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Impact of Urban Expansion on Vegetation Dynamics in Mysuru City (1988-2024): A Multi-Temporal NDVI Analysis

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Abstract: ***Urban expansion has emerged as a major driver of vegetation degradation in rapidly growing cities of the developing countries. This study assesses the long-term impact of urban expansion on vegetation dynamics in Mysuru using multi-temporal Normalized Difference Vegetation Index (NDVI) analysis. Landsat satellite imagery from four representative years -1988, 2000, 2012, and 2024 was processed to generate NDVI maps capturing vegetation density and condition across different stages of urban growth. To examine spatial variability, a direction-wise analytical framework was adopted, dividing the city into eight directional sectors and extracting maximum, mean, and minimum NDVI values for each sector. The results indicate a consistent decline in NDVI values over the 36-year period, confirming progressive vegetation loss associated with outward urban expansion. Vegetation degradation is spatially uneven, with eastern, south-eastern, and north-western sectors experiencing sustained declines in mean and minimum NDVI values, reflecting rapid and largely unregulated urban growth. In contrast, northern and southern sectors exhibit comparatively higher NDVI values and greater vegetation resilience due to the continued presence of agricultural land, tree cover, and relatively regulated development. Temporal analysis reveals a non-linear vegetation response, with limited and short-lived recovery during certain periods that remains insufficient to offset long-term cumulative loss. The study demonstrates that urban expansion in Mysuru has substantially altered vegetation patterns, resulting in green space fragmentation and reduced vegetation density. The direction-wise NDVI approach provides an effective framework for identifying ecologically stressed urban growth corridors and supports the integration of vegetation conservation into future urban planning strategies.***

Keywords: Urban expansion; NDVI; vegetation dynamics; remote sensing; Mysuru City

1. Introduction

Rapid urban expansion has emerged as a defining characteristic of contemporary urbanisation, particularly in cities of the developing countries, where population growth, economic restructuring, and land-market dynamics have driven extensive outward growth of built-up areas (Bhatta, 2010; Angel et al., 2011; Seto et al., 2012). This form of expansion often occurs at the expense of natural and semi-natural landscapes, resulting in the conversion of agricultural land, forest patches, and open spaces into impervious surfaces. Such land-use transformations have significant ecological consequences, including vegetation loss, habitat fragmentation, and disruption of surface energy balances (Sudhira et al., 2004; Foley et al., 2005; Ramachandra et al., 2012).

Urban vegetation plays a critical role in maintaining ecological stability by regulating microclimate, enhancing evapotranspiration, supporting biodiversity, and improving overall environmental quality. Numerous studies have shown that unplanned and dispersed urban growth leads to declining vegetation density and fragmentation of green spaces, thereby reducing ecosystem services and environmental resilience (Li & Yeh, 2004; Weng et al., 2007; McDonald et al., 2010). As a result, vegetation degradation has become a central concern in urban environmental studies.

Remote sensing provides an effective means of monitoring vegetation dynamics associated with urbanisation. Among various vegetation indices, the Normalized Difference Vegetation Index (NDVI) is one of the most robust and widely used indicators for assessing vegetation density, health, and spatial distribution (Tucker, 1979). NDVI is particularly suitable for long-term urban studies because it enables consistent temporal comparison using multi-sensor satellite data and allows spatially explicit assessment of vegetation loss and recovery (Xian & Crane, 2006; Jat et al., 2008; Ramachandra et al., 2012).

Empirical evidence suggests that urban expansion generally results in declining NDVI values due to the replacement of vegetated surfaces with built-up land uses (Sudhira et al., 2004; Weng, 2012; Seto et al., 2012). However, the impact of urbanisation on vegetation is rarely spatially uniform. Directional growth patterns, transport corridors, and variations in planning controls often generate heterogeneous vegetation responses across urban space (Yeh & Li, 2001; Li & Yeh, 2004).

In the Indian context, medium-sized cities such as Mysuru provide important case studies for examining vegetation dynamics under sustained urban expansion. Despite rapid outward growth over recent decades, long-term direction-wise assessments of vegetation change in Mysuru remain limited. In this context, the present study analyses multi-temporal Landsat-derived NDVI data from 1988 to 2024 using a direction-wise analytical framework to capture spatial heterogeneity in vegetation change and identify ecologically stressed growth corridors.

2. Study Area

The study is conducted in Mysuru, located in the southern part of Karnataka on the Deccan Plateau. Mysuru is a major cultural, administrative, and educational centre of the state and has experienced rapid urban growth in recent decades due to population increase, infrastructure development, and economic expansion. The city lies at an average elevation of about 770 m above mean sea level and has a tropical savanna climate, with vegetation influenced by seasonal rainfall and expanding built-up areas.

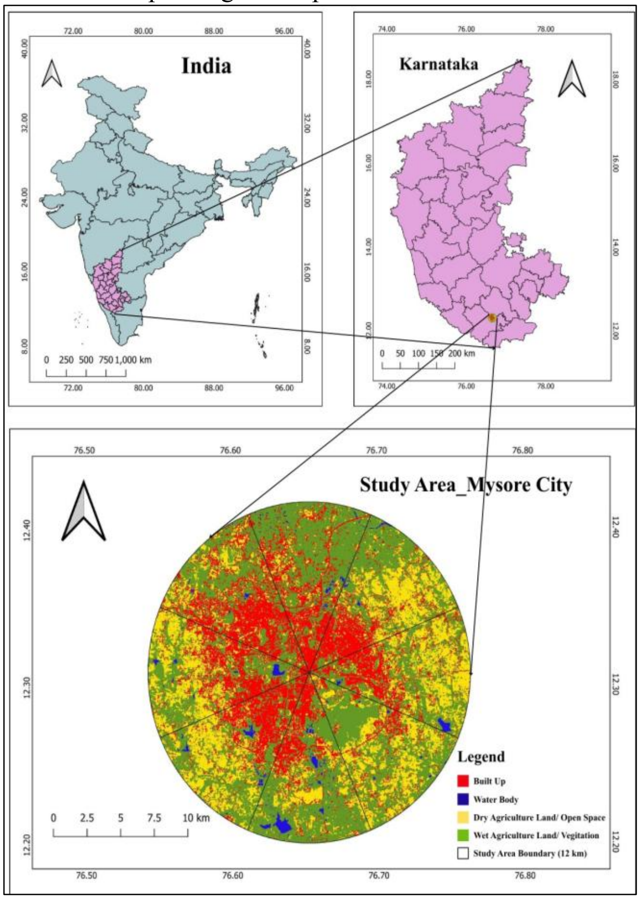

Figure 1: Study area map- Mysore city with 12 km radius from K R circle with 8 wedges

3. Objectives

The study has following objectives;

- To analyse long-term changes in vegetation cover in Mysuru City from 1988 to 2024 using NDVI.
- To assess the impact of urban expansion on vegetation condition and fragmentation over time.

4. Methodology

Normalized Difference Vegetation Index (NDVI) was derived using multi-temporal Landsat satellite imagery processed in the Google Earth Engine (GEE) platform. Landsat 5 TM, Landsat 7 ETM+, and Landsat 8 OLI surface reflectance datasets were selected according to the study periods. Images were filtered spatially and temporally and subjected to cloud and cloud-shadow masking using quality assessment bands. NDVI was calculated using the standard formula:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$

NDVI was derived using the Red and NIR bands of Landsat sensors, namely Band 3 and Band 4 for Landsat 5 TM and Landsat 7 ETM+, and Band 4 and Band 5 for Landsat 8 OLI, respectively.

Median NDVI composites were generated for each period to reduce atmospheric and seasonal effects. The NDVI outputs were clipped to the 12 km study boundary and intersected with the directional wedges to extract minimum, maximum, and mean NDVI values, enabling a spatial-temporal assessment of vegetation changes across different urban growth directions.

5. Impact of Urban Expansion on Vegetation Dynamics (NDVI) in Mysuru City

Urban expansion in Mysuru City over the past few decades has resulted in significant transformation of natural and semi-natural landscapes, particularly affecting vegetation cover. The Normalized Difference Vegetation Index (NDVI) provides an effective means of examining these changes by capturing variations in vegetation density and health over time. An analysis of NDVI from 1988 to 2024 therefore helps to understand how the intensity and direction of urban growth have influenced vegetation dynamics, highlighting the environmental consequences of sustained urban expansion in the city.

Table 1: Direction-wise Variations in NDVI Statistics (Maximum, Mean and Minimum) in Mysuru City (1988-2024)

Directions/ Year	1988			2000			2012			2024		
	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min
North	0.5081	0.2627	-0.0296	0.4790	0.2493	-0.5042	0.4952	0.2482	-0.4118	0.4742	0.2205	-0.0289
North-East	0.4931	0.1994	-0.2903	0.4573	0.2078	-0.0037	0.4831	0.2138	-0.2562	0.4698	0.1781	-0.0367
East	0.4640	0.1617	-0.0653	0.4792	0.2054	-0.1232	0.4460	0.1990	-0.4274	0.4547	0.1594	-0.0213
South-East	0.4596	0.2037	- 0.0147	0.5034	0.2106	-0.0202	0.4630	0.2083	-0.4382	0.4468	0.1696	-0.0310
South	0.5438	0.2252	-0.2754	0.5157	0.2316	-0.2091	0.4515	0.2004	-0.0267	0.4989	0.1952	-0.0220
South-West	0.5011	0.2000	-0.0961	0.4757	0.2078	-0.0223	0.4401	0.1965	-0.0383	0.4704	0.1567	-0.0325
West	0.4767	0.1953	-0.0235	0.4761	0.2167	-0.0159	0.4708	0.2180	-0.4294	0.4555	0.1551	-0.0281
North-West	0.4937	0.1941	-0.0010	0.4542	0.2032	-0.2282	0.4377	0.1963	-0.3554	0.4468	0.1592	-0.0045

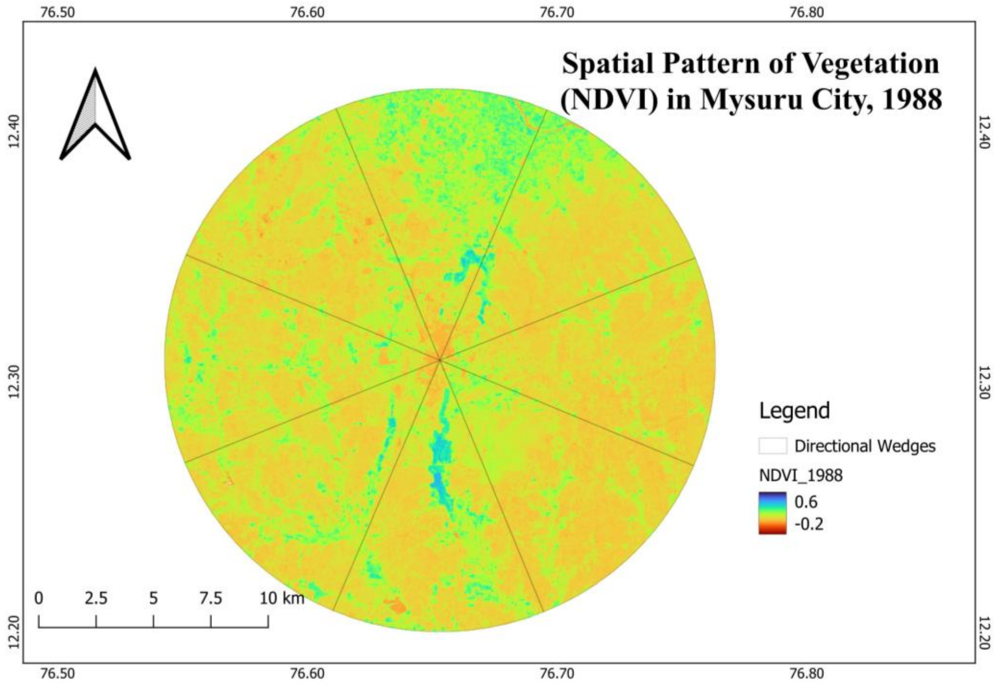

Figure 2: NDVI-Based Vegetation Pattern of Mysuru City, 1988

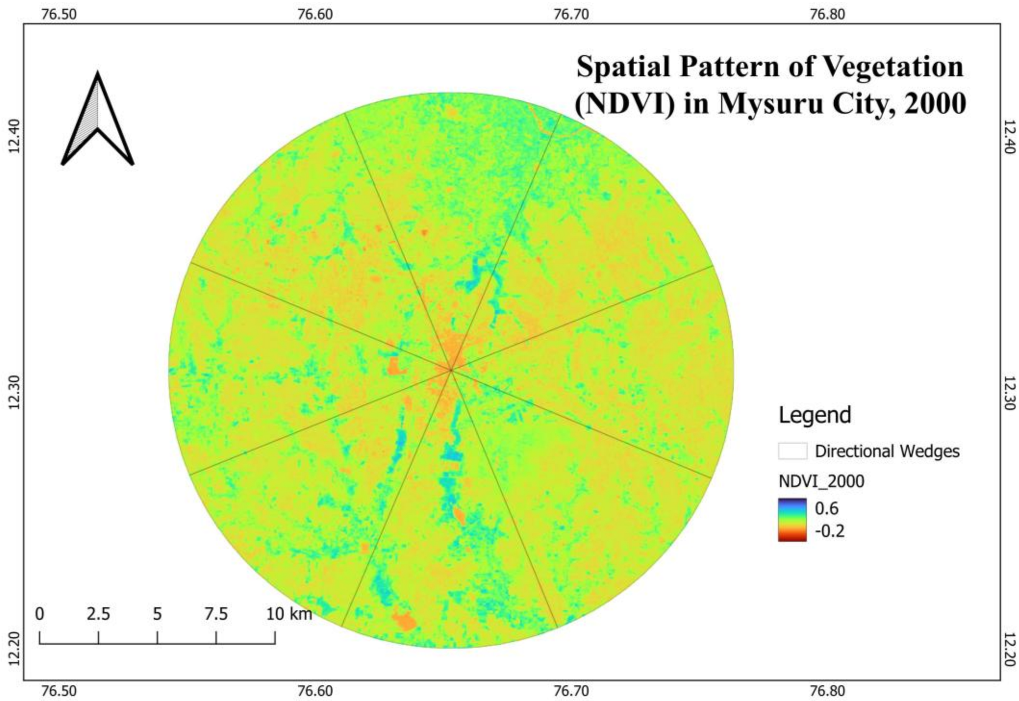

Figure 3: NDVI-Based Vegetation Pattern of Mysuru City, 2000

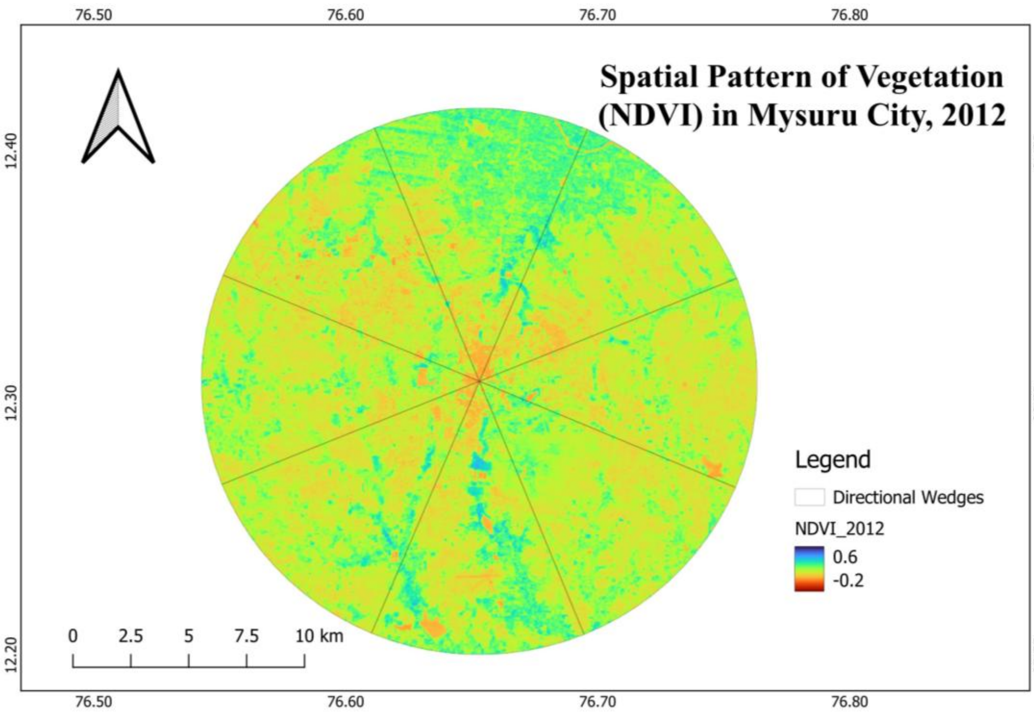

Figure 4: NDVI-Based Vegetation Pattern of Mysuru City, 2012

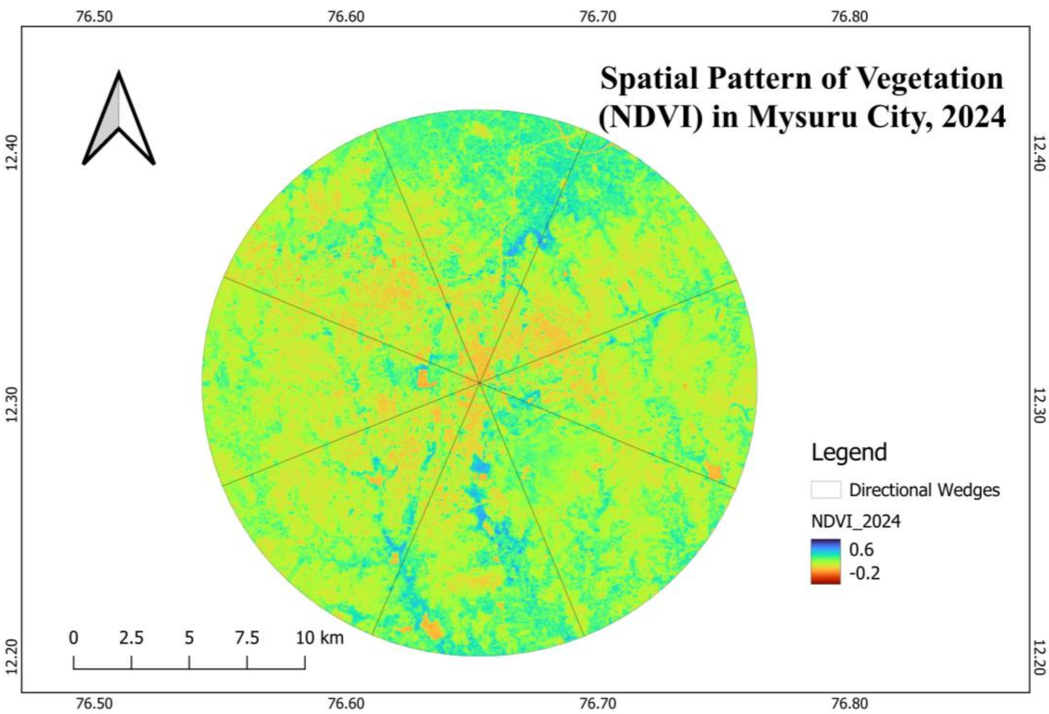

Figure 5: NDVI-Based Vegetation Pattern of Mysuru City, 2024

NDVI-based analysis from 1988 to 2024 provides a clear understanding of how vegetation density and condition in Mysuru have responded to the intensity, timing, and spatial pattern of urban expansion. Long-term trends indicate that vegetation loss has accompanied successive phases of outward urban growth, although the magnitude and nature of change vary considerably across directional sectors.

In the northern sector, vegetation conditions were relatively strong in 1988, as reflected by a high maximum NDVI (0.5081) and mean NDVI (0.2627). Over time, both indicators show a gradual decline, with mean NDVI decreasing to 0.2205 by 2024, indicating a steady reduction in vegetation vigour. Extremely low minimum NDVI values in 2000 (–0.5042) and 2012 (–0.4118) point to extensive land exposure and surface disturbance associated with construction activity and peri-urban infrastructure development. Although the minimum NDVI improves to-0.0289 by 2024, the recovery remains limited, suggesting partial surface stabilisation rather than full ecological restoration.

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The north-eastern sector exhibits a transitional vegetation trajectory. Moderate vegetation conditions in 1988 (mean NDVI: 0.1994) were followed by an improvement by 2012 (0.2138), indicating partial regrowth in stabilised land parcels. However, this improvement is not sustained, as mean NDVI declines to 0.1781 by 2024, reflecting renewed urbanisation pressure. Minimum NDVI values remain negative throughout the study period, though their magnitude reduces from –0.2903 in 1988 to –0.0367 in 2024, indicating a relative reduction in barren or highly disturbed surfaces but not complete recovery. Overall, this sector reflects a mixed pattern of disturbance and partial recovery shaped by phased urban development.

The eastern and south-eastern sectors consistently emerge as zones of high ecological stress. Mean NDVI values remain comparatively low across all years, while minimum NDVI values decline sharply in 2012 (–0.4274 in the East and –0.4382 in the South-East), indicating extensive bare soil exposure. These sectors have experienced rapid and linear urban growth along major transportation corridors, leading to systematic conversion of agricultural and vegetated lands into residential and commercial uses. Although slight improvements in minimum NDVI are observed by 2024, the overall trend confirms persistent vegetation degradation driven by continuous and largely unregulated expansion.

In contrast, the southern sector demonstrates comparatively stronger vegetation resilience. High maximum NDVI in 1988 (0.5438) indicates dense vegetation cover, and although both maximum and mean NDVI decline over time, the reduction is moderate compared to eastern sectors. The improvement in minimum NDVI from –0.2754 in 1988 to –0.0220 in 2024 suggests reduced land exposure and better surface cover. The presence of agricultural fields, irrigated landscapes, and tree-covered areas, combined with relatively regulated urban development, has enabled vegetation to coexist more successfully with built-up land uses.

The south-western and western sectors display heterogeneous vegetation responses. In the south-west, gradual declines in maximum and mean NDVI reflect steady conversion of vegetated land into built-up areas through incremental residential and infrastructure development. In the west, relatively stable maximum NDVI values contrast with sharply negative minimum NDVI in 2012 (–0.4294), indicating a fragmented landscape where healthy vegetation patches persist alongside severely degraded surfaces. This pattern reflects uneven sprawl intensity influenced by dispersed development, industrial activity, and transport infrastructure.

The north-western sector records the most consistent vegetation decline across the study period. Continuous reductions in maximum and mean NDVI, along with persistently negative minimum NDVI values, indicate sustained land degradation resulting from long-term conversion of agricultural and open lands into built-up areas. This sector represents one of the most ecologically stressed urban growth corridors in Mysuru.

Overall, the direction-wise NDVI analysis clearly demonstrates that urban sprawl in Mysuru has produced spatially selective environmental impacts. Northern and southern sectors retain relatively higher vegetation cover due to continued agricultural presence and comparatively regulated development, whereas eastern, south-eastern, and north-western sectors exhibit sustained vegetation loss driven by rapid and unplanned expansion. Over the 36-year period, urban growth has fragmented green spaces, reduced vegetation density, and increased impervious surfaces, underscoring the need for direction-sensitive urban planning and targeted vegetation conservation strategies.

6. Conclusion

This study presents a comprehensive assessment of long-term vegetation dynamics in Mysuru from 1988 to 2024 using multi-temporal NDVI analysis. The results demonstrate that urban expansion has exerted a sustained, directionally selective impact on vegetation cover, resulting in gradual decline, fragmentation, and reorganisation of urban and peri-urban green spaces over time.

The direction-wise analysis reveals pronounced spatial heterogeneity in vegetation response to urbanisation. The eastern, south-eastern, and north-western sectors consistently emerge as the most ecologically stressed areas, exhibiting persistent reductions in mean and minimum NDVI values due to rapid land conversion and intensive development pressure. In contrast, the northern and southern sectors retain relatively higher vegetation cover and show greater resilience, supported by the continued presence of agricultural land, tree cover, and comparatively regulated urban growth.

Temporal patterns further indicate that vegetation degradation has occurred in phases, closely aligned with periods of accelerated urban expansion. Although limited and spatially constrained recovery is observed in certain sectors during phases of development consolidation, such recovery remains insufficient to compensate for cumulative vegetation loss. Overall, the findings confirm that urban growth in Mysuru has progressively reduced vegetation density and increased landscape fragmentation. The direction-wise NDVI framework adopted in this study effectively captures spatial asymmetries in ecological impact and provides valuable insights for identifying priority growth corridors where targeted vegetation conservation, green buffers, and sustainable urban planning interventions are urgently required.

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