ENVIRONMENTAL CONSEQUENCES OF TRANSPORTATION INFRASTRUCTURE EXPANSION IN RAJSHAHI: A CASE STUDY ON ROAD AND FLYOVER PROJECTS (2015-2025)

Fahim Montasir [*1] and M. A. Sayeed [2]

[1] *Undergraduate Student, Department of Civil Engineering, RUET, Bangladesh, e-mail: fahimmontasir.ce@gmail.com*
[2] *Professor, Department of Civil Engineering, RUET, Bangladesh*

[*]**Corresponding Author**

ABSTRACT

Rajshahi is one of the fastest-growing urban centers in Bangladesh. In recent years, rapid urban development, particularly through the construction of new roads and flyovers, has significantly reshaped the city's landscape. This development has also led to the expansion of residential areas, industrial zones and commercial spaces. While these initiatives aim to improve connectivity and urban functionality, they have also raised growing concerns regarding their environmental impacts. This study aims to explore the environmental consequences of the rapid expansion of roads and flyovers in Rajshahi between 2015 and 2025. Multi-temporal remote sensing imagery from 2015 and 2025 was analysed within a GIS framework for geospatial analysis and field-based environmental monitoring. A significant portion of the city's area has been converted from agricultural land to built-up infrastructure. Concurrent noise monitoring near these new infrastructures reveals sound levels that exceed typical urban noise thresholds, indicating increased acoustic pollution from traffic. Air quality assessments further report elevated levels of PM 2.5, NO_2 and aerosol optical depth (AOD) surpassing World Health Organization (WHO) guidelines. Land surface temperature is also fluctuating during the period. These findings demonstrate that the expansion of transportation infrastructure is contributing to environmental degradation through land cover change, noise pollution and deteriorating air quality. This situation highlights the urgent need for comprehensive urban planning and effective mitigation strategies.

Keywords: *GIS; remote sensing; land cover change; infrastructure expansion; environmental impact.*

1. INTRODUCTION

Rajshahi is a major metropolitan city which is located in northern Bangladesh along the Padma River. It has undergone significant urbanization and infrastructure development in recent years. Rajshahi has experienced an average urban growth rate of about 8% per year which was influenced by population increase and economic expansion. In response to this growth, city authorities have focused on upgrading the road network and constructing new flyovers to improve connectivity. Notably, the Rajshahi City Corporation implemented several major infrastructure projects between 2015 and 2020, including five road development initiatives worth approximately Tk 702 crore(Sun, 2020). These projects involved widening roads and constructing new links to alleviate traffic congestion. A key example was the construction of a 327.5-meter flyover over a railway crossing, as part of a new 6.8 km arterial road, with a budget of Tk 182.68 crore(Sun, 2020). These infrastructure developments aim to enhance mobility and drive economic growth.

However, the rapid expansion of transportation infrastructure has raised several environmental concerns. The conversion of open land and agricultural areas into urban infrastructure leads to a reduction in green spaces, which disrupts the urban ecosystem. Increased number of vehicles and construction activities on the new roads contribute to the rise of vehicular emissions and airborne dust degrading air quality. Moreover, the growing number of vehicles and construction noise levels creates urban noise pollution, affecting public health and overall livability. Rajshahi, once considered a "clean air" city, has seen a recent decline in environmental quality as pollution levels rising rapidly. In last some years no significant industrialization wasn't done in Rajshahi. Only the transportation facility got seriously developed that as a side business promoted residential growth in the city. Though environmental degradation is a part of a vast system, the rapid expansion of urban infrastructure was one of the most serious local agents behind it.

This study aims to investigate the environmental impacts of Rajshahi's transportation infrastructure expansion from 2015 to 2025, focusing on land cover change, land surface temperature (LST) variation and air quality, specifically particulate matter (PM 2.5) and nitrogen dioxide (NO_2) levels. By analyzing satellite-derived data, including MODIS Land Cover (MCD12Q1), Landsat LST and MODIS AOD and Sentinel-5P NO_2 measurements, the study seeks to assess how the construction of new roads and flyovers has influenced the city's environmental conditions. The analysis will also examine the relationship between urban heat islands, air pollution and land use change, providing valuable insights for sustainable urban planning and policy development aimed at mitigating the adverse environmental effects of urbanization in Rajshahi.

2. METHODOLOGY

2.1 Study Area

Rajshahi is a major metropolitan city located in the northwestern region of Bangladesh along the Padma River and it is considered as a significant administrative, educational and commercial hub. It is often said to be the country's "education city." The city is lies between approximately 24°20′ to 24°30′ N latitude and 88°30′ to 88°40′ E longitude, covering an area of about 96.7 square kilometers.

Climatically, Rajshahi falls into the tropical wet and dry (savanna) climate zone, having hot summers, a distinct monsoon season and mild winters. The average annual rainfall is around 1400 mm, most of this precipitation occurs between June and September and the average temperature varies from 10°C in winter to 40°C in summer.

Rajshahi City Corporation (RCC) plays a pivotal role in promoting district-level development and driving regional economic growth through investment, industrial expansion and employment opportunities. This institution is responsible for managing essential urban services such as waste management, transportation, sanitation and water supply system: that directly influence the quality of life of the residents. Moreover, RCC oversees health, education and social welfare programs that benefit not only city residents but also neighboring peri-urban communities.

Being a regional administrative and infrastructural hub, Rajshahi is responsible for coordinating major activities in transportation, education and public works within the northwestern zone of the country. Over the period 2018–2023, the city has exhibited moderate but systematic urban expansion, driven by population inflows, enhanced road connectivity and targeted government initiatives. In contrast to the rapid, often unregulated industrialization seen in other metropolitan centers, Rajshahi's growth has been

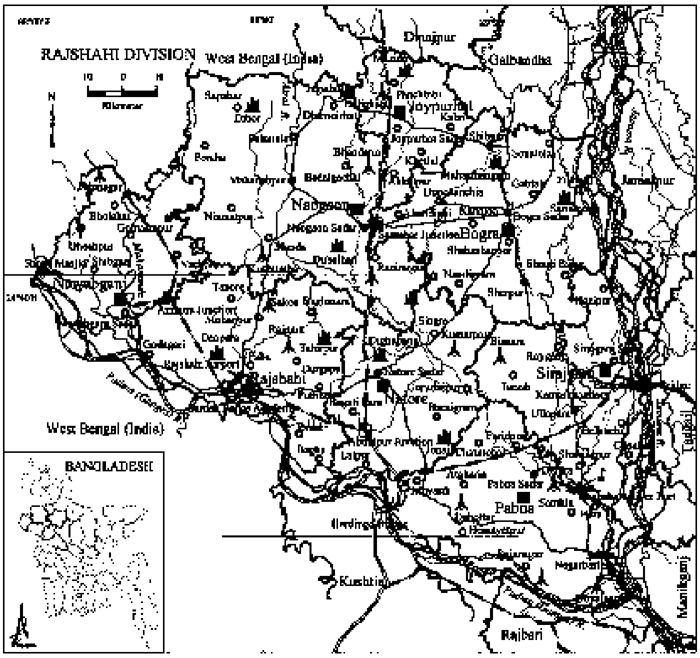

Figure 1: Map of Rajshahi (Source: Banglapedia)

characterized by a strategic balance between urbanization and environmental stewardship. Municipal planning emphasizes green-space preservation, sustainable infrastructure development and improved service delivery, positioning Rajshahi as an emerging model for sustainable urban governance in Bangladesh.

2.2 Description of Data and Collection Procedure

This study focuses on Rajshahi City Corporation, with the spatial extent of this study being its official administrative boundary. The period under study considers three reference years: 2015, 2020 and 2025; for cases where data is not available in 2025, the proxy year 2023 is used. Data for this study were derived from various satellite-based sources and were processed on the GEE platform.

Annual land use and land cover (LULC) maps were obtained from the MCD12Q1, Collection 6.1 product of MODIS Land Cover Type, which provides global land cover classifications at 500 m resolution. The classification comprises major land cover types, including forests, croplands, grasslands, urban areas and water bodies. Further, in this study, direct LULC maps for 2015 and 2020 were used, but for 2025, the 2023 map was taken as a temporal proxy. This was considered plausible because changes in the overall land cover pattern are limited within a short time span. These LULC maps will be used to analyze land cover dynamics and urban expansion within Rajshahi City Corporation.

Land surface temperature (LST) data were derived from Landsat Collection 2 Level-2 products, specifically from the thermal infrared band (Band 10) of Landsat 8 and Landsat 9. These products provided surface temperature data that was converted to degrees Celsius after atmospheric correction. The LST data for 2015 and 2020 were computed using Landsat 8, while for 2025, both Landsat 8 and Landsat 9 were used. In cases where 2025 data were not sufficient, the 2023 data were used as a proxy. The resulting LST composites were used to analyze urban heat patterns and the impact of land cover changes on temperature dynamics.

Air quality indicators, specifically aerosol optical depth (AOD) and tropospheric nitrogen dioxide (NO_2) were used to assess pollution levels in Rajshahi City Corporation. AOD data were obtained from the MODIS MCD19A2 product, which provides daily aerosol optical depth at 1 km resolution. Annual mean AOD composites were generated for 2015, 2020 and 2025, with 2023 used as a proxy for 2025 where necessary. NO_2 data were derived from the Sentinel-5P TROPOMI product, which provides global NO_2 column densities. Due to the availability of NO_2 data only from mid-2018, data for 2015 were not available and the analysis was limited to 2020 and 2025, with 2023 used as a proxy for 2025 where full data were unavailable.

Both tabular data (mean values for LULC, LST, AOD and NO_2) and raster products (showing the spatial distribution of LULC, LST, AOD and NO_2) were produced for each year. These figures were combined and produced as CSV files for the whole Rajshahi City Corporation. While the LST and air quality data allowed for an examination of the relationship between urban heat and pollution, the LULC maps offered insight into changes in land cover, providing a thorough look at the city's environmental conditions. These data were then contrasted with local sources and statistics from previous research investigations. Fig:2 shows the interface of Google earth engine while performing the study.

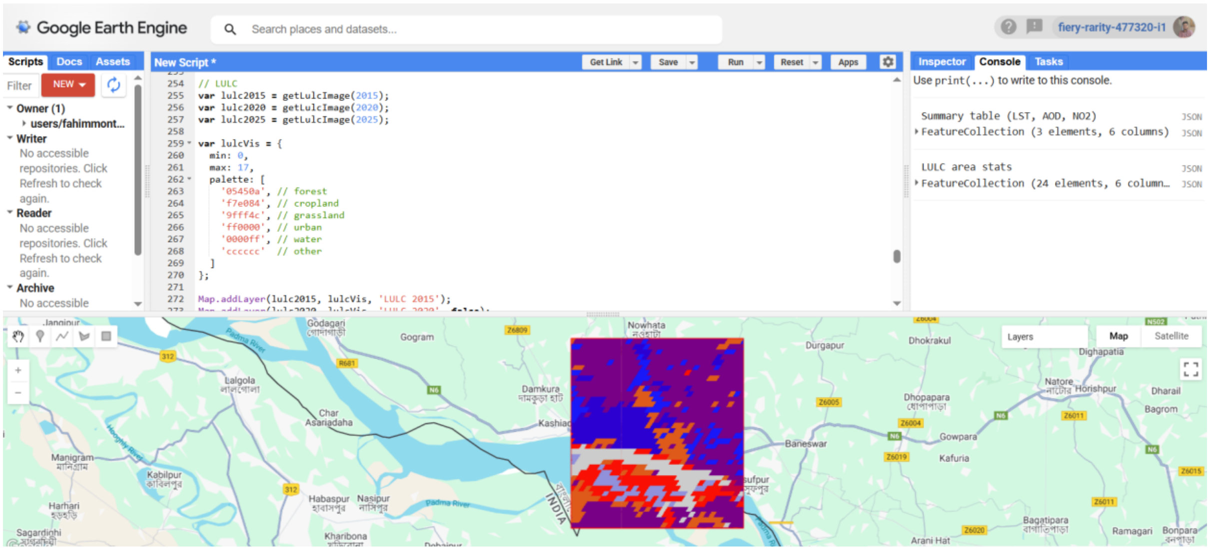

Figure 2: GEE interface for this study

3. RESULT

3.1 Land Cover Change (2015-2025)

Between 2015 and 2022, the Rajshahi City Corporation shows a clear shift from natural and open surfaces towards built-up land. Water bodies declined from 90.28 to 58.65 units, a reduction of about 35%, indicating shrinkage or encroachment of surface water. Vegetation decreased from 294.46 to 207.14 units (around 29.7% loss), while agricultural land fell from 128.70 to 101.21 units (about 21.4% decrease), suggesting that both green and cultivated areas are being converted to other land uses. Bare land, which was the largest class in 2015 (785.52 units), dropped sharply to 458.90 units, a decline of roughly 41.6%. In contrast, built-up area almost doubled, increasing from 409.80 to 757.24 units, an 84.8% rise, making it the most rapidly expanding class. Taken together, these trends clearly indicate that rapid urban growth and infrastructure development in Rajshahi are occurring mainly at the expense of water bodies, vegetation, agricultural land and bare/open spaces, reflecting a strong intensification of urban land use within the city. These changes underscore the land cover transition from rural to urban uses: a large portion of Rajshahi's fringe agricultural lands have been converted into built environments over the decade(Kafy et al., 2020). Fig. 3 shows the LULC comparison and Fig 4,5,6 shows the development, LULC 2015 and 2025 respectively.

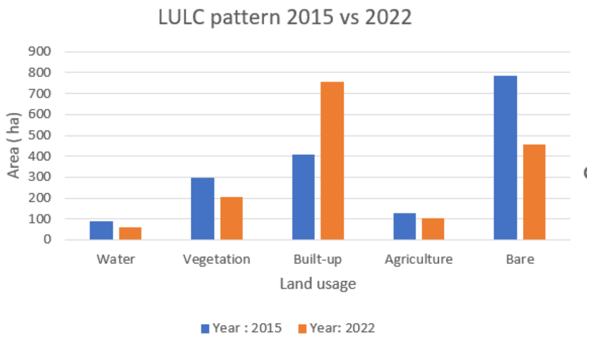

Figure 3: LULC in Rajshahi for 2015 vs. 2022

The spatial distribution of change was observed to concentrate around new infrastructure. Field observations and map analysis indicate that areas along the newly widened roads and around flyover construction sites saw the most pronounced conversion of land use. For instance, the corridor of the new four-lane connecting road (mentioned in the introduction) was previously semi-rural with crop fields, which by 2025 have turned into paved roads, commercial plots and housing. Similarly, the vicinity of the flyover and upgraded intersections experienced infill development. The loss of permeable soil surface and vegetation in these areas may have secondary effects such as increased runoff and urban heat island intensity (though those aspects are beyond this study's immediate scope).

Figure 4:Newly Built Roads (red

Figure 5: LULC 2015

Figure 6: LULC 2025

3.2 Air Quality

3.2.1 PM2.5 Pollution

Ambient air quality is an important factor while rating the environment degradation. The measurements of PM2.5 concentrations in Rajshahi show a definite increase between 2015 and 2025. In advance of the major development of transportation infrastructure in 2015, city-wide levels of PM2.5 averaged in the range of 40 to 50 µg/m³, rather low by Bangladeshi standards. By 2025, however, most monitoring sites demonstrated significantly larger quantities. Daytime PM2.5 levels in 2025 which was then measured near major highways, crossroads and newly expanded thoroughfares. It was ranged from 75 to 85 µg/m³. Compared with those in 2015, this represents an overall rise of about 50–60%. The highest readings were consistently reported within close proximity of large traffic corridors and active construction areas. Residential neighborhoods which are farther away from large roadways showed lower quantities, typically in the range of 50 to 60 µg/m³, although these continued to be higher than those measured ten years earlier.These results are in line with other recent surveys in Rajshahi: for example, a 2021 study reported citywide average $PM_{2.5}$ around 56 µg/m³, with peak spot readings above 100 µg/m³ at traffic-heavy locations(Khan, 2025).

The World Health Organization's recommended limit for annual average PM2.5 is 5 µg/m³ as per the updated 2021 guideline and even its older guideline for 24-hour exposure was 25 µg/m³. Rajshahi's observed concentrations (ranging from ~50 to 80+ µg/m³) are an order of magnitude higher - on the order of 10 to 15 times the WHO guideline(*Bangladesh Air Quality Index (AQI) and Air Pollution Information | IQAir*, n.d.). Spatial patterns in the 2025 dataset indicate that elevated concentrations were primarily located near transportation infrastructure, widened road networks and construction-associated zones, whereas peripheral residential areas displayed relatively lower values. The overall trend in PM2.5 concentrations over the study period is illustrated in Fig. 7, which shows a consistent upward trajectory from 2015 to 2025.

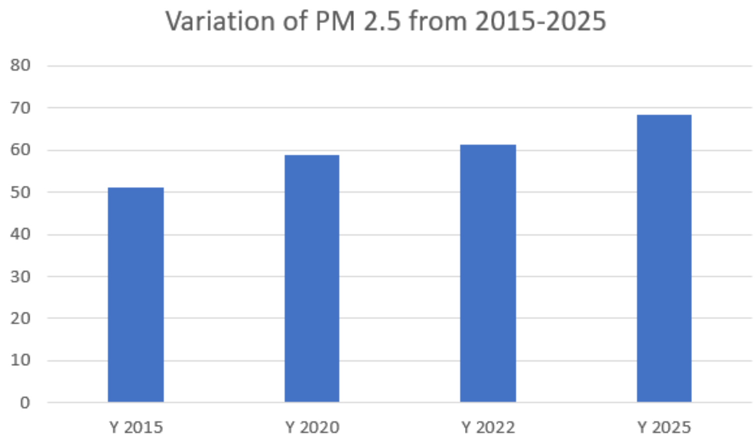

Figure 7: Variation of PM 2.5 from 2015-2025

3.2.2 Aerosol optical depth (AOD) and NO_2

For aerosol optical depth (AOD), the results indicate consistently high aerosol loading in all three time points (Table: 1). But it has a very small variation over time. There is a slight stability between 2015 and 2020. It means despite rapid urban-growth in this period; the overall columnar aerosol levels did not rise at that manner. The rise in mean AOD in 2025 indicates a worsening of particulate pollution in recent years, which may be linked to increasing traffic volume, construction activities and higher power use associated with urban expansion. Mean tropospheric NO_2 over Rajshahi City Corporation rose from 36.50 µmol/m² in 2020 to 42.64 µmol/m² in 2025. It indicates a clear increase in combustion-related pollution over the time.

Table 1: AOD in 2015,2020 and 2015

Mean AOD	Year
0.673913653	2015
0.671499701	2020
0.710850905	2025

Table 2: Mean NO2

Mean NO2(micromole)	Year
36.50169	2020
42.64075	2025

3.3 Noise Pollution

The noise measurements taken from eleven locations across Rajshahi City Corporation reveal a consistently high level of sound exposure. At major traffic intersections such as Zero Point, Vodra, Talaimari, Rail Gate and Kazla; noise levels remain above 70 dB throughout the day. Morning averages hover around 76 dB, rising to nearly 80 dB at noon and in the evening, before dropping slightly to about 74 dB at night. The highest readings are observed at Vodra, where evening levels peak at 86.64 dB and at Kazla, which reaches 84.70 dB at noon, showing how intense traffic activity becomes during busy hours.

Residential neighbourhoods are quieter but still far from peaceful. Motihar maintains moderate yet higher values (around 61–63 dB across the day) while Padma Abashik stands out as unexpectedly loud (specially the 1 no road), reaching 77.42 dB in the evening. Upashahar is the calmest of the three, though even its night-time noise level remains around 55.86 dB, which is above what is generally recommended for residential comfort.

The commercial hubs like RDA Market and New Market - follow a kind of similar trend, with noise ranging between 65 and 77 dB. New Market is consistently louder than RDA Market in every time slot, reflecting its intense commercial and pedestrian activity. The industrial area at BISC shows stable readings of 71–73 dB through morning to evening but jumps sharply to 83.59 dB at night, pointing to continuous or possibly increased industrial operations after dark.

Overall, the average noise levels across all sites vary from about 71.5 dB in the morning to roughly 75.5 dB in the evening, with the lowest recorded value still as high as 55.86 dB. These findings clearly indicate that people living, travelling or working within Rajshahi City Corporation are exposed to consistently elevated environmental noise - not only during peak business hours but also during evenings and late-night periods. All the findings were marked on map which was made with the help of ArcMap and the map is given below in Fig:8.

For context, Bangladesh's Noise Pollution Control Rules (2006) set a maximum of 55 dB in residential areas during daytime. Similar findings were reported by other researchers: a 2024 study in Rajshahi city recorded traffic noise ranging from 57 dB up to 108 dB across different locations(Hossain & Shahriar, 2024). Such levels are known to pose serious health risks, contributing to sleep disturbances, stress and hearing impairment over the long term.

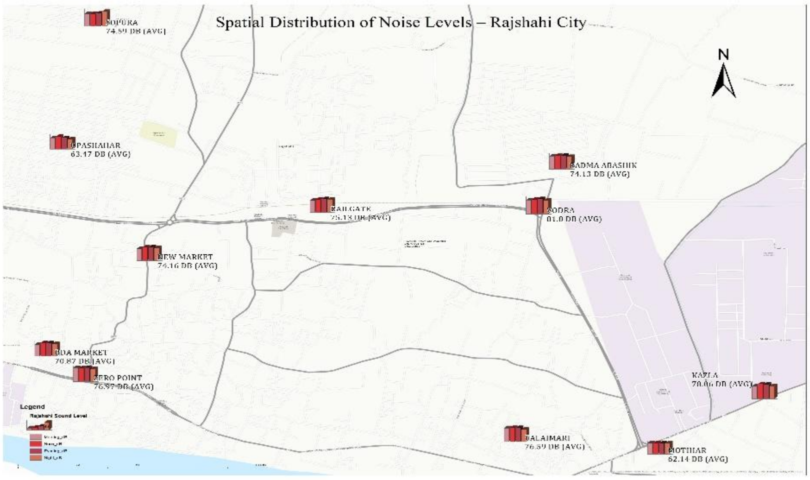

Figure 8: Sound Level at various location at Rajshahi

3.4 Mean Land Surface Temperature (LST)

Mean land surface temperature (LST) in Rajshahi City Corporation was about 30.3°C in 2015, dropping to 28.3°C in 2020 and remaining almost unchanged at 28.5°C in 2025. This indicates a slight overall cooling of the average surface temperature compared to 2015, despite rapid urban expansion. However, the values still reflect a consistently warm urban environment and the modest decrease in mean LST does not rule out the presence of local hot spots or intensified urban heat islands in newly built-up areas, which may not be fully captured by the city-wide average. Winter LST in Rajshahi has increased by an average of 2.66 °C, with some areas experiencing a rise of more than 4 °C(Rahman et al., 2025).

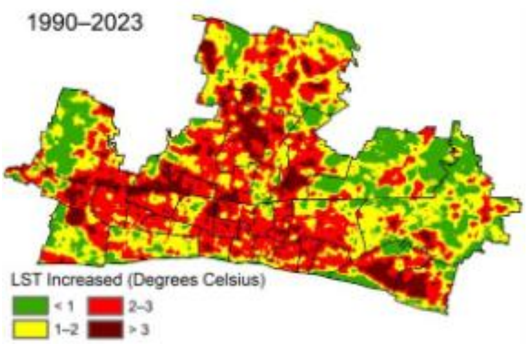

Figure 9: LST 1990-2023

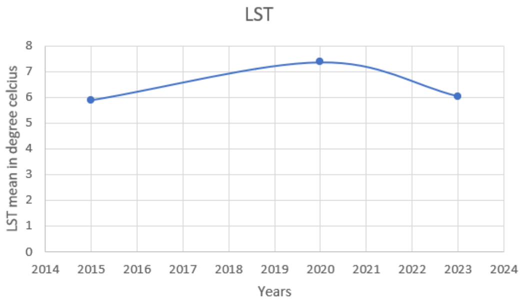

Figure 10: LST changes over the year

4. DISCUSSION & ANALYSIS

The results clearly show that the expansion of transportation infrastructure in Rajshahi has come alongside a major transformation of the urban landscape and a noticeable decline in several areas of environmental quality. The land cover analysis from 2015 to 2022 points to a steady conversion of natural and semi natural surfaces into built up zones. Water bodies, vegetation, agricultural land and open or bare land have all gone down, while the amount of built up land has almost doubled. This kind of pattern is common in fast growing South Asian cities where the agricultural edges around the city slowly get absorbed into the main urban area as new roads, commercial rows and housing clusters are developed.

In Rajshahi, the strongest LULC changes appear around newly widened corridors, flyover entry points and upgraded intersections. This suggests that road infrastructure becomes a kind of spatial magnet that pulls both planned and unplanned growth along its route. The loss of permeable soil and vegetation also has big implications for things like stormwater runoff, groundwater recharge and local climate regulation, although these hydrological impacts are outside the main scope of this study.

Air quality and noise indicators show that the environmental costs of this growth are quite serious. The satellite based PM2.5 levels for Rajshahi are extremely high across all study years, with annual averages staying above 50 micrograms per cubic meter even in the latest period. There is a slow drop from around 61 micrograms per cubic meter in 2015 to roughly 51 in 2022, but these numbers are still far beyond the WHO 2021 guideline of 5 micrograms per cubic meter. They are about an order of magnitude higher than what is considered safe for long term exposure. At the same time, aerosol optical depth stays high and even shows a bit of an increase by 2025. Mean tropospheric NO2 moves from about 36.5 to 42.6 micromoles per square meter. All these indicators together suggest that the overall particulate load remains very high and that traffic and energy related combustion have likely intensified. The small drop in PM2.5 could be linked to broader regional changes, weather patterns or emission control from other sectors, but it does not mean that Rajshahi's air has become healthy.

The noise data add another layer to this picture of a stressed urban environment. Sound levels at busy intersections, commercial centers and even residential areas go beyond national standards and health - based limits. Many places are between 70 and 80 decibels throughout the day and most of the evening. These levels are known to cause annoyance, sleep disruption, mental stress and even cardiovascular risks over time. The highest noise readings mostly occur near roads that were recently upgraded, including flyovers and big junctions. This makes the connection between transport infrastructure and noise burden quite clear. The same projects meant to ease congestion and improve travel time are unintentionally creating new noise hotspots, especially where houses or stores are very close to the road and where horn or speed rules are not enforced properly.

The land surface temperature results give a more mixed picture. At first, the slight decrease in average annual LST between 2015 and 2025 may look like it contradicts what we expect from a stronger urban heat island effect. But citywide averages often hide big variations within the city. Previous studies in

Rajshahi have found winter LST increases of over 2.5 degrees Celsius in some parts and more than 4 degrees in the fastest developing zones. This shows that local hot spots are becoming stronger even if the overall city mean is held down by nearby agricultural land or the cooling influence of the river. In that case, the observed cooling in average LST is better understood as a regional climate influence plus the relatively small size of the city, rather than proof that urbanization is harmless in terms of heat. The replacement of green or bare soil with asphalt and concrete near new roads is still very likely causing higher local temperatures, particularly on clear and dry days. This adds to thermal discomfort and increases cooling demand for buildings along these routes.

Putting all the evidence together, we see a classic tradeoff between better mobility and environmental sustainability. Road widening and flyover projects have definitely improved connectivity and supported economic activity. But they have also helped speed up land cover change, kept air pollution at dangerous levels and caused long term noise exposure for many residents. These findings show why environmental safeguards need to be part of transport planning in Rajshahi. Some possible steps include keeping or restoring roadside green buffers, enforcing dust control at construction sites, encouraging cleaner public transport and safer walking or cycling options and setting up speed control and noise calming measures in residential or sensitive zones. Urban planning should also try to prevent scattered development along road corridors by promoting more compact mixed-use growth with enough green space.

There are some limitations in this study as well. The analysis depends a lot on satellite data with moderate resolution and built in uncertainties and in some cases uses 2023 data as a stand in for 2025. Ground based PM2.5 and NO2 data are limited so the satellite numbers cannot be fully verified at detailed local scale. Using annual averages for LST and air quality may also hide extreme short-term episodes like heat waves or pollution spikes, which are often the most harmful to health. The study also focuses on correlations between infrastructure change and environmental indicators rather than modeling causal pathways or isolating the influence of other factors like regional industry or seasonal biomass burning.

Even with these limitations, the multi-indicator approach gives a consistent picture. Transportation led urbanization in Rajshahi is reshaping land cover and placing strong pressure on air quality, noise levels and the urban microclimate. Dealing with these issues will be important if the city wants to hold on to its reputation as a liveable and pleasant place while it continues to grow as a regional center.

5. CONCLUSION

This study set out to examine the environmental consequences of transportation infrastructure expansion in Rajshahi City Corporation between 2015 and 2025, with particular emphasis on land use and land cover change (LULC), air quality, noise pollution, and land surface temperature (LST). By integrating multi-temporal remote sensing data, GIS-based spatial analysis, and field-based noise measurements, the research provides a comprehensive, indicator-based assessment of how road widening and flyover development have reshaped the urban environment.

The findings clearly demonstrate that transport infrastructure expansion has acted as a major driver of land cover transformation in Rajshahi. Built-up areas increased sharply, nearly doubling during the study period, while water bodies, vegetation, agricultural land, and bare/open surfaces experienced substantial declines. The spatial concentration of these changes along newly developed road corridors and flyover zones confirms that transportation projects function as strong catalysts for both planned and spontaneous urban expansion. This directly fulfills the study's objective of identifying infrastructure-induced land cover change and highlights the gradual replacement of permeable and ecologically functional surfaces with impervious urban materials.

With regard to air quality, the study finds persistent and alarming pollution levels. Satellite-derived PM2.5 concentrations remained far above World Health Organization guidelines throughout the study period, with a marked increase near major roads, intersections, and construction corridors. The observed rise in aerosol optical depth (AOD) and the increase in tropospheric NO_2 between 2020 and 2025 further indicate intensifying combustion-related emissions, most plausibly linked to increased traffic volume, construction activity, and energy demand associated with infrastructure expansion. These results directly address the objective of assessing transportation-related air pollution and confirm that mobility improvements have come at the cost of deteriorating air quality.

The noise pollution analysis reinforces this conclusion. Measurements across residential, commercial, traffic-intensive, and industrial locations consistently exceeded national and health-based noise limits. The highest sound levels were recorded near major intersections, markets, and recently upgraded roads, while even residential areas remained above recommended thresholds, particularly during evening and nighttime hours. This demonstrates that transportation infrastructure development has produced a sustained acoustic burden, exposing residents to chronic noise stress and associated health risks.

The analysis of land surface temperature presents a more nuanced outcome. Although the city-wide mean LST shows a slight decline over time, this does not contradict the presence of localized urban heat intensification. Previous evidence and spatial patterns suggest that newly built-up areas along transport corridors are likely experiencing higher surface temperatures, masked in the city-average values by surrounding agricultural land and the influence of the Padma River. Thus, the findings partially fulfill the objective related to thermal effects, indicating emerging localized heat stress rather than uniform city-wide warming.

Taken together, the results confirm that transport-led urbanization in Rajshahi has generated significant environmental trade-offs. While road and flyover projects have improved connectivity and supported economic activity, they have simultaneously accelerated land cover loss, maintained hazardous air pollution levels, increased environmental noise, and contributed to localized thermal stress. These findings underscore the urgent need to integrate environmental safeguards into transportation and urban planning, including roadside green buffers, dust and emission control during construction, promotion of cleaner and non-motorized transport, strict noise management, and compact, green-oriented land-use planning.

Overall, this study meets its objectives by providing clear, evidence-based insight into how transportation infrastructure expansion influences multiple environmental dimensions in a secondary city context. The results offer practical guidance for policymakers and urban planners seeking to balance infrastructure development with long-term environmental sustainability in Rajshahi and similar rapidly growing citi

6. DECLARATION

During the preparation of this manuscript, the authors used the extension of Grammarly for MS Word only for grammar refinement and language editing ; Gemini (Google) only for debugging and troubleshooting Google Earth Engine (GEE) code for identifying syntax-related programming errors. AI tools were not used to generate manuscript content, analysis, interpretation, academic arguments, results or conclusions. All methodology, analysis, results, interpretations and written content were developed by the author.

The use of AI tools was conducted under full human oversight and control. The recommendations given by AI were then manually checked, validated and implemented if appropriate. AI did not make any decisions regarding research methods, data interpretation, structure or scientific claims. The author takes full responsibility for the originality, accuracy, integrity and scholarly contribution of the final manuscript.

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