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Articles

A STUDY ON THE RELATIONSHIP BETWEEN LAND SURFACE TEMPERATURE AND NORMALIZED DIFFERENCE BUILT-UP INDEX: A CASE OF AIZAWL CITY.

- Vanlalchhuanga
Brototi Biswas
Lalrinmawia

Abstract : *Increase in Land Surface Temperature has been seen as the impact of urban development. The current study has performed determination of Land Surface Temperature (LST) and Normalized Difference Build up Index (NDBI) of Aizawl city using Landsat 8 OLI/TIRS satellite data. The NDBI shows the values ranges from -0.3 to 0.2. The higher NDBI values indicate highly concentrated settlements, while the negative values indicate a water body. LST was identified to range from 8.6°C to 23.9°C, and both variables indicated that the higher values were observed within the city's center. Their functional relationship has been determined through simple linear regression, the LST as dependent and NDBI as the independent variables. The correlation coefficient is 489 and the R2 equals 23.9% with the slope of 16.92 and intercept value as 16.96.*

Keywords : *Land Surface Temperature, Landsat, NDBI, Aizawl City*

1. Introduction

The human impacts on the natural environment have been manifested in urbanization, which leads to the rising of temperature in and around the urban area as compared to their surrounding rural areas. This heat concentration around the urban areas is termed as the Urban Heat Island. The heat released from urban houses, transportation and industry is the main causes of urban heat island (Chakraborty et al., 2014). Remote sensing satellite data is the most suitable way to study the spatial and temporal variations of LST (Li et al., 2013). In remote sensing, Thermal infrared (TIR) sensors can obtain quantitative information of surface temperature (Mallick et al., 2008). For understanding the impact of urban infrastructure development in surface air temperature, the current study will enhance the relationship between Normalized Difference Built up Index (NDBI) and Land Surface Temperature (LST) of Aizawl city.

The land surface temperature does not depend upon a single factor (Mathew et al., 2017), land temperature records are much higher in the built up areas as compared to the other land cover of the urban surrounding areas (Grover & Singh, 2015).Likewise, the vegetation covered area has the lower surface temperature(Li et al., 2013; John et al., 2020).

The land surface temperature is proven to have the positive correlation

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with the urban area (Guha et al., 2018). Although other platforms, such as MODIS (or Moderate Resolution Imaging Spectro-radiometer), provided the open source readily available LST data, the Landsat 8 satellite imagery was employed due to its higher spatial resolution to explore the relationship between the LST and NDBI. Landsat 8 satellite has the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) instruments which were both utilized for determining the Land Surface Temperature and Normalized Difference Built up Index.

2. Study Area

The study area Aizawl city is the capital of Mizoram located between 92°40'E - 92°47'E Longitude, 23°39'45"-23°50'39" N Latitude. As per 2011 census, Aizawl had a population of 293,416. This is 26.89% from the total population of the state. Females constitute 50.61% of the population and males made up the remaining 49.39%. Under the Köppen climate classification, Aizawl features a humid subtropical climate (Cwa). The rapid growth of Aizawl population has put tremendous pressure on the land, economy and physical infrastructure of the city (Saitluanga, 2018). The city has an area of 120.25 sq.km.

2.1 Data and Methodology

Landsat 8 imagery had been retrieved from USGS (United States Geological survey) earth explorer data portal, which provides 11 bands with different wavelengths. For the current study, Landsat 8OLI/TIRS band 10 (10.6 - 11.19 μm) 100 m which was resampled to 30m spatial resolution, band 6 (1.57 - 1.65 μm), 30 m spatial resolution, band 5 (0.85 - 0.88 μm), 30 m spatial resolution and band 4 (0.64 - 0.67 μm) 30 m spatial resolution were used to determine the LST and NDBI, in Arcmap 10.5 platform. For determining the NDBI, the following equation is used:

NDBI =(SWIR–NIR)/(SWIR+NIR)

In the Landsat 8 data band 6 is the SWIR and band 5 is the NIR, Normalize Difference Build-up Index value lies between -1 to +1. Negative value of NDBI represents water bodies where as higher value represents build-up areas (Yuvaraj, 2020). To calculate the Land Surface Temperature, the thermal infrared sensor band 10 as well as near infrared band 5 and red band 4 were used. The following equations have been undertaken to retrieve the LST from Landsat 8 data.

(i) Conversion of Thermal infrared pixel number to Top Of Atmosphere(TOA) radiance

$$L\lambda = ML * Qcal + AL - O_i$$

Where,

$L\lambda$ = Top of Atmosphere Spectral Radiance

ML = Multiplicative rescaling factor of specific badn

Qcal = quantized and calibrated standard product pixel values (DN)

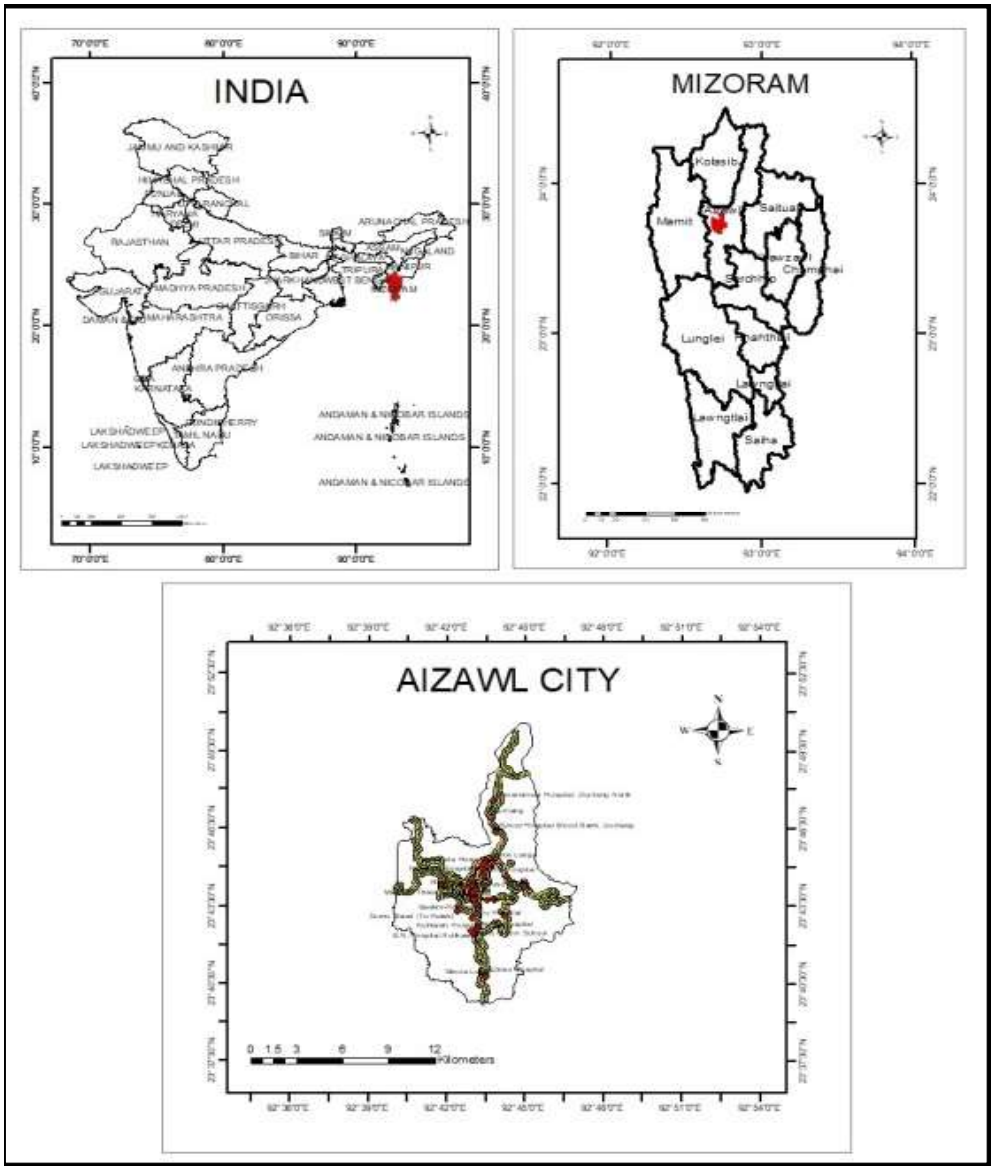

Figure 1. Study area

AL = Additive rescaling factor of specific band

O_i = is the band correction for band 10

(ii) Conversion of TOA to Brightness Temperature (BT)

$$BT = K_2 / \ln(K_1 / L\lambda + 1) - 273.15$$

Where,

BT = TOA brightness temparature

$L\lambda$ = TOA spectral radiance

K_1 = Thermal conversion constants for specific bands

K_2 = Thermal conversion constants for specific bands

(iii) Proportion of Vegetation (P_v)

$$P_V = NDVI - NDVI_{min} / NDVI_{max} - NDVI_{min}$$

Where,

$NDVI_{min}$ = Minimum Dn values from NDVI

$NDVI_{max}$ = Maximum Dn values from NDVI

For determining the NDVI the following equation is used

NDVI = NIR – Red / NIR + Red

(iv) Land Surface Emissivity (LSE)

$$E = 0.004 * PV + 0.986$$

Where,

P_v = Proportion of Vegetation

0.986 = correction value of the equation

0.004 = standard deviation of 49 soil spectra

(v) Land surface Temperature

$$LST = BT / (1 + (\lambda * BT / C_2) * \ln E))$$

Where, BT = TOA brightness tempararure

λ = wavelength of emitted radiance

E = Land surface emissivity

C_2 = h* c/s

h = Plank constant = $6.626 * 10^{54}$ JK

c = velocity of light = $2.998 * 10^{8}$ m/s

s = Boltzman constant = $1.38 * 10^{-23}$ JK

3. Data Analysis

After processing and retrieving the data from Landsat 8 OLI/TIRS, the pixel/ digital numbers (Dn) values were extracted through Fishnet in Arcmap. The Dn values were imported to SPSS, and then statistical analysis of correlation coefficient and regression model of LST AND NDBI were determined.

4. Results and discussion

The land surface temperature (LST) of Aizawl city derived from Landsat 8 has the range of 8.6°C to 23.9° C, the land surface higher zones can be easily interpreted with the patterns of settlement concentration, the map clearly indicates the higher LST zones are found over the high populated area, which were in the central portion of the study area map (see Figure 2). The land temperature was recorded decreasing outward from the central portion of the map which is found to be the city business and settlement concentrated area.

The NDBI is a parameter which represents the rates of urbanization in the area, the study area had given the response of NDVI value ranges from -0.3 to 0.2, the negative value indicates the water body the value ranges from 0-0.1 can be termed as the sparse settlement concentration zones, 0.1-0.2 as the dense settlement and above 0.2 as very dense settlement area (Liviona et al.2020). The NDBI map (see Figure 3) shows the dense settlement area and the patterns of settlements along the roads, the linear sprawl of urban development has been observed in the study area.

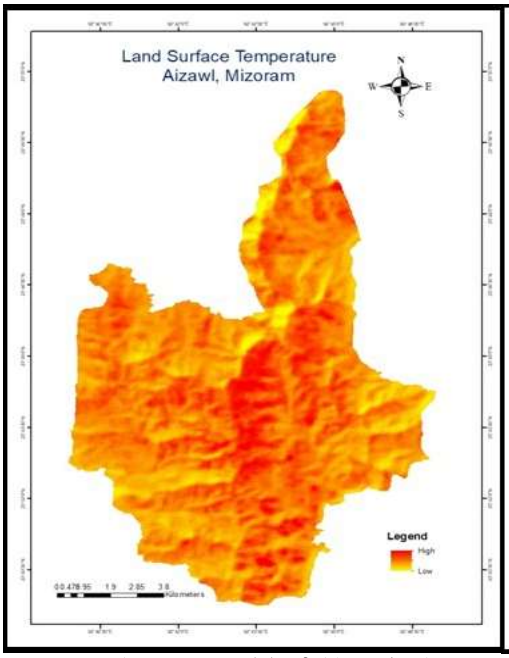

Figure 2. LST of Aizawl City

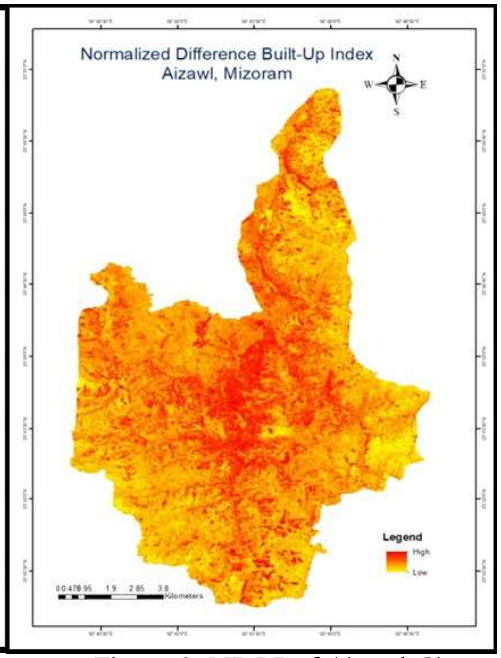

Figure 3. NDBI of Aizawl City

4.1 Effect of NDBI on LST

The functional relationship of NDBI and Land surface temperature was determined using linear regression model. In regression analysis the Land Surface Temperature was taken as dependent variable and NDBI as independent variable. In Table 1, the r value showed the correlation coefficient between NDBI and LST. The coefficient is .489 which shows moderate positive correlation. r^2 explains the percentage contribution of the influence of the independent variable to the dependent variable. r^2 value for the influence of NDBI with LST is 23.9%. Also, Table 2 shows the result of F-test significant value .000which indicates the NDBI has a significant effect on LST, and the scatter plot was created for developing the regression equation, the results shows the slope and intercept variables as 16.92 and 16.96 respectively. Then, the regression equation can be formulated as y=16.96+16.92*x.

Table 1. Percentage of Relations

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.489a	.239	.238	1.71837

Table 2. ANOVA table

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1155.922	1	1155.922	391.467	.000b
	Residual	3685.090	1248	2.953		
	Total	4841.011	1249			

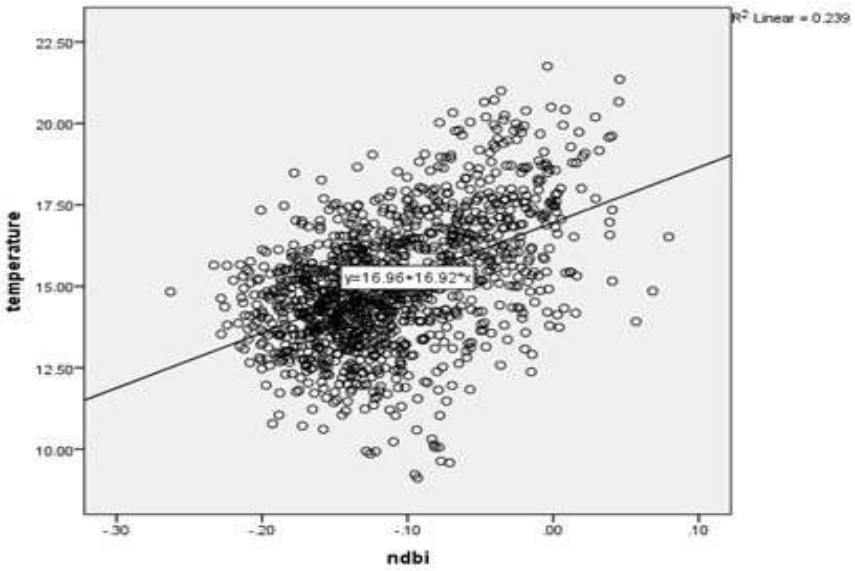

Figure 4. Regression scatter plot

5. Conclusion

The study on Land Surface temperature and NDBI has shown the maximum concentration was found in the central part of the city. The functional relationship between LST and NDBI established through the simple linear regression model had shown little less correlation as compared to other research in different. Which may be due to limited number of parameters, the study concludes that the surface temperature is positively correlated with the built-up area and vegetation plays a significant role on variation in land surface temperature.

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