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Assessing Urban Expansion and Forest Fragmentation in Dhaka Megacity Using Remote Sensing and Landscape Metrics

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Abstract: The spatiotemporal dynamics of urban expansion and its impact on forest fragmentation within Dhaka City Corporation (DCC), a rapidly urbanizing megacity in South Asia, were critically investigated in this study. While prior research has predominantly focused on broad land-use changes and general vegetation loss, detailed analysis of forest fragmentation and its direct correlation with urban expansion intensity remains limited. This gap was addressed by integrating high-resolution Landsat satellite imagery from 2016, 2020, and 2024 with advanced landscape metrics and urban expansion indices, enabling a comprehensive and replicable assessment of urban-driven ecological disruption. Land use and land cover (LULC) classifications were generated through supervised classification in Google Earth Engine. Urban growth was quantified using the Urban Expansion Intensity Index (UEII) and the Annual Urban Expansion Rate (AUER), while forest fragmentation was evaluated via patch density, edge density, and a comprehensive fragmentation index derived from FRAGSTATS. Results indicated a marked intensification of urban expansion, with the urban area increasing from 133 km^2 in 2016 to 139 km^2 in 2024. This growth was accompanied by a rise in UEII from 0.67% to 1.35% and in AUER from 0.37% to 0.73%. Concurrently, forest ecosystems experienced significant fragmentation, as evidenced by an increase in the fragmentation index from 33 to 80 and edge density from 4 to 9 per km^2, indicating a progressive decline in forest continuity and heightened ecological vulnerability. Pearson correlation analysis revealed strong positive relationships between urban expansion and both edge density (r = 0.953) and the fragmentation index (r = 0.922), confirming the direct influence of urban sprawl on forest disintegration. These findings underscore the urgent need for ecologically informed urban planning. By providing a replicable methodological framework for quantifying urbanization-driven ecological disruption, this study contributes to the broader discourse on sustainable urban development and forest conservation in rapidly transforming urban landscapes.

Keywords: Urban expansion; UEII; AUER; FRAGSTATS; Fragmentation index; Pearson correlation

1 Introduction

Urban regions represent some of the most rapidly evolving areas on the planet, and their physical footprint continues to expand globally [1]. Over the last 200 years, the world's population has grown sixfold, while the number of people living in cities has increased one hundredfold [2]. Projections suggest that by 2050, urban rates in regions like Asia and Africa will reach approximately 2.5% [3].

The most accelerated urbanization is occurring in low-income nations, with Dhaka, Bangladesh, standing out as a prime example [4]. Dhaka, the administrative and economic hub of Bangladesh, ranks among the world's most rapidly expanding megacities. Dhaka's urban land cover grew significantly from 11% in 1960 to 34% by 2005 [3]. The city continues to draw rural-urban migrants in large numbers, attracted by employment opportunities as well as access to improved healthcare, education, and other urban services [5]. This rapid and unplanned urban influx has intensified numerous challenges in Dhaka, including the proliferation of slums, persistent traffic congestion, waterlogging, rising poverty, and environmental degradation [6].

Urban sprawl also contributes to the loss and fragmentation of natural landscapes, becoming a major driver of various ecological and environmental issues [7–11]. In Dhaka, the impacts are evident through heightened surface runoff, reduced greenery, escalating air and noise pollution, and the gradual disappearance of trees along the urban fringes. Areas once occupied by forested wetlands and acting as natural barriers against heat and flooding have been overtaken by impermeable urban development. Green spaces in Dhaka are rapidly declining, with Dhaka South City alone losing 36.5% of its green areas [12]. Across the entire city, green and open spaces account for only about 2.24%, while residential zones have just 8.86% coverage, well below the World Health Organization's recommended minimum of 5 m^2 per person. This significant loss of vegetation has intensified the urban heat island effect, causing the city's average winter temperature to rise from 25°C in the early 1990s to 32.5°C by the 2020s [13]. Dhaka's wetlands are steadily diminishing due to rapid urban growth, which simultaneously causes an increase in waterlogged zones [14]. Other studies [15, 16] have similarly identified a connection between the reduction of wetlands and the spread of urban build-up zones driven by accelerated urbanization.

The Buriganga, Balu, and Turag rivers have been declared ecologically critical zones due to alarming pollution levels. Islam et al. [17] found that the concentrations of potassium, manganese, and lead in the Buriganga River exceeded safe drinking water standards, with industrial activities along the riverbanks identified as major pollution sources. Similar conditions were observed in the Turag River, where Riad Khan et al. [18] reported biological oxygen demand (BOD) levels ranging from 112 to 165 mg/L which is far beyond the limits required to maintain a healthy aquatic life.

Forest fragmentation has become a critical global environmental concern [19, 20], as it poses serious threats to biodiversity, disrupts ecosystem processes, and weakens the connectivity of natural habitats [21, 22]. This process often leads to the isolation of forest patches, changes in local microclimates, and intensified edge effects. These effects of fragmentation are especially severe in rapidly urbanizing areas, where continuous forested landscapes are broken into smaller, dispersed sections due to expanding built-up zones [23]. In the case of Dhaka, rapid urban development has caused considerable degradation and division of peri-urban and urban forest areas, leading to a sharp decline in green space and increasing risks to local biodiversity [24]. Of particular concern is the rapid expansion of Dhaka's urban footprint over the decades. The city's built-up area grew from 39 km^2 in 1972 to 58 km^2 in 1980, then to 70 km^2 by 2000, and reached 106 km^2 by 2010 [25]. This spatial expansion has significantly contributed to the fragmentation of urban forests.

Numerous studies have investigated how urban expansion affects forests around the world and in South Asia. For instance, research conducted by Zhang et al. [26] in Nanjing, eastern China, revealed that forest cover became increasingly fragmented, declining by 94 km^2 between 1987 and 2017, while the area covered by urban impervious surfaces expanded by 893 km^2 during the same period. In the context of Bangladesh, various studies have documented significant vegetation decline and uncontrolled urban expansion in Dhaka, using the Normalized Difference Vegetation Index (NDVI) and LULC change detection techniques.

However, there has been less focus on the detailed patterns of forest fragmentation within Dhaka City, especially using high-resolution satellite images and advanced landscape measurements. Most research has focused on general LULC changes or urban growth without closely examining how forest patches break apart or how these changes relate to specific urban growth measures. Previous studies using remote sensing and Geographic Information System (GIS) in Dhaka mostly focus on broad vegetation loss or urban sprawl through indices like NDVI, but these methods cannot capture changes in forest structure. Few studies have combined remote sensing data with spatial metrics like patch density and edge density, along with statistical analysis, to directly link urban growth to ecological fragmentation in Dhaka. This linkage can be effectively assessed using indices such as UEII which measures the concentration of urban growth within a specific area to pinpoint zones of rapid urbanization and AUER which reflects the yearly rate of urban growth, highlighting the rapidity of urban sprawl. The connection between how quickly and intensely the city grows, measured by tools like UEII, AUER, and the forest fragmentation index, has not been fully explored, particularly within Dhaka City limits. Addressing these gaps by using a clear and repeatable approach, this study combines supervised classification of Landsat satellite images over time with fragmentation analysis and urban growth modeling using Google Earth Engine. This study evaluates the urban growth of Dhaka City through indices, including UEII, AUER, and the forest fragmentation index, incorporating metrics like patch density and edge density derived from satellite imagery. These measures elucidate the dynamics of urban development and its ecological consequences, particularly regarding forest fragmentation in Dhaka City.

2 Methodology

2.1 Study Area

This study focuses on Dhaka, Bangladesh, located within the geographical coordinates of 23°52'53.19"N to 23°40'35.43"N latitude and 90°24'0.84"E to 90°27'37.64"E longitude (Figure 1). Dhaka is one of the most densely populated urban areas in the world and is bordered by four major rivers: Buriganga, Turag, Tongi, and Balu [27]. As noted by the World Bank Office in a 2007 report [6], the city experiences high rates of in-migration, with an estimated 300,000 to 400,000 individuals relocating there annually. This rapid influx has significantly contributed to the city's population growth from 10.921 million in 2001 to 22.888 million in recent years. By 2026, the population is expected to reach approximately 24.362 million [28]. This demographic expansion has led to notable changes in land use patterns across the city. Between 1990 and 2010, the built-up area increased by nearly 67%, with 53% of that expansion occurring between 1990 and 2003. As of 2024, Dhaka's urban area spans around 136 km^2. Meanwhile, the extent of urban green spaces and water bodies has shown a continuous decline. The extensive and persistent urbanization process functions as the primary contributor to recent land use change in Dhaka City.

Figure 1. Location of the study area: (A) Built-up infrastructure and (B) Urban green spaces

2.2 Landsat Satellite Images

Satellite images of DCC were collected from USGS Earth Explorer for 2016, 2020, and 2024 to prepare the LULC classification maps (Table 1).

Table 1. Specified information on satellite images utilized (2016-2024)

Satellite	Sensor	Acquisition Date	Resolution
Landsat 8	OLI IRIS	3-March-2016 10 -June-2020 4 -Dec-2024	30 m

2.3 LULC Classification

LULC classification maps for 2016, 2020, and 2024 were firstly generated using supervised image classification in Google Earth Engine. To prepare the LULC maps, satellite images were collected from USGS Earth Explorer. Then, the generated maps were exported into the ArcMap 10.8 software to extract the urban and forest areas. Those LULC maps were classified into four classes: water body, urban area, urban green space and barren land (Table 2).

Table 2. Description of LULC classes

Class	Description
Water body	Rivers, canals, lakes, and wetlands
Urban area	Urban residential, commercial, institutional and industrial area
Urban green space	Parks, gardens, green roofs and walls
Barren land	Bare soil, bare rock, and sand

2.4 Accuracy Assessment

In statistics, accuracy reflects how close data or results are to the true values and is generally influenced by two key elements: bias and precision. It's important to understand the difference between them, as improving one can sometimes reduce the other [29]. When it comes to thematic mapping using remote sensing data, accuracy usually refers to how correctly the map or classification represents real-world features [30]. If a land cover map shows the actual conditions on the ground without systematic distortion, it can be considered accurate [31]. In this context, classification accuracy is about how well the mapped outputs align with what actually exists in the physical environment [32]. Accuracy assessment is a crucial final step in the classification workflow (Table 3). It helps evaluate, in measurable terms, how accurately each pixel has been assigned to the correct land cover category [33].

Table 3. Formula of accuracy assessment

Metric	Formula
Kappa coefficient	$\frac{(\text{TS} \times \text{TCS}) - \int(\text{Column total} \times \text{Row total})}{(\text{TS})^2 - \int(\text{Column total} \times \text{Row total})} \times 100$
Overall accuracy	$\frac{\text{TCP}}{\text{TS}} \times 100$
User accuracy	$\frac{\text{Correctly classified pixels in class}}{\text{Total pixels classified in class}} \times 100$
Producer accuracy	$\frac{\text{Correctly classified pixels in class}}{\text{Total pixels in ground truth class}} \times 100$

2.5 Urban Expansion Measurement

Spatial indices are widely used to measure urban expansion. In this study, two spatial indices were used: UEII and AUER.

$$\text{UEII} = \frac{BLA_i^{t2} - BLA_i^{t1}}{TLA_i - \Delta t} \times 100 \tag{1}$$

$$\text{AUER} = \left\{ \left(\left(\frac{BLA_i^{t2}}{BLA_i^{t1}} \right)^{\frac{1}{t2-t1}} - 1 \right) \right\} \times 100 \tag{2}$$

where, BLA is the build-up area, i is the spatial unit, t_1 is the base year, and t_2 is the ending year, with $\Delta t = t_1 - t_2$, and TLA is the total land of the study area.

2.6 NDVI Value Selection for Identifying the Forest Area

To identify and estimate forest coverage in Dhaka City, a threshold-based classification technique was employed using NDVI values. Given the temporal variations in vegetation patterns and the characteristics of the data, distinct threshold values were applied for each study year to ensure consistent classification of the forest area. In 2016, areas with NDVI values greater than 0.43 were classified as forest coverage. For 2020, the threshold was adjusted to 0.36, and for 2024, it was further lowered to 0.30. These thresholds were determined based on the statistical distribution of NDVI values across the study area and visual interpretation of vegetation presence, ensuring an accurate representation of forest cover. The classified layers produced from this process allowed for the extraction and quantification of forest coverage for each year, forming the basis for temporal comparisons and further analysis of forest fragmentation dynamics within the city.

2.7 Forest Fragmentation

Forest fragmentation was measured using three metrics: patch density, edge density and the fragmentation index. These metrics were calculated using Google Earth Engine (Table 4). Forest fragmentation maps were generated using the ArcMap 10.8 software with the FRAGSTATS tool. In the forest fragmentation maps, the areas were classified into four classes: patch, edge, perforated and core. In many studies, the core has been classified into three classes: small (<250 acres), medium (250-500 acres), and large (>500 acres). In this study, the core classes covered a tiny area ($< 0.1\ \text{km}^2$). Therefore, the core classes were dissolved and combined into one class. Lastly, a Pearson correlation analysis between urban area, patch density, edge density and the fragmentation index was performed (Figure 2).

Table 4. Formula for the calculation of indices

Metric	Formula
Patch density	$\frac{\text{Number of patches}}{\text{Total area of region}}$
Convert edge length from pixel to km	$\frac{\text{Edge length} \times 100}{1000}$
Edge density	$\frac{\text{Edge length}}{\text{Total area of region}}$
Fragmentation index	Patch density $\times$ Edge density

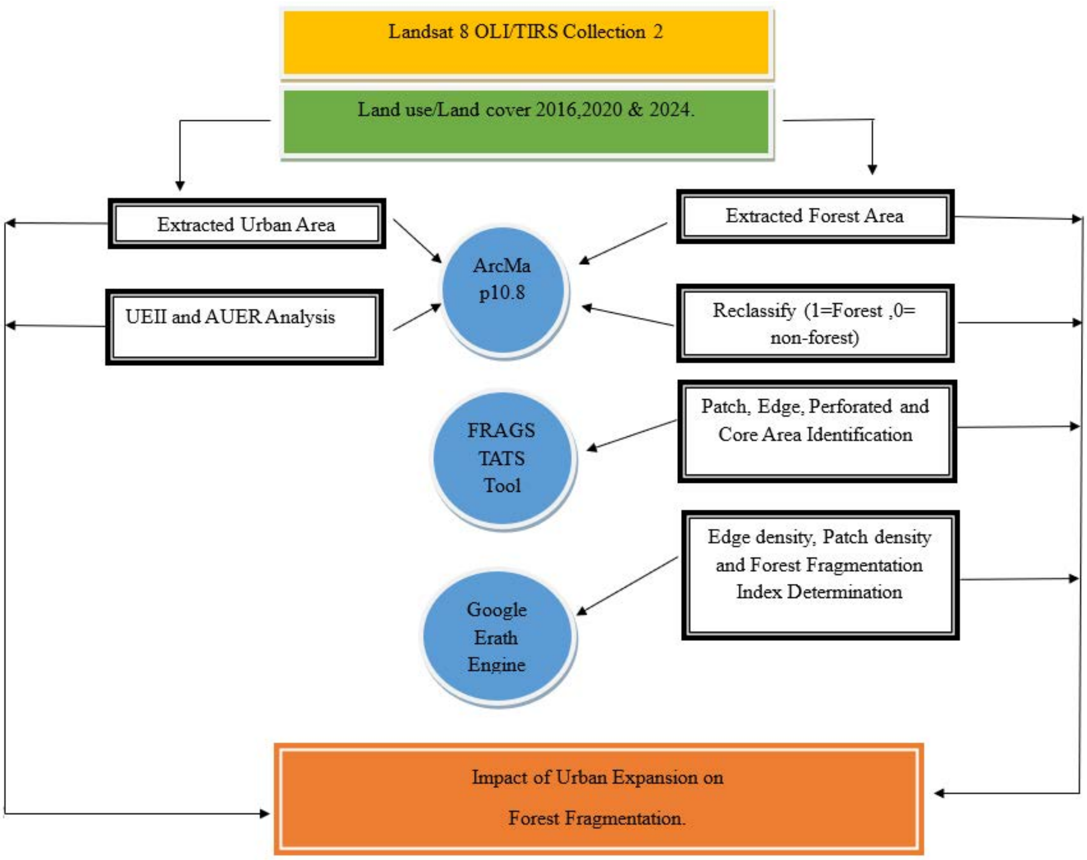

Figure 2. Methodological framework of this study

3 Results and Discussion

3.1 Accuracy Assessment

As shown in Table 5, for 2016, the producer accuracy of the urban area was 95%, the user accuracy was 95%, the kappa coefficient for the whole study area was 92%, and the overall accuracy was 94%. For 2020, the producer accuracy of the urban area was 93%, the user accuracy was 93%, the kappa coefficient for the whole study area was 86%, and the overall accuracy was 90%. For 2024, the producer accuracy of the urban area was 96%, the user accuracy was 100%, the kappa coefficient for the whole study area was 85%, and the overall accuracy was 89%.

Table 5. Accuracy assessment results

Year	Urban Area		For the Whole Study Area	
	Producer Accuracy (%)	User Accuracy (%)	Kappa Coefficient (%)	Overall Accuracy (%)
2016	95	95	92	94
2020	93	93	86	90
2024	96	100	85	89

3.2 Urban Expansion

From 2016 to 2024, Dhaka City experienced a consistent and noteworthy increase in urban expansion. Between 2016 and 2020, the urban area grew modestly from 133 km² to 135 km², reflecting a 0.35% increase (Figure 3a and Figure 3b and Table 6). The expansion area during this phase constituted 44.65% of the total urban area, indicating a steady urbanization process that, while significant, remained relatively controlled (Table 6). In contrast, the period from 2020 to 2024 saw more marked growth, with the urban area expanding from 135 km² to 139 km², reflecting a 1.34% increase (Figure 3b and Figure 3c and Table 6). The expansion area accelerated to 46.34% of the total urban area, suggesting an increased demand for urban space (Table 6). Over the years, the unchanged area of 96 km² remained consistent, indicating that some areas stayed unaffected by the expansion (Figure 3d and Table 6). This shift from gradual to accelerated urban expansion between 2016 and 2024 underscores the growing dynamism of Dhaka's urban development.

Table 6. Expansion of urban area in 2016, 2020 and 2024

Year	Area (km^2)	Area (%)	Unchanged Urban Area (%)	Net Change	
				2016-2020	2020-2024
2016	133	44.65			
2020	135	45	96	-0.35	-1.34
2024	139	46.35			

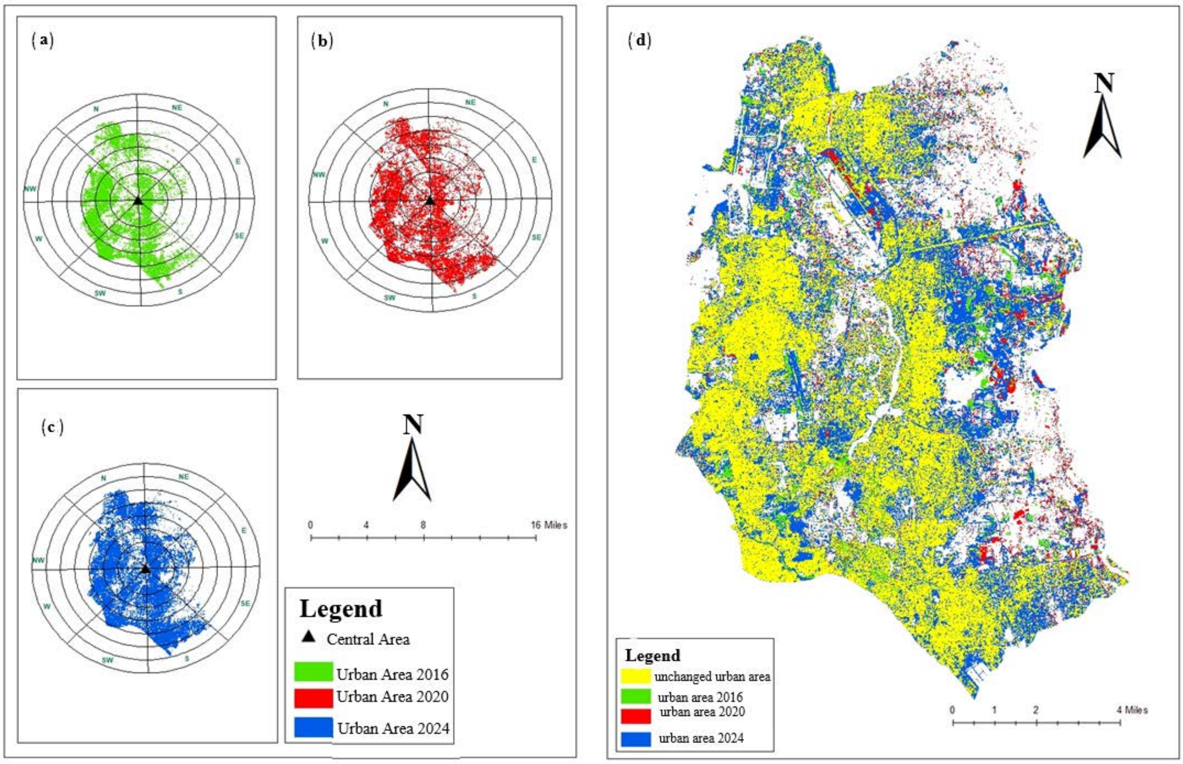

Figure 3. Urban area expansion (a) 2016, (b) 2020, (c) 2024, and (d) Unchanged urban area between 2016 and 2024

3.3 UEII

As shown in Figure 4, between 2016 and 2024, the urban extent of Dhaka City expanded at varying intensities, as reflected by UEII. During the period from 2016 to 2020, UEII was recorded at 0.67%, indicating a relatively moderate rate of urban growth. In contrast, the period from 2020 to 2024 exhibited a higher expansion intensity, with UEII rising to 1.35%. This increase denotes a more accelerated phase of urban expansion in the latter period, suggesting intensified land conversion and urban development activities. The observed trend highlights a shift toward a more rapid urbanization trajectory in recent years.

3.4 AUER

As shown in Figure 4, AUER for Dhaka City between 2016 and 2020 was approximately 0.37%, indicating a moderate level of urban growth during this period, reflecting a relatively measured expansion of the city's spatial footprint, with minimal alterations to the urban fabric. Between 2020 and 2024, AUER increased to approximately 0.73%, reflecting a discernible rise in the rate of urban expansion. Although the overall magnitude of growth remains moderate, the upward shift in the rate signals an emerging acceleration in urbanization dynamics.

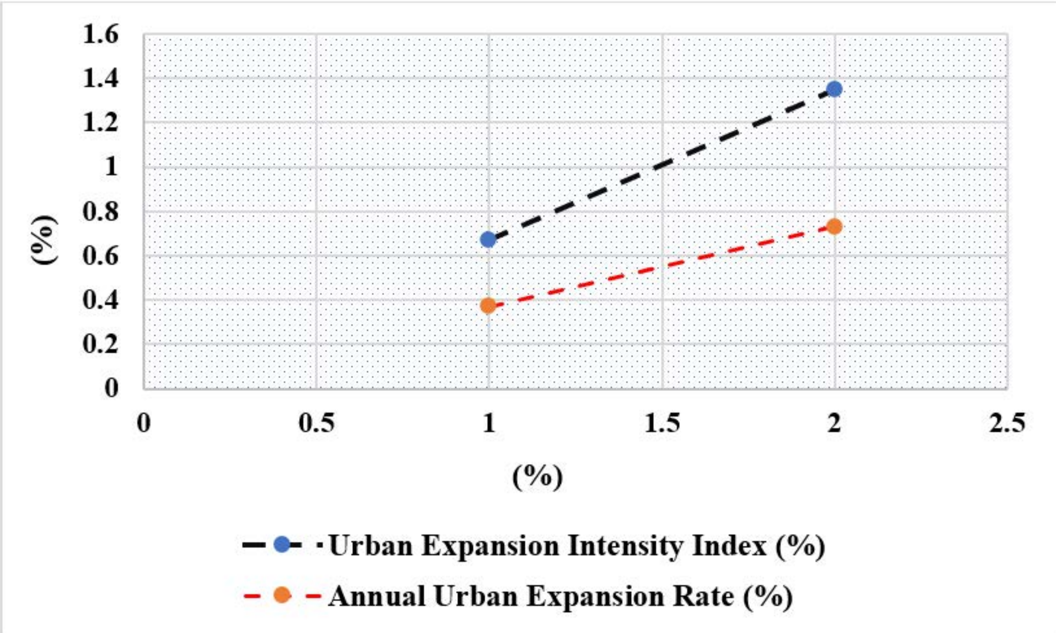

Figure 4. Changes in UEII and AUER between 2016 and 2024

3.5 Forest Fragmentation Analysis

From 2016 to 2024, Dhaka experienced significant changes in its forest fragmentation dynamics (Figure 5), as reflected in key indices such as patch density, edge density, and the fragmentation index. These indices provide a critical understanding of the extent and severity of forest fragmentation in the city over time. In 2016, Dhaka exhibited a relatively moderate level of forest fragmentation, with a patch density of 7 per km^2, an edge density of 4 per km^2, and a fragmentation index of 33 (Figure 6). The moderate patch density indicates that forested areas existed, but they were already fragmented into multiple patches. The relatively low edge density suggests that while fragmentation was present, the degree of exposure of these forest patches to non-forested areas remained limited. The fragmentation index of 33 (Figure 6c) further implies that while forest fragmentation was occurring, it had not yet reached a critical level of disruption in connectivity. By 2020, a significant increase in fragmentation was observed. Patch density rose to 9 per km^2 (Figure 6b), indicating a higher number of forest patches within the landscape, which pointed to more intensified fragmentation. Previously larger, continuous forest areas had been subdivided into smaller, isolated patches. While these patches remained forested, they were now surrounded by non-forested land. Edge density surged to 7 per km^2 (Figure 6a), highlighting a marked increase in the interface between forested and non-forested areas, a clear sign of escalating disturbance. The rise in edge density indicated that more boundaries, or edges, were created where forest patches met non-forest areas. Most notably, the fragmentation index nearly doubled to 65 (Figure 6c), demonstrating a substantial decline in forest connectivity. This sharp increase reflects rapid urban expansion and land-use changes that contributed to the fragmentation of previously larger, more contiguous forest areas.

The trend of increasing fragmentation continued into 2024. Although patch density slightly decreased to 8 patches per km^2, edge density further increased to 9 per km^2 (Figure 6a and Figure 6b), indicating that while some patches may have merged or disappeared, the remaining patches became more irregular and exposed. The fragmentation index peaked at 80 (Figure 6c), the highest recorded during the study period. This significant rise in fragmentation signals a highly disrupted forest landscape, where the connectivity between patches is severely compromised, making the remaining forested areas more vulnerable to ecological degradation, biodiversity loss, and environmental stressors.

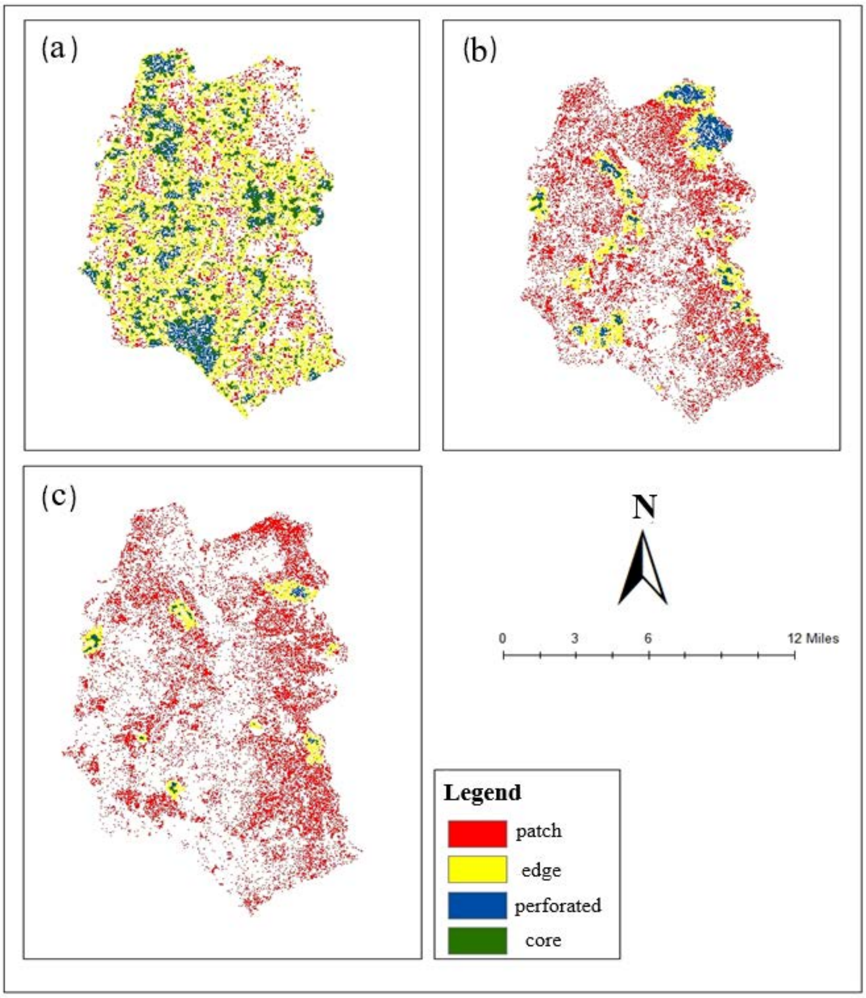

Figure 5. Forest fragmentation maps of Dhaka City in (a) 2016, (b) 2020, and (c) 2024, showing the four fragmentation classes (colored) and non-forest areas (white)

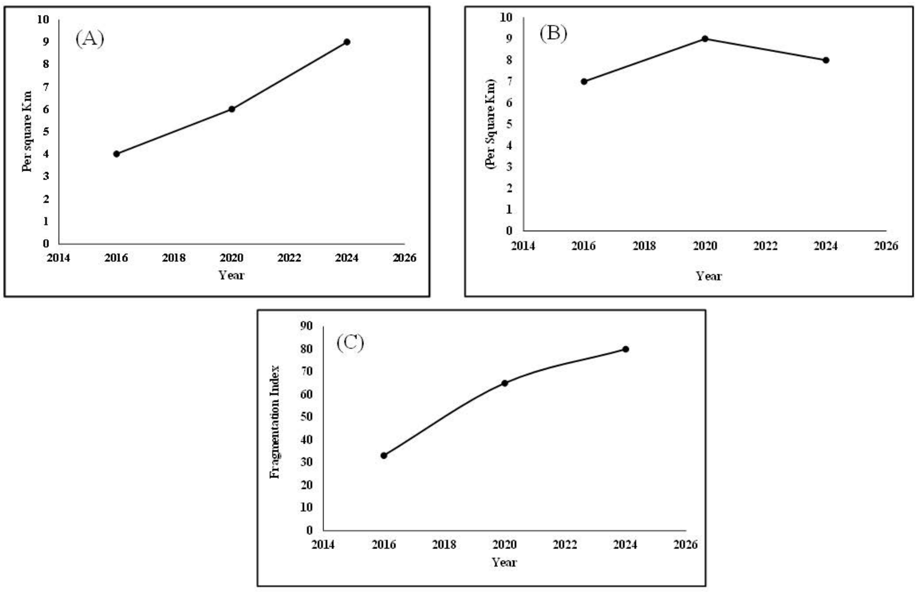

Figure 6. Indices of (a) edge density, (b) patch density, and (c) the forest fragmentation index between 2016 and 2024

The findings from 2016 to 2024 reveal a clear and concerning trend of increasing forest fragmentation in Dhaka. The steady rise in edge density and the fragmentation index, despite a slight reduction in patch density from 2020 to 2024, suggests that the remaining forest patches are becoming more isolated and vulnerable, rather than being consolidated. This pattern reflects the ongoing effects of rapid urbanization, infrastructure development, and deforestation, all of which have significantly altered the forest landscape.

3.6 Correlation Between Urban Expansion and Forest Fragmentation

As shown in Table 7, the analysis of the correlation coefficients between urban area and various forest-related metrics offers valuable insights into how urbanization influences forest fragmentation, patch distribution, and edge complexity. These correlations, which range from 0.327 to 0.953, reveal significant trends in the relationship between urban expansion and the condition of forest ecosystems. The key metrics analyzed include the number of forest patches, forest patch density, edge density, and the fragmentation index. The correlation coefficient of 0.441 between urban area and the number of forest patches indicates a moderate positive relationship. This suggests that as urban areas expand, the number of forest patches tends to increase, but the correlation is not particularly strong. A moderate correlation implies that urbanization leads to the fragmentation of forests into discrete patches, although not in a strictly proportional or linear pattern. While urban growth is commonly associated with forest fragmentation, the increase in the number of patches does not occur at the same rate as urban expansion. This variation could be influenced by differences in land development patterns, urban zoning policies, and how urban growth affects forest landscapes.

The correlation coefficient of 0.327 between urban area and forest patch density reveals a low to moderate positive relationship. This indicates that larger urban areas may have slightly higher forest patch densities, but the correlation is weak. In practical terms, this suggests that urban growth does not consistently lead to an increase in the concentration of forest patches within urban areas. Instead, forest patches may become more dispersed as urban areas expand, with development spreading into previously undeveloped land without significantly increasing the concentration of forest patches. The very strong positive correlation coefficient of 0.953 between urban area and forest edge density reflects a highly significant relationship between urban expansion and the complexity of forest boundaries. As urban areas grow, the edges of forests also become more pronounced and complex, a characteristic of urban sprawl. In this process, the expansion of cities leads to the creation of irregular and fragmented urban boundaries that intersect with forested areas. This results in forest edges growing disproportionately compared to the overall forest area. The high edge density reflects the increase in the amount of boundary relative to the size of the forested area, indicating that urban growth significantly contributes to the fragmentation of the landscape, creating more irregular and jagged forest edges.

Similarly, the correlation coefficient of 0.922 between urban area and the forest fragmentation index demonstrates another very strong positive relationship. As urban areas expand, forest fragmentation increases significantly, leading to a more disjointed and fragmented landscape. A higher fragmentation index suggests that forests become divided into smaller, disconnected patches with reduced cohesion. This correlation supports the notion that urban expansion exacerbates fragmentation, with larger urban areas associated with more scattered patterns of forest patches. Urban sprawl often encroaches upon surrounding forests, creating isolated patches with diminished connectivity. As cities continue to grow, the fragmentation index underscores the increasing disconnection and reduced ecological integrity of forest ecosystems.

Table 7. Pearson correlation coefficient between urban area and the number of patches, patch density, edge density, and the fragmentation index

	Urban Area	**Number of Patches**	**Patch Density**	**Edge Density**	**Fragmentation Index**
Urban area	1				
Number of patches	0.441485861	1			
Patch density	0.327326835	0.992348932	1		
Edge density	0.953820966	0.69061604	0.596039561	1	
Fragmentation index	0.922612906	0.75342125	0.666473849	0.995870595	1

4 Conclusion

This study provides a detailed spatiotemporal analysis of urban expansion and its consequential impact on forest fragmentation within DCC from 2016 to 2024. The findings reveal a clear and accelerating trend in urban growth, accompanied by profound implications for the integrity of the city's remaining forested landscapes. The substantial increases in UEII and AUER reflect an escalating pace of urbanization, with notable acceleration observed between 2020 and 2024. Concurrently, forest ecosystems have experienced pronounced fragmentation, as evidenced by a significant rise in edge density and the fragmentation index. These indices suggest an intensifying disruption of forest connectivity, resulting in increasingly isolated forest patches that threaten biodiversity, ecosystem services, and urban environmental quality. The strong positive correlations between urban expansion and various fragmentation metrics further substantiate the detrimental impact of unchecked urban sprawl on ecological landscapes. The results underscore the pressing need for comprehensive policy interventions that strike a balance between urban development and environmental sustainability. Effective urban planning must prioritize the integration of green infrastructure, enforce robust land use regulations, and foster the preservation and restoration of urban forests to mitigate the ecological impacts of further urban growth. Additionally, the methodological framework established in this study offers a replicable model to monitor the ongoing environmental effects of urbanization, which can be applied to other rapidly urbanizing regions globally. By elucidating the spatial consequences of Dhaka's urban growth, this research provides critical perspectives for policymakers, urban planners, and environmental stakeholders committed to promoting sustainable urban transformation. The study serves as a call to action for integrating ecological considerations into urban development strategies, ensuring that future growth does not come at the expense of environmental integrity and biodiversity conservation.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

References

[1] Md. Monjure Alam Pramanik and D. Stathakis, "Forecasting urban sprawl in Dhaka City of Bangladesh," *Environ. Plan. B*, vol. 43, no. 4, pp. 756–771, 2015. https://doi.org/10.1177/0265813515595406

[2] P. Stalker, *Handbook of the World*. New York: Oxford University Press, 2000.

[3] M. Ashraf Dewan and Y. Yamaguchi, "Using remote sensing and GIS to detect and monitor land use and land cover change in Dhaka Metropolitan of Bangladesh during 1960–2005," *Environ. Monit. Assess.*, vol. 150, no. 1-4, pp. 1960–2005, 2008. https://doi.org/10.1007/s10661-008-0226-5

[4] N. Morshed, C. Yorke, and Q. Zhang, "Urban expansion pattern and land use dynamics in Dhaka, 1989–2014," *Prof. Geogr.*, vol. 69, no. 3, pp. 396–411, 2017. https://doi.org/10.1080/00330124.2016.1268058

[5] N. Islam, "Urbanization, migration and development in Bangladesh: Recent trends and emerging issues," 1999.

[6] "Dhaka: Improving Living Conditions for the Urban Poor, Bangladesh Development Series, Paper No. 17, The World Bank Office, Dhaka, June 2007." 2007. https://documents.worldbank.org/pt/publication/documents-reports/documentdetail/938981468013830990/dhaka-improving-living-conditions-for-the-urban-poor

[7] N. Du, H. Ottens, and R. Sliuzas, "Spatial impact of urban expansion on surface water bodies—A case study of Wuhan, China," *Landsc. Urban Plan.*, vol. 94, no. 3-4, pp. 175–185, 2010. https://doi.org/10.1016/j.landurbplan.2009.10.002

[8] D. Silvia Matteucci and J. Morello, "Environmental consequences of exurban expansion in an agricultural area: The case of the Argentinian Pampas ecoregion," *Urban Ecosyst.*, vol. 12, no. 3, pp. 287–310, 2009. https://doi.org/10.1007/s11252-009-0093-z

[9] S. Su, R. Xiao, Z. Jiang, and Y. Zhang, "Characterizing landscape pattern and ecosystem service value changes for urbanization impacts at an eco-regional scale," *Appl. Geogr.*, vol. 34, pp. 295–305, 2012. https://doi.org/10.1016/j.apgeog.2011.12.001

[10] L. van Delden, D. W. Rowlings, C. Scheer, and P. R. Grace, "Urbanisation-related land use change from forest and pasture into turf grass modifies soil nitrogen cycling and increases N_2O emissions," *Biogeosciences*, vol. 13, no. 21, pp. 6095–6106, 2016. https://doi.org/10.5194/bg-13-6095-2016

[11] W. Zhou, J. Wang, and L. Mary Cadenasso, "Effects of the spatial configuration of trees on urban heat mitigation: A comparative study," *Remote Sens. Environ.*, vol. 195, pp. 1–12, 2017. https://doi.org/10.1016/j.rse.2017.03.043

[12] M. S. Misty, M. A. Hoque, and A. Sharif Mukul, "Assessment of urban green space dynamics in Dhaka South City corporation of Bangladesh using geospatial techniques," *Land*, vol. 13, no. 9, p. 1426, 2024. https://doi.org/10.3390/land13091426

[13] K. T. K. Nahin, H. H. Sara, K. R. Barai, Z. Quayyum, and J. Baumgartner, "Spatiotemporal variability of urban greenspace and surface temperature in Dhaka City: A public health aspect," *Empa. City: An Urban Health Wellbeing Pers.*, pp. 143–169, 2023. https://doi.org/10.1007/978-3-031-32840-4_7

[14] M. Moniruzzaman and M. M. P. Rana, "Spatial and ecological impacts of wetland changes: A case of urban expansion in Dhaka City, Bangladesh," *J. GeoEnviron.*, vol. 9, 2009.

[15] I. Islam, "Wetlands of Dhaka: Alarming depletion," *Daily Star.*, vol. 5, no. 700, 2006.
[16] A. N. M. G. Reza and M. S. Alam, "Wetland transformation in the western part of Dhaka City (1963–2000)," *Bhugal Patrika (J. Geo.)*, vol. 21, pp. 23–40, 2002.
[17] M. S. Islam, R. Afroz, and M. B. Mia, "Investigation of surface water quality of the Buriganga River in Bangladesh: Laboratory and spatial analysis approaches," *Dhaka Univ. J. Biol. Sci*, vol. 28, no. 2, pp. 147–158, 2019. https://doi.org/10.3329/dujbs.v28i2.46501
[18] M. A. J. Riad Khan, M. N. Tahnun, E. Saif, and M. S. Islam, "Recent water quality assessment of Buriganga and Turag River," *Chem. Eng. Res. Bull.*, pp. 79–84, 2023. https://doi.org/10.3329/cerb.v23i10.78501
[19] C. Gong, J. Chen, and S. Yu, "Spatiotemporal dynamics of urban forest conversion through model urbanization in Shenzhen, China," *Int. J. Remote Sens.*, vol. 32, pp. 9071–9092, 2011. https://doi.org/10.1080/01431161.2010.549848
[20] A. John Kupfer, "National assessments of forest fragmentation in the US," *Glob. Environ. Chang.*, vol. 16, no. 1, pp. 73–82, 2006. https://doi.org/10.1016/j.gloenvcha.2005.10.003
[21] N. M. Haddad, L. A. Brudvig, J. Clobert, K. F. Davies, and et al., "Habitat fragmentation and its lasting impact on Earth's ecosystems," *Science Advances*, vol. 1, no. 2, 2015. https://doi.org/10.1126/sciadv.1500052
[22] L. Fahrig, "Effects of habitat fragmentation on biodiversity," *Annu. Rev. Ecol. Evol. Syst.*, vol. 34, no. 1, pp. 487–515, 2003. https://doi.org/10.1146/annurev.ecolsys.34.011802.132419
[23] M. L. McKinney, "Urbanization, biodiversity, and conservation," *BioScience*, vol. 52, no. 2, pp. 883–890, 2002. https://doi.org/10.1641/0006-3568(2002)052[0883:UBAC]2.0.CO;2
[24] A. M. Dewan, Y. Yamaguchi, and M. Ziaur Rahman, "Dynamics of land use/cover changes and the analysis of landscape fragmentation in Dhaka Metropolitan, Bangladesh," *GeoJournal*, vol. 77, no. 3, pp. 315–330, 2012. https://doi.org/10.1007/s10708-010-9399-x
[25] E. Diana Bowler, L. Buyung-Ali, M. Teri Knight, and S. Andrew Pullin, "Urban greening to cool towns and cities: A systematic review of the empirical evidence," *Landsc. Urban Plan*, vol. 97, no. 3, pp. 147–155, 2010. https://doi.org/10.1016/j.landurbplan.2010.05.006
[26] Y. Zhang, W. Shen, M. Li, and Y. Lv, "Assessing spatio-temporal changes in forest cover and fragmentation under urban expansion in Nanjing, eastern China, from long-term Landsat observations (1987–2017)," *Appl. Geogr.*, vol. 117, p. 102190, 2020. https://doi.org/10.1016/j.apgeog.2020.102190
[27] A. K. Pasha, S. Mozumder, M. A. H. Bhuiyan, and M. Parveen, "Monitoring land use and land cover changes of Dhaka City: A remote sensing and GIS-based analysis," *Sci. Int.*, vol. 34, no. 4, pp. 339–348, 2022.
[28] M. Parvin, "Projecting the population size of Dhaka City with migration using growth rate method," *IOSR J. Math.*, vol. 8, no. 5, pp. 29–37, 2013. https://doi.org/10.9790/5728-0852937
[29] J. B. Campbell, *Introduction to Remote Sensing*. London: Taylor and Francis, 1996. https://doi.org/10.1201/b13575
[30] M. Giles Foody, "Status of land cover classification accuracy assessment," *Remote Sens. Environ.*, vol. 80, no. 1, pp. 185–201, 2002. https://doi.org/10.1016/s0034-4257(01)00295-4
[31] J. J.-F. Mas, "Monitoring land-cover changes: A comparison of change detection techniques," *Int. J. Remote Sens.*, vol. 20, no. 1, pp. 139–152, 1999. https://doi.org/10.1080/014311699213659
[32] S. Sophia Rwanga and J. M. Ndambuki, "Accuracy assessment of land use/land cover classification using remote sensing and GIS," *Int. J. Geosci.*, vol. 8, no. 4, pp. 611–622, 2017. https://doi.org/10.4236/ijg.2017.84033
[33] S. K. Sinha, "Spatial metrics: A tool for measurement of urban growth/sprawl," *Spat. Metr.: Tool Meas. Urban Growth/Sprawl*, vol. 11, p. 202, 2018.