

## **SPATIAL AND TEMPORAL ANALYSIS OF LANDSAT IMAGES TO EXPLORE LULC, LST, NDVI AND NDWI CHANGING PATTERN USING GEOSPATIAL TECHNIQUES: A CASE STUDY OF DHAKA DISTRICT, BANGLADESH**

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### **ABSTRACT**

The rapid infrastructure development in developing country has experienced stark impacts of climate change. This study demonstrates a geospatial technology approach for analyzing the changing pattern of Land Use/ Land Cover (LULC), Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) in rapidly expanding Dhaka district, Bangladesh. Landsat Images were acquired with minimum cloud cover (<5%) from US Geological Survey in dry season. Image processing and analysis were conducted using ArcGIS 10.7.1. Landsat TM of 2010 and Landsat OLI/TIRS of 2018, 2025 were used for Land Use and Land Cover (LULC) classification and LST calculation. Besides, NDVI and NDWI were calculated using multispectral bands at various levels. LULC classification of different years was done by unsupervised classification. Thermal band data numbers were converted to Top of Atmospheric Spectral Radiance using radiance rescaling factors. To analyze the vegetation cover of study area, NDVI was calculated using red and near-infrared (NIR) bands. Land Surface Emissivity (LSE) was also calculated for calculation of LST of Dhaka district for different years. Moreover, NDWI was calculated using green and near-infrared (NIR) bands. This study revealed that urban built-up area was increased rapidly from 27.55% to 39.79% between 2010 and 2025, whereas vegetation was declined from 35.98% to 23.35%. Besides, LST was also increased 2.18°C from 2010 to 2025 due to increase of impervious surfaces. In addition, vegetation indices decreased from 0.54472 to 0.37727 until 2018, but increased to 0.39497 in 2025 and water quantity indices also decreased from 0.37037 to 0.12168 till 2018, then it progressively climbed to 0.13547 in 2025. The change in NDVI and NDWI detection from 2010-2025 indicates that the land surface temperature rises in Dhaka year after year. Therefore, Larger scale of vegetative cover and waterbodies should be expanded to mitigate the increasing pattern of LST and to make Dhaka livable for future.

**Keywords:** Land Use/ Land Cover (LULC), Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Remote Sensing.

## **1. INTRODUCTION**

In the twenty-first century, urbanization is one of the major anthropogenic processes that reshapes land surfaces and alters the natural characteristics. The rapid growth of urban localities changes natural land use and land cover (LULC) patterns, which influences land surface temperature (LST), greenery, water bodies and hydrological cycle. Dhaka District, the capital area of Bangladesh, represents one of the fast urbanizing and over populated megacities in this world. Recently, Dhaka has gone through significant changes in LULC-especially a notable rise in built-up areas, leading to a significant drop in agricultural land, vegetation health and water bodies. These changes not only transform the Dhaka's physical environment but also have a larger impact in local climate conditions by altering the surface energy balance, evapotranspiration, air quality and albedo. Investigating the environmental sustainability and climate resilience of Dhaka District, understanding the relationship between LULC, LST, NDVI, and NDWI is vital.

The Land Surface Temperature (LST) denotes the radiative surface temperature of the earth which is detected by USGS satellite images. This is closely associated with surface energy flows and microclimate differences. The Normalized Difference Vegetation Index (NDVI) obtained from satellite images serves as a popular indicator of plant density and health. It illustrates the contrast between near-infrared and red-light reflectance where high NDVI values signifying vibrant and thick vegetation. In the same way, the Normalized Difference Water Index (NDWI) evaluates surface moisture levels and identifies water bodies. NDWI provides important insights about hydrological cycles linked to changes in land use and land cover.

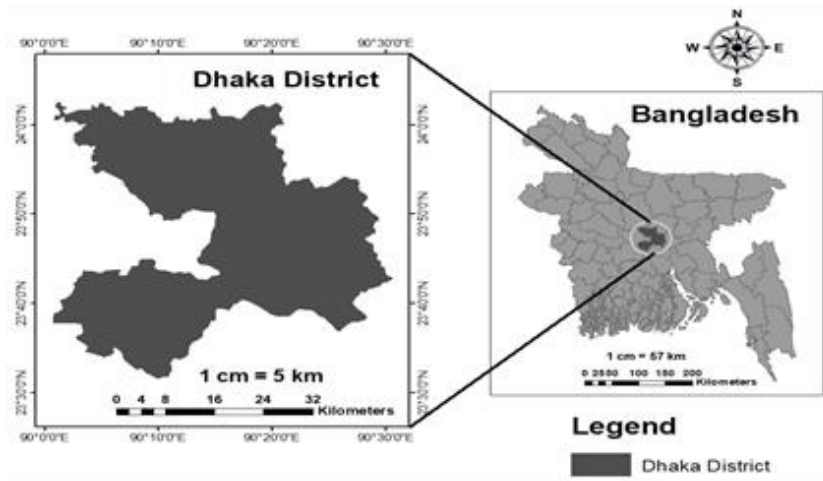
Regions with dense vegetation and large water bodies typically display lower land surface temperatures because of increased evapotranspiration and moisture's ability to absorb heat, while developed areas have higher land surface temperatures due to non-porous surfaces (concrete surface entraps large amount of heat) and diminished shading.

This study aims to thoroughly examine the spatiotemporal changes in Dhaka District's LULC, LST, NDVI and NDWI as well as to investigate their interconnections concerning climate change and global warming driven by urbanization. The research focuses on how the reduction of agricultural land, plant cover, and water bodies, combined with the growth of urban areas, has affected land surface temperatures and environmental quality in recent decades (2010 to 2025). The incorporation of remote sensing indices facilitates quantitative correlation analysis among LST, NDVI, and NDWI, emphasizing how the deterioration of green and blue areas leads to thermal anomalies throughout the district. This study revealed that urban built-up area was increased rapidly from 27.55% to 39.79% between 2010 and 2025, whereas vegetation was declined from 35.98% to 23.35%. Besides, LST was also increased 2.18°C from 2010 to 2025. Thus, this study contributes by using the most recent satellite data i.e., LANDSAT 5 & 8 images and analyzing the urbanization effect in Dhaka district. The article also stresses the need for mitigation strategies that would be effective in reducing the LST in the study area by improving the urban vegetation.

## **2. METHODOLOGY**

### **2.1 Study Area:**

Dhaka is the capital of Bangladesh. It is located in the central part of the country having latitudes 23°42' N to 24°22' N and longitudes 90°20' E to 90°37' E. The district covers an area of about 1,463 km<sup>2</sup> having population approximately 2 crore. Dhaka experiences a tropical monsoon climate, having annual average temperature in the range of 15°C to 35°C and average annual rainfall is about 2,000 mm, most of which occurs between June and September.



**Figure 1: Study Area: Dhaka District**

## **2.2 Data image Extraction:**

In this study, Landsat 5 and Landsat OLI/TIRS images of Dhaka, sourced from the USGS website, were obtained for the outer ring road boundary (WRS Path 144 Row 048) with cloud cover below 5% for the years 2010 to 2025, specifically in January or February. This period corresponds to the winter season, during which elevated temperatures are typically observed alongside reduced cloud cover.

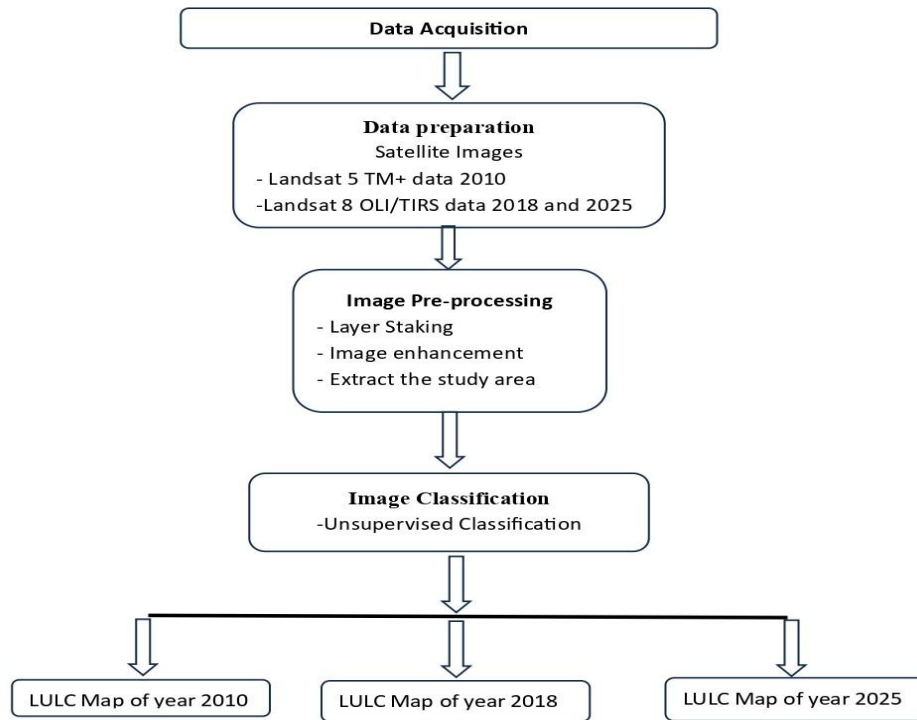
## **2.3 Pre-Image Processing:**

The projection method was applied to adjust images to fit the Universal Transverse Mercator Zone 44 based on the WGS-1984 datum. The thermal infrared resolution for Landsat 5's Band 6 is 120 meters. In contrast, Landsat 8's initial thermal infrared bands (Bands 10 and 11) have a spatial resolution of 100 meters, with Band 10 being preferred for measuring land surface temperature over Band 11. ArcGIS 10.7.1 Software was employed to carry out various tasks, utilizing the raster calculator for calculating LST, LULC classification, as well as determining NDVI and NDWI.

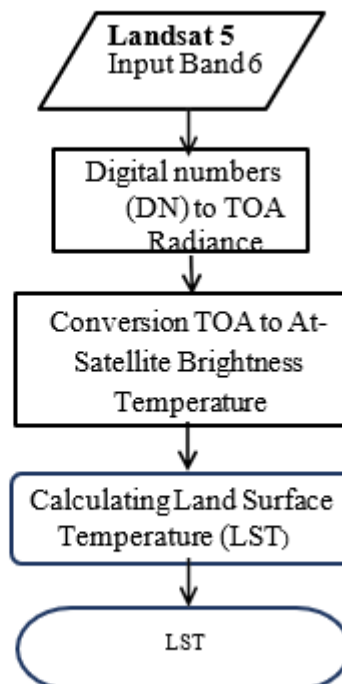
**Table 1: Landsat 5 and 8 images used to calculate LST are**

<b>Date</b>	<b>Sensor</b>	<b>Band No</b>	<b>Resolution</b>	<b>Cloud (%)</b>
30-Jan-10	TM	Band 6	30m	0.01
21-Feb-18	OLI/TIRS	Band 10	30m	0.05
24-Feb-25	OLI/TIRS	Band 10	30m	0.01

## 2.4 LULC Methodology:



## 2.5 Landsat 5: LST Methodology



### 2.5.1 Conversion of Digital Number (DN) to Radiance (L<sub>λ</sub>):

By utilizing Band 6, which is a thermal band, the spectral radiance (L) for Landsat-5 TM imagery was determined.

$$L_{\lambda} = M_L + Q_{CAL} + A_L - O_i \quad (1)$$

Here,

M<sub>L</sub> = Radiance multiplicative band(B10),

A<sub>L</sub> = Radiance additive band(B10),

Q<sub>CAL</sub> = Quantized and calibrated pixel values,

O<sub>i</sub> = correction value specific to the band10 (0.29).

### 2.5.2 Conversion of Radiance to Brightness Temperature (In Celsius):

The temperature at the surface is assessed using the thermal infrared spectrum. Band 6 (10.6-12.51 m) of the Landsat-5 TM provides thermal data. The calculation for brightness temperature (BT) is performed in the following manner.:

$$BT = \frac{K_2}{\ln\left(\frac{K_1}{L} + 1\right)} - 273.15 \quad (2)$$

Where,

BT is the brightness temperature in Celsius,

L is the Top of Atmosphere (TOA) spectral radiance in watts per square meter per steradian per micrometer (W/(m<sup>2</sup>·sr·μm)).

K<sub>1</sub> & K<sub>2</sub> is band-specific thermal conversion constant (W/(m<sup>2</sup>·sr·μm) and (Kelvin) respectively.

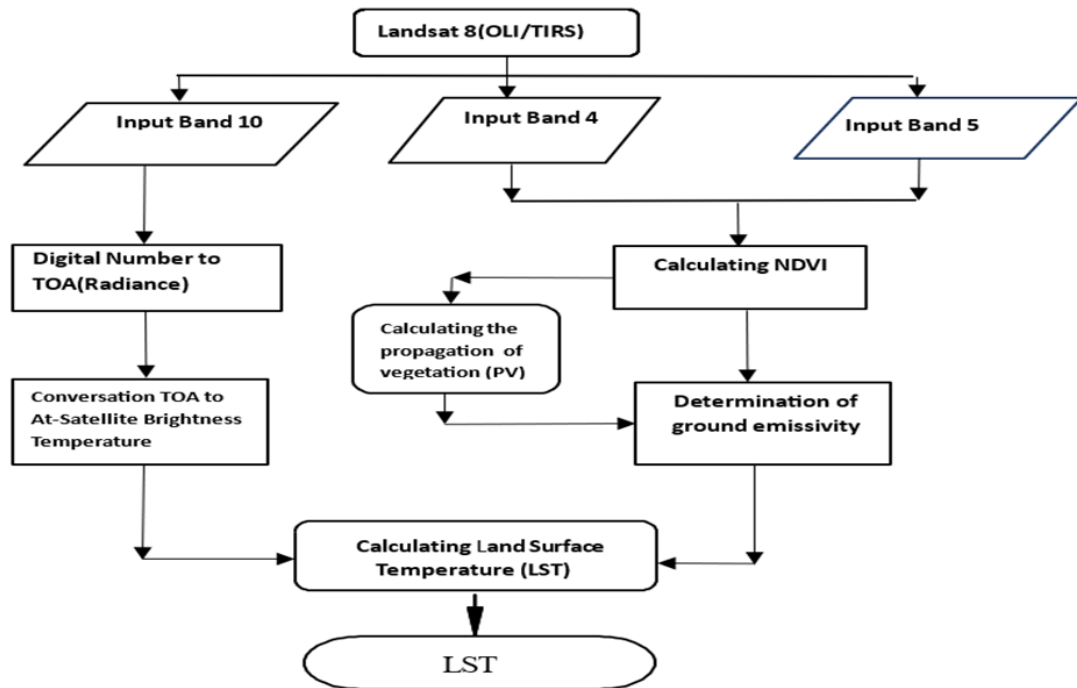
### 2.5.3 Calculation of Normalized Difference Water Index:

Using the Green and Near Infrared bands from Landsat-5 TM, which have spectral ranges of 0.45-0.51 m and 0.85-0.88 m, the NDWI will be computed by:

$$NDWI = \frac{(GREEN - NIR)}{(GREEN + NIR)} \quad (3)$$

$$NDWI = \frac{(Band2 - Band4)}{(Band2 + Band4)} \quad (4)$$

## 2.6 Landsat 8: LST Methodology:



### 2.6.1 Calculation of TOA (Top of Atmospheric) spectral radiance ( $L_{\lambda}$ ):

$$TOA(L_{\lambda}) = M_L \times Q_{CAL} + A_L - 0.29 \quad (5)$$

Where:

$M_L$  = Band-specific multiplicative rescaling factor for radiance BAND 10,  $Q_{cal}$  = The Quantized and calibrated standard product pixel value,  $A_L$  = Band-specific additive rescaling factor for radiance BAND 10,  $O_i$  = Band 10 Correction value (0.29)

### 2.6.2 Calculation of Radiance to Brightness Temperature (BT):

The surface temperature is assessed by utilizing the thermal infrared spectrum. The brightness temperature (BT in °C) is determined through the following calculation:

$$BT = \frac{K_2}{\ln\left(\frac{K_1}{L} + 1\right)} - 273.15 \quad (6)$$

### 2.6.3 Calculating NDVI:

NDVI (for Landsat 8) can be determined using the formula shown below:

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad (7)$$

$$NDVI = \frac{(Band\ 5 - Band\ 4)}{(Band\ 5 + Band\ 4)} \quad (8)$$

### 2.6.4 Calculation of proportion of vegetation Pv:

The PV is calculated using the formula ix. To be applicable under global conditions, NDVI values are proposed, with vegetation having a value of (NDVIV = 0.5) and soil having a value of (NDVIs = 0.2), for estimating PV

$$P_v = \left[ \frac{NDVI - NDVIs}{NDVIV - NDVIs} \right]^2 \quad (9)$$

The NDVI value for vegetation, which is 0.5, is lower because NDVI values can differ depending on the location. Establishing global NDVI values derived from TOA reflectivity would be challenging since NDVIV and NDVIs are affected by atmospheric conditions. Nevertheless, global NDVI values can be obtained using at-surface reflectivity..

### 2.6.5 Calculation of Land Surface Emissivity:

The Emissivity of the terrestrial surface is determined using the NDVI Thresholds Method ( $\epsilon$ ). The examples that follow demonstrate how this method extracts Emissivity information from NDVI:

Here,

=  $\epsilon(\text{soil})$ , if  $\text{NDVI} < 0.2$

=  $\epsilon(\text{veg.})$ , if  $\text{NDVI} > 0.5$

=  $(\epsilon_{\text{veg.}} P_v) + \epsilon_{\text{soil}} (1 - P_v)$  if  $0.2 < \text{NDVI} < 0.5$

$\epsilon(\text{soil})$  is the Emissivity of the soil;

$\epsilon(\text{veg.})$  is the Emissivity of the vegetation;

$P_v$  is the fraction of vegetation cover

"Soil" and "veg" were estimated by "Sorbino et al." Using the values of 0.97 and 0.99, the following equation is derived from the formulas provided. 0.99,

if  $\text{NDVI} > 0.5$

$0.004 P_v + 0.986$ , if  $0.2 < \text{NDVI} < 0.5$

$\epsilon = 0.004 P_v + 0.986$

### 2.6.6 Calculation of LST:

The determination of the Land Surface Temperature (LST) for Landsat 8 is performed, where  $T_s$  denotes LST in degrees Celsius ( $^{\circ}\text{C}$ ), calculated using Brightness Temperature (BT) ( $^{\circ}\text{C}$ ) and the wavelength of the emitted radiance.

$$T_s = \frac{BT}{1 + \left(\frac{\lambda BT}{\rho}\right) \ln \epsilon_\lambda} \quad (10)$$

$$\rho = \frac{hc}{\sigma} = 1.438 \times 10^{-2}$$

Here,

$\sigma$  is Boltzmann constant ( $1.38 \times 10^{-23}$  J/K),

$h$  is the Planck's constant ( $6.626 \times 10^{-34}$  J s), and

$c$  is the light velocity ( $2.998 \times 10^8$  m/s),

$\epsilon$  is denoted as Emissivity =  $1.4388 \times 10^{-4} = 14388$  mK, The values of radiance( $\lambda$ ) for Land sat 8: For Band 10 is 10.653675311351 (10.60 to 11.19  $\mu\text{m}$ )

### 2.6.7 Calculating NDWI:

$$NDVI = \frac{(GREEN - NRI)}{(GREEN + NRI)} \quad (11)$$

$$NDVI = \frac{(Band 3 - Band 5)}{(Band 3 + Band 5)} \quad (12)$$

## 3. RESULTS AND DISCUSSION:

The land surface temperature (LST) data for the Dhaka district has been analyzed using Landsat images from the US Geological Survey. This study explored the changes in LST over time and across different areas, along with Land Use/Land Cover patterns and the associations between NDVI, NDWI, and LST as well as LULC. Since it tracks the vegetation index, NDVI is essential for estimating land surface temperature.

Table.2: Summary of Land Cover/ Land Use of Dhaka District for different years

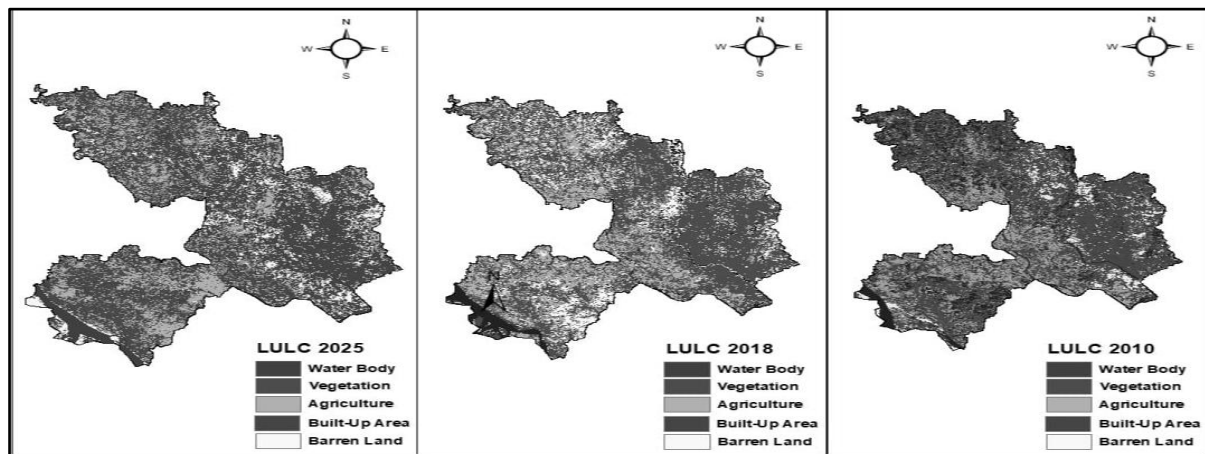
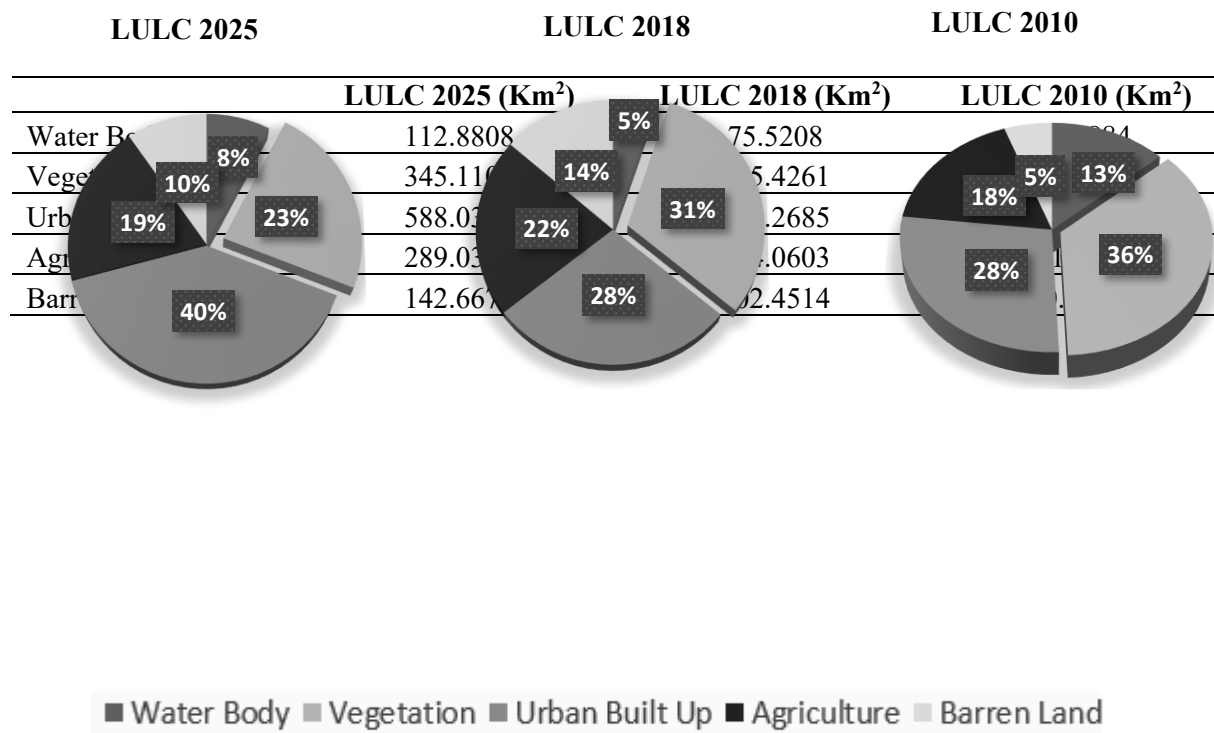


Figure 2: Land Cover/ Land Use (LULC) maps for the years 2010, 2018 and 2025

The result depicts the LULC changing patterns in Dhaka District from 2010 to 2025. In Dhaka District, Urban built-up raised to 407.0484 Km<sup>2</sup>, 420.2685 Km<sup>2</sup> and 588.0348 Km<sup>2</sup> in 2010, 2018 and 2025 (Table-2) respectively whereas Vegetation cover decreased to 521.7503 km<sup>2</sup>, 455.4261 km<sup>2</sup> and 345.1104 km<sup>2</sup> in 2010, 2018 and 2025 respectively. Moreover, Agricultural land initially increased to 261.6993 Km<sup>2</sup> to 324.0603 Km<sup>2</sup> from 2010 to 2018, then it declined to 289.0332 Km<sup>2</sup> in 2025 due to increase of population and their accommodation facilities. On the other hand, from 2010 to 2018, Water bodies decreased to 196.9884 Km<sup>2</sup> to 75.5208 Km<sup>2</sup> and further slightly increased to 112.880.8 Km<sup>2</sup> in 2025.

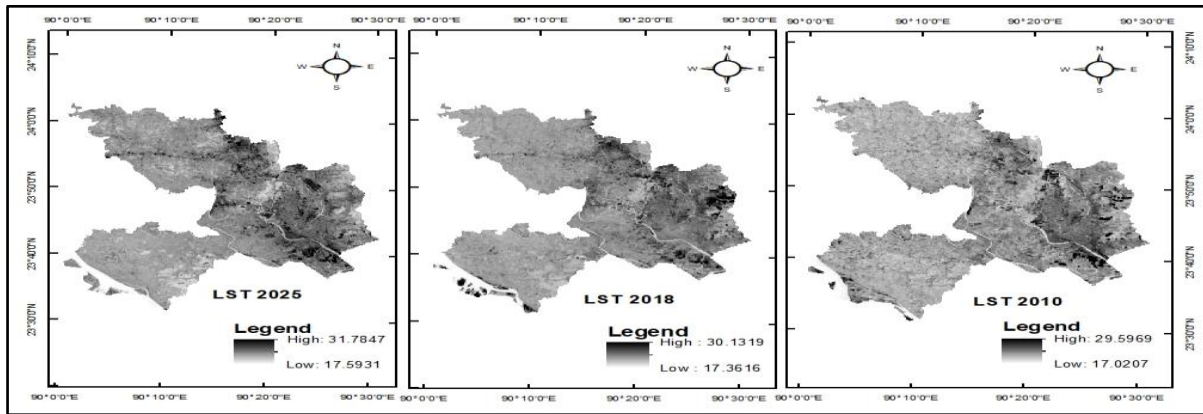


Figure 3: Land Surface Temperature of Dhaka District for the years 2010, 2018 and 2025

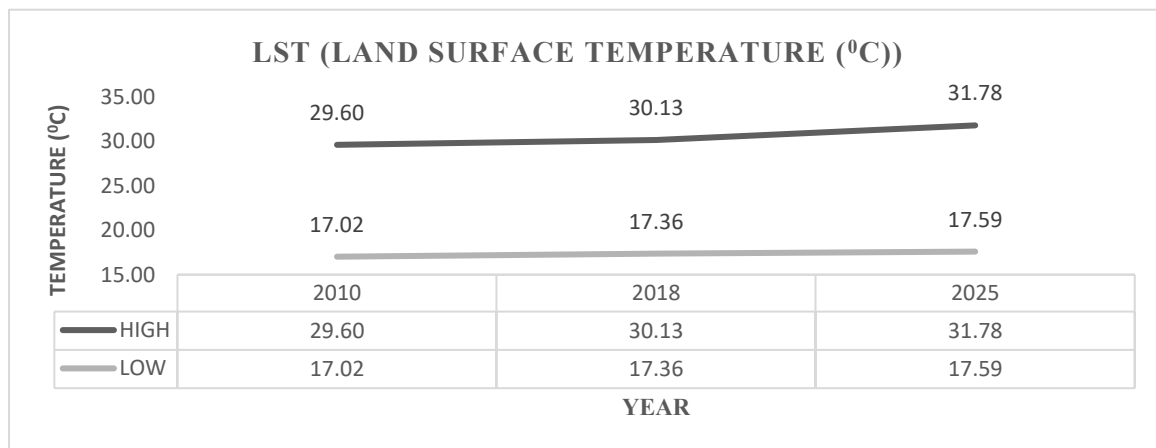


Figure 4: Variation of LST (maximum and minimum) with different of years (2010, 2018 and 2025)

The result indicates that LST from the year 2010 to 2018 with 0.53 °C of maximum temperature variation and from 2018 to 2025 is with 1.68 °C temperature of maximum variation and 0.23 °C (Figure 3) of minimum temperature difference respectively. This demonstrates the gradual increase of LST from 2010, 2018 and 2025 with maximum temperatures of 29.60 °C, 30.13 °C and 31.78 °C respectively. This shows in Dhaka District resulted in raise in temperature from 2010 to 2015 due to urban expansion and loss of vegetation cover, agricultural land and water bodies (Figure 4).

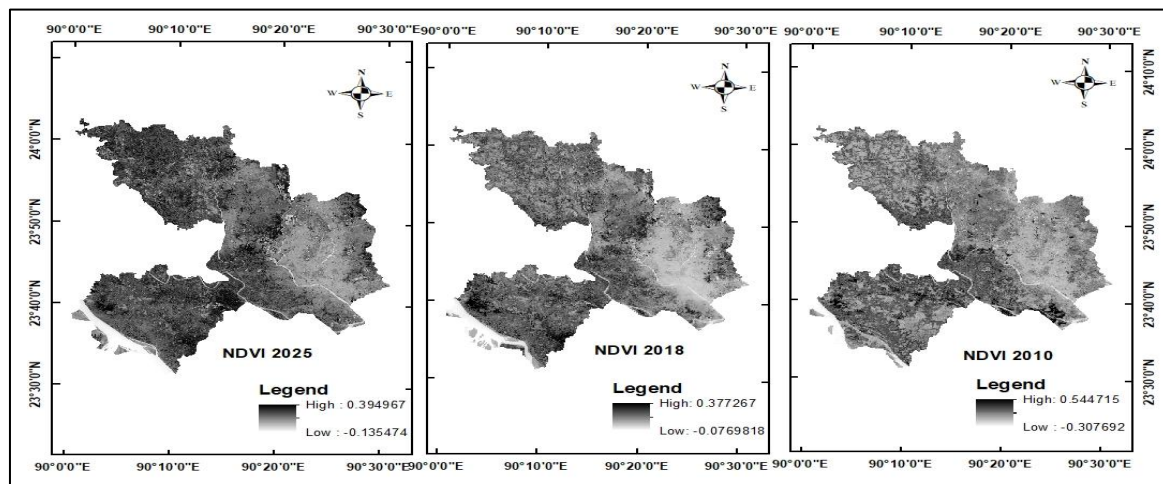


Figure 5: Normalized Difference Vegetation Index(NDVI) for the years 2010, 2018 and 2025

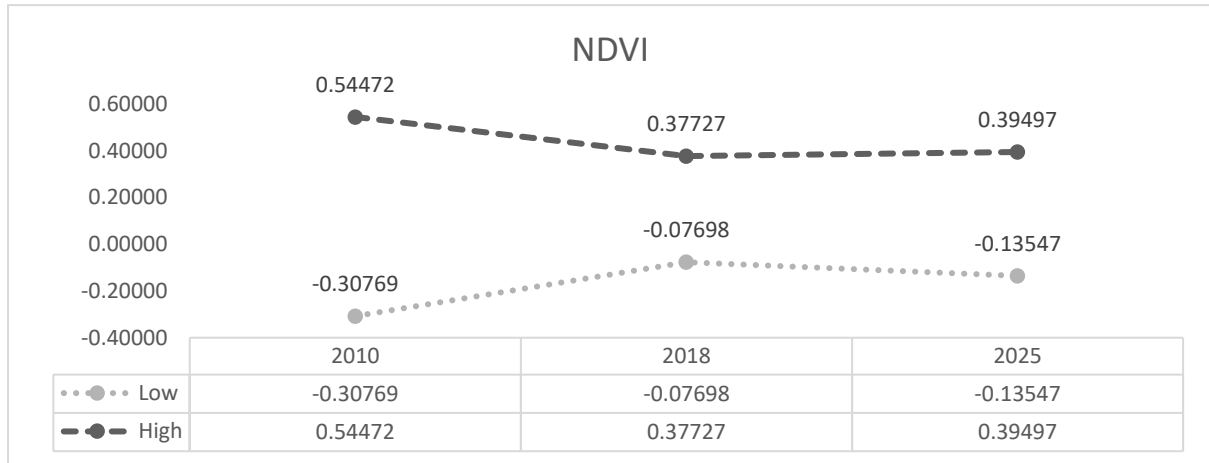


Figure 6: Variation of NDVI with different of years (2010, 2018 and 2025)

In this study, Higher value of NDVI intially decreases from 2010 to 2018 and similarly lower value of NDVI increases. This means, a high proportion of vegetation is cut off for urbanization’s development. But In 2025, higher value of NDVI increases slightly and lower value of NDVI also decreases a bit (figure 5 and figure 6). That’s mean, Amount of green vegetation cover decreases day by day which affects the air quality of Dhaka and daily weather.

The results of the study showed a negative correlation of LST with NDVI and NDWI. The NDVI and NDWI both recorded higher readings in 2010, 0.54472 and 0.37037 respectively. In 2025, these were 0.39497 and 0.13547 respectively. Therefore, LST increases with the increase of NDVI (Figure 5 and Figure 6). Consequently, daily temperature of Dhaka District rises and affects citizen’s health condition.

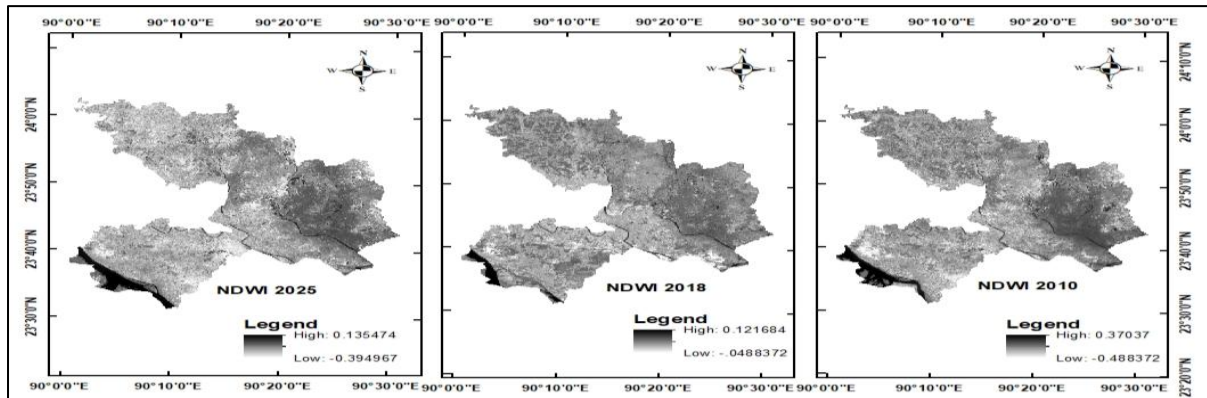


Figure 7: Normalized Difference Water Index(NDWI) for the years 2010, 2018 and 2025

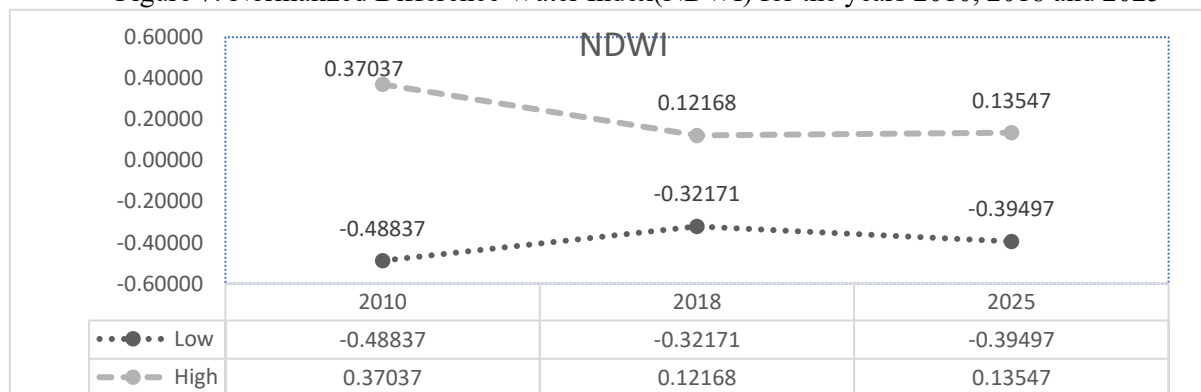


Figure 8: Variation of NDWI of Dhaka with different of years (2010, 2018 and 2025)

The relationship with LST with NDWI with the observations, from the year 2010 to 2025 Water Bodies Index has reduced with 0.37037 to 0.13547 whereas LST has increased from 29.60°C to 31.78°C. This case study describes the strong relationship of LST can be observed with NDWI as the water quantity is decreased, the LST has increased from 2010 to 2025 (Figure 8). Mainly, a large area of water bodies has been occupied for Urban Mobilization. Consequently, now-a-days Dhaka District is undergoing a serious problem on waterlogging and fresh water supplies. Since City is almost full of impervious surface which allows small infiltration. People of this area will be largely depended on underground water sources. It Creates of risk of differential settling of structures.

Similarly, There is a relationship between LST and LULC. With increase of population of Dhaka, urban impervious surface has increased. Evapotranspiration and surface moisture are decreased when built-up surfaces take the place of vegetation and bodies of water. The temperature of the ground surface rises due to the increased absorption and retention of heat by concrete and asphalt. Reduced water bodies diminish natural heat control, while the loss of greenery reduces cooling and shade effects. The urban heat island effect is further exacerbated by vehicle emissions, industrial activity, and population expansion. Together, these factors result in rising LST and falling NDVI and NDWI in cities like Dhaka.

This research's analysis and observation enables the urban planners to expand the urban areas to plan in a sustainable way.

#### **4. CONCLUSION:**

LULC and LST changing pattern provides a vital insights about Dhaka's current situation of land cover distribution. With increase of urban expansion, the surface temperature has been increased. This relation demonstrates future vulnerability of temperature expansion. This will impact people physical and mental health condition as well as Dhaka's current biodiversity.

The NDVI and NDWI also offer estimates of turbidity concerning the basin's plant cover and water resources. From 2010 to 2025, the spatial distribution of the highest NDVI shows a decline while the lowest NDVI exhibits an increase, suggesting that areas prone to erosivity are expanding, leading to higher surface runoff, lower infiltration rates, and decreased groundwater recharge, among other effects. Change detection reveals that the minimum NDWI value consistently rises from 2010 to 2025, indicating that open surface water or vegetation might be experiencing stress, which could signal drought conditions or reduce vegetation cover.

#### **5. DECLARATION OF USE OF AI:**

This research's research gap analysis, methodology, data analysis, preparing result and conclusion was done with the help of AI tools.

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