15).

Table 3.1

K1	K2	ML	AL
774.8853	1321.0789	3.3420E-04	0.10000

Source: USGS

$$T=\frac{k2}{In\left(\frac{k1}{L\lambda}+1\right)-273.15} \quad \textbf{(2)}$$

Lλ – spectral radiance
K_1& K_2 are band specific thermal conversion constant (Band 10& band 11)

3) *Step3:* Land surface emissivity (LSE) was determined from equation (3), before the computation of LSE, the normalized difference vegetation index (NDVI) and proportion of vegetation (PV) were calculated through equation (3&4), and they were inputted into equation (5).

$$P_V = \left(\frac{NDVI-NDVI\min}{NDVImax-NDVImin}\right)^2 \quad (3)$$

P_V – proportion of vegetation

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

e= 0.004P_V+0.986 (5)

STEP4

Land surface temperature was derived from equation (6), BT, W, P and e values were inputted in equation (6) below.

BT/1+W*($BT|P$)*In(e) (6)

BT=Satellite temperature
W= Wavelength of emitted radiance (11.5)
P =h*c/s(1.438*10^{-2}mk)
h=Plancks constant (6.626*10^{-34}js)
s= bohzmann constant (1.38*10^{-23}j/k)
c= velocity of light (2.998*10^{8}m/s)
P=14380

IV. RESULTS AND DISCUSSION

A. Analysis of the land use/ Land Cover

The result of the analysis of land use/land cover change in 2018 is shown in figure 4.1and table 4.1. As discussed earlier, four classes were classified in this study. Table4.1 revealed that bare land has the highest percentage (34.17‰), followed by built up (31.33‰) and vegetation (29.07‰), while the water body has the lowest percentage (5.43‰).

The analysis for 2013 shows that bare land has the highest percentage in the area (42.56‰), the vegetation is the second highest, followed by the built up area, and the water body has the lowest. The results of the analysis of land use/land cover for 2013 and 2018 indicated that change had occurred in the study area over a period of five years. It can be seen from table 4.1 and table 4.2 vegetation and bare land have reduced drastically, in 2013 the vegetation covered about 12.00 km^2 while in 2018 the values reduced to 11.64km^2 and the percentage of the bare land reduced from 17.10 km^2 to 13.68 km^2. On the other hand the water body has increased from 0.95km^2 to 2.17km^2, the reduction of the percentage of bare land and vegetation is due to the recent increased in urbanization in the study area.

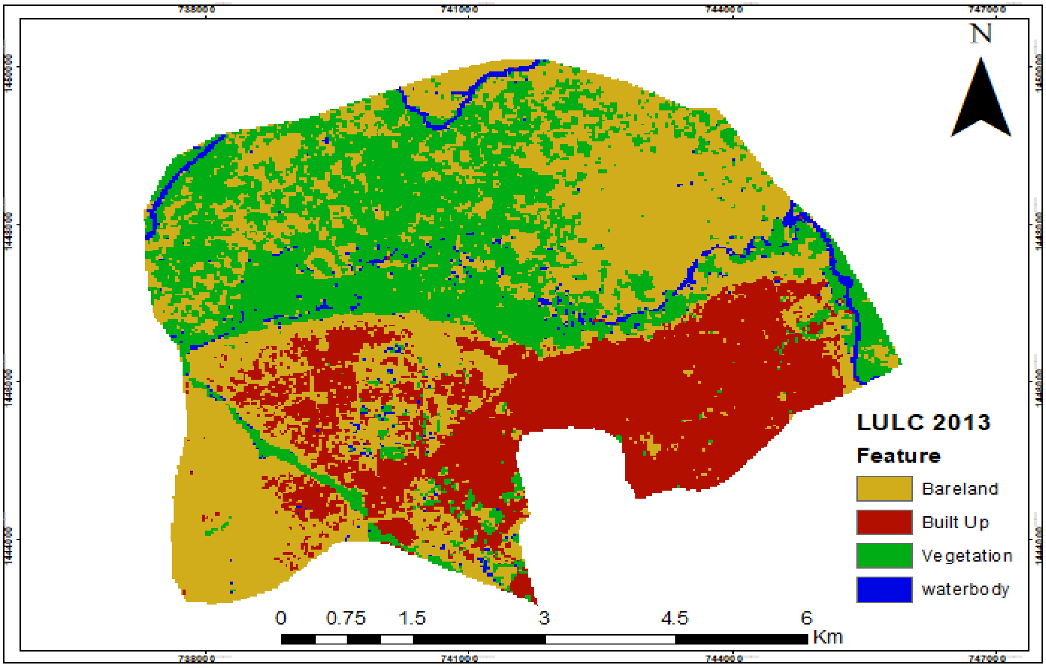

Figure 4.1: Land use/land cover.

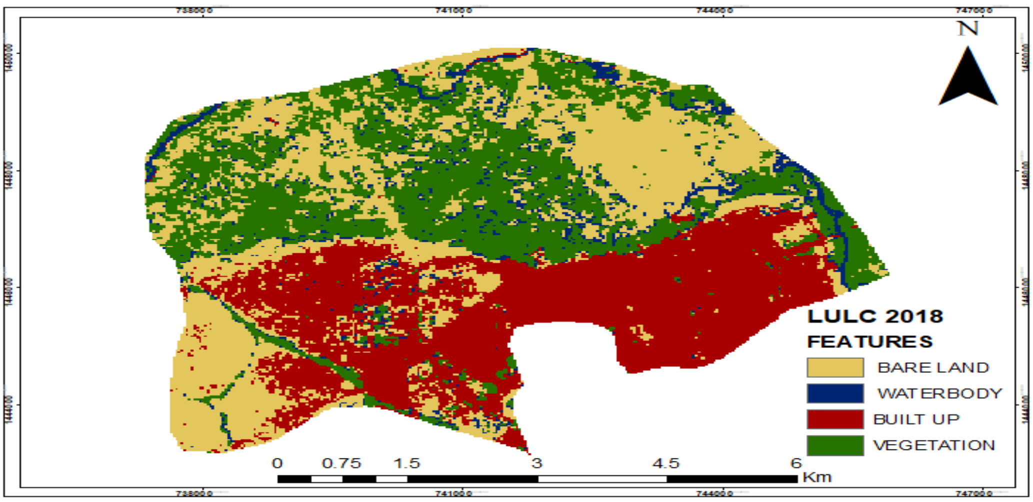

Figure 4.2: Land use/land cover

Table 4.1: LULC 2013

S/NO	Features	Area/km^2	Percentage
1	Built Up	12.55	31.33‰
2	Vegetation	11.64	29.07‰
3	Water body	2.17	5.43‰
4	Bare Land	13.68	34.17‰
	Total	40.04	100‰

Table 4.2: LULC 2018

S/NO	Features	Area /km^2	Percentage
1	Built Up	10.12	25.20‰
2	Vegetation	12	29.88‰
3	Water body	0.95	2.35‰
4	Bare land	17.1	42.56‰
	Total	40.17	100‰

B. Analysis of LST

The LST maps (figure 4.3 and 4.4) show the variations in temperature of the selected years. In 2013, the highest surface temperature observed ranges from 37°C to 41°C and the lowest temperature ranges from 30°C to 35°C(Figure 4.3), while in 2018, the highest surface temperature ranges from 38°C to 43°C and the lowest was between 29°C to 35°C (figure 4.4).From the LST map of 2013 indicates that bare land exhibit more surface temperature than any other feature with a value that ranges from 37°C to 41°C, followed by a built up area with the value from 35°C to 37°C. While vegetation and water body revealed low surface temperature with the value from 30°C to 35°C.The LST map of 2018 depicted similar result with that of 2013.It can be seen from the LST map of 2018, which shows that bare land and built up area exhibit more surface temperature than others with values from 38°C to 43°C and 35°C to 38°C. While vegetation and water body revealed low surface temperature with a value range between 29°C to 35°C.

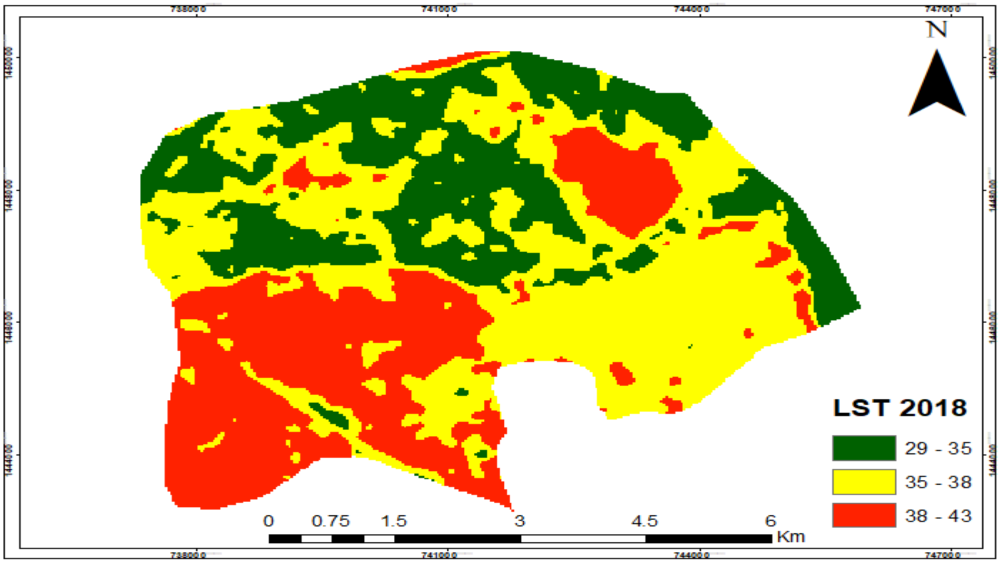

Figure 4.3: land surface temperature

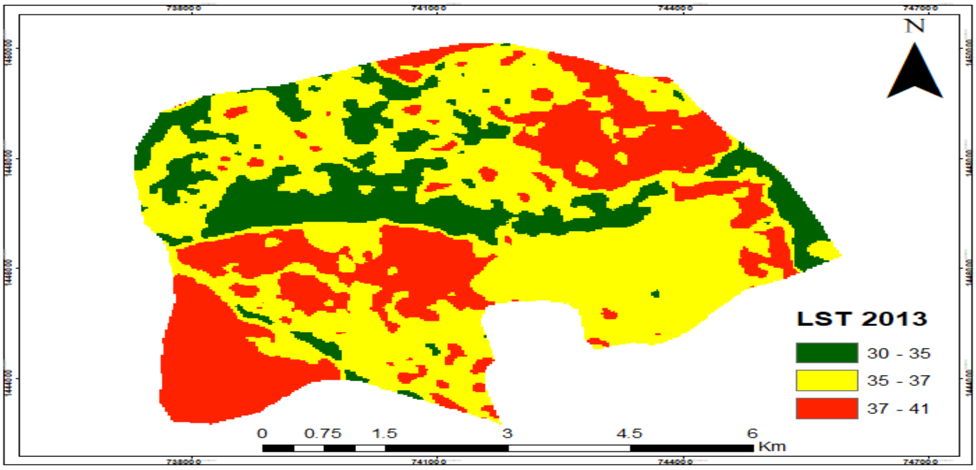

Figure 4.4: land surface temperature

C. Relationship Between LST and NDVI

NDVI play a vital role in LST computation. The outcome of the analysis of NDVI for 2013 and 2018 are shown in figure 4.5 and 4.6). The highest value of NDVI in 2013 is 0.425166 and the lowest is -0.0441518 while in 2018 the high value is 0.389733 and the lowest is -0.0409998. Therefore it can be deduce that the vegetation in the study area has decreased from 2013 to 2018.The r square value obtained (Figure 4.7 and Figure 4.8) shows that there is a strong correlation between LST & NDVI for both 2013 and 2018 analysis.

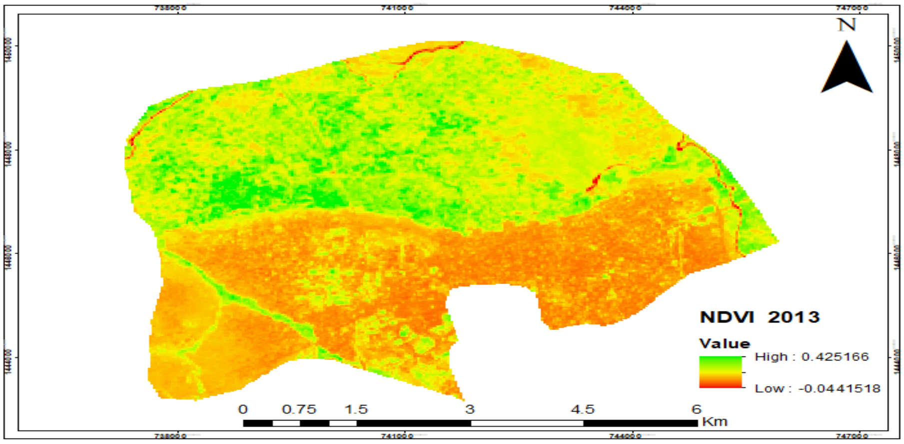

Figure 4.5: NDVI 2013

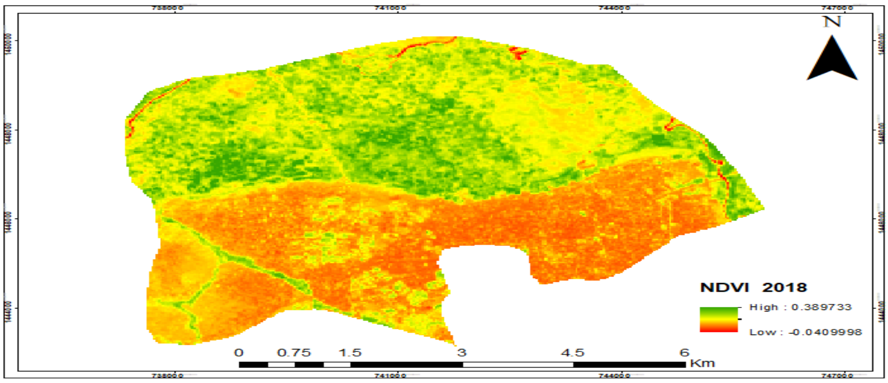

Figure 4.6: NDVI 2018

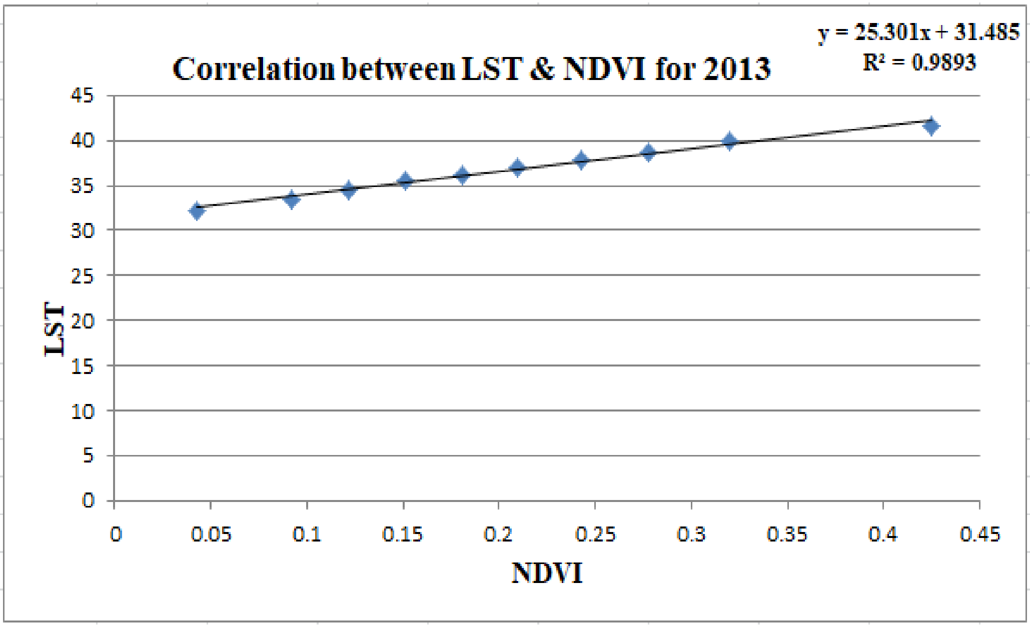

Figure 4.7: Correlation between LST &NDVI 2013 year

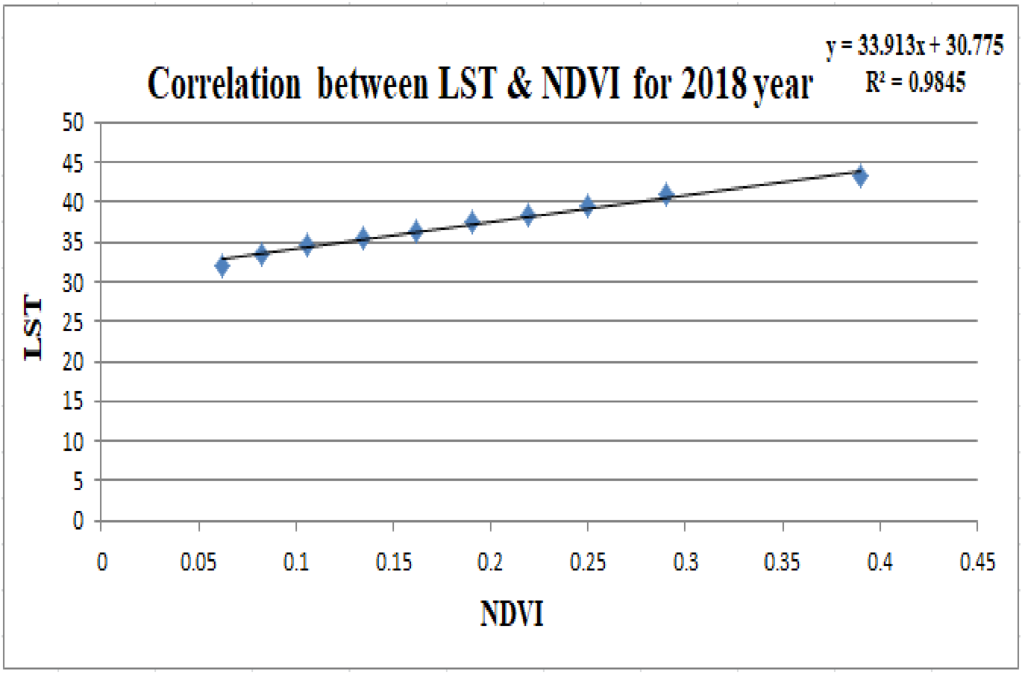

Figure 4.7: Correlation between LST &NDVI in 2018 year

V. CONCLUSION

The integration of remote sensing and GIS was found to be effective in monitoring and analyzing urban growth patterns and in evaluating urbanization impact on surface temperature in this research. The result obtained from this research has demonstrated the capability of GIS and remote sensing in detecting, monitoring and analyzing the impact of land use/land cover on surface temperature. In this study, the impact of LULC on LST was analyzed using the thermal band 10 and 11 from landsat8 image of 2013 and 2018. Based on the analysis of LULC and LST conducted, the outcome revealed that LULC has serious effects on the LST in the study area; higher surface temperature values were recorded in bare land and built up area in 2013 and 2018 year. The correlation analysis carried out has indicated the existence of relationship between NDVI and LST in this study.

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