Geospatial Analysis of Emissions and Air Pollution: A Case Study focusing on Dhaka University Campus, Bangladesh

Nafisa Nandini*

Department of Geography and Environment, University of Dhaka, Dhaka 1000, Bangladesh

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ABSTRACT: Urban university campuses are becoming hotspots of environmental stress due to high energy use, dense infrastructure, and increased traffic flow. This study focuses on the Dhaka University campus to check the status of greenhouse gas emissions and air quality. These are done by integrated analyses of field data, remote sensing, and OpenStreetMap (OSM) data. In this aspect, OSM building and roads were overlaid as vector data on the raster and flow maps. Land Surface Temperature (LST) and Land Use Land cover (LULC) were mapped by Landsat 8 Operational Land Imager (OLI) using Google Earth Engine. Air quality (such as CH_4, CO_2, SO_2, NO_2, PM2.5, and PM10) using the AeroQual Series 500, vehicle counts, and electricity consumption data were all recorded during field surveys. The survey areas of the Dhaka University campus focus on the Institute of Education and Research, Mokarram Hossain Building, MBA Building, Central Library, Nilkhet Residential Quarters, Rokeya Hall, Jagannath Hall, and Residential Halls at Curzon, considered as the hotspots identified by the calculation and map representation of electricity consumption and vehicle flow data. The results indicated that high PM2.5 (AQI: 149) with hotspots are located near Raju Memorial and Doel Chattar. This concentration is well correlated with the existing infrastructure and heavy traffic. The results also significantly identified the microclimatic effect in the specific area, was demonstrated by the positive correlation between Land Surface Temperature (LST) and GHG emissions. Overall, the study shows a replicable data-driven model for climate-responsive campus planning for maintaining urban sustainability in the Global South despite some limitations.

Keywords: Greenhouse Gas Emissions; Air Quality Assessment; Spatial Analysis; Electricity Consumption; Vehicular Emissions

INTRODUCTION

Dhaka City is one of the most polluted cities in the world, where PM2.5 concentrations often exceed the standards of the World Health Organization (WHO). Congestion of vehicles, fossil fuel combustion, industrial activity, and unplanned construction contribute to this crisis (Hasan & Shanto, 2023). There is a lack of localized studies focusing on greenhouse gas (GHG) emissions despite these issues. There are no studies focusing on university campuses; most existing research focuses on the national or city scale. A study conducted by Bun et al. (2018) in Poland developed high-resolution spatial inventories of Greenhouse Gas (GHG) emissions, classifying emission sources into vector geometry to identify regional hotspots. Another research in the Yellow River basin of China used land use models to predict the land cover changes and related carbon emissions, aiming at the importance of land use planning in controlling emissions (Niu et al., 2024).

Corresponding Author: Nafisa Nandini
Email: nafisa-66-2020517436@geoenv.du.ac.bd

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In Bangladesh, studies have primarily focused on emissions from fossil fuel power stations, brickfields, and residential energy consumption. For example, Karmaker et al. (2019) quantitatively assessed GHG emissions from fossil fuel power stations, suggesting that cleaner technologies and fuel switching could significantly reduce emissions. Another study by Shakil et al. (2014) utilized the Ecological Footprint method to calculate carbon emissions from household energy consumption in Dhaka's Dhanmondi residential area, highlighting electricity and natural gas use as primary sources of emissions. Another research revealed brickfields are significant contributors to environmental degradation, emitting large amounts of CO_2, SO_2, NO_x, CO, particulate matter, and black carbon, which deteriorate air quality and cause respiratory and other health issues among workers and nearby residents (Azad & Iqbal, 2022; Parvez et al., 2022).

Recent studies reveal severe environmental challenges in Dhaka caused by rapid urbanization, commercial growth, and population pressure. A study based on Sentinel-5P satellite data and field data collection at 116 sites, the Air Quality Index (AQI) identified PM2.5 as the main pollutant (Ahmed and Ali, 2021). GIS spatial analysis, weighted overlays, and Principal Component Analysis (PCA) showed Dhaka South City Corporation (DSCC) as the most polluted area, with Dhaka North City Corporation (DNCC) at risk of future decline. During lockdown, the air quality improved, indicating the effects of human activities (Ahmed and Ali, 2021).

However, these studies do not address the specific contributions of university campuses to GHG emissions. Critical dynamics, including zone-level emission patterns, the influence of land use and land cover (LULC) changes on carbon output, and the correlation between emission hotspots and land surface temperature (LST) variations, have received limited scholarly attention. This study addresses these gaps by examining the spatial distribution of GHG emissions across the University of Dhaka campus. The study also identifies the principal sources and zones contributing most to its overall carbon footprint, and assesses the relationship between emission hotspots, LST variations, and LULC types. Resolving these gaps is fundamental to developing evidence-based mitigation strategies and sustainable land management frameworks at university campuses in developing-country contexts.

MATERIALS AND METHODS

Study Area

The University of Dhaka was established in 1921 under the Dacca University Act. The oldest and most prestigious public university in Bangladesh is situated in the Ramna area of central Dhaka city. The campus spans approximately 275 acres and accommodates around 39,496 students across 13 faculties, 83 departments, and over 20 residential halls (University of Dhaka, 2024). Strategically located at the heart of the city and flanked by major roads, markets, and administrative infrastructure, the campus is characterized by high vehicular and pedestrian traffic, dense built-up cover, and intensive energy consumption, all significant contributors to GHG emissions. The co-existence of diverse land use types within its boundary, including academic buildings, residential halls, and residual open spaces, makes it suitable for spatially assessing emission patterns and LST variations through remote sensing and GIS techniques.

Dhaka falls within the tropical wet and dry zone (Aw, Köppen classification), with a mean annual temperature of ~25°C, peak temperatures reaching 36.3°C in April. Approximately 80% of its ~2,000 mm annual rainfall is concentrated within the June–September monsoon period (Bokshi et al., 2026). These baseline conditions are increasingly compounded by rapid urban transformation. Over the past three decades, approximately 339 km² of built-up area has expanded across greater Dhaka at an annual rate of 3.5%, accompanied by substantial losses in vegetation and water bodies (Islam & Rahman, 2025). As a consequence, UHI intensity has increased at 0.21°C per decade, summer LST has risen from 34.58°C to 37.66°C, and the city's mean temperature has increased by 0.57°C over the last decade alone (Tabassum et al., 2024b; Sresto et al., 2022; Ryhan & Kabir, 2023). Dhaka is now ranked among the most thermally stressed and air-polluted cities globally. The University of Dhaka campus, embedded within this rapidly transforming urban environment, is a relevant setting for investigating the spatial distribution of GHG emissions, their principal sources, and their interaction with LST dynamics and LULC change.

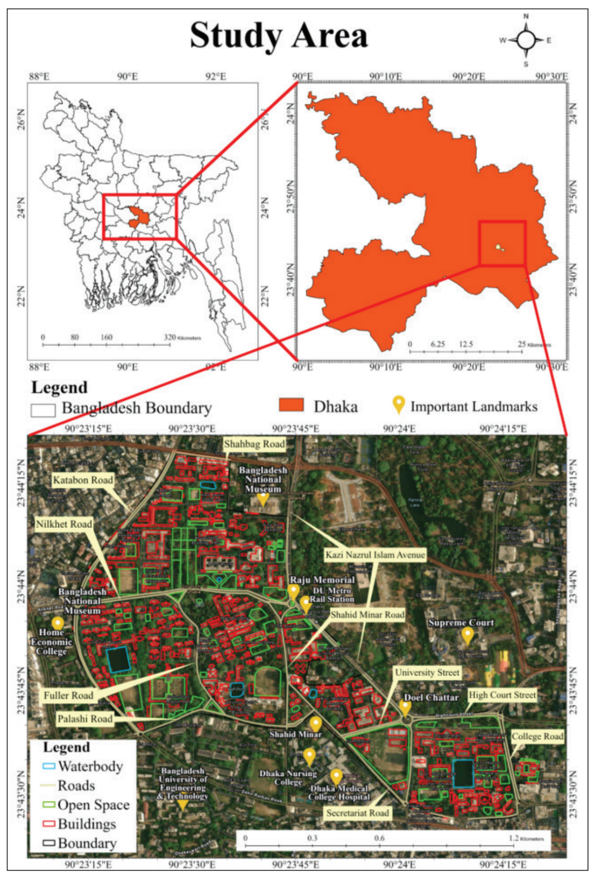

Figure 1: Study Area Map of the University of Dhaka Campus *(Source: Prepared by the Author, 2026)*

Data Collection

Primary Data: The monthly electric bill data of the academic and residential buildings from December 2023 to November 2024 were collected from the Office of the Chief Engineer of the University of Dhaka. There were gaps in the collected data, indicating a limitation for the study. The vehicle flow on the major roads around the campus was recorded through field surveys. The flow of cars, motorbikes, CNG autorickshaws, buses, and trucks on each road was observed for 5 minutes during the peak hour from 9:30 am to 10:00 am. The AeroQual Series 500 device was used to record the air quality for the parameters CH_4, CO_2, SO_2, NO_2, $PM_{2.5}$, and PM_{10}. in selected locations of the campus.

Secondary Data: Landsat 8 Collection 2 Tier 1 TOA Reflectance images and Landsat 8 Collection 2 Tier 1 Raw Scenes were used as inputs in the Google Earth Engine (GEE) to prepare a LULC map of the DU campus. For the LST detection, Landsat 8 OLI Level 2 Collection 2 Tier 1 images were used in the GEE platform. Additionally, the building and road data were downloaded from OpenStreetMap (OSM).

Methodology

Carbon Equivalent Calculations

This research is divided into three phases. The first phase includes identifying the research problem, formulating research questions and objectives, and designing the methodology. The data collection phase continued from March to April at different locations on the campus. Satellite images of the years 2014, 2016, 2020, and 2024 were collected as secondary data. The last phase is data processing and report writing. Thematic maps of GHG emissions from electricity consumption and vehicle flow, and proportional maps of air quality parameters were prepared. Which methods or interpolation techniques are considered to Land Surface Temperature (LST) and Land Use Land Cover (LULC) maps of the study area were also generated, followed by an analysis of the correlation between temperature variations and hotspots of GHG emissions.

Based on the formula provided by the AR6 Synthesis Report: Climate Change 2023, the Intergovernmental Panel on Climate Change (IPCC), the National Energy Balance 2021-22 of Bangladesh, and the Ecoonline website (AR6 Synthesis Report: Climate Change 2023, IPCC; EcoOnline, 2025), greenhouse gas (GHG) emissions from electricity consumption were calculated.

Step 1: Calculate CO_2 Emissions from Electricity

Unit (kWh)= Average bill/ per unit cost ………..(i)

Total GHG Emissions ($kgCO_2$) = *Electricity Consumption (kWh)×Electricity Emission Factor* ($kgCO_2/kWh$)*… …….(ii)*

Step 2: Convert CH_4 and N_2O to CO_2 using Global Warming Potential (GWP) values for the non-CO2 gases.

GHG emissions in carbon equivalence ($kgCO_2e$) = *Total GHG Emissions* ($kgCO_2$) *x GWP……….(iii)*

Step 3: Calculate Total Emissions

Total CO_2e = CO_2e *of* CO_2 + CO_2e *of* CH_4 + CO_2e *of* N_2O*……(iv)*

Following the formula provided by the *AR6 Synthesis Report: Climate Change 2023* by the Intergovernmental Panel on Climate Change (IPCC) and the *E-Mobility Country Profile of Bangladesh 2023*, vehicular greenhouse gas emissions were calculated using a stepwise approach. First, the total fuel use in liters was determined for the vehicles. Next, appropriate emission factors were applied based on the type of fuel used, such as gasoline or diesel. Finally, the total emissions were estimated by multiplying the total fuel consumption by the corresponding emission factor. The formula is:

Total GHG Emissions ($kgCO_2e$) = *Fuel Consumption (liters)×Emission Factor* ($kg\ CO_2e/liter$)*……(v)*

Air Quality Index Calculation

AQI is the highest value for each pollutant calculated using the formula as follows:

$$Ip = \frac{Ihi - Ilo}{Bhi - Blo} * (Cp - Blo) + Ilo \text{………(vi)}$$

where,

I_p = the index for pollutant p

C_p = the truncated concentration of pollutant p

B_{hi} = the concentration breakpoint that is greater than or equal to C_p

B_{lo} = the concentration breakpoint that is less than or equal to C_p

I_{hi}= the AQI value corresponding to B_{hi}

I_{lo}= the AQI value corresponding to B_{lo}

Image Acquisition and Pre-processing for LST and LULC

All satellite imagery was acquired and pre-processed using the Google Earth Engine (GEE) cloud-computing platform. Landsat 8 OLI/TIRS Collection 2 Level-2 surface reflectance and surface temperature products were retrieved for the study years 2014, 2016, 2020, and 2024. The University of Dhaka campus boundary was filtered as the region of interest (ROI). Images were constrained to less than 10% cloud cover, and yearly average composites were generated within GEE using the mean reducer function to produce representative, cloud-minimized annual surfaces for each target year. This approach ensures temporal consistency and reduces the influence of transient atmospheric and phenological variation across the study period (Talukdar et al., 2020).

LULC Classification

LULC classification was performed for 2016, 2020, and 2024 using the yearly average Landsat 8 OLI surface reflectance composites. A supervised Random Forest (RF) classification algorithm was applied, utilizing six multispectral bands (B2–B7) as input features. Built-up Area, Vegetation, Water Body, Bare Land, and Open Space are the five land cover classes. Training samples were collected through visual interpretation of high-resolution Google Earth imagery. Classification accuracy was assessed using a confusion matrix and Kappa coefficient, with an overall accuracy threshold of ≥85% considered acceptable for urban LULC mapping (Faisal et al., 2022).

LST Retrieval

LST was retrieved for 2014, 2016, 2020, and 2024 from yearly average Landsat 8 TIRS Band 10 composites following a single-channel retrieval algorithm. At-satellite brightness temperature (BT) was first derived using band-specific thermal constants (K_1 = 774.89 W m^{-2} sr^{-1} μm^{-1}; K_2 = 1321.08 K). Land surface emissivity (LSE) was subsequently estimated using the NDVI-based fractional vegetation cover method (Sobrino et al., 2004), and LST was finally computed in degrees Celsius.

$$LST = \frac{BT}{1+(\frac{\lambda BT}{\rho})\ln(\varepsilon)} - 273.15 \text{ ....(vii)}$$

where λ is the emitted radiance wavelength (11.5 µm) and ε is surface emissivity.

All outputs were exported as GeoTIFF files at 30 m spatial resolution. LST and LULC outputs exported from GEE were imported into ArcGIS 10.8 for cartographic visualization. All rasters were clipped to the campus boundary and projected to WGS 1984 UTM Zone 45N.

RESULTS AND DISCUSSIONS

Greenhouse Gas Emissions from Electricity Consumption

From the obtained monthly electricity bill data, the average bill for certain months was calculated, from which the cost per unit was extracted. Finally, using the National Electricity Emission Factor and Global Warming Potential (GWP) of the gases, emissions in carbon equivalence were calculated.

Example Calculation: The average bill for the Kazi Motahar Hossain building is Tk. 192528.6.

Per unit cost = Tk 9.73 (set by Dhaka Power Distribution Company)

Unit = 192528.6 / 9.73 = 19787.11202 kWh [Equation (i)]

To estimate the total amount of GHG emissions from electricity consumption, the National Electricity Emission Factor ($kgCO_2/kWh$) was applied. The emission factor values vary according to the type of gas emitted: 0.3 $kgCO_2/kWh$ for CO_2, 0.000003 $kgCO_2/kWh$ for CH_4, and 0.0000005 $kgCO_2/kWh$ for N_2O. The calculations were performed based on these values.

From Equation (ii),

CO_2= (19787.11202 x 0.3) = 5936.133607 $kgCO_2$

CH_4 = (19787.11202 x 0.000003) = 0.05936133607 $kgCO_2$

N_2O = (19787.11202 x 0.0000005) = 0.009893556012 $kgCO_2$

Next, to convert the greenhouse gas emissions into carbon dioxide equivalents (CO_2e), the Global Warming Potential (GWP) values for non-CO_2 gases were applied. The GWP values used were 29.8 $kgCO_2e$ for CH_4 and 273 $kgCO_2e$ for N_2O. Putting these values into the formula [Equation (iii)], total emissions are calculated and expressed in terms of carbon equivalence.

CO_2 = 5936.133607 x 1 = 5936.133607 *$kgCO_2e$*

CH_4 = 0.05936133607 x 29.8 = 1.768967815 *$kgCO_2e$*

N_2O = 0.009893556012 x 273 = 2.700940791 *$kgCO_2e$*

Total CO_2e = 5936.133607 + 1.768967815 + 2.70094079 [Equation (iv)] = 5940.603516 *$kgCO_2e$*

The same procedure was followed for every building on the campus. Then, a thematic map was created with the values in different locations.

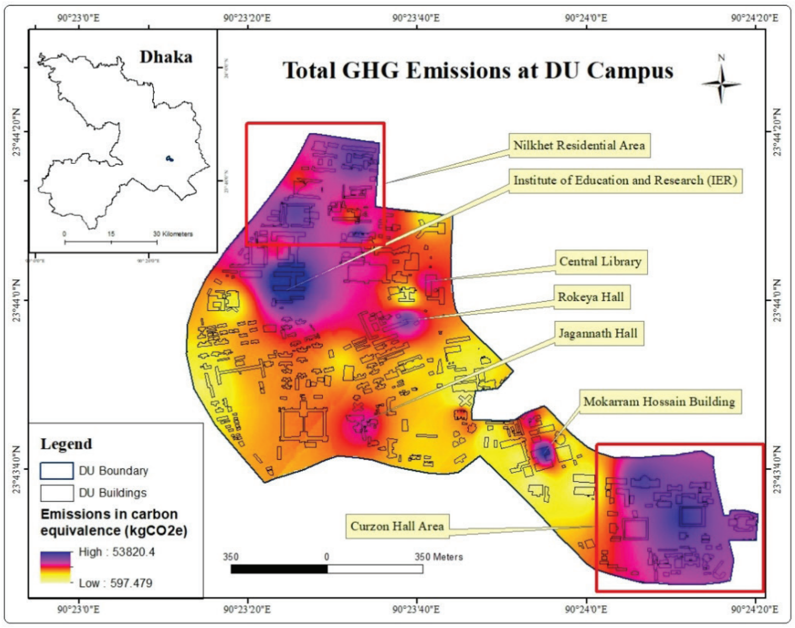

Figure 2: GHG Emissions Hotspots in Dhaka University Campus

The emissions hotspots are present in the northwestern part of the campus at the Institute of Education and Research (IER) Building. Another hotspot can be seen in the upper southeastern part at the Mokarram Hossain Building. The northernmost and southeastern parts fall in the second category of high emissions. The IER building consumes the highest amount of electricity with a yearly average value of 179334.02 kWh, emitting 53,840.72 $kgCO_2e$ pollutants. The University Officers' Training Corps (UOTC) building had the lowest consumption of 1,437.41 kWh, with an emission factor of 431.55 $kgCO_2e$.

Air Quality Parameters

The American National Wildlife Federation developed the Environmental Quality Index (EQI) in the 1960s, including the Air Quality Index (Inhaber, 1976). This index primarily assessed the link between air quality and human health. In 1999, the United States Environmental Protection Agency (EPA) identified five key pollutants for air quality assessment. The five pollutants are carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), particulate matter (PM), and sulfur dioxide (SO_2).

The concentration data for CH4, CO2, SO2, NO2, PM2.5, and PM10 were collected for this study based on the instrument availability in the laboratory. The concentration data for only one season could be collected which indicates a limitation for the study. The data were collected in May 2025 only, representing the summer season. Data from 15 points around the campus were georeferenced using shapefile coordinates which used to create maps.

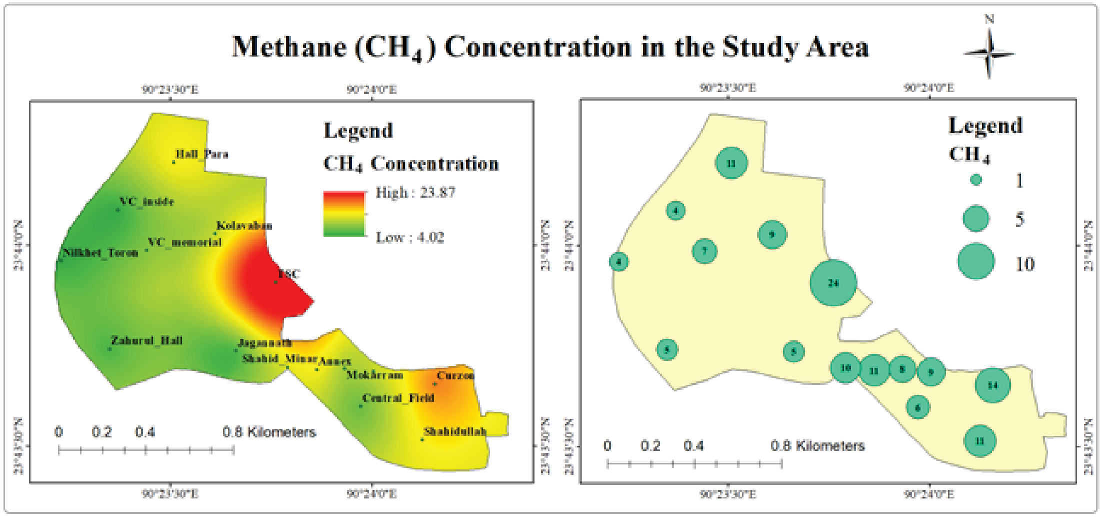

Figure 4: Methane (CH_4) Concentration around the DU Campus

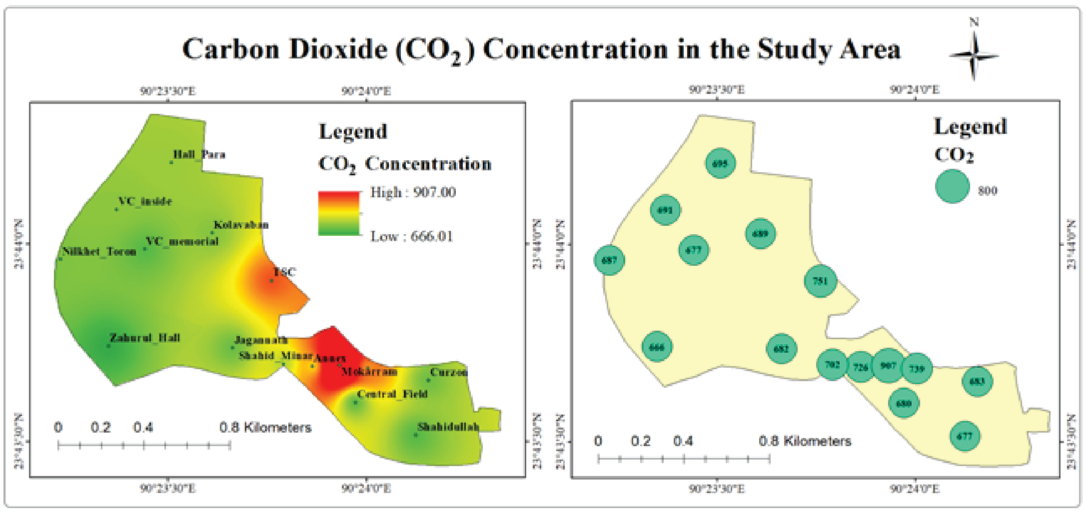

Figure 5: Carbon Dioxide (CO_2) Concentration around the DU Campus

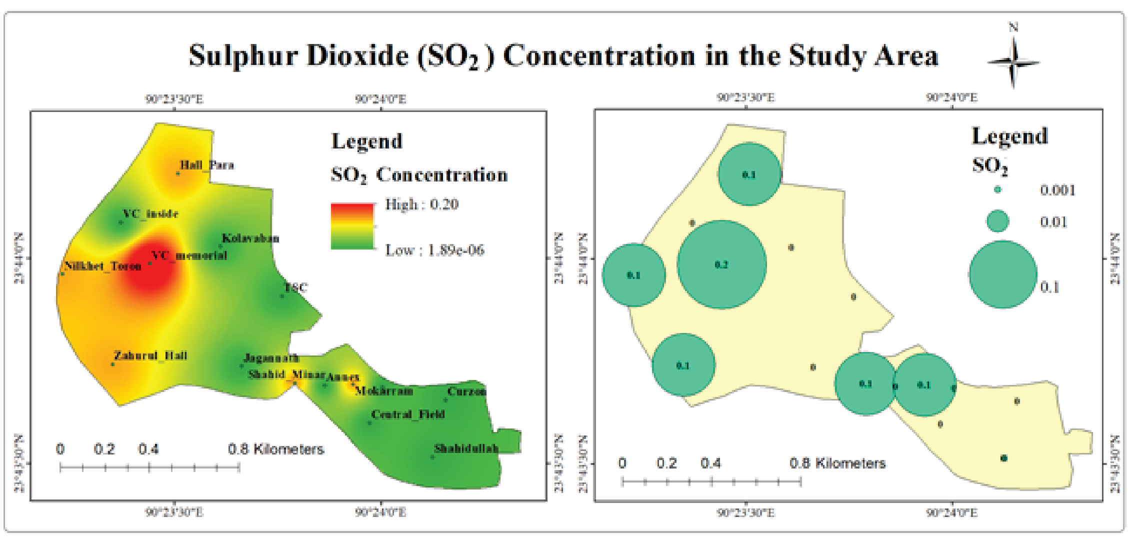

Figure 6: Sulphur Dioxide (SO_2) Concentration around the DU Campus

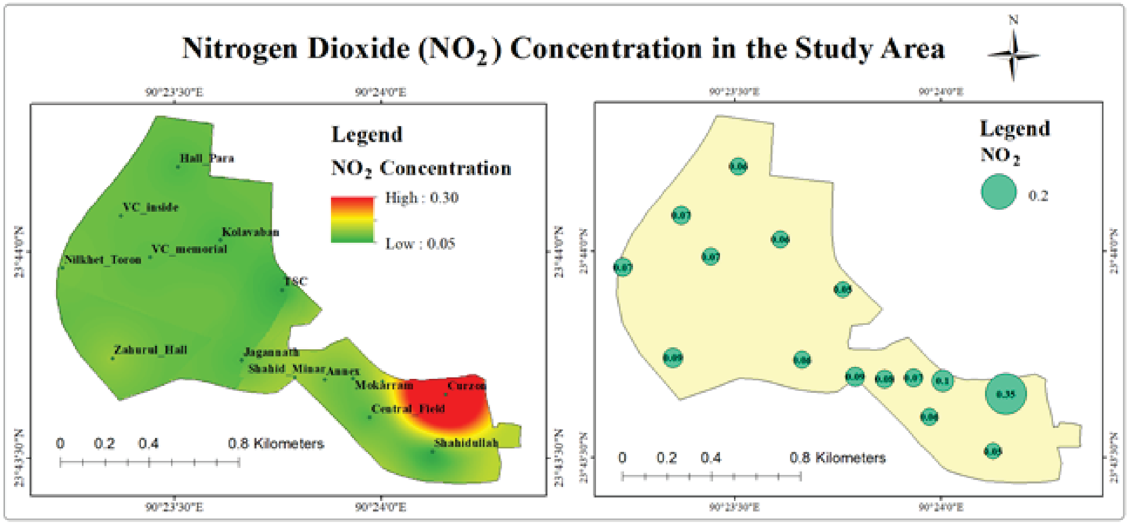

Figure 7: Nitrogen Dioxide (NO_2) Concentration around the DU Campus

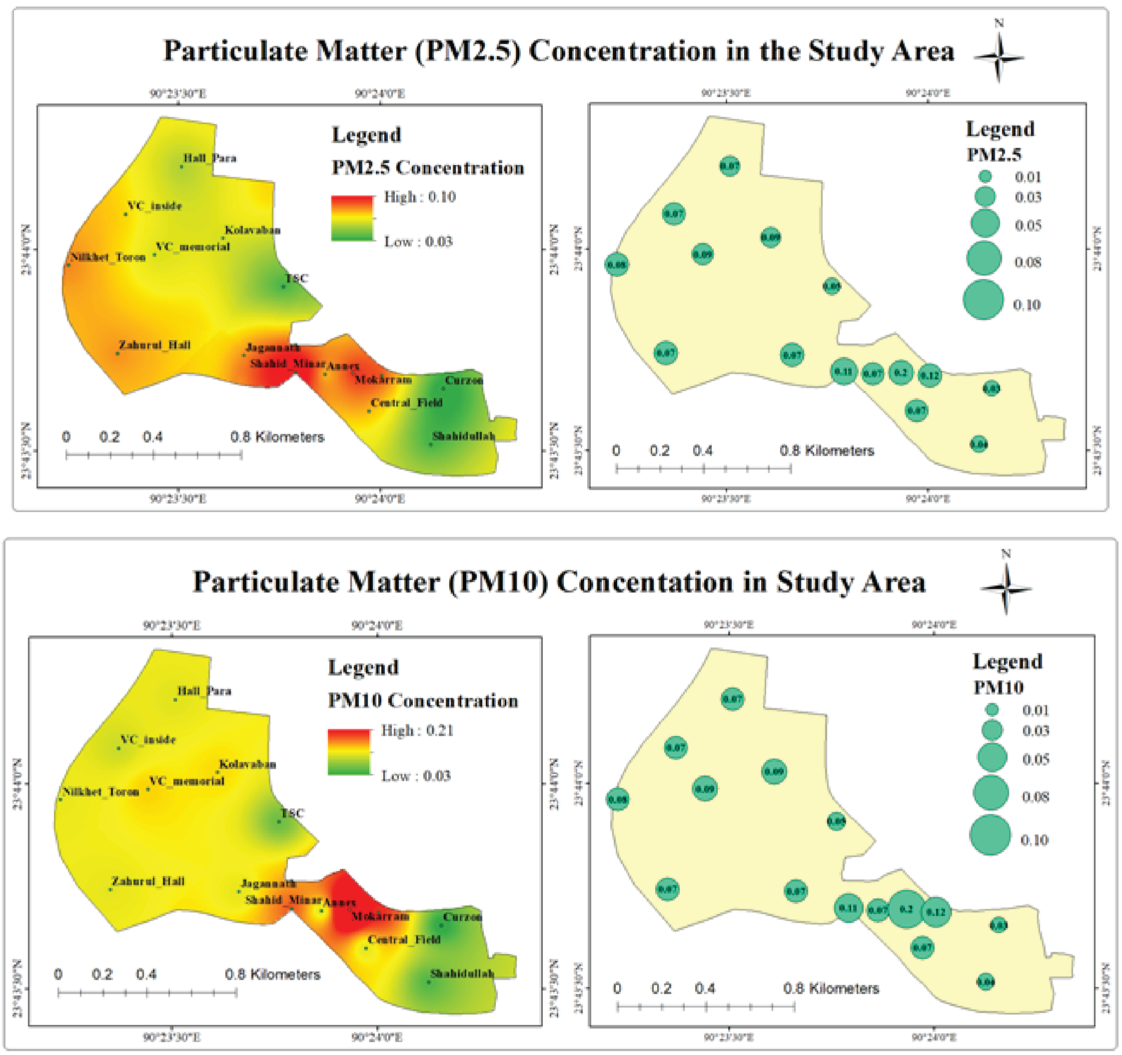

Figure 8: Concentration of Particulate Matter 2.5 and Particulate Matter 10 Concentration around the DU Campus

The highest methane (CH_4) concentration is observed in the TSC area, which is the junction of major roads, and a metro rail station is present. Human activities contribute to approximately 60% of methane emissions with the primary sources being agriculture, fossil fuel burning, and waste decomposition in landfills (Methane Vital Signs – Climate Change: Vital Signs of the Planet, n.d.). In the study area, vehicular emissions are responsible for high CH_4 concentrations. Carbon dioxide (CO_2) is primarily produced through fossil fuel combustion, such as gasoline, diesel, oil, and coal. According to Fig. 5, the highest concentration of CO_2 is observed near Shahid Minar and TSC. These two areas have the highest traffic density, both pedestrians and vehicles.

The combustion of fossil fuels in power plants and industries is the primary source of sulfur dioxide (SO_2) emissions (Sulfur Dioxide Basics US EPA, 2025). The Fig. 6 indicates that the highest SO_2 concentration is found around the VC Memorial, mainly due to the increased electricity consumption by the surrounding buildings. On the other hand, NO_2 concentration is mainly influenced by road traffic. The highest level in the study area is observed around Curzon Hall.

The complex reactions involving SO_2 and NO_2 are responsible for the particulate matter (PM) formation in the atmosphere. Particulate matters are mainly emitted from power plants, industries, and vehicles (Particulate Matter (PM) Basics | US EPA, 2024). In the Fig. 8, we can see that higher levels of both $PM_{2.5}$ and PM_{10} are around high-traffic zones such as Shahid Minar. $PM_{2.5}$ is showing higher intensity than PM_{10} due to its finer particle size and greater potential for atmospheric accumulation.

Developing the Index

Following the guidelines of "Technical Assistance Document for the Reporting of Daily Air Quality – the Air Quality Index (AQI)" published by the United States Environmental Protection Agency (USEPA) in 2016, the air Quality Index (AQI) calculation was conducted. They also provide standard methods to convert pollutant concentrations into AQI values. The breakpoints of 6 greenhouse gases were fixed in this document, shown in the table below.

Table 1: Breakpoints of Air Quality Parameters

O_3 (ppm) (8-hours)	**PM2.5 (µg/m3) (24-hours)**	**PM10 (µg/m3) (24-hours)**	**CO (ppm) (8-hours)**	**SO_2 (ppb) (1-hour)**	**NO_2 (ppb) (1-hour)**	**AQI**	**Remarks**
0.000 - 0.054	0.0 – 12.0	0 - 54	0.0 - 4.4	0 - 35	0 - 53	0 - 50	Good
0.055 - 0.070	12.1 – 35.4	55 - 154	4.5 - 9.4	36 - 75	54 - 100	51 - 100	Moderate
0.071 - 0.085	35.5 – 55.4	155 - 254	9.5 - 12.4	76 - 185	101 - 360	101 - 150	Unhealthy for Sensitive Groups
0.086 - 0.105	55.5 - 150.4	255 - 354	12.5 - 15.4	186 - 304	361 - 649	151 - 200	Unhealthy
0.106 - 0.200	150.5 - 250.	355 - 424	15.5 - 30.4	305 -604	650 - 1249	201 - 300	Very unhealthy
-	250.5 - 350.4	425 - 504	30.5 - 40.4	605 - 804	1250 - 1649	301 - 400	Hazardous
-	350.5 - 500.4	505 - 604	40.5 - 50.4	805 - 1004	1650 - 2049	401 - 500	Hazardous

Average concentrations of PM2.5, PM10, SO_2, and NO_2 were calculated and converted using standard guidelines (Table 1). Individual pollutant indices (I_p) were computed using Equation (vi), with PM2.5 showing the highest index of 149, making it the main contributor to poor air quality.

The NO_2 concentration at the Kazi Motahar Hossain building was found to be 0.076 ppm

We know, 1 ppm = 1000 ppb

Therefore, 0.076 ppm = 0.076 X 1000 = 76 ppb

76 ppb falls in the second range (54-100) ppb

Now, from equation (vi)

$$Ip = \frac{100-51}{100-54} * (76 - 54) + 51 = 74.43$$

So, Ip for NO_2 at 0.076 ppm (76 ppb) ≈ 74. As a result, it falls in the moderate category.

PM2.5 is the responsible pollutant for air quality in the study area because it has the highest index value (149). Other indices were as follows (in descending order): ***NO_2: 74 > PM10: 64 > SO_2: 48.***

Greenhouse Gas Emissions from Vehicle Flow

Vehicle transportation is a major contributor to CO_2, CH_4, and N_2O emissions, with total GHG output influenced by both the number and type of vehicles, as well as the type of fuel used. By combining data on vehicle flow, vehicle types, and fuel types, it is possible to estimate emissions per unit of time. Depending on the fuel type, the emission rate varies. A sample calculation is shown in the Table 2.

Table 2: Calculations to Find Out Emissions from Vehicle Flow

Type of Vehicle	Number	Total Flow	Type of Fuel used	Fuel Consumption liters per 100km	Total Fuel Consumption per vehicle, liters	Total Fuel Consumption liters	Emission Factor kg CO_2e	GHG emission	Total GHG Emissions kg CO_2e
Private car	51		Gasoline	6.90	351.90		2.31	812.89	
Motorbike	43		Gasoline	2.50	107.50		2.31	248.33	
CNG Autorickshaw	25	123	CNG	3.50	87.50	686.9	2.75	240.63	1677.04
Bus	4		Diesel	35	140.00		2.68	375.20	
Truck	0		Diesel	45	0		2.68	0	

Due to the channeling of traffic from busy commercial areas like Motijheel and Ramna, the higmotorbikes and CNG autorickshaws. The highest GHG emissions were recorded on Shahid Minar Road. It was 1,772.87 kgCO_2e due to high volumes of private cars, CNGs, and frequent stop-and-go traffic. As usual, Fuller Road had the lowest emissions at 382.07 kgCO_2e.

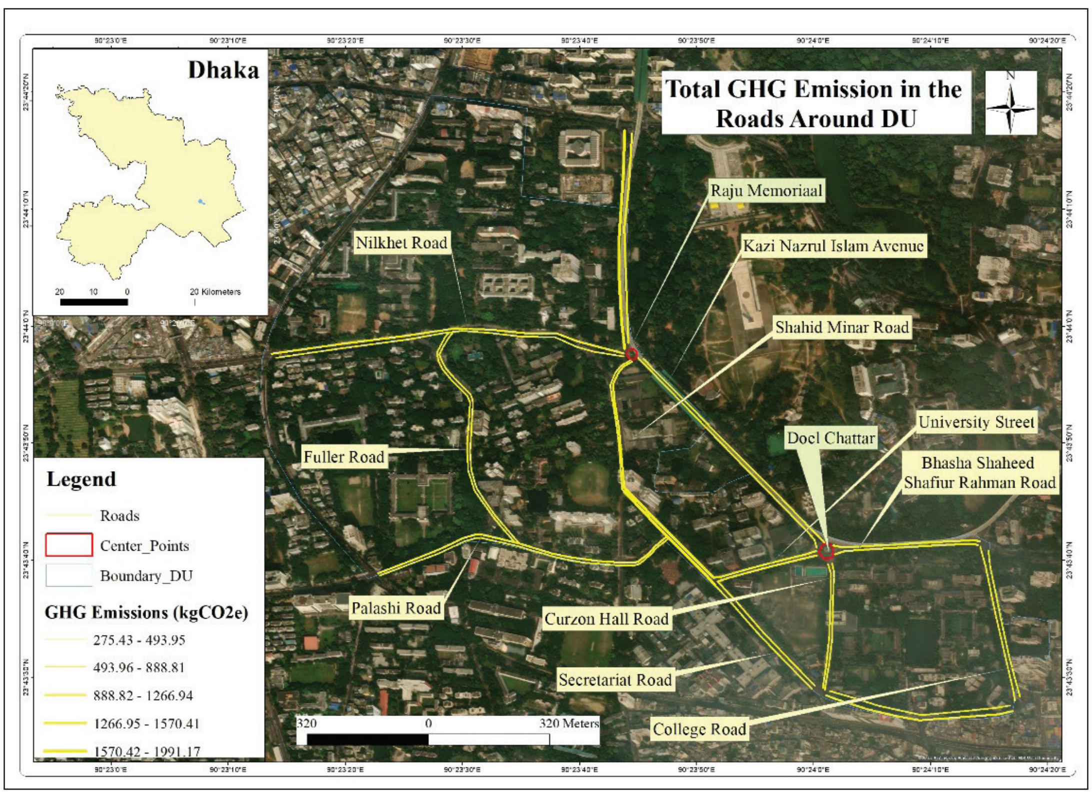

Figure 9: Greenhouse Gas Emissions from Vehicle Flow inside the DU Campus

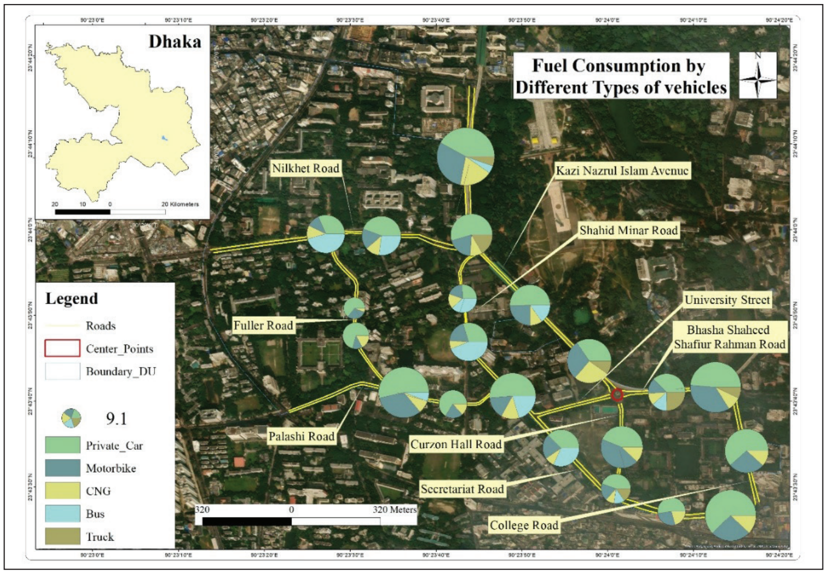

Figure 10: Fuel Consumption Map by Different Types of Vehicles

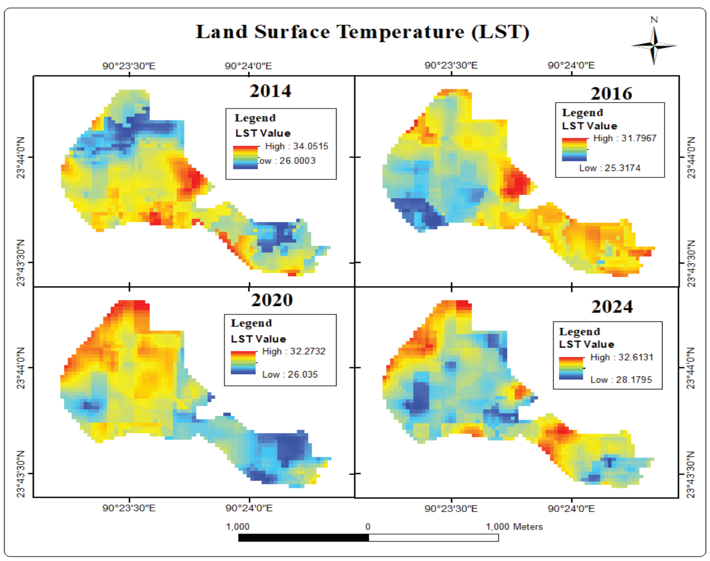

Figure 11: Land Surface Temperature (LST) Map of the DU Campus

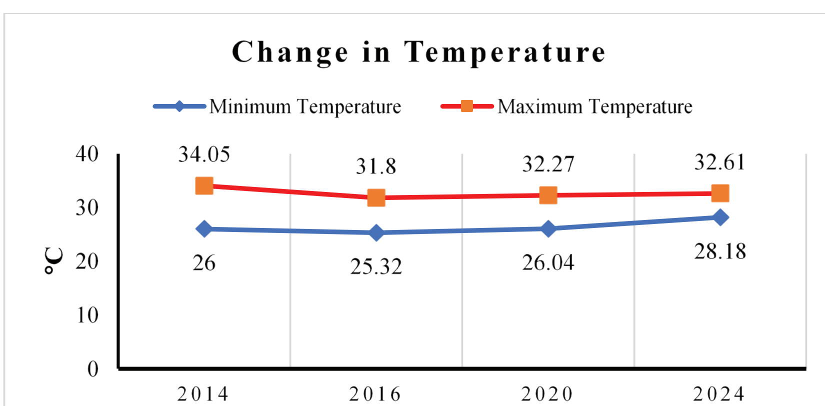

Figure 12: Change in LST (°C) at DU Campus from 2014 to 2024

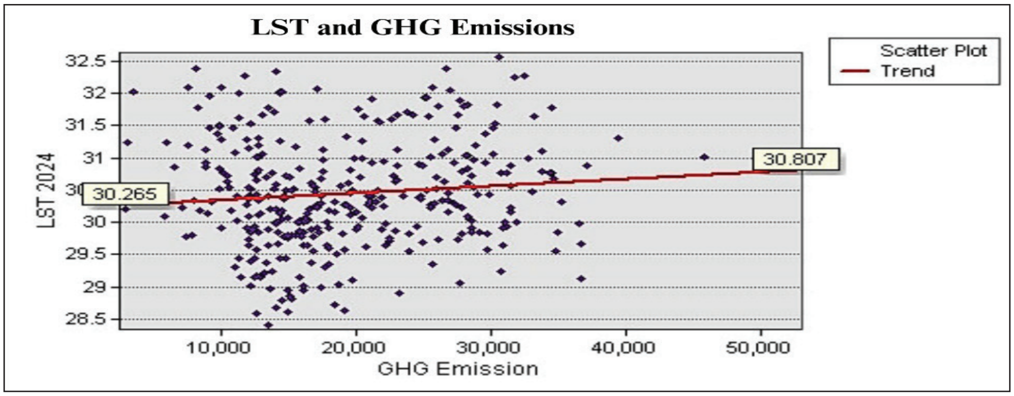

Figure 13: Correlation between LST and GHG Emissions

The proportional symbol map represents the fuel consumption by vehicles on the main roads. Larger circles indicate higher use of fuel, and the pie charts illustrate the percentage of different types of vehicles. The vehicles on the roads leading to Shahbag near Charukola, in front of Jagannath Hall, Shahid Minar, and Around Curzon Hall consume the highest amount of fuel.

Correlation

The correlation between LST and LULC shows a clear positive trend, indicating that changes in land-use patterns affect surface temperatures in urban settings.

The maximum and minimum temperatures slightly fluctuate across the study area, indicating a stable pattern. The temperatures show a gradual upward trend from 2016, rising by less than 1°C. This indicates low but consistent warming over the campus area.

There is a weak positive correlation between temperature change and greenhouse gas emissions. The LST (Figure 11) shows an upward trend from 30.29°C to 30.81°C. The LULC map indicates the increase in built-up area in the campus from 2016 to 2024.

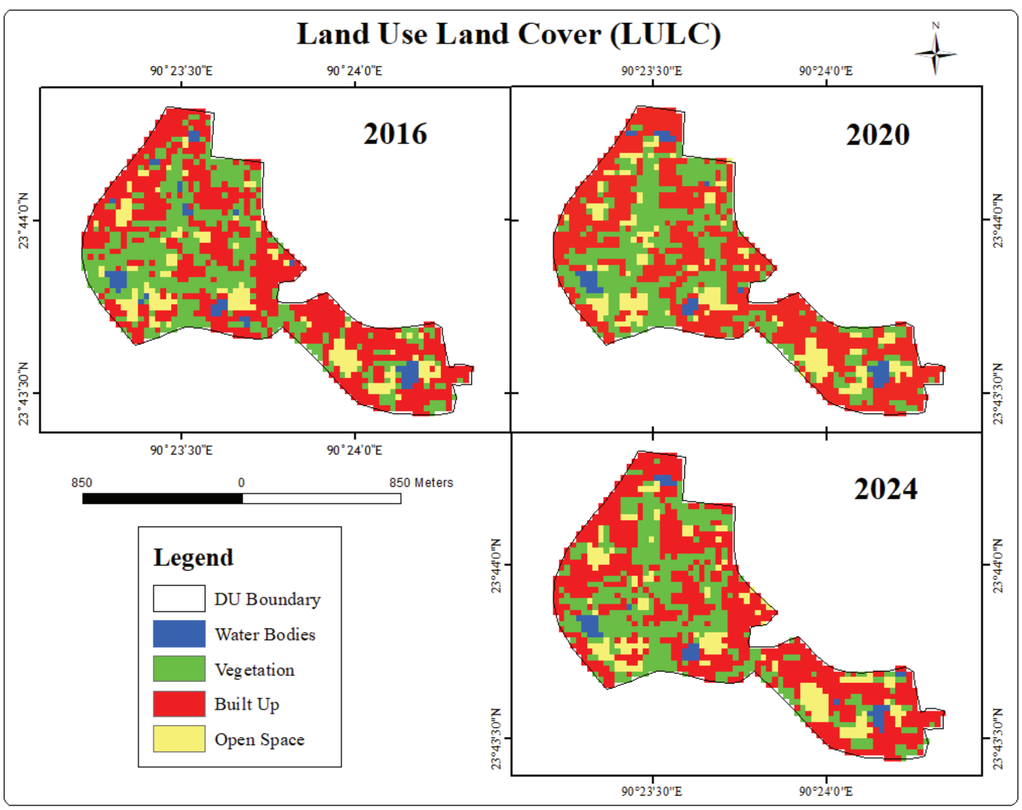

Figure 14: LULC Change in DU Campus

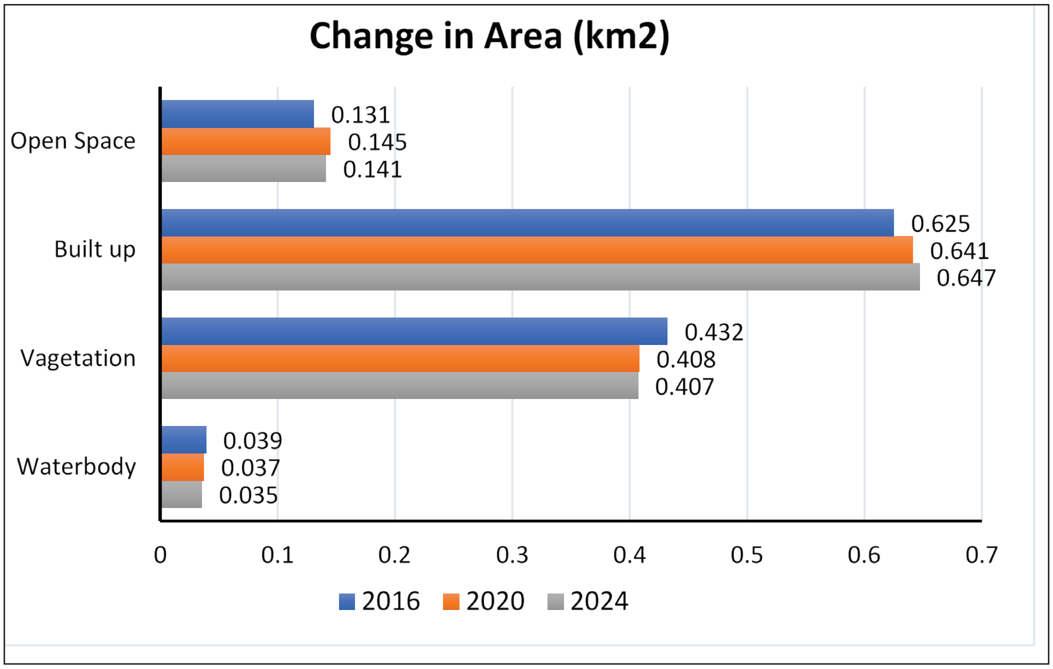

Figure 15: LULC Area Change in DU Campus

The built-up area in the campus has increased by 3.52% over the past decade. This reflects the continuous development of infrastructure for residential and academic purposes. In contrast, the waterbodies and vegetation cover have declined by 10.26% and 5.79% respectively. The decline increased the surface temperature of the area. Again, although open space increased from 2016 to 2020, it again decreased in 2024 by 2.76%. These changes in land use and land cover altered the overall ecological balance in the campus environment.

These findings are consistent with LULC trends documented across Dhaka and other rapidly urbanizing South Asian cities. At the city scale, Islam and Rahman (2025) reported that greater Dhaka experienced approximately 339 km² of urban expansion over three decades at an annual growth rate of 3.5%, accompanied by substantial losses in vegetation and water bodies. At the national level, studies on Rajshahi, Chittagong, and Gazipur support this pattern. Salam et al. (2024) and Naim and Kafy (2021) confirmed that rapid replacement of vegetated and water-covered surfaces with impervious built-up land is the dominant driver of LST increase and urban heat island (UHI) intensification across cities. Internationally, comparable dynamics have been well-documented in megacities of South and Southeast Asia, including Delhi, Kolkata, and Dhaka. Built-up expansion consistently correlates positively with LST and negatively with vegetation indices such as NDVI (Grover & Singh, 2016; Imran et al., 2021). The Intergovernmental Panel on Climate Change (IPCC, 2022) further affirms that land cover conversion from vegetated to impervious surfaces is among the foremost anthropogenic drivers of localized warming and increased GHG concentrations in urban environments globally.

The causes driving LULC change and associated thermal stress within the DU campus are multiple and intersecting. Sustained enrolment growth has generated persistent demand for new residential halls, academic blocks, and paved infrastructure, directly converting vegetated and open land to impervious surfaces. Vehicular emissions from dense traffic corridors contribute substantially to localized concentrations of CO_2, NO_x, and particulate matter (Parvez et al., 2022). Energy consumption from academic and residential buildings is intensified by artificial cooling demand under rising ambient temperatures. This constitutes compounding feedback between built-up expansion, LST increase, and GHG accumulation (Shakil et al., 2014).

While this study provides a spatially explicit characterization of LULC change, LST variation, and GHG emission patterns within the University of Dhaka campus, several limitations should be acknowledged. A methodological constraint pertains to vehicular emission estimation. Traffic flow counts were conducted as a single five-minute observation per road, which may not adequately represent diurnal, weekly, or seasonal fluctuations in vehicle volume and composition. This temporal limitation introduces uncertainty in emission load calculations derived from traffic data, as peak-hour and off-peak conditions may differ substantially from the recorded snapshot. Future studies should adopt continuous or multi-period traffic monitoring protocols to improve the robustness of vehicle-based emission inventories.

The findings carry direct policy implications for campus environmental governance. The documented decline in vegetation and water bodies necessitates a campus-wide Green Infrastructure Policy mandating canopy preservation, water body restoration, and incorporation of green roofs and permeable pavements into future development. This is consistent with the Bangladesh Delta Plan 2100 and Dhaka Structure Plan (Bokshi et al., 2026). New infrastructure should require mandatory thermal impact assessments before approval. Vehicular GHG contributions warrant the implementation of a low-emission zone policy, while energy efficiency retrofitting and rooftop solar installations would reduce building-level emissions and alleviate UHI-driven cooling loads, aligned with Bangladesh's NDC target of 6.73% unconditional GHG reduction by 2030 (Climate Centre, 2024). At the institutional level, establishing a Campus Carbon Observatory would provide a replicable sustainability governance model for universities across Bangladesh and the Global South. The inventory integrating remote sensing, IoT-based energy metering, and continuous traffic monitoring would generate longitudinal data to support SDG 11 and SDG 13 commitments.

CONCLUSION

This study provides a spatial assessment of greenhouse gas emissions, air quality variation, and land conversion in the University of Dhaka campus. The findings highlight the urgent need for integrated and sustainable campus planning. The emission hotspots are concentrated around buildings and major roads, likely due to electricity consumption patterns and vehicular emissions. The increased emissions contribute to increased surface temperature. Air quality analysis identifies $PM_{2.5}$ and NO_2 as the key pollutants in dense infrastructure and traffic zones due to high energy use. The land use classification shows the dominance of built-up areas over vegetation cover. The correlation between GHG emissions and increased land surface temperatures (LST) supports the urban heat island (UHI) effect. Although the study has limitations in terms of temporal data, institutional access, and short-term monitoring, it is a replicable and cost-effective approach for campus environment monitoring. To build on these findings, it is recommended that the university develop a centralized monitoring system of utility use and emissions in real-time. This will enable the authority to retrofit high-emission buildings with energy-efficient technologies, expand low-emission transport, and improve green cover. Additionally, integrating emission reduction targets into university policies, capturing multi-year and seasonal emission trends, and employing advanced remote sensing for high-resolution GHG mapping would enhance the accuracy and scope of future research. Apart from this, integrating qualitative methods like interviews and focus group discussions can also offer valuable insights. Overall, this research offers a data-driven foundation for targeted interventions and policy formulation for improving environmental quality, reducing emissions, and enhancing campus livability.

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